FREIGHTLINER

Run Smart

108SD AND 114SD WORKSHOP MANUAL

Models: 108SD
114SD

STI-497, S0 (4/11P)

Published by
Daimler Trucks North America LLC
4747 N. Channel Ave.
Portland, OR 97217
Printed in U.S.A.

Foreword

The purpose of this manual is to assist the service technician when the vehicle is serviced. Major drivetrain component service information is not included in this manual, but is located in each manufacturer's service manual. For service and repair information of major components, refer to the OEM's website. A listing of many OEM websites can be found in **Section 00.02** . The list also includes OEM websites for a number of other vehicle component or system providers.

Instructions and procedures are those recommended by Freightliner Trucks or the component manufacturer.

Maintenance schedules and additional service information are included in the *108SD and 114SD Maintenance Manual*.

IMPORTANT: Descriptions and specifications in this manual were in effect at the time of printing. Freightliner Trucks reserves the right to discontinue models, and to change specifications or design at any time without notice and without incurring obligation. Descriptions and specifications contained in this publication provide no warranty, expressed or implied, and are subject to revision and editions without notice.

Refer to **www.Daimler-TrucksNorthAmerica.com** and **www.FreightlinerTrucks.com** for more information, or contact Daimler Trucks North America LLC at the address below.

Environmental Concerns and Recommendations

Whenever you see instructions in this manual to discard materials, you should attempt to reclaim and recycle them. To preserve our environment, follow appropriate environmental rules and regulations when disposing of materials.

IMPORTANT: Parts Replacement Considerations

Do not replace suspension, axle, or steering parts (such as springs, wheels, hubs, and steering gears) with used parts. Used parts may have been subjected to collisions or improper use and have undetected structural damage.

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Daimler Trucks North America LLC
Service Systems and Documentation (CVI-SSD)
P.O. Box 3849
Portland, OR 97208-3849

Descriptions of Service Publications

Daimler Trucks North America LLC distributes the following major service publications in paper and electronic (via ServicePro®) formats.

Workshop/Service Manual

Workshop/service manuals contain service and repair information for all vehicle systems and components, except for major components such as engines, transmissions, and rear axles. For service and repair information of major components, refer to the OEM's website. A listing of many OEM websites can be found in **Section 00.02** . Each workshop/service manual section is divided into subjects that can include general information, principles of operation, removal, disassembly, assembly, installation, and specifications.

Maintenance Manual

Maintenance manuals contain routine maintenance procedures and intervals for vehicle components and systems. They have information such as lubrication procedures and tables, fluid replacement procedures, fluid capacities, specifications, and procedures for adjustments and for checking the tightness of fasteners. Maintenance manuals do not contain detailed repair or service information.

Driver's/Operator's Manual

Driver's/operator's manuals contain information needed to enhance the driver's understanding of how to operate and care for the vehicle and its components. Each manual contains a chapter that covers pre-trip and post-trip inspections, and daily, weekly, and monthly maintenance of vehicle components. Driver's/operator's manuals do not contain detailed repair or service information.

Service Bulletins

Service bulletins provide the latest service tips, field repairs, product improvements, and related information. Some service bulletins are updates to information in the workshop/service manual. These bulletins take precedence over workshop/service manual information, until the latter is updated; at that time, the bulletin is usually canceled. The service bulletins manual is available only to dealers. When doing service work on a vehicle system or part, check for a valid service bulletin for the latest information on the subject.

IMPORTANT: Before using a particular service bulletin, check the current service bulletin validity list to be sure the bulletin is valid.

Parts Technical Bulletins

Parts technical bulletins provide information on parts. These bulletins contain lists of parts and BOMs needed to do replacement and upgrade procedures.

Web-based repair, service, and parts documentation can be accessed using the following applications on the AccessFreightliner.com website.

ServicePro

ServicePro® provides Web-based access to the most up-to-date versions of the publications listed above. In addition, the Service Solutions feature provides diagnostic assistance with Symptoms Search, by connecting to a large knowledge base gathered from technicians and service personnel. Search results for both documents and service solutions can be narrowed by initially entering vehicle identification data.

PartsPro

PartsPro® is an electronic parts catalog system, showing the specified vehicle's build record.

EZWiring

EZWiring™ makes Freightliner, Sterling, Western Star, Thomas Built Buses, and Freightliner Custom Chassis Corporation products' wiring drawings and floating pin lists available online for viewing and printing. EZWiring can also be accessed from within PartsPro.

Descriptions of Service Publications

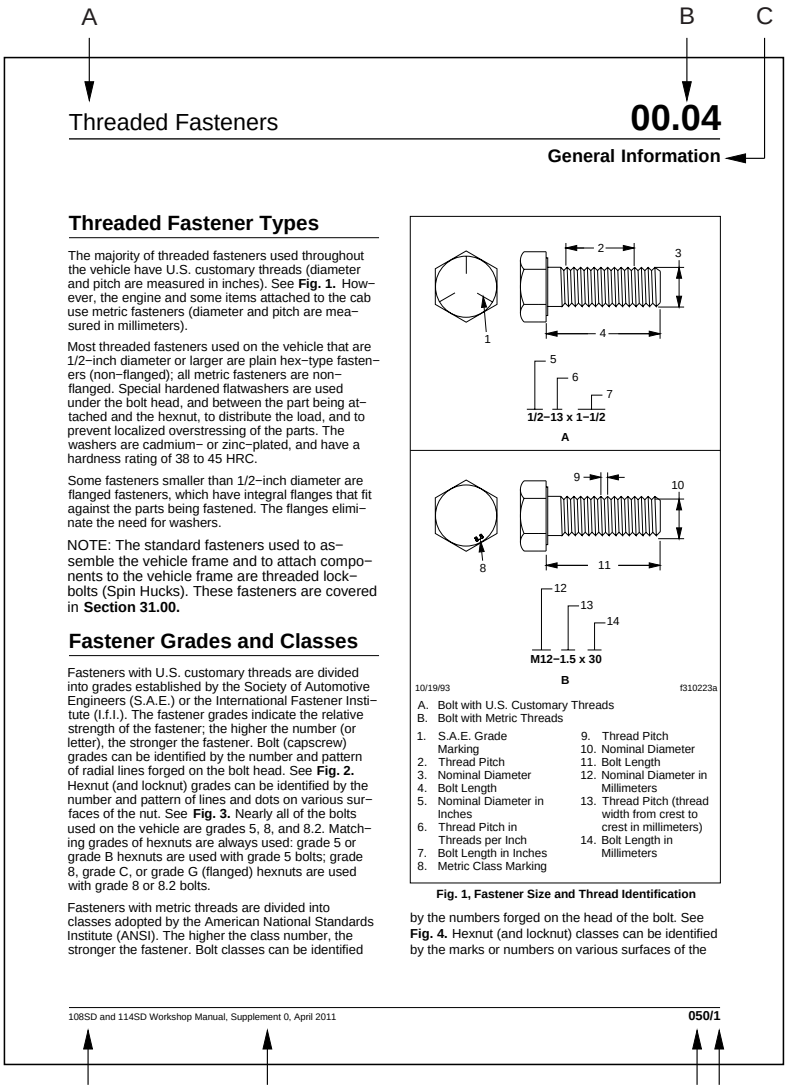
Warranty-related service information available on the AccessFreightliner.com website includes the following documentation.

Recall Campaigns Recall campaigns cover situations that involve service work or replacement of parts in connection with a recall notice. These campaigns pertain to matters of vehicle safety. All recall campaigns are distributed to dealers; customers receive notices that apply to their vehicles.

Field Service Campaigns Field service campaigns are concerned with non-safety-related service work or replacement of parts. All field service campaigns are distributed to dealers; customers receive notices that apply to their vehicles.

Page Description

For an example of a *108SD and 114SD Workshop Manual* page, see **Fig. 1**.



A. Section Title
B. Section Number (made up of the Group Number—first two digits, followed by a sequence number—last two digits)
C. Subject Title
D. Manual Title
E. Release (Supplement) Date
F. Subject Number
G. Subject Page Number

Fig. 1, Example of a 108SD and 114SD Workshop Manual Page

Workshop Manual Contents

Group No.	Group Title
00	General Information
01	Engine
09	Air Intake
13	Air Compressor
15	Alternators and Starters
20	Engine Cooling/Radiator
25	Clutch
26	Transmission
30	Throttle Control
31	Frame and Frame Components
32	Suspension
33	Front Axle
35	Rear Axle
40	Wheels and Tires
41	Driveline
42	Brakes
46	Steering
47	Fuel
49	Exhaust
54	Electrical, Instruments, and Controls
60	Cab
72	Doors
82	Windshield Wipers and Washer
83	Heater and Air Conditioner
88	Hood, Grille, and Cab Fenders
91	Seats and Restraint Systems
98	Paint

VIN Information

Federal Motor Vehicle Safety Standard 115 specifies that all vehicles sold in the U.S. be assigned a 17-character Vehicle Identification Number (VIN). Using a combination of letters and numerals, the VIN defines the manufacturer, model, and major characteristics of the vehicle. See **Table 1** for the character positions of a typical Freightliner VIN, 1FUPABAV11PA12345.

The VIN can be found on the Vehicle Specification Decal (see the vehicle driver's manual for decal location), and the last six digits (designating the chassis serial number) are stamped into the metal frame.

Each product line has its own model list; that is, positions 5 and 6 are product-specific. For example, the code AB in positions 5 and 6 for a Freightliner vehicle indicates an FLD112 conventional truck. Code AB in the same position for a FCCC chassis vehicle represents an MB45 chassis.

For all vehicles, a check digit (9th character) is determined by assignment of weighted values to the other 16 characters. These weighted values are processed through a series of equations designed to check validity of the VIN and to detect VIN alteration.

NOTE: Always specify the VIN when ordering parts.

Seventeen-Character Vehicle Identification Number (VIN)								
Typical VIN	**1 F U**	**P**	**A B**	**A V**	**1**	**1**	**P**	**A 1 2 3 4 5**
Character Position	1, 2, 3	4	5, 6	7, 8	9	10	11	12–17
Code Description	World Manufacturer Identification	Chassis Configuration	Model, Cab, GVWR	Engine, Brakes	Check Digit Calculation	Model Year	Build Location	Production Serial Number
Decoding Table*	**Table 2**	**Table 3**	**Table 4**	**Table 5**	—	**Table 6**	**Table 7**	—

* For corresponding decoding information, see the applicable tables in this subject.

Table 1, Seventeen-Character Vehicle Identification Number (VIN)

VIN Positions 1, 2, and 3 (World Manufacturer Identification)			
Code	**Vehicle Manufacturer**	**Vehicle Make**	**Vehicle Type**
1FU	Freightliner, U.S.A.	Freightliner	Truck-Tractor
1FV	Freightliner, U.S.A.	Freightliner	Incomplete Vehicle
3AK	Daimler AG, Mexico	Freightliner	Truck-Tractor
3AL	Daimler AG, Mexico	Freightliner	Incomplete Vehicle
RSA	NAI, Saudi Arabia	Freightliner	Incomplete Vehicle
RSB	NAI, Saudi Arabia	Freightliner	Truck-Tractor

Table 2, VIN Positions 1, 2, and 3 (World Manufacturer Identification)

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
A	4 x 2 Truck
B	4 x 2 Truck-Tractor
C	8 x 8 Truck
D	4 x 4 Truck
E	4 x 4 Truck-Tractor

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
F	6 x 2 Truck
G	6 x 2 Truck-Tractor
H	6 x 4 Truck
J	6 x 4 Truck-Tractor
K	6 x 6 Truck

VIN Information

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
L	6 x 6 Truck-Tractor
M	8 x 4 Truck
N	8 x 4 Truck-Tractor
P	8 x 6 Truck
R	8 x 6 Truck-Tractor
S	10 x 4 Truck
T	10 x 4 Truck-Tractor
U	10 x 6 Truck

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
V	10 x 6 Truck-Tractor
W	12 x 4 Truck
X	Glider
Y	8 x 2 Truck
Z	14 x 4 Truck
1	12 x 6 Truck

Table 3, VIN Position 4 (Chassis Configuration)

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
AA	FLB Glider	COE	Glider
AB	FLD112	Conventional	Class 7
AC	FLD112	Conventional	Class 8
AD	FLD112 Glider	Conventional	Glider
AE	FLD112 SD	Conventional	Class 8
AF	FLD112 SD Glider	Conventional	Glider
AG	FLD120	Conventional	Class 7
AH	FLD120	Conventional	Class 8
AJ	FLD120 Glider	Conventional	Glider
AK	FLD120 SD	Conventional	Class 7
AL	FLD120 SD	Conventional	Class 8
AM	FLD120 SD Glider	Conventional	Glider
AN	FLD132 XL Classic	Conventional	Class 7
AP	FLD132 XL Classic	Conventional	Class 8
AR	FLD132 XL Glider	Conventional	Glider
AS	FLD120 Military	Conventional	Class 7
AT	FLD120 Military	Conventional	Class 8
AU	FLD120 Military Glider	Conventional	Glider
AV	Argosy	COE	Class 7
AW	Argosy	COE	Class 8
AX	Argosy Glider	COE	Glider
AY	C112	Conventional	Class 7
AZ	C112	Conventional	Class 8
A1	C112 Glider	Conventional	Glider
A2	C120	Conventional	Class 7

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
A3	C120	Conventional	Class 8
A4	C120 Glider	Conventional	Glider
A5	Columbia 120	Conventional	Class 7
A6	Columbia 120	Conventional	Class 8
A7	Columbia 120 Glider	Conventional	Glider
A8	CST112	Conventional	Class 7
A9	CST112	Conventional	Class 8
A0	CST112 Glider	Conventional	Glider
BA	CST120	Conventional	Class 7
BB	CST120	Conventional	Class 8
BC	CST120 Glider	Conventional	Glider
BD	FLD120 Classic Legacy	Conventional	Class 8
BE	FLS112 Legacy	Conventional	Class 8
BF	FL112	Conventional	Class 7
BG	FL112	Conventional	Class 8
BH	FL112 Glider	Conventional	Glider
BJ	FL50	Conventional	Class 4
BK	FL50	Conventional	Class 5
BL	FL50	Conventional	Class 6
BM	FL50	Conventional	Class 7
BN	FL60	Conventional	Class 5
BP	FL60	Conventional	Class 6
BR	FL60	Conventional	Class 7
BS	FL70	Conventional	Class 6
BT	FL70	Conventional	Class 7
BU	FL70	Conventional	Class 8
BV	FL80	Conventional	Class 6
BW	FL80	Conventional	Class 7
BX	FL80	Conventional	Class 8
BY	FL106	Conventional	Class 6
BZ	FL106	Conventional	Class 7
B1	FL106	Conventional	Class 8
B2	FC70 Cargo	COE	Class 6
B3	FC70 Cargo	COE	Class 7
B4	FC70 Cargo	COE	Class 8
B5	FC80 Cargo	COE	Class 6

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
B6	FC80 Cargo	COE	Class 7
B7	FC80 Cargo	COE	Class 8
B8	RIV	None	Class 8
B9	Sport Chassis	Conventional	Class 6
B0	Sport Chassis	Conventional	Class 7
CA	FL106 Glider	Conventional	Glider
CB	FL60 Glider	Conventional	Glider
CC	FL70 Glider	Conventional	Glider
CD	FL80 Glider	Conventional	Glider
CE	Condor	COE	Class 7
CF	Condor	COE	Class 8
CG	FLD120/84" Sleeper MY2001	Conventional	Class 7
CH	FLD120/84" Sleeper MY2001	Conventional	Class 8
CJ	FLD120 Glider/84" Sleeper MY2001	Conventional	Glider
CK	FLD132 XL Classic/84" Sleeper MY2001	Conventional	Class 7
CL	FLD132 XL Classic/84" Sleeper MY2001	Conventional	Class 8
CM	FLD 132 XL Glider/84" Sleeper	Conventional	Glider
CN	FL112	Conventional	Class 6
CP	FLD120 Military Reman	Conventional	Class 8
CR	Coronado CC132	Conventional	Class 8
CS	M2 100	Conventional	Class 4
CT	M2 100	Conventional	Class 5
CU	M2 100	Conventional	Class 6
CV	M2 106 Medium Duty	Conventional	Class 5
CW	M2 106 Medium Duty	Conventional	Class 6
CX	M2 106 Medium Duty	Conventional	Class 7
CY	M2 106 Medium Duty	Conventional	Class 8
CZ	M2 106V Heavy Duty	Conventional	Class 5
C1	M2 106V Heavy Duty	Conventional	Class 6
C2	M2 106V Heavy Duty	Conventional	Class 7
C3	M2 106V Heavy Duty	Conventional	Class 8
C4	M2 112 Medium Duty	Conventional	Class 7
C5	M2 112 Medium Duty	Conventional	Class 8
C6	M2 112V Heavy Duty	Conventional	Class 7
C7	M2 112V Heavy Duty	Conventional	Class 8
C8	M2 106 Medium Duty	Conventional	Class 4

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
C9	Sport Chassis	Conventional	Class 5
F1	Sport Chassis 112	Conventional	Class 6
F2	FLB High COE	COE	Class 8
F3	Sport Chassis 112	Conventional	Class 7
F4	Coronado CC132	Conventional	Class 7
F5	Classic 120	Conventional	Class 7
F6	Classic 120	Conventional	Class 8
F7	Condor Glider	Conventional	Glider
F8	M2 106 Medium Glider	Conventional	Glider
F9	Columbia 112	Conventional	Class 7
F0	Columbia 112	Conventional	Class 8
FA	Columbia 112	Conventional	Glider
FB	Coronado CC132 Glider	Conventional	Glider
FC	M2 106 Sport Chassis	Conventional	Class 5
FD	M2 106 Sport Chassis	Conventional	Class 6
FE	M2 106 Sport Chassis	Conventional	Class 7
FF	M2 112 Sport Chassis	Conventional	Class 5
FG	M2 112 Sport Chassis	Conventional	Class 6
FH	M2 112 Sport Chassis	Conventional	Class 7
FJ	Classic 120	Conventional	Glider
GA	Cascadia 113 Day Cab	Conventional	Class 7
GB	Cascadia 113 Day Cab	Conventional	Class 8
GC	Cascadia 113 Sleeper Cab	Conventional	Glider
GD	Cascadia 125 Day Cab	Conventional	Class 7
GE	Cascadia 125 Day Cab	Conventional	Class 8
GF	Cascadia 125 Sleeper Cab	Conventional	Glider
GG	Cascadia 113 Sleeper Cab	Conventional	Class 7
GH	Cascadia 113 Sleeper Cab	Conventional	Class 8
GJ	Cascadia 132	Conventional	Glider
GK	Cascadia 125 Sleeper Cab	Conventional	Class 7
GL	Cascadia 125 Sleeper Cab	Conventional	Class 8
GM	Coronado 132	Conventional	Class 8
GN	Coronado SD 122	Conventional	Class 8
GP	Coronado 122	Conventional	Class 8
GR	Coronado 122	Conventional	Glider
GS	Coronado SD 122 Glider	Conventional	Glider

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**GVWR**
GT	Coronado 132	Conventional	Glider
GU	M2 106V Glider	Conventional	Glider
GV	Coronado 122 RHD	Conventional	Class 8
GW	Coronado 122 RHD Glider	Conventional	Glider
GX	Coronado 132	Conventional	Class 7
GY	Coronado SD 122	Conventional	Class 7
GZ	Coronado 122	Conventional	Class 7
G1	M2 112 Glider	Conventional	Glider
G2	MD109 Military	Conventional	Class 8
G3	114SD	Conventional	Class 8
G4	114SD	Conventional	Glider
G5	108SD	Conventional	Class 8
G6	108SD	Conventional	Glider
G7	Coronado 114 RHD	Conventional	Class 8
G8	Coronado 114 RHD	Conventional	Glider
G9	114SD	Conventional	Class 7
G0	108SD	Conventional	Class 7
HA	Cascadia 113 Day Cab	Conventional	Glider
HB	Cascadia 125 Day Cab	Conventional	Glider
HC	108SD	Conventional	Class 6
HD	M2 100	Conventional	Class 7

Table 4, VIN Positions 5 and 6 (Model, Cab, Class/GVWR)

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
AA	Caterpillar 3176	Diesel	10.3 Liter	I-6	Air
AB	Caterpillar 3176	Diesel	10.3 Liter	I-6	Hydraulic
AC	Caterpillar 3176	Diesel	10.3 Liter	I-6	Air/Hydraulic
AD	Caterpillar 3406	Diesel	14.6 Liter	I-6	Air
AE	Caterpillar 3406	Diesel	14.6 Liter	I-6	Hydraulic
AF	Caterpillar 3406	Diesel	14.6 Liter	I-6	Air/Hydraulic
AG	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Air
AH	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Hydraulic
AJ	Caterpillar 3406 E	Diesel	15.8 Liter	I-6	Air/Hydraulic
AK	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Air
AL	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Hydraulic

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
AM	Caterpillar 3126/CFE	Diesel	7.2 Liter	I-6	Air/Hydraulic
AN	Caterpillar C10	Diesel	10.3 Liter	I-6	Air
AP	Caterpillar C10	Diesel	10.3 Liter	I-6	Hydraulic
AR	Caterpillar C10	Diesel	10.3 Liter	I-6	Air/Hydraulic
AS	Caterpillar C12	Diesel	12.0 Liter	I-6	Air
AT	Caterpillar C12	Diesel	12.0 Liter	I-6	Hydraulic
AU	Caterpillar C12	Diesel	12.0 Liter	I-6	Air/Hydraulic
AV	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Air
AW	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Hydraulic
AX	Caterpillar C15	Diesel	14.6 Liter pre 2008/15.2 Liter	I-6	Air/Hydraulic
AY	Caterpillar C16	Diesel	15.8 Liter	I-6	Air
AZ	Caterpillar C16	Diesel	15.8 Liter	I-6	Hydraulic
A1	Caterpillar C16	Diesel	15.8 Liter	I-6	Air/Hydraulic
A2	Cummins L10	Diesel	10.8 Liter	I-6	Air
A3	Cummins L10	Diesel	10.8 Liter	I-6	Hydraulic
A4	Cummins L10	Diesel	10.8 Liter	I-6	Air/Hydraulic
A5	Cummins M11	Diesel	10.8 Liter	I-6	Air
A6	Cummins M11	Diesel	10.8 Liter	I-6	Hydraulic
A7	Cummins M11	Diesel	10.8 Liter	I-6	Air/Hydraulic
A8	Cummins ISM	Diesel	10.8 Liter	I-6	Air
A9	Cummins ISM	Diesel	10.8 Liter	I-6	Hydraulic
A0	Cummins ISM	Diesel	10.8 Liter	I-6	Air/Hydraulic
BA	Cummins NTC	Diesel	14 Liter	I-6	Air
BB	Cummins NTC	Diesel	14 Liter	I-6	Hydraulic
BC	Cummins NTC	Diesel	14 Liter	I-6	Air/Hydraulic
BD	Cummins N14	Diesel	14 Liter	I-6	Air
BE	Cummins N14	Diesel	14 Liter	I-6	Hydraulic
BF	Cummins N14	Diesel	14 Liter	I-6	Air/Hydraulic
BG	Cummins ISX	Diesel	14.9 Liter	I-6	Air
BH	Cummins ISX	Diesel	14.9 Liter	I-6	Hydraulic
BJ	Cummins ISX	Diesel	14.9 Liter	I-6	Air/Hydraulic
BK	Cummins C 8.3	Diesel	8.3 Liter	I-6	Air
BL	Cummins C 8.3	Diesel	8.3 Liter	I-6	Hydraulic
BM	Cummins C 8.3	Diesel	8.3 Liter	I-6	Air/Hydraulic

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
BN	Cummins B5.9	Diesel	5.9 Liter	I-6	Air
BP	Cummins B5.9	Diesel	5.9 Liter	I-6	Hydraulic
BR	Cummins B5.9	Diesel	5.9 Liter	I-6	Air/Hydraulic
BS	Cummins ISC	Diesel	8.3 Liter	I-6	Air
BT	Cummins ISC	Diesel	8.3 Liter	I-6	Hydraulic
BU	Cummins ISC	Diesel	8.3 Liter	I-6	Air/Hydraulic
BV	Cummins ISB	Diesel	5.9 Liter	I-6	Air
BW	Cummins ISB	Diesel	5.9 Liter	I-6	Hydraulic
BX	Cummins ISB	Diesel	5.9 Liter	I-6	Air/Hydraulic
BY	Cummins B5.9	Propane	5.9 Liter	I-6	Air
BZ	Cummins B5.9	Propane	5.9 Liter	I-6	Hydraulic
B1	Cummins B5.9	Propane	5.9 Liter	I-6	Air/Hydraulic
B2	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Air
B3	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Hydraulic
B4	Cummins B5.9	Natural Gas	5.9 Liter	I-6	Air/Hydraulic
B5	Cummins C8.3	Natural Gas	8.3 liter	I-6	Air
B6	Cummins C8.3	Natural Gas	8.3 liter	I-6	Hydraulic
B7	Cummins C8.3	Natural Gas	8.3 liter	I-6	Air/Hydraulic
B8	Detroit Series 50	Diesel	8.5 liter	I-4	Air
B9	Detroit Series 50	Diesel	8.5 liter	I-4	Hydraulic
B0	Detroit Series 50	Diesel	8.5 liter	I-4	Air/Hydraulic
CA	Detroit Series 55	Diesel	12.Liter	I-6	Air
CB	Detroit Series 55	Diesel	12.Liter	I-6	Hydraulic
CC	Detroit Series 55	Diesel	12.Liter	I-6	Air/Hydraulic
CD	Detroit Series 60	Diesel	11.1 Liter	I-6	Air
CE	Detroit Series 60	Diesel	11.1 Liter	I-6	Hydraulic
CF	Detroit Series 60	Diesel	11.1 Liter	I-6	Air/Hydraulic
CG	Detroit Series 60	Diesel	12.7 Liter	I-6	Air
CH	Detroit Series 60	Diesel	12.7 Liter	I-6	Hydraulic
CJ	Detroit Series 60	Diesel	12.7 Liter	I-6	Air/Hydraulic
CK	Detroit Series 60	Diesel	14.0 Liter	I-6	Air
CL	Detroit Series 60	Diesel	14.0 Liter	I-6	Hydraulic
CN	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Air
CP	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Hydraulic
CR	Mercedes-Benz MBE-900	Diesel	4.3 liter	I-4	Air/Hydraulic
CS	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Air

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
CT	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Hydraulic
CU	Mercedes-Benz MBE-900	Diesel	6.4 liter	I-6	Air/Hydraulic
CV	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Air
CW	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Hydraulic
CX	Mercedes-Benz MBE4000	Diesel	12.8 Liter	I-6	Air/Hydraulic
CY	Cummins ISL	Diesel	8.9 Liter	I-6	Air
CZ	Cummins ISL	Diesel	8.9 Liter	I-6	Hydraulic
C1	Cummins ISL	Diesel	8.9 Liter	I-6	Air/Hydraulic
C2	Cummins B 3.9	Diesel	3.9 Liter	I-4	Air
C3	Cummins B 3.9	Diesel	3.9 Liter	I-4	Hydraulic
C4	Cummins B 3.9	Diesel	3.9 Liter	I-4	Air/Hydraulic
C5	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Air
C6	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Hydraulic
C7	Cummins ISB 3.9	Diesel	3.9 Liter	I-4	Air/Hydraulic
C8	John Deere 6081H	CNG	8.1 Liter	I-6	Air
C9	John Deere 6081H	CNG	8.1 Liter	I-6	Hydraulic
DA	Caterpillar C9	Diesel	8.8 Liter	I-6	Air
DB	Caterpillar C9	Diesel	8.8 Liter	I-6	Hydraulic
DC	Caterpillar C7	Diesel	7.2 Liter	I-6	Air
DD	Caterpillar C7	Diesel	7.2 Liter	I-6	Hydraulic
DE	Caterpillar C13	Diesel	12.5 Liter	I-6	Air
DF	Caterpillar C13	Diesel	12.5 Liter	I-6	Hydraulic
DG	Mercedes-Benz MBE-900	Diesel	4.8 Liter	I-4	Air
DH	Mercedes-Benz MBE-900	Diesel	4.8 Liter	I-4	Hydraulic
DJ	Mercedes-Benz MBE-900	Diesel	7.2 Liter	I-6	Air
DK	Mercedes-Benz MBE-900	Diesel	7.2 Liter	I-6	Hydraulic
DL	Caterpillar C11	Diesel	11.1 Liter	I-6	Air
DM	Caterpillar C11	Diesel	11.1 Liter	I-6	Hydraulic
DN	Cummins L Gas Plus	Natural Gas	8.9 Liter	I-6	Air
DP	Cummins L Gas Plus	Natural Gas	8.9 Liter	I-6	Hydraulic
DR	Detroit DD15	Diesel	14.8 Liter	I-6	Air
DS	Detroit DD15	Diesel	14.8 Liter	I-6	Hydraulic
DT	Cummins ISB	Diesel	6.7 Liter	I-6	Air
DU	Cummins ISB	Diesel	6.7 Liter	I-6	Hydraulic
DV	Detroit DD13	Diesel	12.8 Liter	I-6	Air
DW	Detroit DD13	Diesel	12.8 Liter	I-6	Hydraulic

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement**	**Configuration**	**Brakes**
DX	Cummins ISL G	Natural Gas	8.9 Liter	I-6	Air
DY	Cummins ISL G	Natural Gas	8.9 Liter	I-6	Hydraulic
D1	Detroit DD16	Diesel	15.6 Liter	I-6	Air
D2	MDEG 7.7	Diesel	7.7 Liter	I-6	Air
D3	MDEG 7.7	Diesel	7.7 Liter	I-6	Hydraulic
D4	Cummins ISX12	Diesel	11.9 Liter	I-6	Air
D5	Detroit DD15 EV	Diesel	14.8 Liter	I-6	Air
D6	Detroit DD15 STD	Diesel	14.8 Liter	I-6	Air
D7	Detroit DD15 EV	Diesel	14.8 Liter	I-6	Hydraulic
D8	Detroit DD15 STD	Diesel	14.8 Liter	I-6	Hydraulic
D9	Cummins ISX12	Natural Gas	11.9 Liter	I-6	Air
00	NO ENGINE				

Table 5, VIN Positions 7 and 8 (Engine and Brakes)

VIN Position 10 (Model Year)	
Code	**Model Year**
Y	2000
1	2001
2	2002
3	2003
4	2004
5	2005
6	2006
7	2007
8	2008
9	2009
A	2010
B	2011
C	2012
D	2013

Table 6, VIN Position 10 (Model Year)

VIN Position 11 (Build Location)	
Code	**Plant of Manufacture**
L	Cleveland, North Carolina
P	Portland, Oregon
D	Daimler AG, Santiago, Mexico
S	Daimler AG, Saltillo, Coahuila Mexico
H	Mt. Holly, North Carolina

Table 7, VIN Position 11 (Build Location)

General Information

Daimler Trucks North America LLC distributes service and repair information for all vehicle systems, except major components such as engines, transmissions, and rear axles. Information on major components can often be found on the orignial equipment manufacturers' (OEM) website, many of which are listed below. The list also includes OEM websites for a number of other vehicle component or system providers, but is not comprehensive, and does not include websites for all OEMs.

OEM Websites

Click on the website address.

AC Delco www.acdelco.com

Accuride Corp. www.accuride.com

Aisin Transmission www.aisin.com

Allied Signal Inc. www.honeywell.com

Allison Transmission www.allisontransmission.com

Arctic Fox www.arctic-fox.com

Arvin Meritor www.arvinmeritor.com

Bendix www.bendix.com

Borg Warner www.borgwarner.com

Bosch www.bosch.com

Bostrom www.bostromseating.com

Caterpillar Inc. www.ohe.cat.com

Chicago Rawhide www.skf.com

ConMet www.conmet.com

Cummins Engine www.cummins.com

Dana Corp. www.dana.com

DAVCO www.davcotec.com

Delco Remy www.delcoremy.com

Denso Corp. www.densocorp-na.com

Detroit Diesel www.detroitdiesel.com

Dometic-Tundra Refrigerators www.dometic.com

Donaldson Company www.donaldson.com

Eaton Corp. www.eaton.com

Enviromech Industries www.emifuel.com

Espar Heating Systems www.espar.com

Fleetguard www.cumminsfiltration.com

Fontaine www.fontaineintl.com

Grote www.grote.com

Haldex Brake Systems www.haldex.com

Hendrickson www.hendrickson-intl.com

Holland Fifth Wheels www.thehollandgroupinc.com

Horton, Inc. www.hortonww.com

Jost Fifth Wheels www.jostinternational.com

Lang Mekra www.lang-mekra.com

Marmon Group www.marmon-herrington.com

Meritor-WABCO www.meritorwabco.com

MGM Brakes www.mgmbrakes.com

National Seating www.cvgrp.com

Nexgen Fueling www.nexgenfueling.com

Parker (Racor) www.parker.com

RoadRanger www.roadranger.com

R. A. Miller Antenna www.rami.com

Sears Seating www.searsseating.com

Simplex Fifth Wheels www.thehollandgroupinc.com

Truck-Lite www.truck-lite.com

TRW Inc. www.trucksteering.com

Visteon www.visteon.com

ZF www.zf.com

List of Abbreviations

The following is a list of definitions for abbreviations and symbols used in Freightliner publications.

A ..... amperes
AAVA ..... auxiliary air valve assembly
ABS ..... antilock braking system
ABS ..... acrylonitrile-butadiene-styrene
A/C ..... air conditioner
AC ..... alternating current
acc ..... accessories
ACM ..... aftertreatment control module
ACPU ..... air conditioning protection unit
ADLO ..... auto-disengagement lockout
AGM ..... absorbed glass mat
AGS ..... automated gear shift
AG2 ..... Aluminum Generation 2
a.m. ..... *ante meridiem* (midnight to noon)
AM ..... amplitude modulation
amp(s) ..... ampere(s)
AMT ..... automated mechanical transmission
AMU ..... air management unit
ANSI ..... American National Standards Institute
API ..... American Petroleum Institute
API ..... application programming interface
ARI ..... Air Conditioning and Refrigeration Institute
ASA ..... American Standards Association
ASF ..... American Steel Foundries
ASR ..... automatic spin regulator
assy. ..... assembly
ASTM ..... American Society for Testing and Materials
ATC ..... automatic temperature control
ATC ..... automatic traction control
ATC ..... automatic transmission control
ATD ..... aftertreatment device
ATF ..... automatic transmission fluid
ATS ..... aftertreatment system
attn ..... attention
aux. ..... auxiliary
av ..... *avoirdupois* (British weight system)
AWD ..... all-wheel drive
AWG ..... American wire gauge
AWS ..... American Welding Society
BAT ..... battery
BBC ..... bumper-to-back-of-cab
BHM ..... bulkhead module
BOC ..... back-of-cab
BOM ..... bill of material
BTDC ..... before top dead center
Btu(s) ..... British thermal unit(s)
C ..... common (terminal)
CAC ..... charge air cooler
CAN ..... controller area network
CARB ..... California Air Resources Board
CAT ..... Caterpillar
CB ..... circuit breaker
CB ..... citizens' band
CBE ..... cab behind engine
CCA ..... cold cranking amperes
CCR ..... California Code of Regulations
CD-ROM .. compact-disc/read-only memory
CDTC ..... constant discharge temperature control
CEL ..... check-engine light
CFC ..... chlorofluorocarbons (refrigerant-12)
cfm ..... cubic feet per minute
CFR ..... Code of Federal Regulations
CGI ..... clean gas induction
CGW ..... central gateway
CHM ..... chassis module
CIP ..... cold inflation pressure
CLDS ..... cab load disconnect switch
CLS ..... coolant level sensor
cm ..... centimeters
cm^3 ..... cubic centimeters
CMVSS .... Canadian Motor Vehicle Safety Standard
Co. ..... company
COE ..... cab over engine
Corp. ..... corporation
CPC ..... common powertrain controller
CPU ..... central processing unit
CRT ..... cathode ray tube
cSt ..... centistokes (unit of measurement for describing the viscosity of general liquids)
cu ft ..... cubic feet
cu in ..... cubic inches
CUM ..... Cummins
CVSA ..... Commercial Vehicle Safety Alliance
CWS ..... collision warning system
DC ..... direct current
DCA ..... diesel coolant additive
DCDL ..... driver-controlled differential lock
DDA ..... Detroit Diesel Allison (obs)
DDC ..... Detroit Diesel Corporation
DDDL ..... Detroit Diesel Diagnostic Link
DDE ..... Detroit Diesel Engines
DDEC ..... Detroit Diesel Electronic (engine) Control
DDR ..... diagnostic data reader
DDU ..... driver display unit
def ..... defrost
DEF ..... diesel exhaust fluid
DFI ..... direct fuel injection
DGPS ..... differential global positioning system
DHD ..... dealer help desk
dia. ..... diameter
DIAG ..... diagnosis
DIP ..... dual inline package (switch)
DIU ..... driver interface unit
DLA ..... datalink adaptor
DLM ..... datalink monitor
DLU ..... data logging unit
DMM ..... digital multimeter
DOC ..... diesel oxidation catalyst
DOT ..... Department of Transportation
DPF ..... diesel particulate filter
DRL ..... daytime running lights
DRM ..... dryer reservoir module
DSM ..... district service manager
DTC ..... diagnostic trouble code
DTC ..... discharge temperature control
DTNA ..... Daimler Trucks North America
DVOM ..... digital volt/ohm meter
ea. ..... each
EBS ..... electronic braking system
ECA ..... electric clutch actuator
ECAP ..... electronic control analyzer programmer
ECAS ..... electronically controlled air suspension

List of Abbreviations

ECI ..... electronically controlled injection
ECL ..... engine coolant level
ECM ..... electronic control module
ECT ..... engine coolant temperature
ECU ..... electronic control unit
EDM ..... electronic data monitor
EEPROM .. electrically erasable programmable read-only memory
EFG ..... electric fuel gauge
EFPA ..... electronic foot pedal assembly
EGR ..... exhaust gas recirculation
ELC ..... extended-life coolant
EMC ..... electromagnetic compatibility
EMI ..... electromagnetic interference
EOA ..... electric over air
EP ..... extreme pressure (describes an antiwear agent added to some lubricants)
EPA ..... Environmental Protection Agency
EPS ..... engine position sensor
ESC ..... electronic stability control
ESC ..... enhanced stability control
ESD ..... electrostatic discharge
ESS ..... engine syncro shift (transmission)
etc. ..... *et cetera* (and so forth)
ETEC ..... electronic truck engine control
EUI ..... electronic unit (fuel) injectors
EVA ..... electronic vibration analyzer
EXM ..... (chassis) expansion module
E85 ..... 85% ethanol fuel
FAS ..... Freightliner air suspension
FCCC ..... Freightliner Custom Chassis Corporation
FCU ..... forward control unit
FET ..... field effect transistor
Fig. ..... figure
fl oz ..... fluid ounces
FLA ..... post-1984 advancements Freightliner COE
FLB ..... enhanced Freightliner FLA COE
FLC ..... steel-cab Freightliner 112 Conventional
FLD ..... post-1984 advancements Freightliner 112/120 aluminum-cab Conventional
FLR ..... forward-looking radar
FM ..... frequency modulation
FMCSA .... Federal Motor Carrier Safety Administration
FMEA ..... failure mode effects analysis
FMI ..... failure mode indicator
FMSI ..... Friction Materials Standards Institute
FMVSS .... Federal Motor Vehicle Safety Standard
FRP ..... fiberglass reinforced plastic
FSA ..... field service authorization
FSM ..... fleet service manager
ft ..... feet
ft^3 ..... cubic feet
ft^3/min ..... cubic feet per minute
FTL ..... Freightliner
F.U.E.L. .... fuel usage efficiency level
g ..... grams
gal ..... gallons
GAWR ..... gross axle weight rating
GHG ..... greenhouse gas
GHG14 .... greenhouse gas and fuel efficiency regulations
GL ..... gear lubricant
GND ..... ground
gpm ..... gallons per minute
GPS ..... global positioning system
GVWR ..... gross vehicle weight rating
HBED ..... hard-braking event data
HCM ..... hybrid control module
HCOE ..... high cab over engine
HCU ..... hydraulic control unit
HD ..... heavy-duty
HDU ..... hybrid drive unit
HEPA ..... high-efficiency particulate air (filter)
HEST ..... high exhaust system temperature
HEV ..... hybrid electric vehicle
HFC ..... hydrogenated fluorocarbons (refrigerant-134a)
hp ..... horsepower
hp ..... high pressure
HRC ..... Rockwell "C" hardness
hr(s) ..... hour(s)
HSA ..... hill start aid
HSD ..... high-side driver
htr. ..... heater
HVAC ..... heating, ventilating, and air conditioning
HVLP ..... high velocity, low pressure
H/W ..... hardware
Hz ..... hertz
IAD ..... interaxle differential
ICS ..... integrated child seat
ICU ..... instrumentation control unit
i.d. ..... inside diameter
ID ..... identification
IFI ..... Industrial Fasteners Institute
IFS ..... independent front suspension
IGN ..... ignition
ILB ..... intelligent lightbar
ILO ..... *in lieu of* (in the place of)
in ..... inches
in^3 ..... cubic inches
Inc. ..... incorporated
inH_2O ..... inches of water
inHg ..... inches of mercury
I/O ..... input/output
IP ..... instrument panel
ISO ..... International Organization for Standardization
IVS ..... idle validation switch
k ..... kilo (1000)
kg ..... kilograms
km ..... kilometers
km/h ..... kilometers per hour
kPa ..... kilopascals
kW ..... kilowatts
L ..... liters
lb ..... pounds
LBCU ..... lightbar control unit
lbf·ft ..... pounds force feet
lbf·in ..... pounds force inches
LCD ..... liquid crystal display
LCOE ..... low cab over engine
LED ..... light-emitting diode
LFL ..... lower flammability limit
LH ..... left-hand
LHD ..... left-hand drive
LH DR ..... left-hand-drive
LHK ..... liters per hundred kilometers
LHS ..... low-hydrogen steel
LIN ..... Local Interconnect Network
LLC ..... limited liability company
L/min ..... liters per minute
LNG ..... liquefied natural gas
LPG ..... liquefied petroleum gas

List of Abbreviations

LPG ..... liquid propane gas
LPI ..... liquid propane injection
LPR ..... low pressure reservoir
LRR ..... low-rolling resistance
LSD ..... low-side driver
LVD ..... low-voltage disconnect
m ..... meters
max. ..... maximum
M-B ..... Mercedes-Benz
MCM ..... motor control module
MESA ..... Mining Enforcement Safety Act
mfr. ..... manufacturer
mi ..... miles
MID ..... message identifier
MIL ..... malfunction indicator lamp (light)
MIL ..... military specification
min. ..... minutes
min. ..... minimum
misc. ..... miscellaneous
mL ..... milliliters
mm ..... millimeters
mod. ..... module
mpg ..... miles per gallon
mph ..... miles per hour
MSF ..... modular switch field
MMT ..... methylcyclopentadienyl manganese tricarbonyl
MSHA ..... Mining Safety and Health Administration
MVDA ..... Motor Vehicle Dealers Association
n ..... negative (front axle wheel alignment specification)
N ..... nitrogen
N/A ..... not applicable
N·cm ..... Newton-centimeters
NC ..... normally closed (terminal or switch)
NCG ..... noncondensable gases
NHTSA ..... National Highway Traffic Safety Administration
NIOSH ..... National Institute for Occupational Safety and Health
NITE ..... no idle thermal environment
NLA ..... no longer available
NLGI ..... National Lubricating Grease Institute
N·m ..... Newton-meters
NO ..... normally open (terminal or switch)
NOAT ..... Nitrited Organic Acid Technology
NOx ..... nitrogen oxides
no. ..... number
NPT ..... national pipe thread
NPTF ..... national pipe thread fitting
NT ..... nylon tube or nylon tubing
NTSB ..... National Transportation Safety Board
OAT ..... Organic Acid Technology
OBD(s) ..... on-board diagnostic(s)
obs ..... obsolete
OC ..... open circuit
OCV ..... open circuit voltage
o.d. ..... outside diameter
O.D. ..... overdrive
OEM ..... original equipment manufacturer
OPD ..... overfill protection device
OSHA ..... Occupational Safety and Health Administration
oz ..... ounces
ozf·in ..... ounces force inches
p ..... positive (front axle wheel alignment specification)
PACE ..... programmable electronically controlled engine
PAG ..... polyalkylene glycol (oil)
parm ..... parameter
PAS ..... passenger advisory system
PC ..... personal computer
PCB ..... printed circuit board
PDC(s) ..... parts distribution center(s)
PDI ..... pre-delivery inspection
PDM ..... power distribution module
PEC ..... power electronics carrier
PEEC ..... programmable electronic engine control
PID ..... parameter identifier
PKP ..... Purple-K powder
PLC ..... power line carrier
PLD ..... *Pumpe-Linie-Düse* (pump-line-nozzle)
PNDB ..... power-net distribution box
PM ..... particulate matter
p.m. ..... *post meridiem* (noon to midnight)
p/n ..... part number
PO ..... purchase order
POE ..... polyol ester
PRD ..... pressure relief device
PRD ..... product requirements document
PSA ..... pressure-sensitive adhesive
PSG ..... pressure sensor governor
psi ..... pounds per square inch
psia ..... pounds per square inch, atmosphere
psig ..... pounds per square inch, gauge
pt ..... pints
PTCM ..... pressure time control module
PTO ..... power takeoff
PTP ..... powertrain protection
PTPDM ..... powertrain power distribution module
pvc ..... polyvinyl chloride
PWM ..... pulse width modulation
pwr ..... power
qt ..... quarts
qty. ..... quantity
R & O ..... rust inhibitors and oxidants
R–12 ..... refrigerant-12 (CFC)
R–134a ..... refrigerant-134a (HFC)
RAM ..... random access memory
RC ..... reserve capacity
recirc. ..... recirculation
Ref(s). ..... reference(s)
regen ..... regeneration
RELS ..... reduced engine load at stop
RFI ..... radio frequency interference
RH ..... right-hand
RHD ..... right-hand drive
RH DR ..... right-hand-drive
R/I ..... removal and installation
RMA ..... return material authorization
ROM ..... read-only memory
rpm ..... revolutions per minute
R/R ..... removal and replacement
RSA ..... roll-stability advisor
RSG ..... road speed governor
RSM ..... regional service manager
RTS ..... ready-to-spray
RTV ..... room temperature vulcanizing
RV ..... recreational vehicle
SA ..... source address
S-ABA ..... self-setting automatic brake adjusters

List of Abbreviations

SAE ..... Society of Automotive Engineers
SB ..... service bulletin
SBT ..... seat back thickness
SBW ..... shift-by-wire
SCA(s) .... Supplemental Coolant Additive(s)
SCR ..... selective catalytic reduction
SCU ..... system control unit (speedometer)
SD ..... severe-duty
SDU ..... step deployment unit
SEL ..... shutdown engine light
SEM ..... switch expansion module
SEO ..... stop engine override
SHM ..... switch hub module
SI ..... service information
SI ..... *Système International*
SID ..... subsystem identifier
SM ..... system malfunction
SMC ..... sheet molded compound
S/N ..... serial number
SOC ..... state-of-charge
SPACE .... seat pretensioner activation for crash survival enhancement
SPG ..... special purpose grease
SPN ..... suspect parameter number
sq in ..... square inches
SRP ..... seating reference point
SRS ..... supplemental restraint system
SRS ..... synchronous reference sensor
SRT ..... standard repair time
SSD ..... side sensor display
SSID ..... smart switch identification
SST ..... stainless steel
std. ..... standard
S/W ..... software
SW ..... switch
TAM ..... thermocouple amplifier module
TBB ..... Thomas Built Buses
TBS ..... turbo boost sensor
TCM ..... transmission control module
TCU ..... transmission control unit
TDC ..... top dead center
TDR ..... technician diagnostic routine
TEM ..... truck equipment manufacturer
temp ..... temperature
TIG ..... tungsten inert gas
TIR ..... total indicator reading
TMC ..... Technology and Maintenance Council
TPMS ..... tire pressure monitoring system
TPS ..... thermal protection switch
TPS ..... throttle position sensor
TRS ..... timing reference sensor
TSO ..... truck specification order
TSU ..... transmission shift unit
TXV ..... thermal expansion valve
U.D. ..... underdrive
ULSD ..... ultralow-sulfur diesel
UNC ..... unified national coarse
UNF ..... unified national fine
U.S. ..... United States
U.S.A. ..... United States of America
USC ..... United States customary (measures)
V ..... volts
VCU ..... vehicle control unit
VDC ..... vehicle data computer
Vdc ..... volts, direct current
VIMS ..... vehicle information management system
VIN ..... vehicle identification number
VIP ..... vehicle instrumentation and protection (Kysor)
VIW ..... vehicle interface wiring (connector)
VOC ..... volatile organic compounds
VOM ..... volt-ohmmeter
VRS ..... variable resistance sensor
VSG ..... variable speed governor
VSS ..... vehicle speed sensor
VSU ..... vehicle security unit
WB ..... wire braid
WI ..... work instructions
WIF ..... water-in-fuel
WOT ..... wide open throttle
– ..... minus or negative
+ ..... plus or positive
± ..... plus-or-minus
> ..... greater than
< ..... less than
x ..... by (used in fastener size descriptions)
" ..... inches
° ..... degrees (of an angle)
°C ..... degrees Celsius (centigrade)
°F ..... degrees Fahrenheit
..... number
% ..... percent
& ..... and
© ..... copyright
™ ..... trademark
® ..... registered trademark

Threaded Fastener Types

The majority of threaded fasteners used throughout the vehicle have U.S. customary threads (diameter and pitch are measured in inches). See **Fig. 1**. However, the engine and some items attached to the cab use metric fasteners (diameter and pitch are measured in millimeters).

Most threaded fasteners used on the vehicle that are 1/2-inch diameter or larger are plain hex-type fasteners (non-flanged); *all* metric fasteners are non-flanged. Special hardened flatwashers are used under the bolt head, and between the part being attached and the hexnut, to distribute the load, and to prevent localized overstressing of the parts. The washers are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

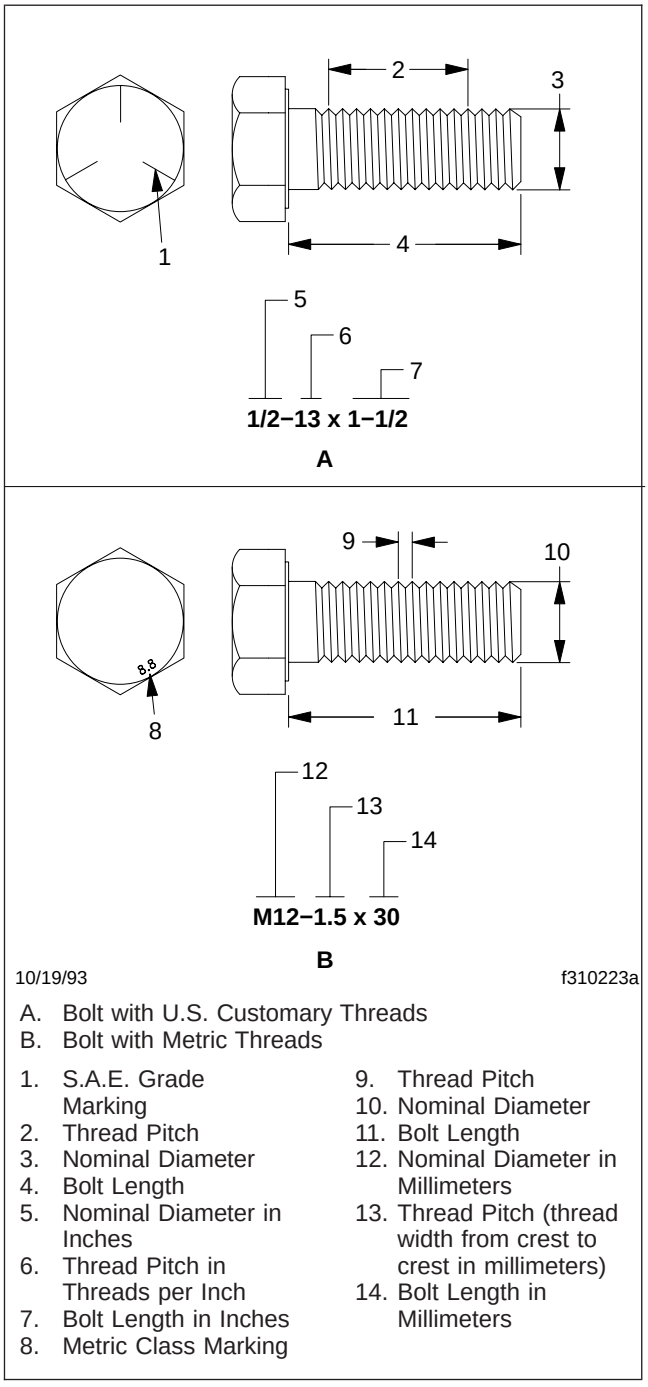
Some fasteners smaller than 1/2-inch diameter are flanged fasteners, which have integral flanges that fit against the parts being fastened. The flanges eliminate the need for washers.

NOTE: The standard fasteners used to assemble the vehicle frame and to attach components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00**.

Fastener Grades and Classes

Fasteners with U.S. customary threads are divided into grades established by the Society of Automotive Engineers (S.A.E.) or the International Fastener Institute (I.F.I.). The fastener grades indicate the relative strength of the fastener; the higher the number (or letter), the stronger the fastener. Bolt (capscrew) grades can be identified by the number and pattern of radial lines forged on the bolt head. See **Fig. 2**. Hexnut (and locknut) grades can be identified by the number and pattern of lines and dots on various surfaces of the nut. See **Fig. 3**. Nearly all of the bolts used on the vehicle are grades 5, 8, and 8.2. Matching grades of hexnuts are always used: grade 5 or grade B hexnuts are used with grade 5 bolts; grade 8, grade C, or grade G (flanged) hexnuts are used with grade 8 or 8.2 bolts.

Fasteners with metric threads are divided into classes adopted by the American National Standards Institute (ANSI). The higher the class number, the stronger the fastener. Bolt classes can be identified by the numbers forged on the head of the bolt. See **Fig. 4**. Hexnut (and locknut) classes can be identified by the marks or numbers on various surfaces of the

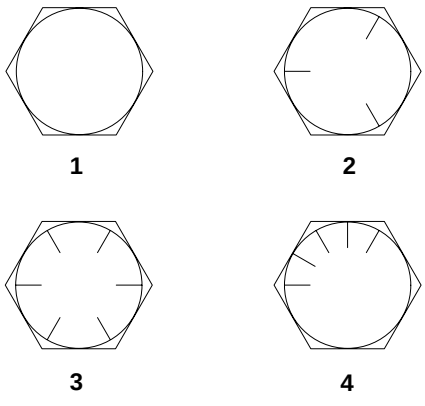


A. Bolt with U.S. Customary Threads
B. Bolt with Metric Threads

1. S.A.E. Grade Marking
2. Thread Pitch
3. Nominal Diameter
4. Bolt Length
5. Nominal Diameter in Inches
6. Thread Pitch in Threads per Inch
7. Bolt Length in Inches
8. Metric Class Marking
9. Thread Pitch
10. Nominal Diameter
11. Bolt Length
12. Nominal Diameter in Millimeters
13. Thread Pitch (thread width from crest to crest in millimeters)
14. Bolt Length in Millimeters

Fig. 1, Fastener Size and Thread Identification

nut. See **Fig. 5**. Class 8 hexnuts are always used with class 8.8 bolts; class 10 hexnuts with class 10.9 bolts.



NOTE: Grade 2 bolts have no grade marking; grade 2 bolts are rarely used by Freightliner.These grade markings are used on plain hex-type and flanged bolts (capscrews). In addition to the grade markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Grade 2
2. Grade 5
3. Grade 8
4. Grade 8.2

Fig. 2, Bolt Grades

Frame Fasteners

The standard fasteners used to assemble the vehicle frame and to attach most components to the vehicle frame are threaded lockbolts (Spin Hucks). These fasteners are covered in **Section 31.00**.

For some other components attached to the frame, grade 8 and 8.2 phosphate-and oil-coated hexhead bolts, grade C cadmium-plated and wax-coated prevailing torque locknuts, and Geomet 321XL coated or waxed fasteners are used. The prevailing torque locknuts have distorted sections of threads to provide torque retention. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. See **Fig. 6**.

Tightening Fasteners

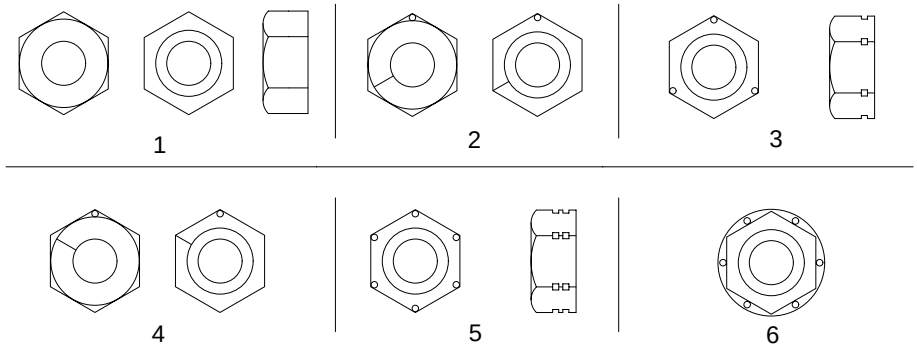
When a capscrew is tightened to its torque value in a threaded hole, or a nut is tightened to its torque value on a bolt, the shank of the capscrew or bolt is stretched slightly. This stretching (tensioning) results in a preload that reduces fatigue of the fasteners. The torque values given in the tables in **Specifications, 400** have been calculated to provide enough clamping force on the parts being fastened, and the correct tensioning of the bolt to maintain the clamping force.

Use of a torque wrench to tighten fasteners will help prevent overtensioning them. Overtensioning causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

When torquing a fastener, typically 80 to 90 percent of the turning force is used to overcome friction; only 10 to 20 percent is used to stretch the capscrew or bolt. About 40 to 50 percent of the turning force is needed to overcome the friction between the underside of the capscrew head or nut and the washer. Another 30 to 40 percent is needed to overcome the friction between the threads of the capscrew and the threaded hole, or the friction between the threads of the nut and bolt.

The amount of torque required to tighten a fastener is reduced when the amount of friction is reduced. If a fastener is dry (unlubricated) and plain (unplated), the amount of friction is high. If a fastener is wax-coated or oiled, or has a zinc phosphate coating or cadmium plating, the amount of friction is reduced. Each of these coatings and combinations of coatings has a different effect. Using zinc-plated hardened flatwashers under the bolt (capscrew) head and nut reduces the amount of friction. Dirt or other foreign material on the threads or clamping surfaces of the fastener or clamped part also changes the amount of friction.

Even though each different condition affects the amount of friction, a different torque value cannot be given for each different condition. To ensure they are always torqued accurately, Freightliner recommends that all fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or anti-seize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.



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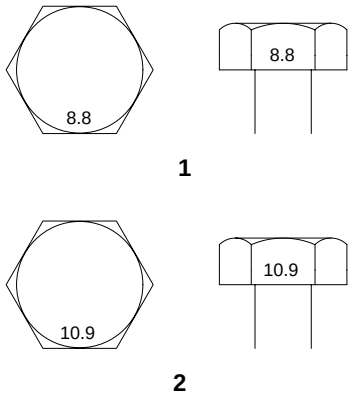
NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification marks at 60 degrees, or 12 notches. Grade G (I.F.I.) flanged nuts have six identification marks as shown; each identification mark may be a dot, line, pair of dots or lines, or any other symbol at the manufacturer's option.

1. S.A.E. Grade 2 or I.F.I. Grade A Nut (strength compatible with grade 2 bolt.)
2. S.A.E. Grade 5 Nut (strength compatible with grade 5 bolt.)
3. I.F.I. Grade B Nut (strength compatible with grade 5 bolt.)
4. S.A.E. Grade 8 Nut (strength compatible with grade 8 or grade 8.2 bolt.)
5. I.F.I. Grade C Nut (strength compatible with grade 8 or grade 8.2 bolt.)
6. I.F.I. Grade G Nut (flanged locknut; strength compatible with grade 8 or grade 8.2 bolt.)

Fig. 3, Nut Grades



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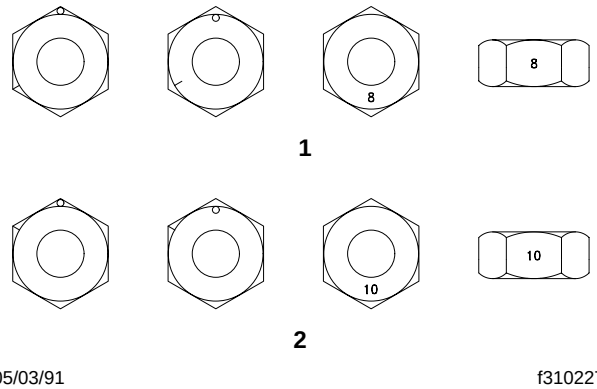
NOTE: In addition to the class markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Class 8.8 2. Class 10.9

Fig. 4, Bolt Classes



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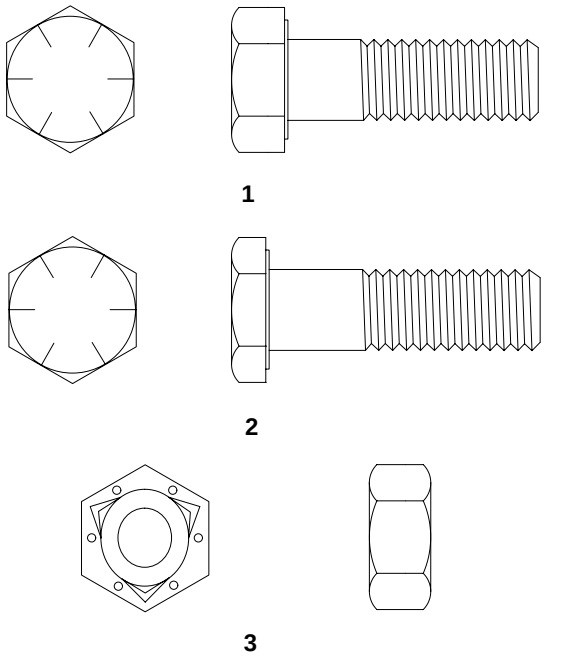
1. Class 8 Nut 2. Class 10 Nut

Fig. 5, Nut Classes

General Information



1. Grade 8 Hexhead Bolt
2. Grade 8 Low-Profile Hexhead Bolt
3. Grade C Prevailing Torque Locknut

Fig. 6, Frame Fastener Identification

Fastener Replacement

When replacing fasteners, use only identical bolts, washers, and nuts; they must be the same size, strength, and finish as originally specified. See the Freightliner Service Parts Catalog for fastener specifications.

When replacing graded (or metric class) bolts and capscrews, use only fasteners that have the manufacturer's trademark or identification on the bolt head; do not use substandard bolts. Inferior, counterfeit fasteners are difficult to identify; buy your fasteners from a reputable supplier.

Fastener Selection and Installation

When using nuts with bolts, use a grade (or class) of nut that matches the bolt.

When installing non-flanged fasteners, use hardened steel flatwashers under the bolt (capscrew) head, and under the hexnut or locknut.

For bolts 4 inches (100 mm) or less in length, make sure that at least 1-1/2 threads and no more than 5/8-inch (16-mm) bolt length extends through the nut after it has been tightened. For bolts longer than 4 inches (100 mm), allow a minimum of 1-1/2 threads and a maximum of 3/4-inch (19-mm) bolt length.

Never hammer or screw bolts into place. Align the holes of the parts being attached, so that the nut and bolt surfaces are flush against the washers, and the washers are flush against the parts.

When installing fasteners in aluminum or plastic parts with threaded holes, start the fasteners by hand, to ensure straight starting and to prevent damaged threads.

Do not use lockwashers (split or toothed) next to aluminum surfaces.

When installing studs that do not have an interference fit, install them with thread locking compound, as instructed in this subject.

When installing parts that are mounted on studs, use free-spinning (non-locking) nuts and helical-spring (split) lockwashers or internal-tooth lockwashers. Do not use locknuts, because they tend to loosen the studs during removal. Do not use plain washers (flatwashers).

Do not use lockwashers and flatwashers in combination (against each other); each defeats the other's purpose.

Use stainless steel fasteners against chrome plating, unpainted aluminum, or stainless steel.

Fastener Tightening

Before installing fasteners, clean all fastener (and parts) threads, and all surfaces being clamped.

To ensure they are always torqued accurately, Freightliner recommends that *all* fasteners be lubricated with oil (unless specifically instructed to install them dry), then torqued to the values for lubricated- and plated-thread fasteners. When locking compound or antiseize compound is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.

Bring parts and fasteners into contact, with no gaps between them, before using a torque wrench to tighten fasteners to their final torque values.

Tighten the nut, not the bolt head. This will give a truer torque reading by eliminating bolt body friction.

Always use a torque wrench to tighten fasteners, and use a slow, smooth, even pull on the wrench. Do not overtorque fasteners; overtightening causes permanent stretching of the fasteners, which can result in breakage of the parts or fasteners.

If specific torque values are not given for countersunk bolts, use the torque value for the corresponding size and grade of regular bolt, as given in **Specifications, 400**.

Always follow the torque sequence or torque interval when provided, to ensure that clamping forces are even, and parts and fasteners are not distorted.

Thread Locking Compound Application

When the use of thread locking compound is recommended or desired, for studs, capscrews, and bolts with a thread diameter of 1 inch (25 mm) or less, use Loctite® 271 or Perma-Lok® HM-128.

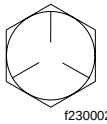
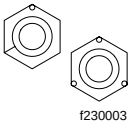
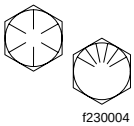
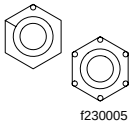
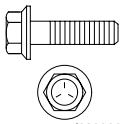
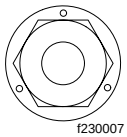
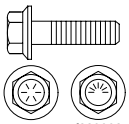
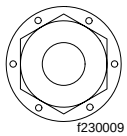
For thread diameters over 1 inch (25 mm), use Loctite 277.

General Instructions

NOTE: Follow the safety precautions given on the locking compound container.

1. Clean the male and female threads of the fasteners, removing all dirt, oil, and other foreign material. If parts are contaminated, use Stoddard solvent for cleaning; then allow the fasteners to air dry for 10 minutes. Be sure solvent is completely gone before applying adhesive.
2. Transfer a small amount of the locking compound from the container to a paper cup or small non-metal dish.
3. Using a plastic brush (a metal brush will contaminate the compound), apply a small amount of compound to the entire circumference of three or four of the male threads that will be covered by the nut after it has been tightened. Be sure enough compound is applied to fill the inside of the nut threads, with a slight excess.
4. Install and torque the nut. Readjustment of the nut position is not possible after installation is complete, without destroying the locking effect.

NOTE: To disassemble the fasteners, heat the bond line to 400°F (200°C) before removing the nut. Every time the fasteners are disassembled, replace them. If any parts are damaged by overheating, replace the parts.

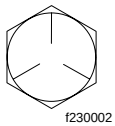
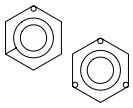
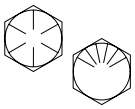
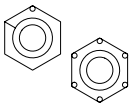
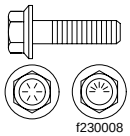
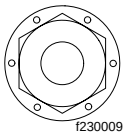
Torque Values for U.S. Customary Thread Fasteners With Lubricated* or Plated Threads†								
Thread Diameter–Pitch	Regular Hex				Flanged			
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade B Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230002	 f230003	 f230004	 f230005	 f230006	 f230007	 f230008	 f230009
1/4–20	7 (9)		8 (11)		6 (8)		10 (14)	
1/4–28	8 (11)		9 (12)		7 (9)		12 (16)	
5/16–18	15 (20)		16 (22)		13 (18)		21 (28)	
5/16–24	16 (22)		17 (23)		14 (19)		23 (31)	
3/8–16	26 (35)		28 (38)		23 (31)		37 (50)	
3/8–24	30 (41)		32 (43)		25 (34)		42 (57)	
7/16–14	42 (57)		45 (61)		35 (47)		60 (81)	
7/16–20	47 (64)		50 (68)		40 (54)		66 (89)	
1/2–13	64 (87)		68 (92)		55 (75)		91 (123)	
1/2–20	72 (98)		77 (104)		65 (88)		102 (138)	
9/16–12	92 (125)		98 (133)		80 (108)		130 (176)	
9/16–18	103 (140)		110 (149)		90 (122)		146 (198)	
5/8–11	128 (173)		136 (184)		110 (149)		180 (244)	
5/8–18	145 (197)		154 (209)		130 (176)		204 (277)	
3/4–10	226 (306)		241 (327)		200 (271)		320 (434)	
3/4–16	253 (343)		269 (365)		220 (298)		357 (484)	
7/8–9	365 (495)		388 (526)		320 (434)		515 (698)	
7/8–14	402 (545)		427 (579)		350 (475)		568 (770)	
1–8	—		582 (789)		—		—	
1–12	—		637 (863)		—		—	
1–14	—		652 (884)		—		—	

* Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.

† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, Geomet 321XL coated, or waxed).

Table 1, Torque Values for U.S. Customary Thread Fasteners With Lubricated or Plated Threads

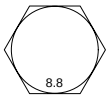
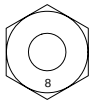
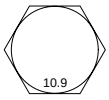
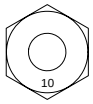
Specifications

Torque Values for U.S. Customary Thread Fasteners With Dry (Unlubricated)* Plain (Unplated) Threads†						
Thread Diameter–Pitch	Regular Hex				Flanged	
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230002	 f230003	 f230004	 f230005	 f230008	 f230009
1/4–20	8 (11)		10 (14)		—	
1/4–28	9 (12)		12 (16)		—	
5/16–18	15 (20)		22 (30)		22 (30)	
5/16–24	17 (23)		25 (34)		—	
3/8–16	28 (38)		40 (54)		40 (54)	
3/8–24	31 (42)		45 (61)		—	
7/16–14	45 (61)		65 (88)		65 (88)	
7/16–20	50 (68)		70 (95)		—	
1/2–13	70 (95)		95 (129)		95 (129)	
1/2–20	75 (102)		110 (149)		—	
9/16–12	100 (136)		140 (190)		140 (190)	
9/16–18	110 (149)		155 (210)		—	
5/8–11	135 (183)		190 (258)		190 (258)	
5/8–18	155 (210)		215 (292)		—	
3/4–10	240 (325)		340 (461)		340 (461)	
3/4–16	270 (366)		380 (515)		—	
7/8–9	385 (522)		540 (732)		—	
7/8–14	425 (576)		600 (813)		—	
1–8	580 (786)		820 (1112)		—	
1–12	635 (861)		900 (1220)		—	
1–14	650 (881)		915 (1241)		—	

* Threads may have residual oil, but will be dry to the touch.

† Male and female threads (bolt and nut) must both be unlubricated and unplated; if either is plated or lubricated, use **Table 1**. Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.

Table 2, Torque Values for U.S. Customary Thread Fasteners With Dry (Unlubricated) Plain (Unplated) Threads

Torque Values for Metric Thread Fasteners With Lubricated* or Plated Threads†				
Thread Diameter–Pitch	Class 8.8 Bolt	Class 8 Nut	Class 10.9 Bolt	Class 10 Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)	
	 f230010	 f230011	 f230012	 f230013
M6	5 (7)		7 (9)	
M8	12 (16)		17 (23)	
M8 x 1	13 (18)		18 (24)	
M10	24 (33)		34 (46)	
M10 x 1.25	27 (37)		38 (52)	
M12	42 (57)		60 (81)	
M12 x 1.5	43 (58)		62 (84)	
M14	66 (89)		95 (129)	
M14 x 1.5	72 (98)		103 (140)	
M16	103 (140)		148 (201)	
M16 x 1.5	110 (149)		157 (213)	
M18	147 (199)		203 (275)	
M18 x 1.5	165 (224)		229 (310)	
M20	208 (282)		288 (390)	
M20 x 1.5	213 (313)		320 (434)	
M22	283 (384)		392 (531)	
M22 x 1.5	315 (427)		431 (584)	
M24	360 (488)		498 (675)	
M24 x 2	392 (531)		542 (735)	
M27	527 (715)		729 (988)	
M27 x 2	569 (771)		788 (1068)	
M30	715 (969)		990 (1342)	
M30 x 2	792 (1074)		1096 (1486)	

* Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.

† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, Geomet 321XL, or waxed).

Table 3, Torque Values for Metric Thread Fasteners With Lubricated Or Plated Threads

U.S. Customary to Metric			Metric to U.S. Customary		
When You Know	**Multiply By**	**To Get**	**When You Know**	**Multiply By**	**To Get**
Length					
inches (in)	25.4	millimeters (mm)	0.03937	inches (in)	
inches (in)	2.54	centimeters (cm)	0.3937	inches (in)	
feet (ft)	0.3048	meters (m)	3.281	feet (ft)	
yards (yd)	0.9144	meters (m)	1.094	yards (yd)	
miles (mi)	1.609	kilometers (km)	0.6215	miles (mi)	
Area					
square inches (in^2)	645.16	square millimeters (mm^2)	0.00155	square inches (in^2)	
square inches (in^2)	6.452	square centimeters (cm^2)	0.15	square inches (in^2)	
square feet (ft^2)	0.0929	square meters (m^2)	10.764	square feet (ft^2)	
Volume					
cubic inches (in^3)	16387.0	cubic millimeters (mm^3)	0.000061	cubic inches (in^3)	
cubic inches (in^3)	16.387	cubic centimeters (cm^3)	0.06102	cubic inches (in^3)	
cubic inches (in^3)	0.01639	liters (L)	61.024	cubic inches (in^3)	
fluid ounces (fl oz)	29.54	milliliters (mL)	0.03381	fluid ounces (fl oz)	
pints (pt)	0.47318	liters (L)	2.1134	pints (pt)	
quarts (qt)	0.94635	liters (L)	1.0567	quarts (qt)	
gallons (gal)	3.7854	liters (L)	0.2642	gallons (gal)	
cubic feet (ft^3)	28.317	liters (L)	0.03531	cubic feet (ft^3)	
cubic feet (ft^3)	0.02832	cubic meters (m^3)	35.315	cubic feet (ft^3)	
Weight/Force					
ounces (av) (oz)	28.35	grams (g)	0.03527	ounces (av) (oz)	
pounds (av) (lb)	0.454	kilograms (kg)	2.205	pounds (av) (lb)	
U.S. tons (t)	907.18	kilograms (kg)	0.001102	U.S. tons (t)	
U.S. tons (t)	0.90718	metric tons (t)	1.1023	U.S. tons (t)	
Torque/Work Force					
inch-pounds (lbf·in)	11.298	Newton-centimeters (N·cm)	0.08851	inch-pounds (lbf·in)	
foot-pounds (lbf·ft)	1.3558	Newton-meters (N·m)	0.7376	foot-pounds (lbf·ft)	
Pressure/Vacuum					
inches of mercury (inHg)	3.37685	kilo Pascals (kPa)	0.29613	inches of mercury (inHg)	
pounds per square inch (psi)	6.895	kilo Pascals (kPa)	0.14503	pounds per square inch (psi)	

When You Know	Subtract	Then Divide By	To Get	When You Know	Multiply By	Then Add	To Get
degrees Fahrenheit (°F)	32	1.8	degrees Celsius (°C)	1.8	32	degrees Fahrenheit (°F)	

Principles of Operation

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). The ATS will rely on existing EPA07 technology, which includes an aftertreatment device (ATD), with the addition of SCR. See **Fig. 1**. The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream.

The ATS is always chassis-mounted, with several different installation options available to fit various vehicle configurations. ATS exhaust piping is made of stainless steel. The ATS includes all piping and equipment between the turbocharger outlet and the end of the exhaust pipe, including the aftertreatment device (ATD), SCR catalyst, DEF tank, DEF tank header unit, DEF pump, DEF metering unit, and the DEF, coolant, and air lines that run between each component.

All EPA10-compliant DTNA vehicles require the use of ultra-low sulfur diesel (ULSD) fuel with a sulfur content of 15 parts per million (ppm) for low emissions and long life of the diesel particulate filter (DPF) in the ATD. In addition, DTNA vehicles require the use of CJ-4 engine oils with less than 1% ash.

Inside the ATD, the exhaust first passes over the diesel oxidation catalyst (DOC), where combustion gases are chemically broken down into water and carbon dioxide. The exhaust then passes through the DPF, a honeycomb-like filter that traps solid soot particles. The soot particles trapped in the DPF are reduced to ash during regeneration (regen).

If the exhaust temperature is high enough, a process called passive regen occurs as the vehicle is driven normally. Passive regen, however, cannot always keep the DPF clean, so the ATD must also periodically undergo active regen. During active regen, extra fuel is injected into the exhaust stream to superheat and reduce the soot trapped in the DPF to ash. Active regen happens only when the vehicle is moving above a certain speed, as determined by the engine manufacturer.

Both active and passive regen happen automatically, without driver input. When operating conditions do not allow for active or passive regen, the vehicle may require a driver-activated parked regen, which takes 20 to 60 minutes, depending on ambient conditions.

Despite the regen process, ash collects in the DPF over time and needs to be removed through cleaning at specific intervals. For DPF maintenance intervals and repair information, see the engine manufacturer's service literature.

After exhaust gases leave the ATD, a controlled quantity of diesel exhaust fluid (DEF) is injected into the exhaust stream. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the selective catalyst chamber to yield nitrogen and water vapor, which exit through the tailpipe.

EPA10-compliant DTNA vehicles are equipped with an additional tank to carry the DEF necessary for the SCR process. DEF is colorless, non-toxic, and biodegradable. DEF consumption will vary depending on ambient conditions and vehicle application.

Service Literature Coverage

Service procedures in this manual are limited to components installed by Daimler Trucks North America. See **Group 49, Exhaust**, for information on EPA10-compliant exhaust systems installed by Daimler Trucks North America:

Complete engine coverage including engine adjustment, preventive maintenance, and engine repair are covered in each engine manufacturer's service literature:

- Cummins: **www.cummins.com**
- Detroit Diesel: **www.detroitdiesel.com**

Periodic inspection of the ATS is required. For instructions, see the *Severe Duty® Maintenance Manual*.

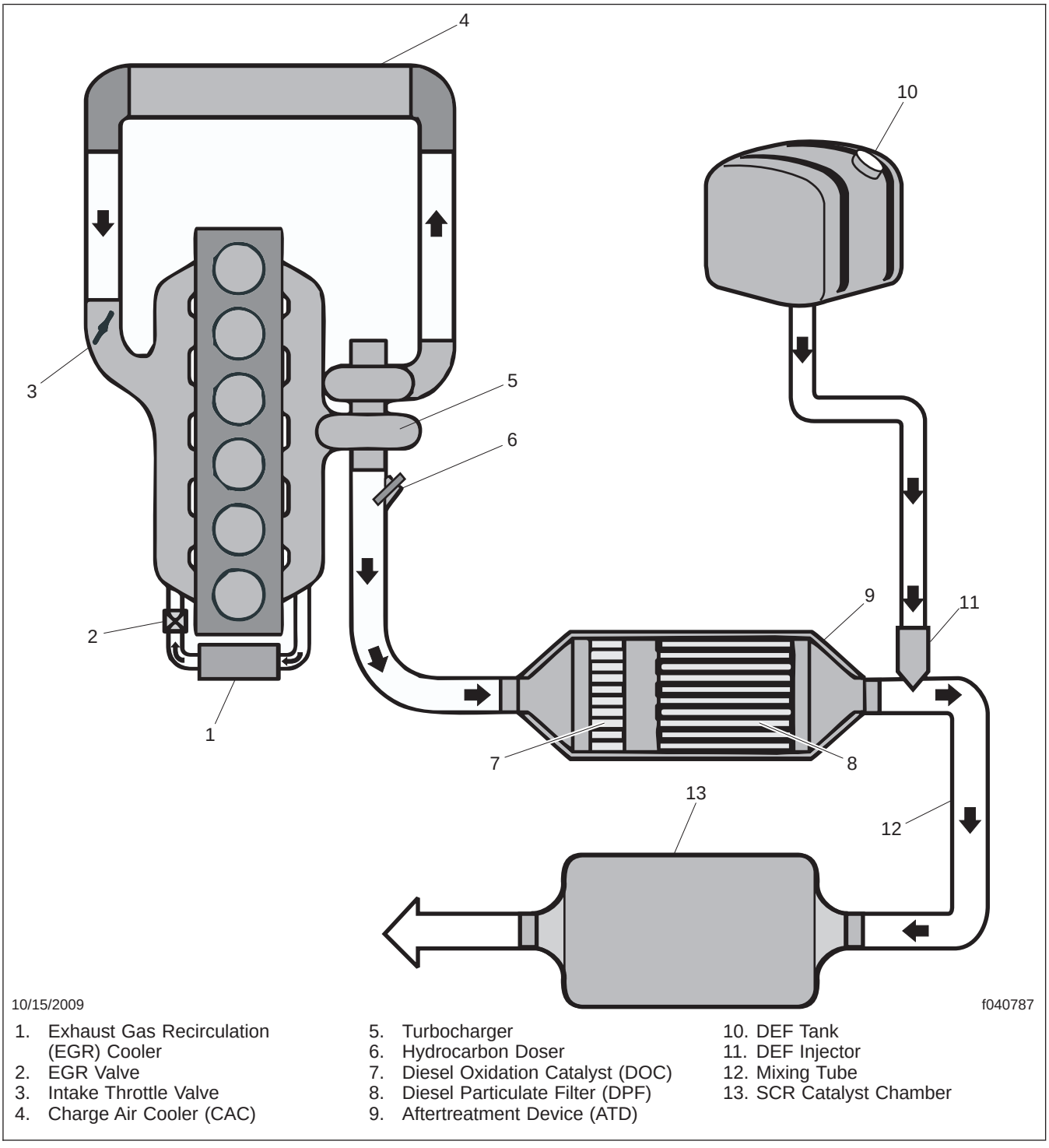
For driver pre- and post-trip inspection information, see the *108SD and 114SD Driver's Manual*.

Definition of Terms

Refer to the following terms for a better understanding of EPA10 vehicles.

Ash Unburnable solids that remain after regeneration in the ATD.

General Information



1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. DEF Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 1, EPA10 ATS (Detroit Diesel engine shown)

Aftertreatment Device (ATD) A device that removes pollutants from exhaust gas after the gas leaves the combustion chamber.

Aftertreatment System (ATS) The entire exhaust system from the turbocharger to the exhaust stack or tail pipe.

Diesel Exhaust Fluid (DEF) A colorless, non-toxic, and biodegradable fluid used in the SCR process.

Diesel Oxidation Catalyst (DOC) A flow-through device that enhances the oxidation of hydrocarbons in the ATD on Cummins, Detroit Diesel, and Mercedes-Benz engines.

Diesel Particulate Filter (DPF) A component in the ATD that captures particulate matter from the exhaust gas, preventing discharge from the tailpipe.

Exhaust Gas Recirculation (EGR) A process whereby exhaust is recirculated into the air intake system, creating lower cylinder temperatures.

Nitrogen Oxides (NOx) Air pollutants composed of nitrogen and oxygen in various forms that contribute to the formation of smog.

Particulate Matter (PM) Soot particles formed by incomplete combustion of fuel that contribute to atmospheric pollution.

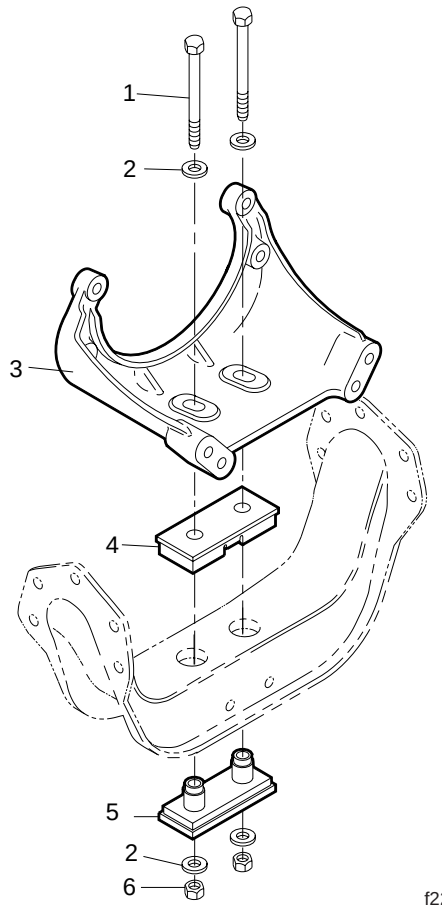
Regeneration (Regen) A process that occurs inside the ATD whereby accumulated soot is superheated and burned to ash, carbon dioxide, and water.

Selective Catalytic Reduction (SCR) A vehicle emissions control technology to reduce diesel engine emissions for passenger cars, and light and heavy-duty trucks.

ULSD (Ultra-Low Sulfur Diesel) Fuel A clean burning diesel fuel containing a maximum of 15-ppm sulfur. To meet EPA requirements, all highway diesel fuel sold in the U.S. must be ULSD.

General Information

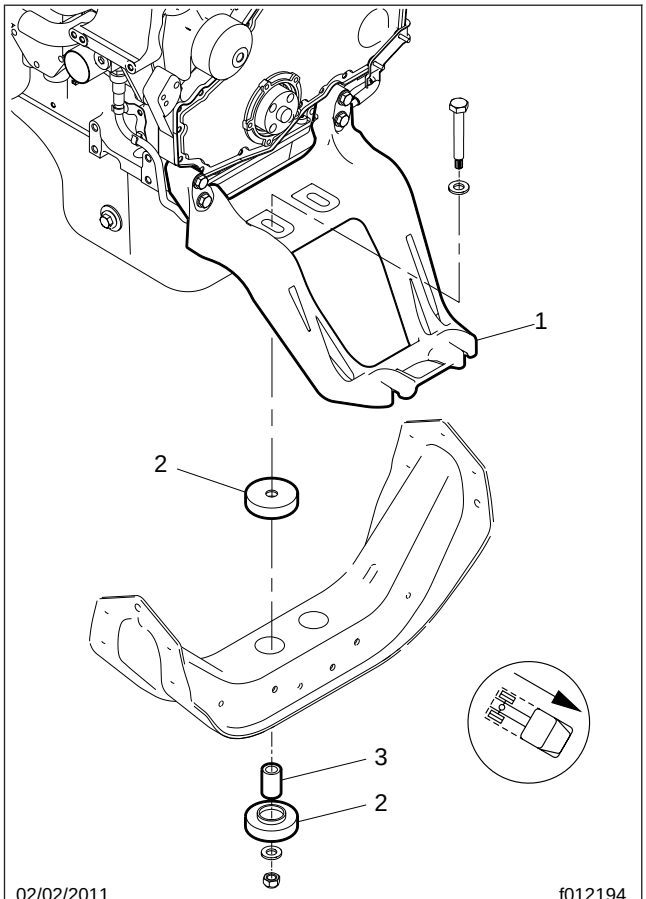
The front engine-support bracket is fastened to the front of the engine, then mounted on the engine crossmember. Isolators are installed between the bracket and the crossmember to protect the engine from road shock, and isolate the vehicle frame from engine vibration. See **Fig. 1** for a DD13 front engine-support installation. See **Fig. 2** for a Cummins ISC/ISL front engine-support installation.



1. Hexbolt, 3/4–10
2. Hardened Washer
3. Front-Engine Support Bracket
4. Upper Isolator
5. Sleeve
6. Lower Isolator
7. Hexnut, 3/4–10

Fig. 1, Front-Engine Support Installation, DD13

The rear of the engine is supported by frame brackets that attach to brackets mounted on the flywheel housing. Isolators are installed between the two metal brackets to reduce engine vibration transmitted to the frame.



1. Front-Engine Support Bracket
2. Isolator
3. Sleeve

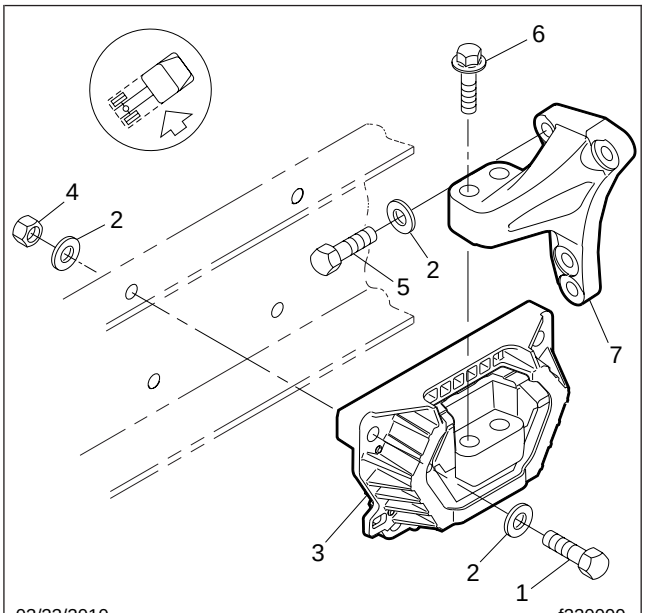
Fig. 2, Front-Engine Support Installation, Cummins ISC/ISL

NOTE: On the DD13 frame brackets the isolator is bonded to the metal and cannot be replaced separately. The rear engine-mount isolators are replaceable on the Cummins ISC/ISL engine.

See **Fig. 3** for the rear-engine mounts for DD13 engines.

See **Fig. 4** for the rear-engine mounts for Cummins ISC/ISL engines.

General Information



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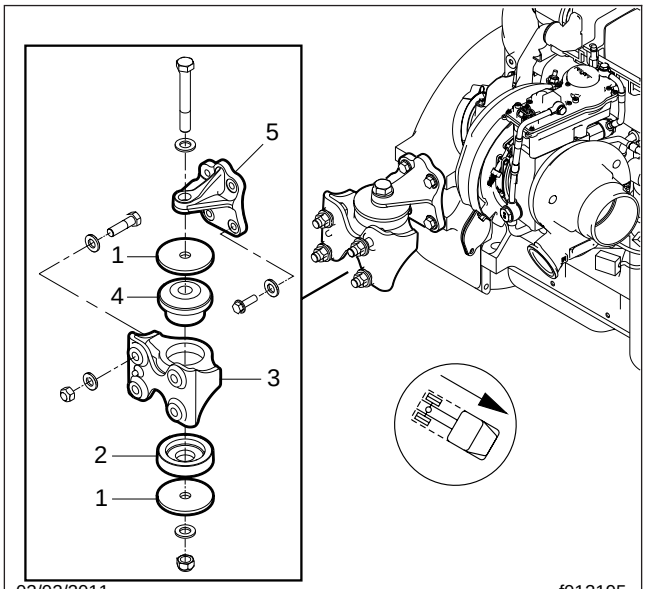
1. Capscrew, 5/8–11
2. Hardened Washer
3. Frame Bracket, Rear-Engine Mount
4. Hexnut, 5/8–11
5. Hexbolt, M16–1.5
6. Flanged Hexbolt, 3/4–10
7. Engine Bracket, Rear-Engine Mount

Fig. 3, Rear-Engine Mounts, DD13



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1. Washer, Rear Engine Support
2. Lower Isolator
3. Frame Bracket, Rear Engine Mount
4. Upper Isolator
5. Engine Bracket, Rear Engine Mount

Fig. 4, Rear-Engine Mounts, Cummins ISC/ISL

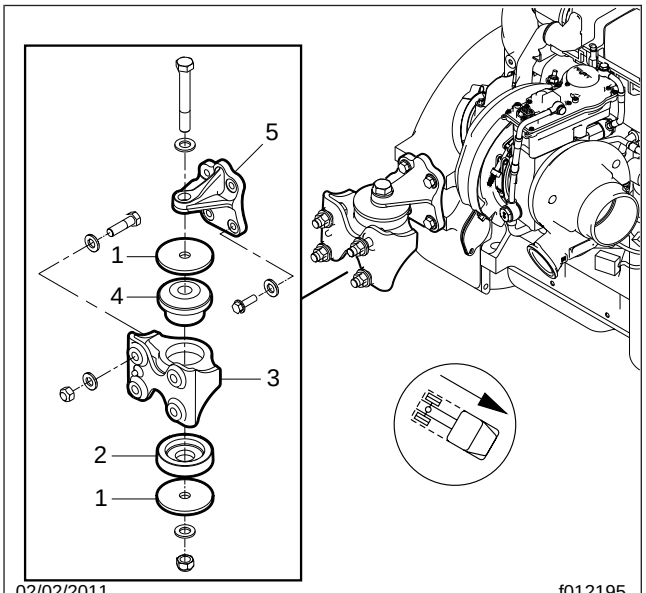
Cummins ISC/ISL Rear-Engine Mount Replacement

⚠ WARNING

The jack used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

Replacement

1. Apply the parking brakes, chock the tires, and drain the air brake system.
2. Place a jack under the rear of the engine and raise the jack until it's braced against the engine.
3. Remove the bolt that fastens the isolator and bracket assembly together. Save the fasteners, isolators, and washers. See **Fig. 1**.



1. Washer
2. Lower Isolator
3. Frame Bracket
4. Upper Isolator
5. Engine Bracket

Fig. 1, Rear Engine Mount, Cummins ISC/ISL

4. Lift the engine slightly to take the weight off the engine brackets. Place engine stands under the engine.
5. Remove the fasteners that secure the frame bracket to the frame, then remove the bracket from the frame rail.
6. Remove the four bolts that secure the engine bracket to the flywheel housing, then remove the bracket.
7. Place a new frame bracket on the inside of the frame rail, and secure it with the bolts, washers, and nuts that had been removed. Tighten to 163 lbf·ft (120 N·m).
8. Install the engine bracket on the side of the flywheel housing. Apply thread lock compound to the bracket mounting bolts and tighten to 58 lbf·ft (79 N·m).
9. Inspect the isolators for wear or damage and replace them if necessary.

NOTICE

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.

10. Place the upper isolator and washer in the frame bracket.
11. Lift the engine slightly and remove the engine stands, then carefully lower the engine until the engine bracket rests on the frame bracket and isolator.
12. Holding the lower isolator and washer in place, install the bolt through the engine bracket, isolators, and frame bracket, then secure it with the nut and hardened washer. Tighten to 241 lbf·ft (327 N·m).

DD13 Rear-Engine Mount Replacement

Replacement

NOTE: The isolators on the DD13 rear engine support frame brackets are bonded to the metal and cannot be replaced separately.

If the frame brackets need replacing due to damage, or if you are removing and installing the engine, follow this procedure.

1. Shut down the engine, set the parking brake, and chock the tires.
2. Drain the air tanks.
3. Disconnect the batteries.
4. Open the hood.
5. Remove the rain tray as follows.
   - 5.1 Mark the position of each wiper arm on the splined shaft, then remove the wiper arms.
   - 5.2 Disconnect any hoses or drains from the bottom of the rain tray.
   - 5.3 Remove the fasteners that hold the rain tray to the frontwall.
   - 5.4 Remove the rain tray from the vehicle.
6. Remove the right and left quarter fenders and the inner splash shields.
7. Remove the air cleaner assembly.
8. Disconnect the air lines from the primary air tank, then remove the tank from the vehicle.
9. Remove the cab skirts from both sides of the vehicle.
10. Remove the exhaust pipes, as an assembly. Refer to **Group 49** in this manual for instructions.

NOTICE

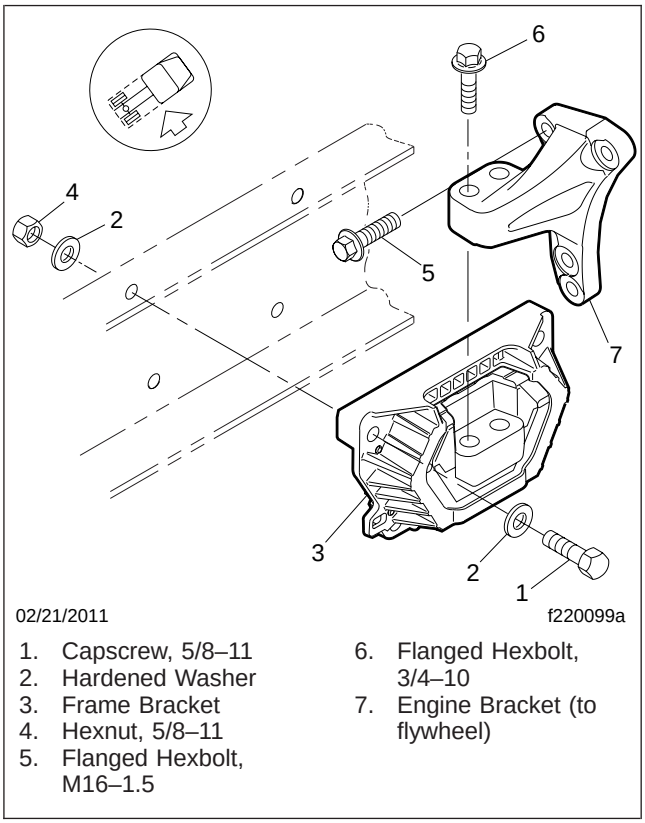
Do not disassemble or bend the exhaust, or damage could occur to the exhaust bellows.

11. As applicable, remove the steps, air fairings, fuel tank(s), and/or the battery box.

    For instructions on removing the fuel tank(s), refer to **Group 47** in this manual.
12. Remove the fasteners that hold the driveline midship-bearing bracket to the frame crossmember.
13. Using suitable straps, secure the driveline and the midship bearing to the frame crossmember. Make sure the driveshaft is supported loosely enough so that the slip joint aft of the midship bearing will be able to extend when the engine is raised.
14. Remove the overslung crossmember. If applicable remove the transmission support spring.
15. Disconnect both ends of the clutch linkage and remove it from the vehicle.
16. Remove the shifter and shifter boot from the transmission.
17. Disconnect the shocks from both sides of the vehicle.
18. Raise the front of the vehicle so the tires are off the ground, and support it with safety stands. Put the safety stands behind the rear spring hangers for the front suspension.
19. On both sides of vehicle, remove the two 3/4–10 capscrews that fasten the rear-engine-support engine bracket to the frame bracket. See **Fig. 1**.
20. Place a jack under the flywheel housing or the transmission and gradually raise the back of the engine until the engine brackets are above the top of the frame rail.
21. Remove the five fasteners that hold the frame bracket to the frame rail.
22. Remove the frame bracket from the vehicle.
23. If needed, remove the four 5/8–11 capscrews that attach the engine bracket to the flywheel. Remove the engine bracket.
24. If applicable, install the engine bracket on the flywheel. Apply Loctite® 271 (or equivalent) to the threads of the hexbolts. Tighten to 195 lbf·ft (264 N·m).
25. With the engine supported, install the frame bracket in the frame rail. Install the five 5/8–11 capscrews with the bolt heads inboard. Tighten the hexnuts 136 lbf·ft (184 N·m).
26. Repeat the above step for the second engine mount.
27. Lower the engine onto the frame bracket.

NOTE The right-hand engine bracket has oval holes to allow for alignment. Install the left-side

DD13 Rear-Engine Mount Replacement



1. Capscrew, 5/8–11
2. Hardened Washer
3. Frame Bracket
4. Hexnut, 5/8–11
5. Flanged Hexbolt, M16–1.5
6. Flanged Hexbolt, 3/4–10
7. Engine Bracket (to flywheel)

Fig. 1, Rear Engine Support DD13

engine bracket with the round holes first, then install the right-side with the oval holes.

28. Apply Loctite 271 to the threads of the two 3/4–10 hexbolts, then install a hardened washer, and insert the hexbolts through the holes of the engine bracket and frame bracket. Tighten the bolts to 241 lbf·ft (327 N·m).
29. Install the clutch linkage.
30. Install the transmission support spring.
31. Install the shifter and shifter boot on the transmission.
32. Attach the driveline midship bearing and its bracket to the frame crossmember.
33. Install the exhaust system. See **Group 49** in this manual for instructions.
34. Attach the cab skirts to the bottom of the cab.
35. Install the primary air tank and connect the air lines.
36. Install the air-intake filter assembly
37. Install the right and left inner splash shields.
38. Install the right and left quarter fenders.
39. As applicable, install the steps, air fairings, fuel tank(s), and/or the battery box.

    For instructions on installing the fuel tank(s), refer to **Group 47** in this manual.
40. Using the previously removed fasteners, install the rain tray on the frontwall.
41. Connect the hoses and drains to the bottom of the rain tray.
42. As previously marked, install the wiper arms.
43. If they were removed, install the two tow hooks on the side of the right frame rail.
44. Close the hood.
45. Connect the batteries.

Front-Engine Mount and Isolator Replacement

⚠ WARNING

The lifting device and chain used to lift the engine must be capable of safely lifting and supporting two metric tons. Once the engine mount is disconnected, do not get under the engine until it is securely supported on engine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

Replacement

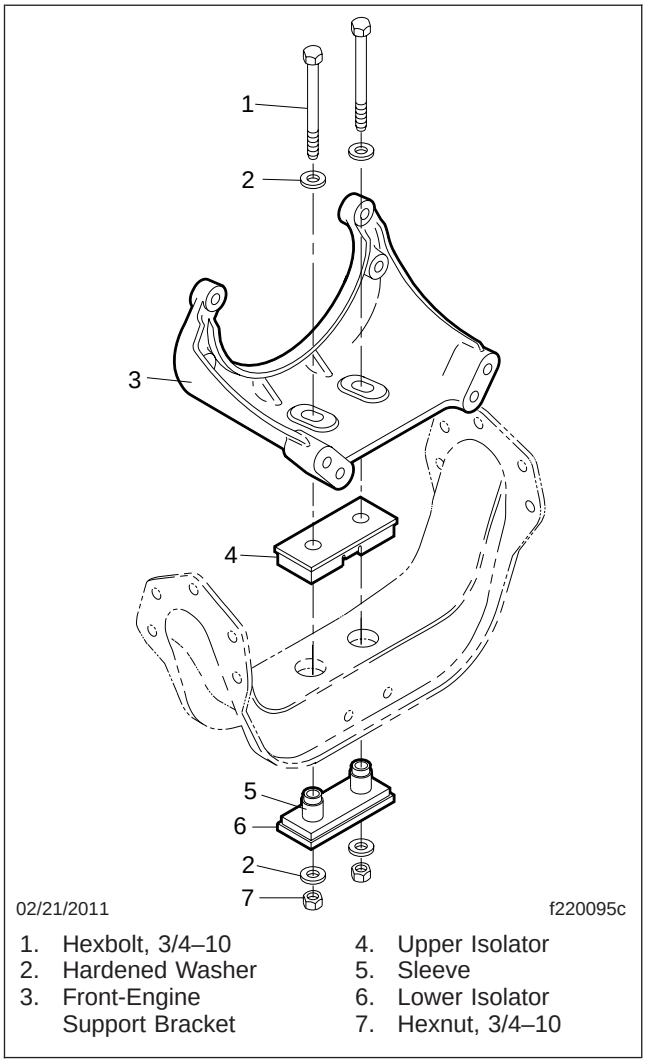
1. Apply the parking brakes, chock the tires, and drain the air brake system.
2. Attach a chain to the front-engine lifting hook(s), and position a lifting device. Attach the chain to the lifting device, and raise the chain to remove any slack.
3. Remove the fasteners that attach the front-engine mount to the engine crossmember. Save the fasteners, rubber isolator cushions, and sleeves. See **Fig. 1** for a DD13 front engine-support installation. See **Fig. 2** for a Cummins ISC/ISL front engine-support installation.
4. Lift the engine slightly to take its weight off the front-engine mount. Place engine stands under the engine to keep the weight off the engine mount.

NOTE: In order to raise the front of the engine, you may need to loosen the bolts that run through the rear-engine mounts.

5. Remove the bolts that secure the engine mount to the front of the engine.
6. Attach a new engine mount to the front of the engine. For DD13 engines, tighten the bolts to 195 lbf·ft. (264 N·m) . For Cummins ISC/ISL engines, tighten the bolts to 58 to 72 lbf·ft. (79 to 98 N·m).
7. Inspect the isolators for wear or damage and replace them if necessary.

NOTICE

Do not lubricate the components with oil, grease, or silicone lubricants; they will deteriorate the rubber isolators.



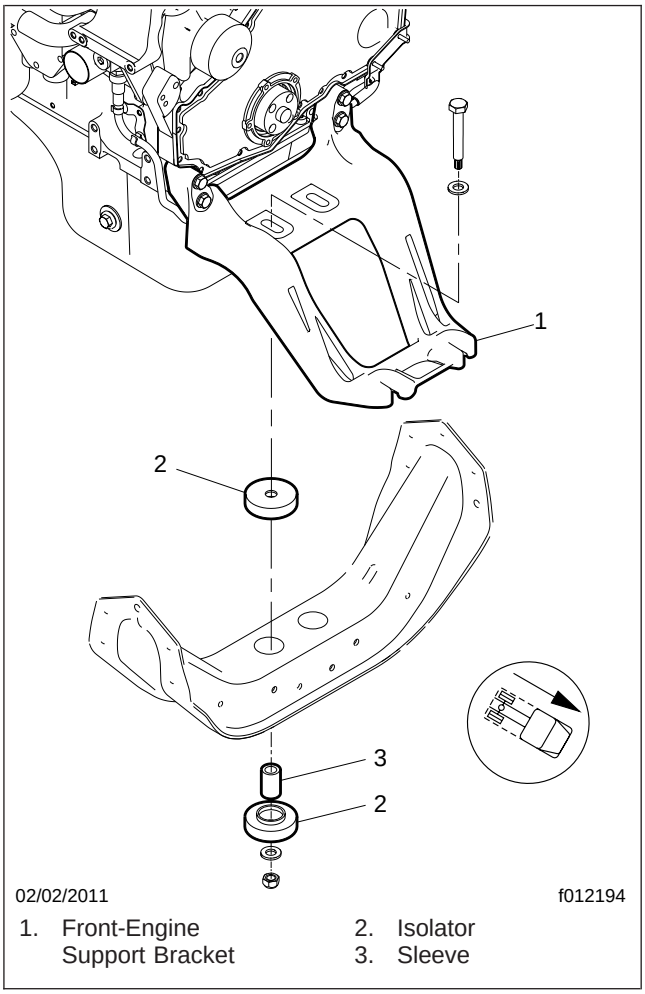
1. Hexbolt, 3/4–10
2. Hardened Washer
3. Front-Engine Support Bracket
4. Upper Isolator
5. Sleeve
6. Lower Isolator
7. Hexnut, 3/4–10

Fig. 1, Front-Engine Support Installation, DD13

8. Install the upper isolators in the engine crossmember.
9. Lift the engine slightly, then remove the stands and carefully lower the front-engine mount onto the crossmember.
10. Holding the lower isolators and sleeves in place, install the bolts in the front-engine mount and tighten to 136 lbf·ft (184 N·m).

    NOTE: If the bolts that run through the rear engine mounts were loosened, tighten them 241 lbf·ft (327 N·m) for all engines.

Front-Engine Mount and Isolator Replacement



1. Front-Engine Support Bracket
2. Isolator
3. Sleeve

Fig. 2, Front-Engine Support Installation, Cummins ISC/ ISL

11. Remove the lifting chain from the engine lifting hooks.
12. Remove the chocks from the tires.

Specifications

Engine Mount Torques			
Description	**Capscrew Size**	**Grade**	**Torque: lbf·ft (N·m)**
Frame Rail Capscrews	5/8–11	8	163 (220)
DD Front Engine Mount to Flywheel Housing Capscrews	M16-1.5 x 65	8	195 (264)
Cummins ISC/ISL Front Engine Mount to Flywheel Housing Capscrews	M12	10.9	58 to 72 (79 to 98)
Cummins ISC/ISL Block	M12	10.9	74 to 92 (100 to 125)
Rear Engine Bracket to Frame Bracket Capscrews	3/4–10	8	241 (327)
DD Front Engine Bracket to Crossmember Capscrews	3/4–10 x 4	8	241 (327)
Cummins ISC/ISL Front Engine Bracket to Crossmember Capscrews	M16-2.0 x 100		136 (184)

Table 1, Engine Mount Fastener Torques

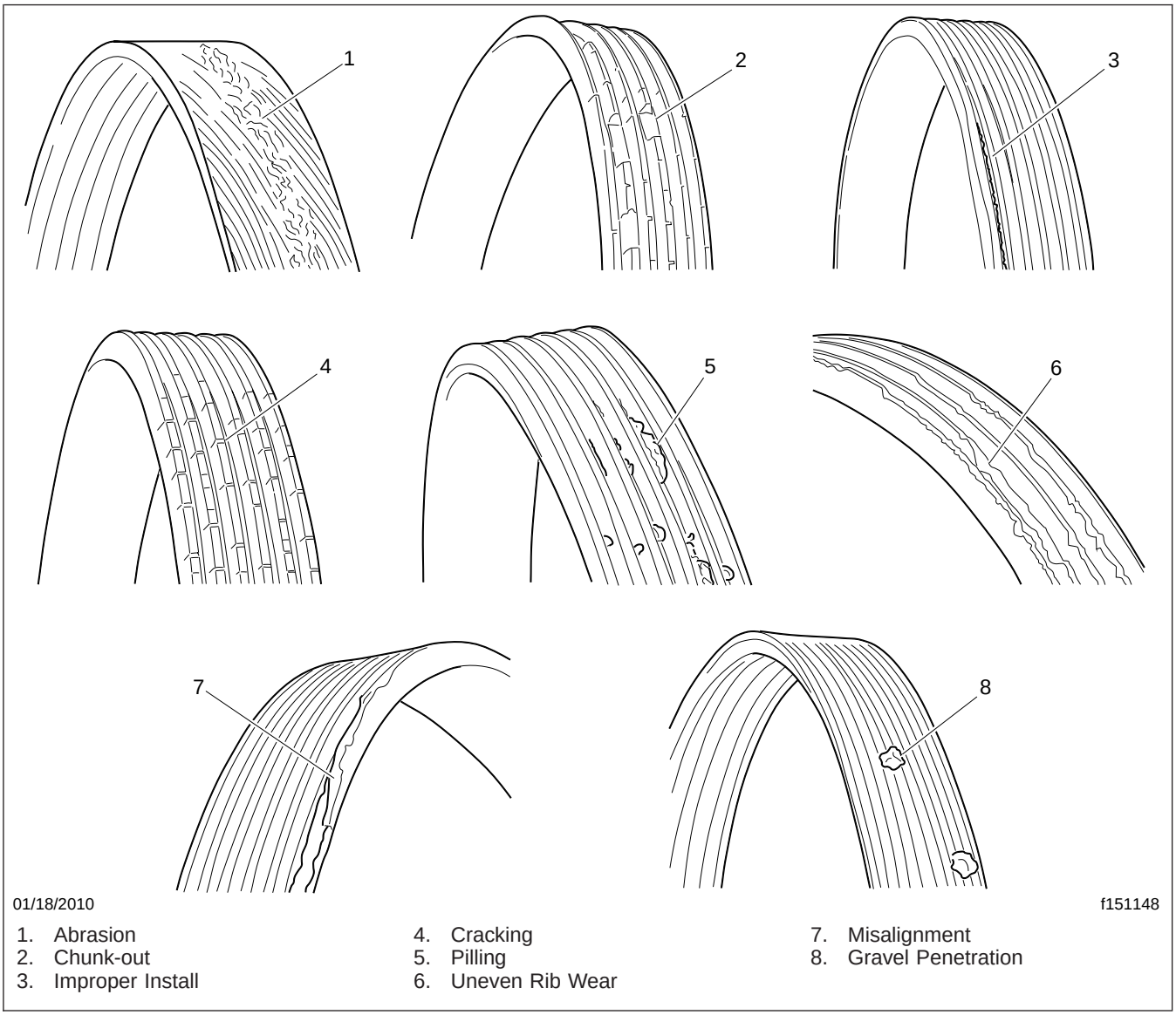
Drive Belt Inspection

NOTE: For diagnostic procedures and engine component replacement, refer to the engine manufacturer's service literature. See **Detroit Diesel www.detroitdiesel.com** or **Cummins Engine www.cummins.com**.

Inspection

1. Inspect the belt contact surfaces for chips, flaking, cracks, discoloration, and other damage. See **Fig. 1**.
2. Inspect the bearings in the idler pulleys, and accessories, by rotating the pulleys to look for bearing slop, or choppy feeling bearings.
3. Inspect the springs on the belt tensioner. If the spring is damaged, change the belt tensioner following the engine manufacturer's instructions.
4. Inspect the pulleys for damage. If the pulleys are damaged, change both the damaged pulley and the belt following the engine manufacturer's instructions. See **Fig. 2**.
5. Check the belt allignment on all idler pulleys. If the alignment is incorrect as shown in **Fig. 3**, and pulley wear is visible, replace the pulley and bracket following the engine manufacturer's instructions.

Drive Belt Inspection



1. Abrasion
2. Chunk-out
3. Improper Install
4. Cracking
5. Pilling
6. Uneven Rib Wear
7. Misalignment
8. Gravel Penetration

Fig. 1, Damaged Belts

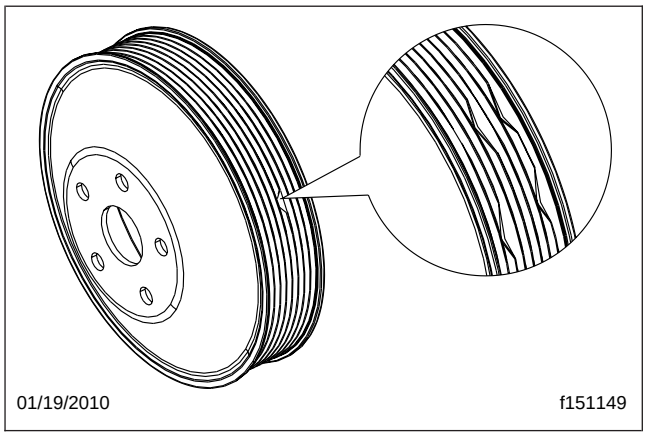
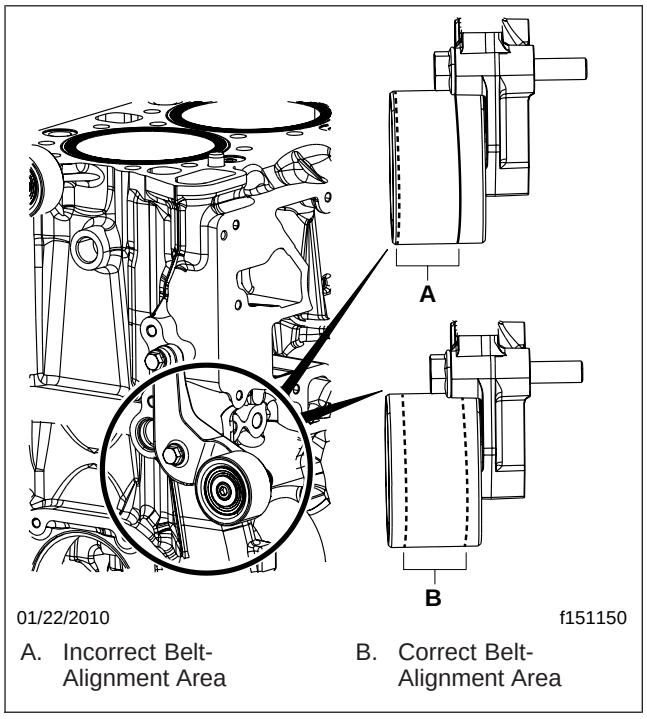


Fig. 2, Damaged Pulley



A. Incorrect Belt-Alignment Area

B. Correct Belt-Alignment Area

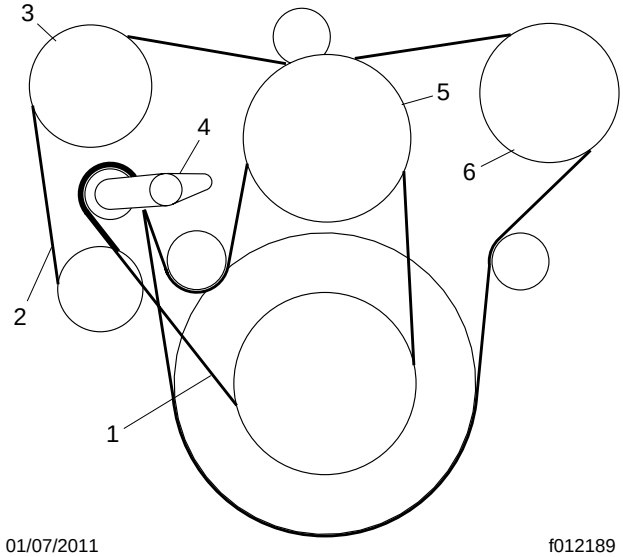
Fig. 3, Idler-Pulley Belt Alignment

Drive Belt Replacement, Detroit Diesel Engines

Detroit Diesel engines are equipped with two serpentine poly-V drive belts. The rear belt (closest to the engine block surface) drives the alternator, the A/C compressor, and the water pump. The front belt drives the engine fan. See **Fig. 1**. Both drive belts are kept at the correct tension with pulleys and a dual automatic belt-tensioner assembly.

NOTICE

When replacing the drive belts for the DD engine, it is crucial to use the correct procedure for releasing and locking the belt tensioners. Because they are part of the same assembly, it may appear that both belt tensioners can be released at the same time by releasing just one, but this is not the case. They must be released and locked separately, and in the correct sequence, or the assembly may be damaged.

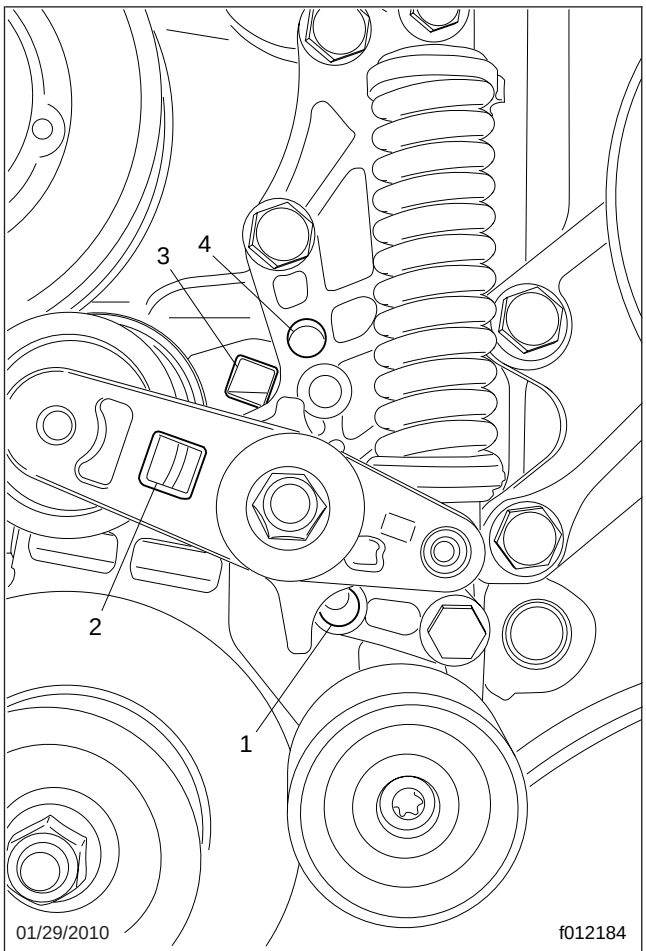


1. Front Drive Belt
2. Rear Drive Belt
3. AC Compressor
4. Spring Loaded Tensioner
5. Fan Clutch
6. Water Pump

Fig. 1, DD13 Drive Belt routing

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Raise the hood.
4. Locate the automatic belt tensioner assembly, on the left (passenger) side of the engine, as you are facing it. Familiarize yourself with the location of the square, front and rear 1/2-inch drive holes, and the round, front and rear holes for the locking bolts. See **Fig. 2**.



1. Front Round Hole for 10-mm Locking Bolt
2. Front Square1/2-inch Drive Hole
3. Rear Square 1/2-inch Drive Hole
4. Rear Round Hole for 10-mm Locking Bolt

Fig. 2, Belt Tensioners Assembly

Drive Belt Replacement, Detroit Diesel Engines

NOTICE

Never rotate the automatic belt tensioners clockwise. To do so may damage them, and require replacement of the entire assembly. To prevent damage to the belt tensioners, always rotate them counterclockwise. Never use more force than 66 to 73 lbf (90 to 100 N), or you could damage the tensioner.

IMPORTANT: When releasing the automatic belt tensioners and removing the drive belts, always work on the front tensioner and belt (fan drive) first, then the rear tensioner and belt (alternator, A/C compressor, and water pump). When you unlock the belt tensioners, reverse the procedure; unlock the rear belt tensioner first, then front one.

5. Insert a 1/2-inch breaker bar, or 1/2-inch ratchet into the square hole in the idler arm of the front belt tensioner (grooved pulley), then smoothly rotate it downward (counterclockwise) until you feel resistance. See **Fig. 3**.

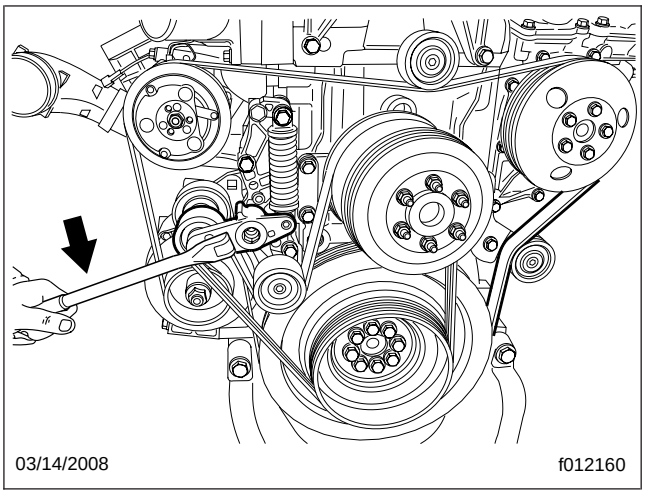
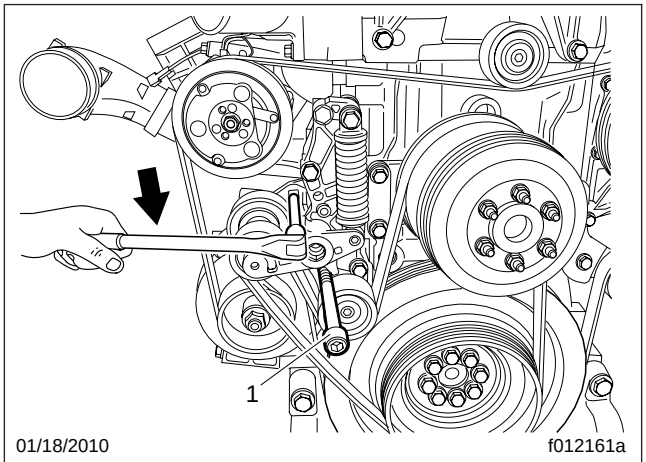


Fig. 3, Releasing the Front Tensioner

6. Insert a 10-mm diameter x 80 mm long bolt into the round hole on the idler arm of the tensioner as shown in **Fig. 4**, then push it all the way in. After the bolt is pushed all the way in, the tensioner will be locked in the released position. Remove the socket wrench from the square hole.
7. Insert a 1/2-inch breaker bar, or 1/2-inch ratchet, into the square hole in the idler arm of the rear belt tensioner (smooth pulley), then smoothly rotate it downward (counterclockwise) until you feel resistance. See **Fig. 4**.



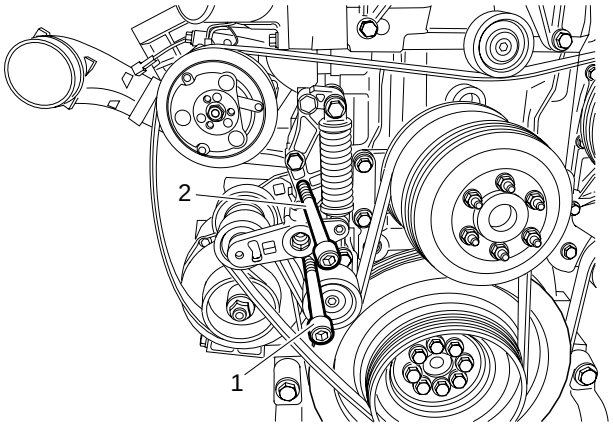
Note: For clarity, the locking bolt is shown in position but not pushed all the way in.

1. Front Belt Tensioner Locking Bolt Position

Fig. 4, Releasing the Rear Tensioner (smooth pulley)

8. Insert a second 10-mm diameter x 80 mm long bolt into the round hole on the idler arm of the rear tensioner as shown in **Fig. 5**, then push it all the way in. After the bolt is pushed all the way in, the tensioner will be locked in the released position. Remove the wrench from the square hole.
9. Replace the drive belts, making sure the new belts are correctly installed on all the pulleys.
10. Using the 1/2-inch breaker bar, or 1/2-inch ratchet, rotate the idler arm on the rear (smooth pulley) tensioner downward (counterclockwise), until you can remove the locking bolt. Smoothly release the idler arm all the way up, being careful not to jerk it.
11. In the same manner as the previous step, remove the locking bolt from the front tensioner.
12. Do a final check to make sure both drive belts are configured correctly, and correctly installed on all the pulleys.
13. Close the hood, connect the batteries, then remove the chocks.

Drive Belt Replacement, Detroit Diesel Engines



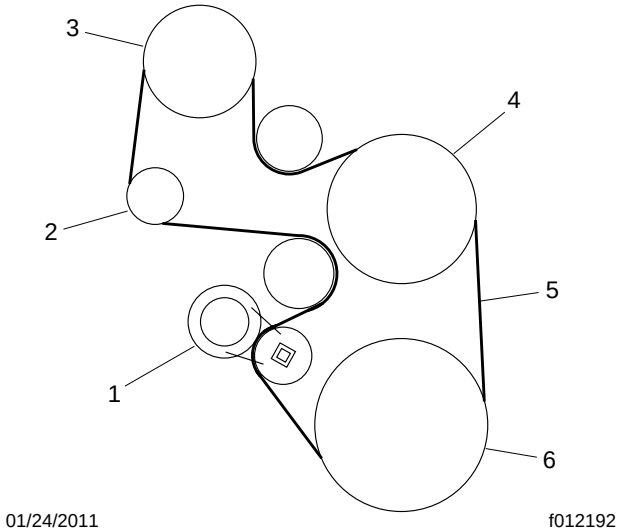
Note: For clarity, the locking bolts are shown in position but not pushed all the way in.

1. Locking Bolt for Front-Belt Tensioner
2. Locking Bolt for Rear-Belt Tensioner

Fig. 5, Front- and Rear-Belt Tensioner Locking Bolts in Position

Drive Belt Replacement, Cummins ISC/ISL Engine

Cummins ISC/ISL engines are equipped with a serpentine, poly-V accessory drive belt and an automatic belt tensioner. The accessory drive belt drives the fan, alternator, water pump, and the A/C compressor. See **Fig. 1**. The drive belt is kept at the correct tension by a system of pulleys and the automatic belt tensioner.

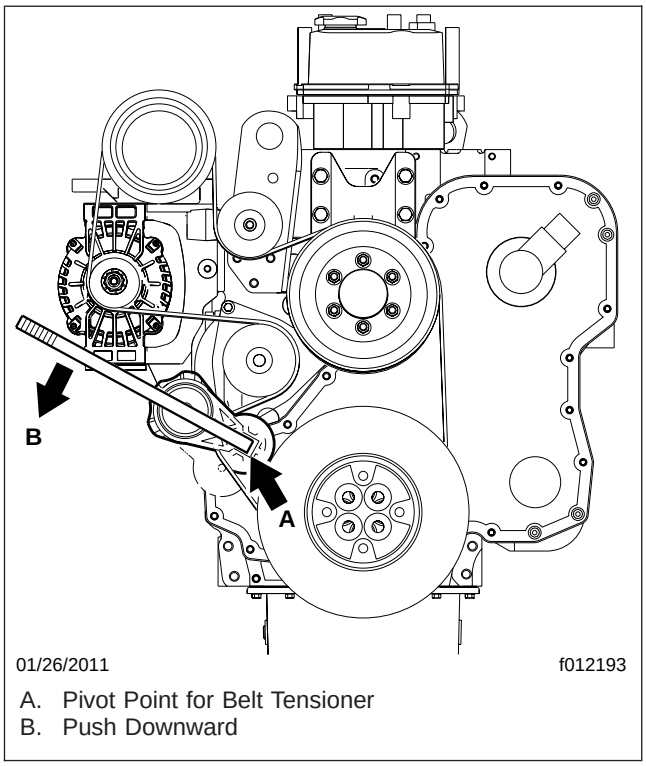


1. Spring Loaded Tensioner
2. Alternator Pulley
3. AC Compressor
4. Fan Clutch
5. Drive Belt
6. Crank Shaft Pulley

Fig. 1, Cummins ISC/ISL Drive Belt Routing

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Raise the hood.
4. Locate the drive-belt-tensioner assembly on the left (passenger) side of the engine, as you are facing it. Insert a 1/2-inch-drive ratchet or 1/2-inch breaker bar into the pivot point on the small end of the tensioner. See **Fig. 2**. Push downward on the breaker bar, rotating the tensioner counter-clockwise until you feel resistance.
5. While the tensioner is released, remove the drive belt.



A. Pivot Point for Belt Tensioner
B. Push Downward

Fig. 2, Releasing the Tensioner

6. Install a new drive belt, ensuring it is routed correctly, and centered on all the pulleys.
7. Smoothly release the pressure from the breaker bar. Never allow the tensioner to slam back against the stop, or damage may occur.
8. Start the engine, standing clear of belts and accessories. Check the belt tracking on all pulleys to ensure correct belt operation.
9. Close the hood and connect the batteries.

Removal

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

Do not operate the engine with any component of the air intake system removed. Serious physical injury can occur if the turbocharger impeller is touched when it is rotating.

NOTICE

Do not operate the vehicle with the air filter element or any air intake component removed. All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners.

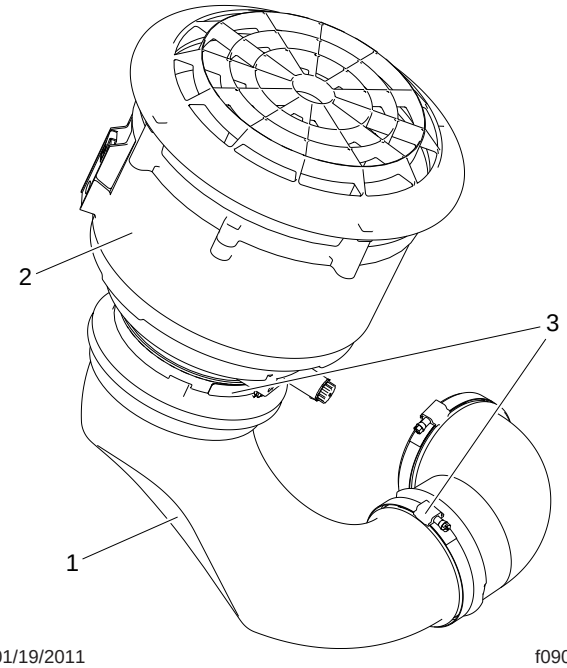
NOTE: The duct assembly may consist of the duct itself and an elbow to the turbocharger.

3. Remove the hose clamps that attach the air intake duct assembly to the air cleaner and the turbocharger. See **Fig. 1**.
4. Remove the air compressor suction hose, if equipped.
5. Remove the air intake duct.

Installation

1. Determine which new air intake duct assembly to install. Use PartsPro® to determine specific part numbers.
2. Inspect the new air intake duct assembly for debris that may have collected during shipping. Remove any debris or dirt before installation.

NOTE: P-80 Emulsion eases installation of tight-fitting rubber and plastic parts by reducing the force needed for assembly. Once assembly is complete, P-80 Emulsion dries and the part returns to its original condition. Use P-80 Emulsion when a thin film of lubricant is desired.



1. Air Intake Duct
2. Air Cleaner
3. Hose Clamps

Fig. 1, Air Intake Duct Assembly

3. Install the air intake duct over each connection so that it overlaps at least 1 inch (25 mm).

   P80 emulsion, or equivalent rubber lubricant, can be used to ease assembly at the air cleaner and duct joint.
4. Check the duct for any interference or contact with adjacent components. Loosen and adjust as necessary.

NOTE: Be sure all hose connections are square and have proper overlap before tightening the clamps.

5. Tighten the hose clamps 40 lbf·in (450 N·cm). If the elbow to the turbocharger was removed, install it and tighten the clamp 95 lbf·in (1074 N·cm).
6. Connect the air compressor suction line, if equipped, to the air compressor outlet on the duct.

Removal and Installation

7. Start the engine and bring it up to operating temperature, then shut the engine down. Check all clamps for correct torque value.

Removal

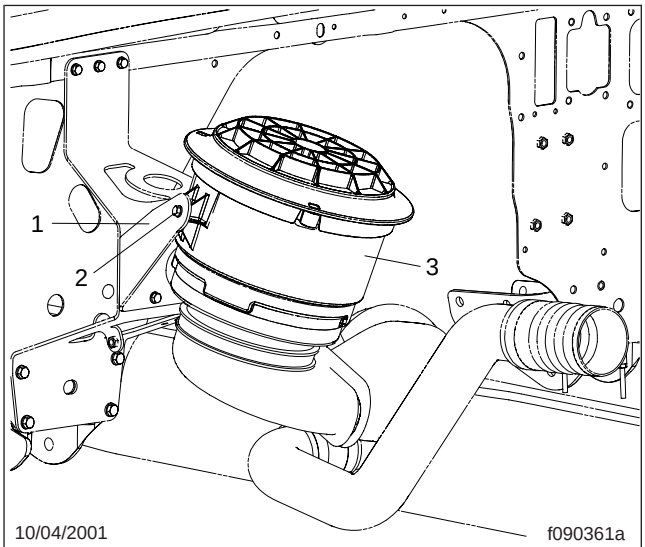
IMPORTANT: Do not modify, or use modified air cleaners or duct components.

1. Park the vehicle on a level surface, shut down the engine, and apply the parking brakes.
2. Chock the tires and open the hood.

NOTICE

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air cleaner element or any air intake component removed.

3. Remove the air restriction indicator or sensor, if equipped.
4. Loosen the hose clamp that attaches the air intake duct to the air cleaner outlet port, then pull the duct off the port. See **Fig. 1**.



1. Mounting Bracket
2. Capscrew
3. Air Cleaner

Fig. 1, Air Cleaner Installation

5. Remove the three capscrews that attach the air cleaner to the air cleaner mounting bracket.

Installation

1. Check the air cleaner housing for damage, and check all ducts and connections for leakage. Adjust or replace parts as necessary.

NOTICE

Do not clean or reuse air filter elements. Cleaning and reusing elements increases the chances of dirt entering the engine. Always replace with a new one.

2. Using three capscrews, install the air cleaner housing on the mounting bracket.
3. Install the air intake duct on the air cleaner outlet port so that it overlaps by at least 1 inch (25 mm). P80® Rubber Lubricant Emulsion, or equivalent rubber lubricant, can be used to ease assembly.

NOTE: To locate your local International Products Corporation distributor, call 1-609-386-877 or visit **www.ipcol.com**.

4. Check the duct for any interference or contact with adjacent components. Loosen and adust as necessary.
5. Tighten the hose clamp at the air cleaner outlet 40 lbf·in (450 N·cm).
6. Install the air restriction indicator on the air cleaner, if equipped.

Restriction Checking

Restriction of air flow through the air cleaner element is measured at the tap in the air cleaner outlet. Check the restriction indicator at the air cleaner, or in the cab if the vehicle is equipped with a dash-mounted restriction gauge.

NOTICE

Use the air intake restriction gauge rather than visual inspection to determine if servicing the air filter element is necessary. Removal of the air filter element can cause damage to the primary seal, which may allow contaminants into the engine, potentially causing engine damage.

Vehicles may be equipped with either a manual-reset restriction indicator with graduations (**Fig. 1**), or a go/no-go restriction indicator without graduations (**Fig. 2**).

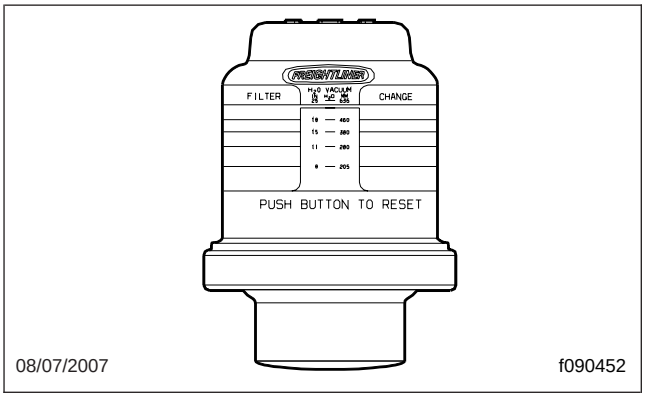


Fig. 1, Manual-Reset Air Restriction Indicator, Graduated

1. For vehicles equipped with a manual-reset indicator with graduations, check the indicator with the engine off to see if air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction.

   For vehicles equipped with a go/no-go restriction indicator without graduations, check the indicator with the engine off to see if the colored bar shows through the clear window.

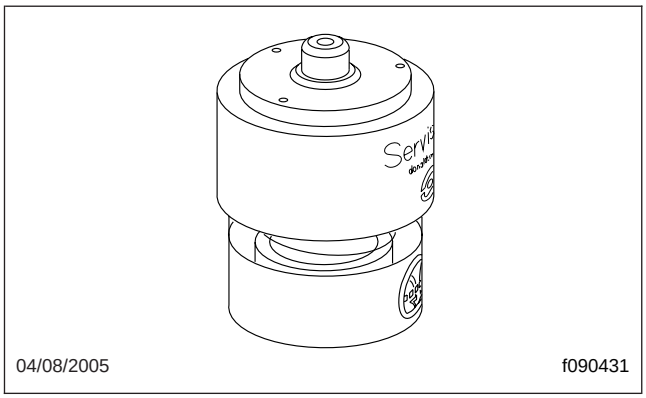


Fig. 2, Manual-Reset Air Restriction Indicator, Go/No-Go

Air Cleaner Element Maximum Restriction	
Engine	**Maximum Restriction**
Cummins	25 inH_2O
Detroit Diesel	22 inH_2O

Table 1, Air Cleaner Element Maximum Restriction

2. If air restriction is below the maximum, no further work is necessary.

   If air restriction is at or above the maximum, push the reset button on the indicator.

3. Operate the engine to see if air restriction exceeds recommended values again. This can be done by running the vehicle on a dynamometer at **full-load and rated rpm**, or by driving the vehicle for one day in the vehicle's typical operating environment while not exceeding the rated rpm. See the engine manufacturer's service literature for information on rated rpm for your engine.

4. Check the indicator again. If air restriction continues to equal or exceed the maximum air restriction value in **Table 1** on an indicator with graduations, or if the colored bar shows through the clear window on a go/no-go indicator, replace the air cleaner element, then reset the indicator.

   For air cleaner element replacement instructions, see **Subject 120** for instructions.

Replacement

IMPORTANT: Do not modify, or use modified air cleaners or duct components.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake.
2. Chock the tires and open the hood.

NOTICE

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Most of the dirt and dust particles are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air cleaner element or any air intake component removed.

3. Check the air cleaner housing for damage and check all ducts and connections for leakage. Adjust or replace parts as necessary.
4. Remove the capscrews that secure the primary air cleaner element in the air cleaner housing.

   Remove the primary air cleaner element. See **Fig. 1**.

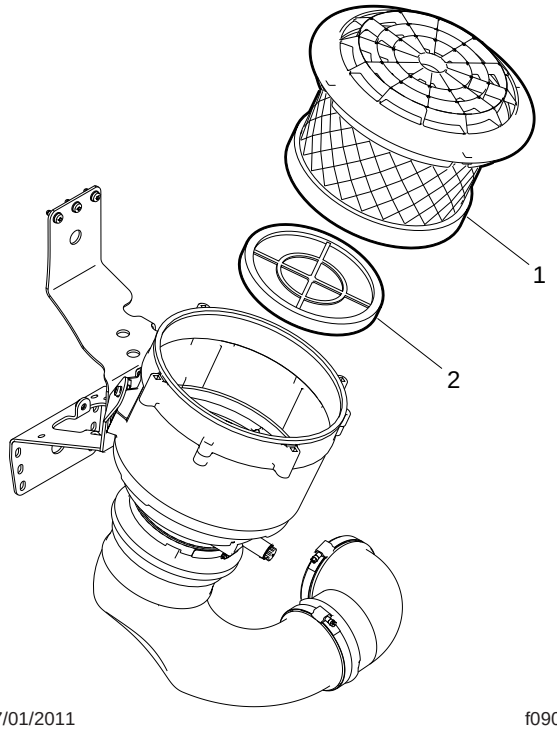
NOTE: The vehicle is equipped with either a stainless steel safety screen or a safety air cleaner element. Replace the safety screen or the safety element with every third primary air cleaner element replacement.

5. Remove the safety screen or element from the air cleaner and wipe the inside of the air cleaner with a clean, damp cloth. Check the housing and sealing surfaces for damage, dust, or foreign matter that could cause sealing problems. Clean surfaces or replace parts as necessary.

NOTICE

Do not clean or reuse air filter elements. Cleaning and reusing the elements increases the chances of dirt entering the engine. Always replace with a new one.

6. Inspect the safety screen or element for damage. Replace if necessary, or according to the recommended maintenance interval (see the NOTE before step 5).
7. Install the safety screen or element in the air cleaner housing.
8. Inspect the new primary air cleaner element for damage or holes.
9. Using capscrews, install the air cleaner element in the air cleaner housing. Tighten the capscrews 25 to 35 lbf·in (280 to 400 N·cm).
10. Check all connections for tightness.



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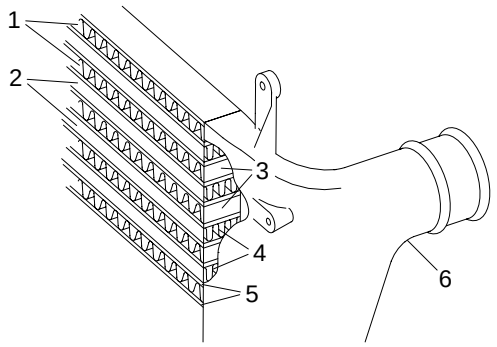
1. Primary Air Cleaner Element
2. Stainless Steel Safety Screen or Safety Air Cleaner Element

Fig. 1, Air Cleaner Elements

General Information

The charge air cooler (CAC) is attached to the front of the radiator. See **Fig. 1**. The air charge leaving the turbocharger is hot compressed air which then passes through the CAC. Outside ambient air passing through the CAC core cools the air charge temperature before the air enters the engine intake manifold. This temperature reduction lowers exhaust emissions, improves fuel economy, and increases horsepower.



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1. Cold Fins
2. Hot Bars
3. Cold Bars
4. Hot Fins
5. Tube Plates
6. Header Tank

Fig. 1, CAC Assembly

Detroit Diesel Engines

Removal

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Remove the grille. For instructions, see **Group 88**.
3. Open the hood.
4. Remove the side air-recirculation baffles from the CAC.

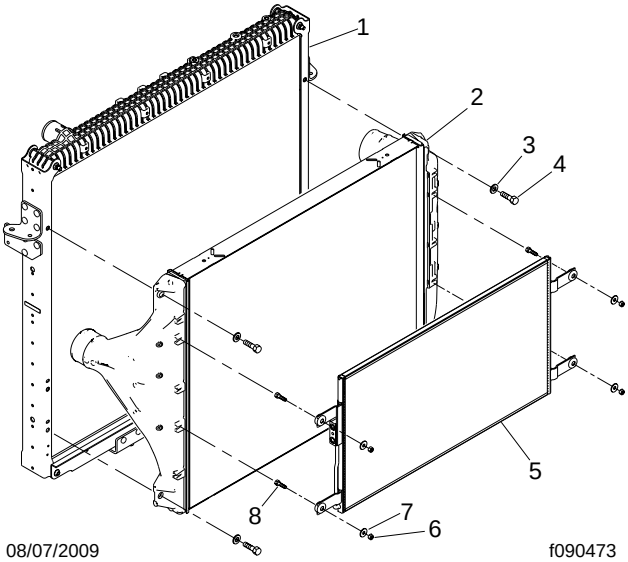
NOTE: Do not open or remove any A/C hoses. Opening the A/C system is not necessary for this procedure.

5. Allow extra slack in the A/C condenser hoses by removing the receiver-drier mounting bracket and the A/C hose support clamps that secure the hoses near the radiator.
6. Remove the A/C condenser mounting fasteners. See **Fig. 1**.
7. With the A/C hoses still connected, swing the condenser around and carefully set it on top of the passenger-side tire, see **Fig. 2**.

   If the proximity of the bumper makes it impossible to swing the A/C condenser around to the passenger side tire, carefully swing the condenser up over the radiator to rest on the engine. Make sure the receiver-drier is adequately supported by the radiator support strut, see **Fig. 3**.
8. Remove the constant tension hose clamps from the convoluted hoses on the CAC inlet and outlet tubes. Remove the convoluted hoses and CAC tubes.
9. Loosen the two upper screws that secure the CAC to the radiator and completely remove the two lower screws.
10. Support the CAC, then remove the two upper screws that secure it to the radiator and remove the it.

Installation

NOTE: Installing the CAC may be more difficult than removing it, and the fit may be tight. Be sure nothing hinders the fit between the CAC and the radiator.



1. Radiator
2. CAC
3. CAC Mounting Washer (4 qty.)
4. CAC Mounting Capscrew (4 qty.)
5. A/C Condenser
6. A/C Condenser Mounting Nut (4 qty.)
7. A/C Condenser Mounting Washer (4 qty.)
8. A/C Condenser Mounting Bolt (4 qty.)

Fig. 1, Charge Air Cooler (CAC) and A/C Condenser Assembly (Detroit Diesel shown)

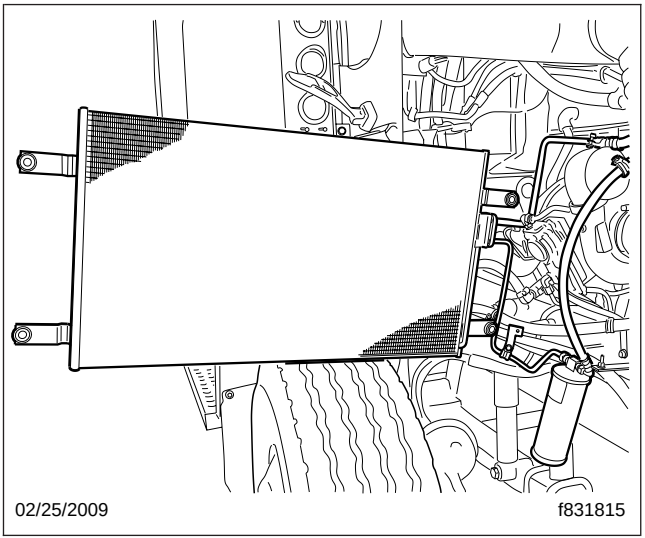
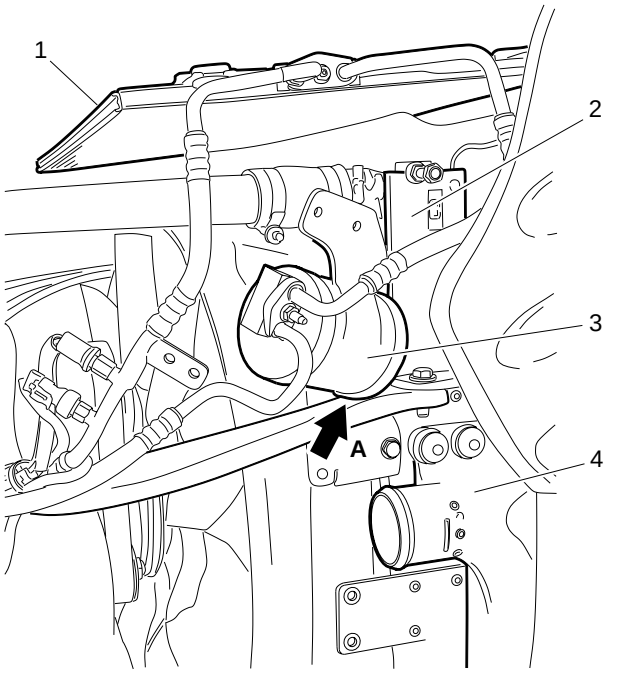


Fig. 2, A/C Condenser On Tire

Removal and Installation



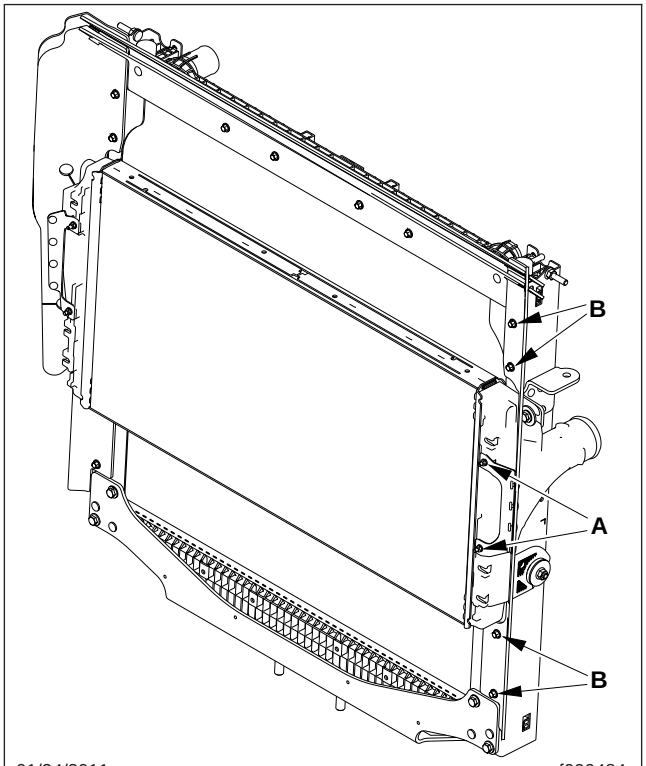
A. Rest the receiver-drier on the radiator support strut.

1. A/C Condenser
2. Radiator
3. Receiver-Drier
4. CAC

Fig. 3, A/C Condenser On Radiator

1. Install the CAC on the lower mounting bolts, then rotate it vertically until it rests against the radiator.
2. Install the fasteners that secure the CAC to the radiator. Tighten all CAC mounting fasteners 36 to 42 lbf·ft (49 to 57 N·m).
3. Install the side air-recirculation baffles. Tighten M6 capscrews 64 to 96 lbf·in (720 to 1085 N·cm); tighten 1/4–20 capscrews 80 to 112 lbf·in (904 to 1266 N·cm). See **Fig. 4**.
4. Install the A/C condenser on the front of the CAC. Tighten the condenser mounting fasteners 11 to 13 lbf·ft (15 to 18 N·m).
5. Install any A/C condenser hose support clamps that were removed and install the receiver-drier mounting bracket. Tighten all A/C condenser hose support clamps and the receiver-drier mounting bracket fasteners 14 to 16 lbf·ft (19 to 22 N·m).
6. Install the convoluted hoses and CAC tubes on the CAC, turbocharger, and engine intake manifold.
7. Install all constant tension hose clamps. Turn the constant tension hose clamps so their tightening screws are under the hoses or facing inboard. Tighten the clamp screws 98 lbf·in (1100 N·cm).

IMPORTANT: The constant tension clamps adjust to changes in diameter at the hose connection. Do not re-tighten a clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).



A. Tighten M6 capscrews 64 to 96 lbf·in (720 to 1085 N·cm) on both side baffles.
B. Tighten 1/4–20 capscrews 1/4–20 capscrews 80 to 112 lbf·in (904 to 1266 N·cm) on both side baffles.

Fig. 4, Side Air-Recirculation Baffle Mounting Fasteners

8. Close the hood and install the grille and grille bezel. For instructions, see **Group 88**.

Cummins Engines

Removal

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Remove the grille. For instructions, see **Group 88**.
3. Open the hood.
4. Remove the constant tension hose clamps from the convoluted hoses on the CAC inlet and outlet tubes. Remove the convoluted hoses and CAC tubes.
5. Remove the side air-recirculation baffles from the CAC.
6. Disconnect the hood strap from the radiator.

NOTE: Do not open or remove any A/C hoses. Opening the A/C system is not necessary for this procedure.

7. Allow extra slack in the A/C condenser hoses by removing the receiver-drier mounting bracket.
8. Remove the A/C condenser mounting fasteners. See **Fig. 1**.
9. With the A/C hoses still connected, swing the condenser around and carefully set it on top of the passenger-side tire, see **Fig. 2**.

   If the proximity of the bumper makes it impossible to swing the A/C condenser around to the passenger side tire, carefully swing the condenser up over the radiator to rest on the engine. Make sure the receiver-drier is adequately supported by the radiator support strut, see **Fig. 3**.
10. Loosen the two upper screws that secure the CAC to the radiator and completely remove the two lower screws.
11. Support the CAC, then remove the two upper screws that secure it to the radiator and remove the it.

Installation

NOTE: Installing the CAC may be more difficult than removing it, and the fit may be tight. Be sure nothing hinders the fit between the CAC and the radiator.

1. Install the CAC on the lower mounting bolts, then rotate it vertically until it rests against the radiator.
2. Install the fasteners that secure the CAC to the radiator. Tighten all CAC mounting fasteners 36 to 42 lbf·ft (49 to 57 N·m).
3. Install the A/C condenser on the front of the CAC. Tighten the condenser mounting fasteners 11 to 13 lbf·ft (15 to 18 N·m).
4. Install the receiver-drier mounting bracket. Tighten the receiver-drier mounting bracket fasteners 14 to 16 lbf·ft (19 to 22 N·m).
5. Install the side air-recirculation baffles. Tighten M6 capscrews 64 to 96 lbf·in (720 to 1085 N·cm); tighten 1/4–20 capscrews 80 to 112 lbf·in (904 to 1266 N·cm).
6. Connect the hood strap to the radiator. Tighten the hood strap bolt 15 lbf·ft (20 N·m).
7. Install the convoluted hoses and CAC tubes on the CAC, turbocharger, and engine intake manifold.
8. Install all constant tension hose clamps. Turn the constant tension hose clamps so their tightening screws are under the hoses or facing inboard. Tighten the clamp screws 98 lbf·in (1100 N·cm).

IMPORTANT: The constant tension clamps adjust to changes in diameter at the hose connection. Do not re-tighten a clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

9. Close the hood and install the grille. For instructions, see **Group 88**.

Inspection

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Check the charge air cooler (CAC) convoluted hoses and the inlet and outlet tubes for holes or other damage. Also, check for loose or damaged constant tension hose clamps. Replace damaged parts. If hose clamp torque has dropped below 50 lbf·in (560 N·cm), turn the clamp so its tightening screw is under the hoses or facing inboard and tighten the screw 98 lbf·in (1100 N·cm).

IMPORTANT: Do not re-tighten a clamp unless the measured torque drops below 50 lbf·in (560 N·cm).

4. Check the CAC core fins. If the fins are bent, use a small pair of needlenose pliers or a small screwdriver to straighten them.
5. Check the CAC core for clogged fins. Use compressed air or water to dislodge any material restricting airflow through the core.
6. Perform the "CAC Core Leakage Test."

CAC Core Leakage Test

Charge air coolers are designed in such a way that they may bleed an insignificant amount of air. The allowable leakage rate in **Table 1** represents a loss of less than 0.1 percent of charge airflow. Based on this rate, there should be no measurable loss of performance.

Leakage Rate Specifications	
Start Pressure: psi (kPa)	**Pressure Drop in 15 Seconds: psi (kPa)**
30 (207)	5 (34)

Table 1, Leakage Rate Specifications

The CAC core leakage test should be performed using a CAC test kit, part number 5039, which can be purchased from Kent-Moore/SPX at 1-800-328-6657.

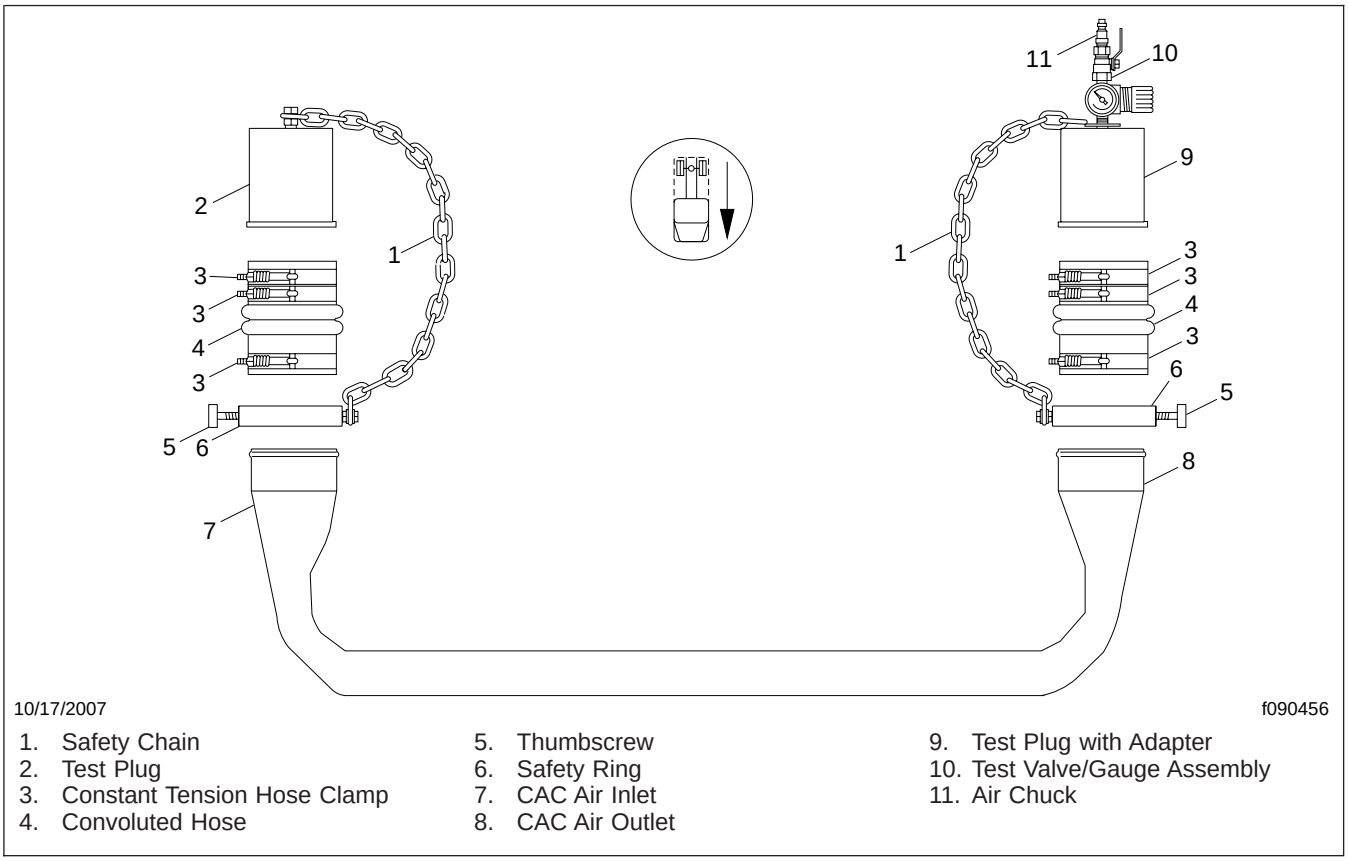
1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Connect the test equipment to the CAC core as follows. See **Fig. 1**.
   - 3.1 Remove the CAC air inlet tube from the convoluted hose that attaches it to the CAC.
   - 3.2 Remove the rear convoluted hose that attaches the CAC air inlet tube to the turbocharger. Leave the forward convoluted hose attached to the CAC air inlet port in place.
   - 3.3 Remove the outlet air tube from the CAC air outlet port. Install the rear convoluted hose from the CAC inlet side on the CAC outlet port.
   - 3.4 Slip a safety ring with thumbscrew over each convoluted hose, and onto the CAC air inlet and air outlet ports. Turn the rings so the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.
   - 3.5 Install an additional constant tension hose clamp on each convoluted hose.
   - 3.6 Install the test plug without an adapter in the CAC air inlet, and turn the plug so the safety chain is inboard. Tighten each constant tension hose clamp 72 lbf·in (810 N·cm).
   - 3.7 Install the test plug with an adapter in the CAC air outlet, and turn the plug so the safety chain is inboard. Tighten each constant tension hose clamp 72 lbf·in (810 N·cm).

⚠ WARNING

Always secure the test plugs with the safety rings. Test pressures could blow out an unsecured test plug at high speed, possibly causing eye injury or other serious personal injury.

   - 3.8 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adapter.
   - 3.9 Attach a pressurized air line to the air chuck on the pressure regulator valve.
4. Test the CAC core as follows.

Inspection and Leakage Test



1. Safety Chain
2. Test Plug
3. Constant Tension Hose Clamp
4. Convoluted Hose
5. Thumbscrew
6. Safety Ring
7. CAC Air Inlet
8. CAC Air Outlet
9. Test Plug with Adapter
10. Test Valve/Gauge Assembly
11. Air Chuck

Fig. 1, CAC Core Testing

⚠ WARNING

Always wear safety glasses and hearing protection when doing this procedure. Do not stand in front of the test plugs while the core is pressurized. A plug could suddenly release debris at high speed, possibly resulting in eye injury or other serious personal injury.

4.1 Open the test valve, then slowly open the pressure regulator valve and allow the CAC to gradually fill with air to 30 psi (207 kPa).

4.2 Close the test valve, and watch the gauge for 15 seconds. If the pressure drops below 5 psi (34 kPa) in 15 seconds, replace the CAC.

IMPORTANT: Do not attempt to repair the CAC.

4.3 When testing is complete, reduce the pressure on the pressure regulator valve to bleed air from the CAC.

5. Remove the test equipment (and the additional constant tension hose clamps) from the convoluted hoses.
6. Remove the convoluted hose from the CAC air outlet port and install it on the CAC air inlet tube.
7. Install the CAC air inlet tube and convoluted hose assembly on the turbocharger and forward convoluted hose. Ensure the convoluted hoses cover about 1-1/2 inches (38 mm) of the CAC air inlet tube.
8. Turn the constant tension hose clamps so their tightening screws are under the hoses or facing inboard. Tighten the clamp screws 98 lbf·in (1100 N·cm).

9. Install the CAC air outlet tube on the CAC and engine intake manifold. Tighten the constant tension hose clamp screws 98 lbf·in (1100 N·cm).

IMPORTANT: The constant tension clamps adjust to changes in diameter at the hose connection. Do not re-tighten a clamp unless the measured torque drops below 50 lbf·in (560 N·cm), at which time it should be tightened again 98 lbf·in (1100 N·cm).

Flushing

If the charge air cooler (CAC) is suspected of being contaminated, flush it.

1. Apply the parking brakes and chock the tires.
2. Remove the CAC. For instructions, see **Subject 100**.
3. Set the CAC in a horizontal position with the inlet and outlet ports facing up.

IMPORTANT: Use only naphtha or mineral spirits to clean the CAC. Do not use caustic solutions such as those that are commonly used in radiator shops. Do not use steam or high-temperature cleaning operations. Caustic solutions, steam, and high-temperature cleaning operations will damage the RTV that seals the charge air cooler tubes to the headers, which may result in leakage.

4. Pour a filtered naphtha or mineral spirits solution into the CAC until it is 40 percent full.
5. Cap the inlet and outlet ports on the CAC.
6. Rock the CAC back and forth so that the solvent travels from one tank, through the tubes, to the other tank and back. Repeat this process ten times.

NOTE: Do not leave the solvent in the CAC for more than ten minutes.

7. Remove the caps from the inlet and outlet ports.
8. Drain the CAC and properly dispose of the solvent.
9. Leave the caps off and allow the residual solvent to evaporate, then tip the upright CAC sideways to allow any remaining vapor to leave the CAC.
10. Install the CAC. For instructions, see **Subject 100**.

Test

After flushing the charge air cooler (CAC) because of turbocharger or engine damage, test the pressure drop across the CAC and air piping.

1. Perform the CAC core leakage test. For instructions, see **Subject 110**.
2. Remove the pipe plug (if equipped) from the tapped hole in the turbocharger air outlet elbow.

   Remove the pipe plug or the air line to the turbocharger air-pressure gauge (if equipped), from the tapped hole in the left-hand rear of the intake manifold.

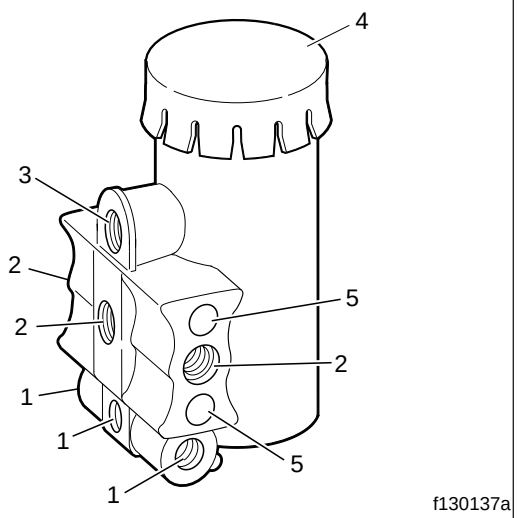
   Install an air pressure gauge in each tapped hole.
3. Operate the engine at rated speed and horsepower; there is no need to operate the engine at its peak torque rating. While operating the engine, read both air pressure gauges.

   Because of the turbulence of the air at the turbocharger outlet, subtract 0.3 inHg (1 kPa) from the pressure measurement taken at the turbocharger outlet, to make it a true reading.
4. From that reading, subtract the reading taken at the intake manifold. This is the pressure drop of the CAC.

   If the pressure drop is more than 4 inHg (14 kPa), flush or replace the CAC as needed.

General Information

The air governor may be mounted on the air compressor, on the air dryer, or remote-mounted on the engine block. The governor has three reservoir ports, three unloader ports, and one exhaust port. See **Fig. 1**.



1. Reservoir Port
2. Unloader Port
3. Exhaust Port
4. Top Cover
5. Mounting Hole

Fig. 1, Air Governor

The air governor operates in conjunction with the air compressor to maintain pressure in the air brake or air supply system between a maximum (cut-out) and minimum (cut-in) pressure.

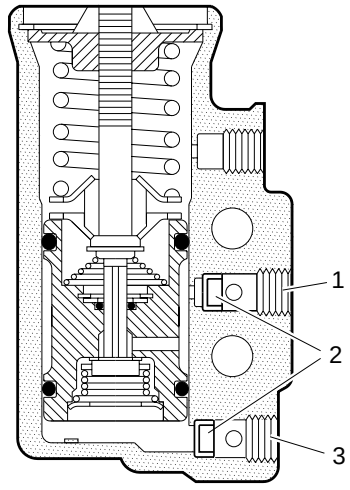
The cut-out setting of the air governor is typically 130 psi (896 kPa). When pressure in the air system reaches that point, the governor releases a signal to the air compressor and air dryer. The signal shifts the compressor to the unloaded cycle and opens the air dryer purge valve.

The cut-in setting of the governor is typically 105 psi (724 kPa). When pressure in the air system drops to that point, the governor stops the signal to the air compressor and the air dryer. At that time, the compressor shifts to the loaded cycle and closes the air dryer purge valve, building pressure in the air system.

Removal

NOTE: The governor may be mounted on the air compressor, on the air dryer, or remote-mounted on the engine block.

1. Shut down the engine, apply the parking brake, and chock the tires. Drain the air system and open the hood.
2. Disconnect the reservoir and unloader port lines. See **Fig. 1**. Mark the lines for later reference. Cap the air lines tightly to keep out contaminants.



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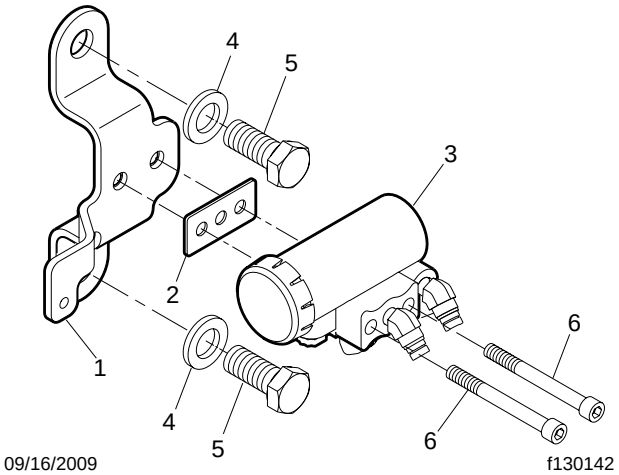
1. Unloader Port
2. Port Filters
3. Reservoir Port

Fig. 1, Air Governor Ports

3. Remove the governor mounting capscrews (see **Fig. 2**) and remove the governor.

Installation

1. Clean the mating surfaces on the air governor and the component it mounts to (air compressor, air dryer, or engine block). Ensure the governor unloading port is free of dirt and debris.
2. If the governor requires a governor adaptor, install a new governor mounting gasket between the governor and the adaptor.



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1. Governor Mounting Bracket
2. Governor Mounting Gasket
3. Air Governor
4. Mounting Bracket Lockwasher (2 Qty)
5. Mounting Bracket Capscrew (2 Qty)
6. Governor Mounting Capscrew (2 Qty)

Fig. 2, Air Governor Installation

3. Using capscrews and lockwashers, install the governor, or governor and adaptor assembly. Tighten the capscrews 14 to 16 lbf·ft (19 to 22 N·m).
4. If necessary, install new filters (**Fig. 1**) in the reservoir and unloader ports. The cup-shaped filters can be installed with the eraser end of a pencil.
5. Clean the reservoir and unloader port air lines after removing the caps, and apply sealant in small quantities to the fittings.

NOTICE

Make sure excess sealant does not get inside the fittings. Loose material inside the plumbing may clog the governor or other components, causing damage.

6. Connect the reservoir and unloader port air lines. Tighten the fittings 11 to 13 lbf·ft (15 to 18 N·m).
7. Perform the governor operation and leakage tests in **Subject 110**.

NOTE: The top cover may snap on or screw on, depending on the governor model.

Removal and Installation

8. After the tests have been completed and the governor is operating properly, install the top cover tightly on the governor body to prevent the entry of any foreign matter.

The following test should be performed whenever the vehicle air pressure is incorrect and the causes are unknown, and whenever the air governor has been replaced or reinstalled.

Operation Test

NOTE: The governor may be mounted on the air compressor, on the air dryer, or remote-mounted on the engine block.

1. Apply the parking brakes and chock the tires. Open the hood.
2. Start the engine and build up air pressure in the air system.

IMPORTANT: Make sure the test gauge is registering accurately before using it to check the air governor. Do not use the vehicle's dash pressure gauge to check the governor pressure setting.

3. Using a test gauge attached to the supply reservoir, check the pressure at the time the air governor cuts out. For vehicles with a dryer reservoir module (DRM), install the pressure gauge in either the primary or secondary reservoir.

   The cut-out pressure should be 125 to 135 psi (860 to 930 kPa).

4. With the engine still running, make a series of brake applications to reduce the air pressure and observe at what pressure the air governor cuts in.

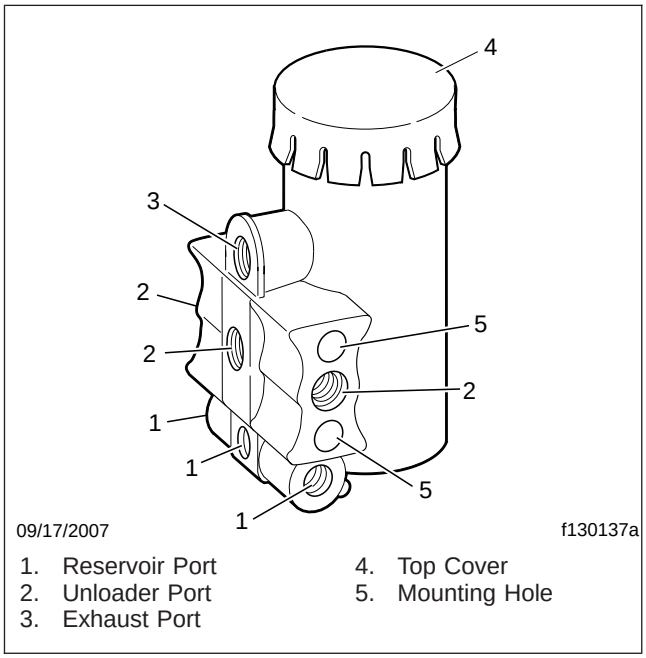
   For vehicles without a DRM, the minimum cut-in pressure should be 100 psi (689 kPa).

   For vehicles with a DRM, the minimum cut-in pressure should be 105 psi (724 kPa).

5. If the air governor does not function as described, replace the governor. See **Subject 100** for instructions.

Leakage Test

1. Apply the parking brakes and chock the tires. Start the engine and open the hood.
2. With the compressor in the cut-in position, apply a soap solution to the air governor exhaust port and around the governor top cover. See **Fig. 1**. Slight bubble leakage is permitted. Excessive leakage indicates that the inlet valve or lower piston O-ring is worn out.



1. Reservoir Port
2. Unloader Port
3. Exhaust Port
4. Top Cover
5. Mounting Hole

Fig. 1, Air Governor

3. With the compressor in the cut-out position, apply a soap solution to the air governor exhaust port and around the governor top cover. See **Fig. 1**. Slight bubble leakage is permitted. Excessive leakage indicates that the exhaust valve seat, exhaust stem O-ring, or upper piston O-ring is worn out.
4. If leakage is excessive, replace the governor. See **Subject 100** for instructions.

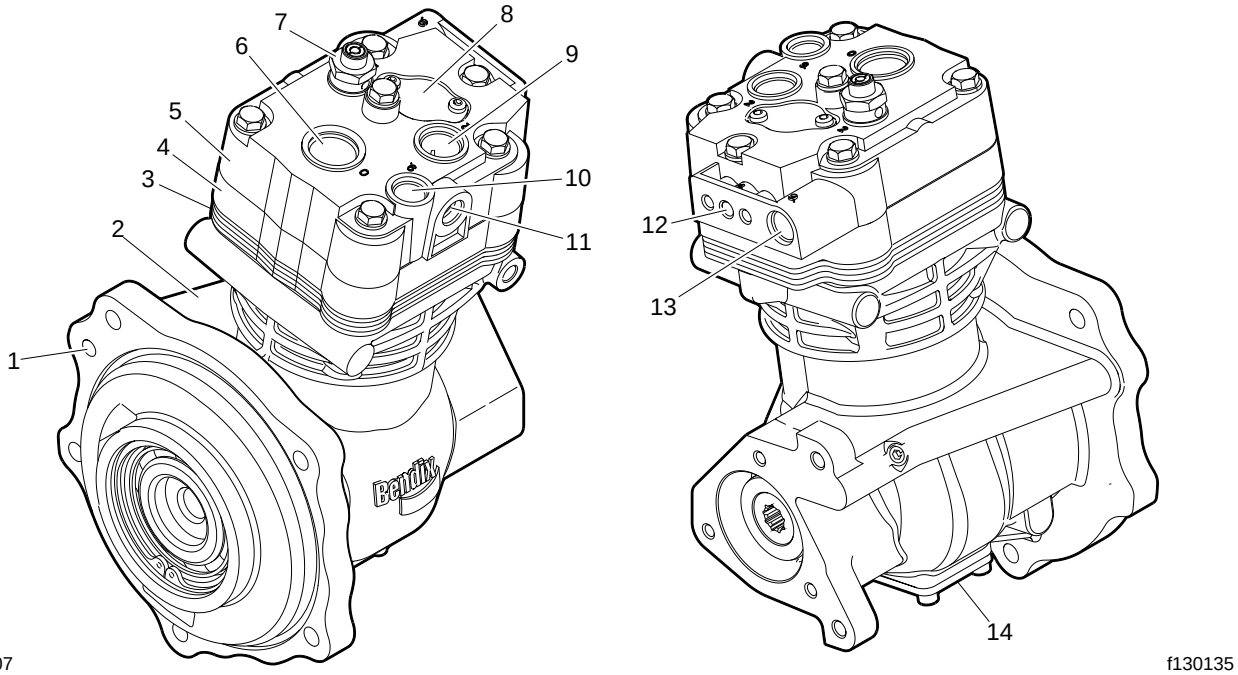
General Description

The function of the air compressor is to provide and maintain air under pressure to operate devices in the air brake system. See **Fig. 1**. The Bendix BA-921 air compressor is a single-cylinder reciprocating compressor with a rated displacement of 15.8 cubic feet per minute (cfm) at 1250 rpm. The Bendix LK-862 compressor is very similar to the BA-921 compressor, but has two cylinders and a rated displacement of 29.0 cfm at 1250 rpm.

The air governor operates in conjunction with the air compressor to maintain the air pressure in the air system between a maximum (cut-out) and minimum (cut-in) pressure. The air compressor turns continuously while the engine is on, but actual compression of air is controlled by the governor, which actuates the air compressor unloading mechanism. Unloading stops or starts based on the cut-in and cut-out pressure settings of the governor.

The cylinder head assembly is made up of the cylinder head, cooling plate, and a valve plate assembly. The cylinder head contains the air and coolant ports as well as an unloader piston. The cooling plate is located between the cylinder head and valve plate assemblies, and assists in cooling the cylinder head assembly. The valve plate assembly, consisting of brazed steel plates, has several valve openings and channels for conducting air and engine coolant into and out of the cylinder head. The compressor is cooled by air flowing through the engine compartment as it passes the compressor's cooling fins, and by the flow of engine coolant through the cylinder head. The vehicle's engine provides a continuous supply of oil to lubricate the compressor.

Bendix air compressors are typically equipped with a safety valve in the cylinder head safety valve port, directly connected to the discharge port. The safety valve protects the cylinder head assembly in the event of excessively high discharge line pressure.



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1. Oil Supply Bore
2. Crankcase
3. Valve Plate Assembly
4. Cooling Plate
5. Cylinder Head
6. Air Supply Port
7. Discharge Safety Valve
8. Unloader Valve Cover
9. Discharge Port
10. Coolant Supply Port
11. Freeze Plug
12. Governor Connection Port
13. Coolant Return Port
14. Crankcase Cover

Fig. 1, Bendix BA-921 Air Compressor

General Information

Excessive air pressure causes the safety valve to unseat, releases air pressure, and gives an audible alert to the operator.

Replacement

1. Shut down the engine, apply the parking brakes, chock the tires, and open the hood.
2. Drain the air system.
3. Disconnect the batteries.

⚠ WARNING

Wear goggles when using compressed air to clean or dry parts, as permanent eye injury could result from flying debris.

4. Using a cleaning solvent, remove road dirt and grease from the outside of the air compressor, then dry the compressor with compressed air.
5. Depending on the vehicle's engine and chassis specifications, the air compressor may be difficult to access behind the frame rail. It may be necessary to reposition or remove components above and below the frame rail that interfere with access to the compressor, such as battery cables and transmission oil cooler lines.

   Clear any wiring harnesses out of the way, removing P-clamps as necessary.
6. Remove any components attached to the air compressor, such as the power steering pump (DD13/15/16 engines).
7. Drain the coolant from the radiator and cylinder block. For instructions, see **Group 20**.
8. Remove the coolant supply and return lines from the compressor. See **Fig. 1**.
9. Identify and disconnect all air and oil lines attached to the air compressor.
10. Remove the air governor and the air governor mounting gasket, if equipped, or remove the air governor remote line.

NOTICE

Do not allow the air compressor drive gear to make contact with the gear train during removal. Damage to the seal surface could cause oil leakage.

11. Support the air compressor and remove the mounting fasteners that attach the compressor to the engine. Remove the air compressor.
12. Ensure all mating surfaces on the air compressor and the cylinder block are free of dirt or any other foreign material.

IMPORTANT: Ensure new seals are clean and not damaged.

13. Install new seals between the engine and the compressor.

NOTICE

Ensure the correct mounting capscrews are used to install the air compressor. If the wrong length is used, the cup plugs installed in the cylinder block can be pushed out into the gear train, causing damage to the gear train.

14. Using capscrews, attach the air compressor to the gear case. See **Table 1** for torque specifications.

Mounting Fastener Torque Values	
Description	**Torque: lbf·ft (N·cm)**
BA-921 Mounting Capscrews M10 1.50 x 85 (4 qty) M10 1.50 x 35 (1 qty)	43–54 (58–73)
LK-862 Mounting Capscrews	44 (60)
Power Steering Pump Mounting Fasteners	27–32 (37–43)
Fuel Pump Mounting Fasteners	22–28 (30–38)
Air Governor Mounting Fasteners	11–15 (15–20)

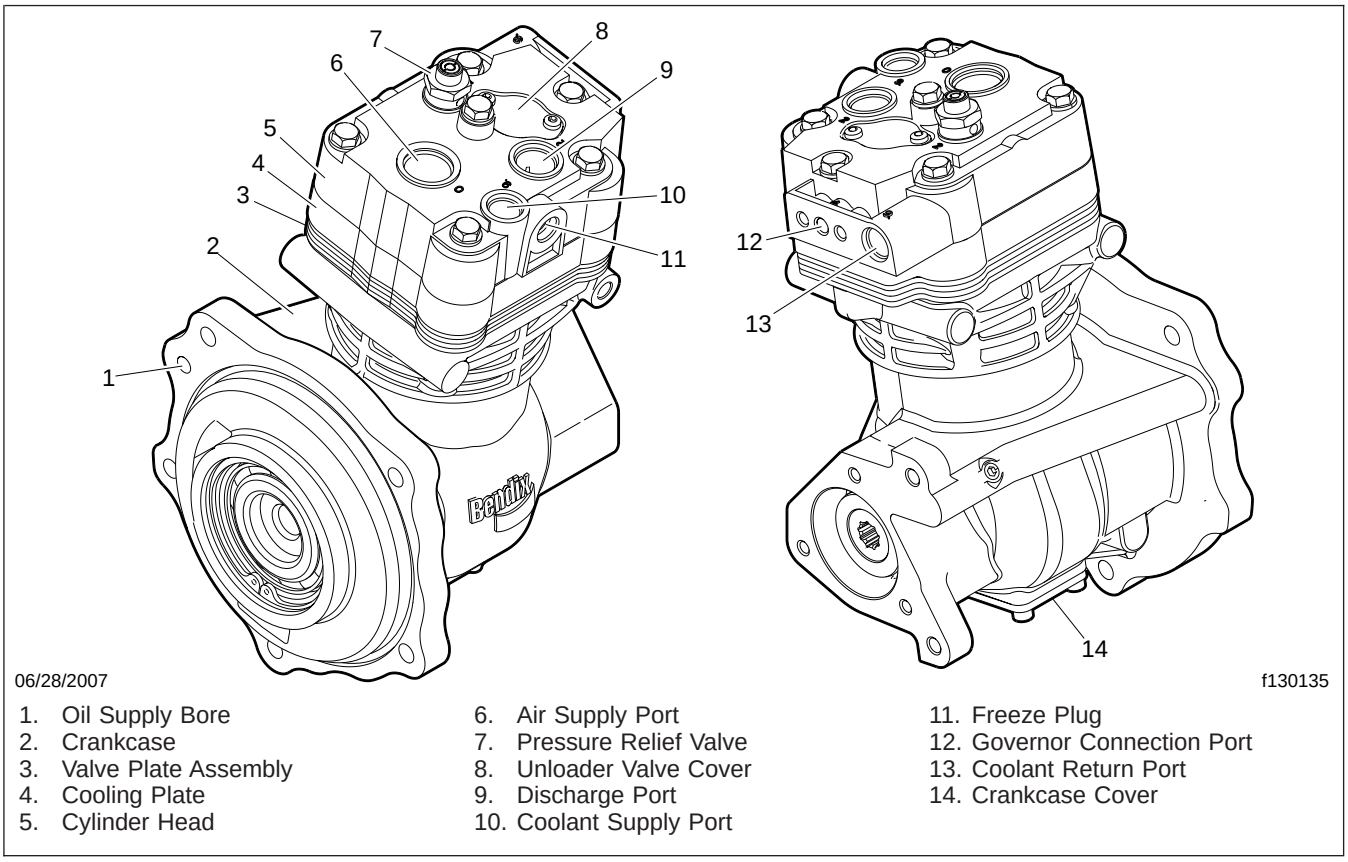
Table 1, Mounting Fastener Torque Values

15. If equipped with a compressor-mounted air governor, install a new gasket on the air governor and install the air governor on the compressor. If the vehicle has a remote-mounted air governor, connect the air governor remote line to the compressor.

NOTICE

Ensure the coolant lines are correctly installed with the coolant line retainer engaged in the locked position. Improperly connected coolant lines could cause a leak.

Air Compressor Replacement



1. Oil Supply Bore
2. Crankcase
3. Valve Plate Assembly
4. Cooling Plate
5. Cylinder Head
6. Air Supply Port
7. Pressure Relief Valve
8. Unloader Valve Cover
9. Discharge Port
10. Coolant Supply Port
11. Freeze Plug
12. Governor Connection Port
13. Coolant Return Port
14. Crankcase Cover

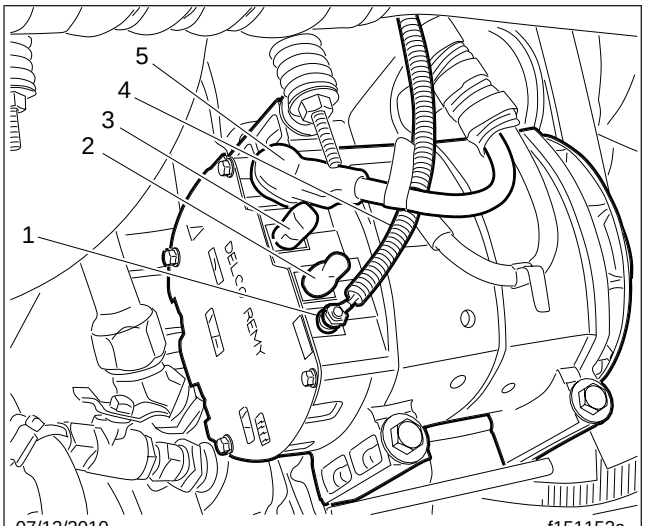
Fig. 1, Bendix Air Compressor (BA-921 shown)

16. Connect the air and coolant lines to the air compressor. Connect the oil line, if equipped, to the compressor.
17. Install any components that were removed from the air compressor, such as the power steering pump. See **Table 1** for torque specifications.
18. Move all wiring harnesses back into place and install any wiring harness P-clamps that were previously removed.
19. Fill the engine cooling system. For instructions, see **Group 20**.
20. Connect the batteries.
21. Start the engine and check for leaks.

General Information

Both Leece-Neville and Delco Remy alternators are available as original equipment on Freightliner vehicles. Installation and removal are the same for all alternators on a given engine design.

Many alternators are equipped with a remote-sense terminal that connects to the batteries, and adjusts the alternator output to keep the system at full charge. See **Fig. 1** for a Delco Remy alternator with remote sense. See **Fig. 2** for a Leece-Neville alternator with remote sense.



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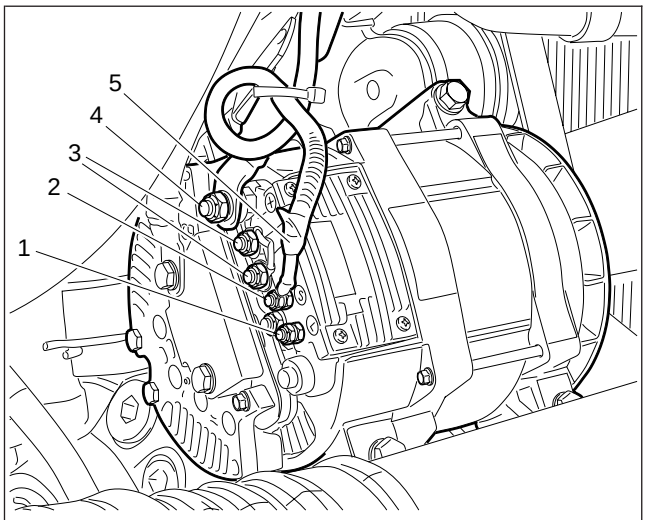
1. Remote-Sense Terminal
2. Indicator Terminal (lamp)
3. Relay Terminal 'R'
4. Remote Sense Circuit 123E
5. Positive Terminal (Battery)

Fig. 1, Delco Remy Alternator with Remote Sense



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1. Lamp Terminal 'L'
2. Remote-Sense Terminal 'S'
3. A.C. Terminals
4. Positive Terminal (Battery)
5. Remote Sense Circuit 123E

Fig. 2, Leece-Neville Alternator with Remote Sense

Removal

1. Apply the parking brake, shut down the engine, and chock the rear tires. Open the hood.
2. Disconnect the batteries.

NOTICE

Some vehicles are equipped with a cab load disconnect switch (CLDS). The CLDS does not disconnect power to the alternator and starter, so a short-circuit hazard still exists when working on the vehicle.

The batteries must be disconnected to remove the short-circuit hazard, when working on the charging system.

3. Remove the alternator drive belt, following the instructions in **Section 01.01** of this manual.

NOTE: Be sure the belt is working correctly before replacing the alternator. Many charging system problems originate in the drive belt. Inspect the belt for glazing, wear (frayed edges), damage (breaks or cracks), or oil contamination. Replace the belt if any of these conditions are present.

4. Note the wire connections on the terminals, then disconnect the wiring harness. Refer to **Subject 050** in this section for wiring connections.
5. Remove the alternator-mounting capscrews. Remove the alternator.
6. Remove the pulley for use on the new alternator. If the alternator is a Delco Remy, remove the pulley as follows:

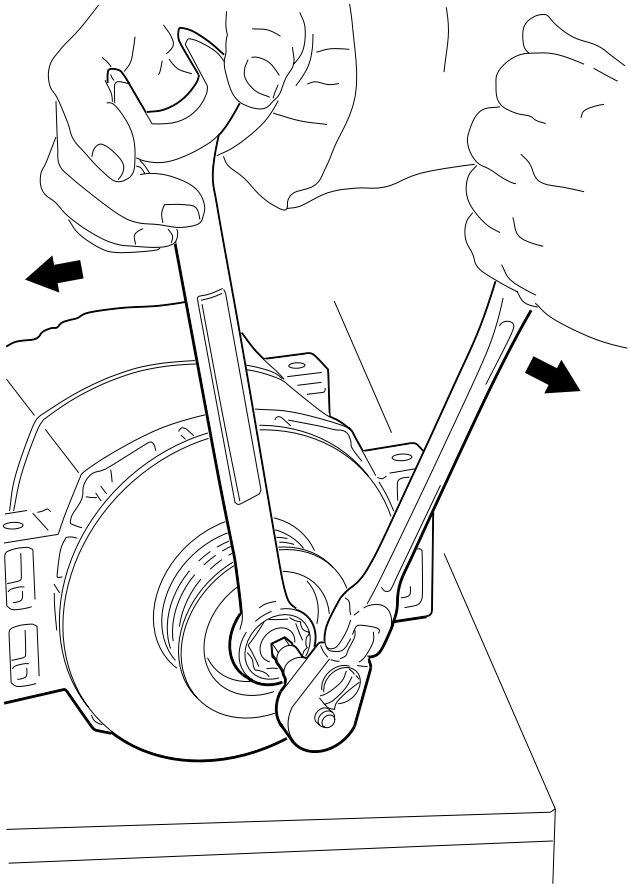
⚠ WARNING

Do not attempt to keep the pulley from turning with your hand, and do not jam a screwdriver into the cooling fins to keep it from turning, as you attempt to loosen the pulley nut. Using pulley nut removal and installation methods other than the one described below may cause personal injury, or damage the alternator and void the warranty.

6.1 Hold the alternator pulley retaining nut with a box-end wrench.

6.2 Insert a 5/16-inch Allen wrench into the Allen fitting in the rotor shaft.

6.3 Hold the rotor shaft with the Allen wrench, and turn the pulley nut counterclockwise to remove it. See **Fig. 1**. Remove the nut, washer, and pulley.



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Hold the rotor shaft with the Allen wrench, and turn the pulley nut counterclockwise to remove it. Remove the nut, washer, and the pulley.

Fig. 1, Loosening a Delco Remy Alternator Pulley Nut

Installation

1. For a Delco Remy alternator, install the pulley on the new alternator.

1.1 Hold the alternator pulley retaining nut with a box-end wrench.

Removal and Installation

1.2 Insert a 5/16-inch Allen wrench into the Allen fitting in the rotor shaft.

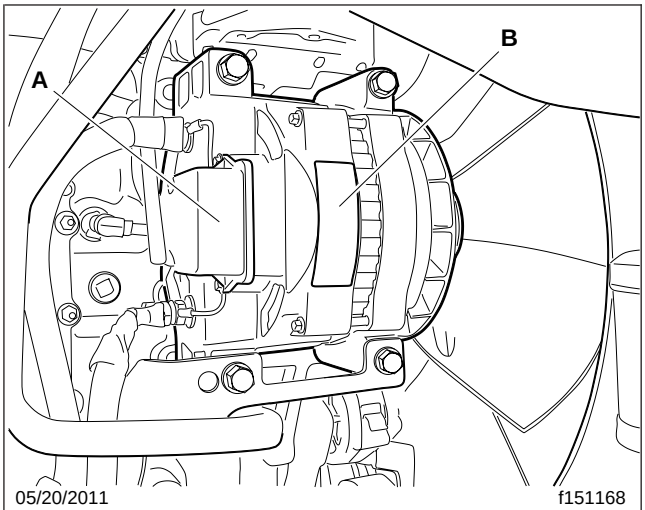
1.3 Hold the rotor shaft with the Allen wrench, and turn the pulley nut clockwise to tighten.

1.4 Tighten the pulley nut 75 lbf·ft (101 N·m).

2. Install the alternator.

2.1 Position the alternator on the engine. and start the mounting capscrews.

On Leece Neville pad-mounted alternators, belt alignment is obtained by the two mounting bolt holes closest to the alternators pulley. These holes are precision drilled so the alternator is positioned correctly on the engine bracket for proper belt alignment. When mounting a Leece-Neville alternator, it is important that the label or regulator face away from the engine block. If this is not adhered to then the belt alignment will not be correct. See **Fig. 2**.



A. Regulator must face away from the engine block.
B. Label must face away from the engine block.

Fig. 2, Leece-Neville Pad-Mounted Alternator Installation

2.2 Tighten the mounting capscrews 35 lbf·ft (48 N·m).

2.3 Install the drive belt following the instructions in **Section 01.01** of this manual.

3. As noted during removal, connect the wiring harness to the alternator terminals. Tighten the output-terminal hexnut 100 lbf·in (1140 N·cm). Tighten the ground-terminal hexnut 65 lbf·in (730 N·cm). Tighten the other terminal hexnuts 20 lbf·in (225 N·cm).

4. Protect any exposed terminal connectors with dielectric red enamel.

5. Connect the batteries.

6. Close and latch the hood, and remove the tire chocks.

Troubleshooting

IMPORTANT: Before testing, make sure:

- All belts are tensioned and are not cracked, worn, or glazed;
- The wiring and terminals are free of corrosion, properly torqued, and protected with dielectric enamel.

Pre-Test Checks

1. Shut down the engine, apply the parking brake, and chock the tires. Raise the hood.
2. If the vehicle is equipped with a remote-sense circuit, inspect as follows:
   - 2.1 Verify that the remote-sense wire (circuit # 123E) is connected to the remote sense terminal.
   - 2.2 Verify the fuse for the remote-sense circuit is not open. This fuse is located in the PNDB. The remote sense terminal on the alternator will measure approximately 1/2 volt below battery voltage when the remote sense circuit (123E) fuse is open.
3. Check all connections between the battery, starter and alternator for tightness and signs of corrosion. Tighten, clean, and protect as necessary.

Using the Intelli-Check 2 Systems Analyzer

NOTE: The Intelli-Check 2 tester is recommended for alternator testing. It is capable of testing alternators with an output that is greater than the limit of the Intelli-Check (original) tester limit of 145 amps.

IMPORTANT: The batteries should be charged to at least 12.6 volts before performing the following tests. Remove the surface charge from freshly charged batteries by turning the headlights and blower fan on high for several minutes.

1. Using the Intelli-Check 2, perform a voltage drop test on the alternator cables. See **Fig. 1**.

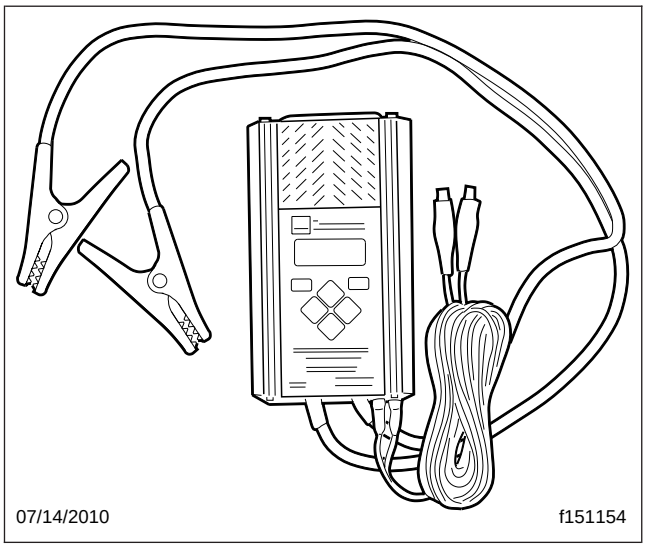


Fig. 1, Intelli-Check 2 Alternator Analyzer

   - 1.1 With the vehicle shut down, begin by turning the tester on. Select “Voltage Drop” Test and press Enter. Press ESC to bypass the vehicle ID screen.
   - 1.2 Select “Charging Cables” and press Enter. Enter the rated alternator output from the label on the alternator and press Enter.
   - 1.3 Connect the large leads to the alternator output terminal and ground and press Enter.

   NOTE: Disregard the tester summary of pass/fail. A voltage drop of 1/2 volt or less is acceptable.

   - 1.4 Connect the small leads to the battery. Press Enter to run the test. Use caution as the tester becomes warm during the test. If there is ½ volt or less voltage drop measured on each cable, the cables and connections are acceptable. If there is voltage drop in excess of ½ volt, locate and repair the cause before continuing with further testing.
2. Test the alternator using the Intelli-Check 2.
   - 2.1 With the vehicle shut down, begin by turning the tester on. Select “Alternator Test” and press Enter. Press ESC to bypass the vehicle ID screen.

Troubleshooting

2.2 Remove the small leads from the battery, leaving the large leads connected as they were in the voltage drop test and press Enter. The alternator rated output will 'stick' from the value used in the voltage drop test. Press Enter.

2.3 Start the engine. The amount of time it takes to walk back to the tester should have given the system enough time for the voltage to stabilize. Press Enter to begin the test.

2.4 When prompted, accelerate the engine to governed speed for 10 seconds.

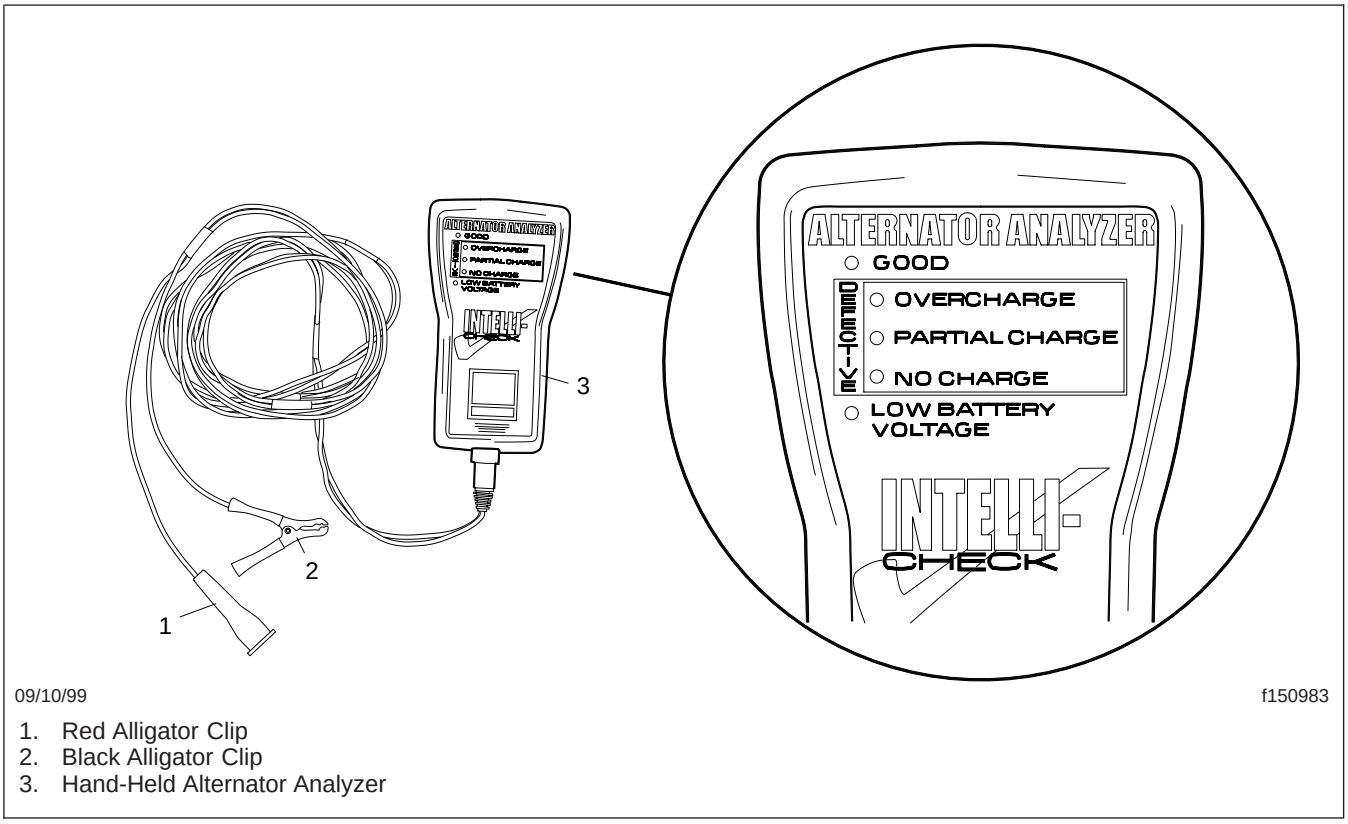
2.5 Turn the engine off. The results will be displayed on the Intelli-Check 2.

Using the Intelli-Check (Original) Systems Analyzer

See **Fig. 2**.

1. With the engine off, connect the red alligator clip to the output terminal of the alternator. Connect the black alligator clip to the alternator ground. An optional ground connection is to the body of the alternator. The tester LEDs will illuminate and then go off as it performs a self-test.
2. After 4 seconds the tester will activate. The following LEDs may illuminate depending on the condition of the batteries:

   2.1 **GOOD** (green) LED indicates the battery voltage is above 12.8 and has a surface charge. The surface charge must be removed before proceeding with the alternator test. To remove the surface charge, turn on the headlights and blower fan for 2 minutes without restarting the engine. Reset the tester by disconnecting, then reconnecting the tester alligator clips. The analyzer will again perform its self-test.



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1. Red Alligator Clip
2. Black Alligator Clip
3. Hand-Held Alternator Analyzer

Fig. 2, Intelli-Check Alternator Analyzer (original)

2.2 **NO CHARGE** (red) LED indicates the battery voltage is below 12.8. This LED should illuminate for most tests. Proceed with the alternator test.

2.3 **LOW BATTERY VOLTAGE** (blue) LED indicates the battery voltage is below 12.35. If the batteries will start the vehicle, proceed with the alternator test.

3. Start the engine using onboard batteries only. If the batteries will not start the engine, they must be charged. Start the test again after charging the batteries and removing the surface charge.
4. Verify the engine is at idle and all electrical loads are off.
5. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
   - If the **GOOD** (green) LED illuminates, proceed to the next step.
   - If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator.
6. With the engine running, turn on all electrical loads.
7. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
8. If the **GOOD** (green) LED illuminates, the alternator is OK and the test is complete.
9. If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator.

Specifications

Delco Remy Alternator, Terminal Fastener Torque		
Description	**Size**	**Torque: lbf·in (N·cm)**
Output ("BAT") Terminal Hexnut	5/16–18	100 (1140)
Ground ("GND") Terminal Hexnut	1/4–20	50 to 60 (565 to 675)
	5/16–18	60 to 90 (675 to 1016)
Terminal Hexnuts	10–24	20 (220)

Table 1, Delco Remy Alternator, Terminal Fastener Torque

Leece Neville Alternator, Terminal Fastener Torque		
Description	**Size**	**Torque: lbf·in (N·cm)**
Output ("BAT") Terminal Hexnut	5/16–24	100 (1140)
Ground ("GND") Terminal Hexnut	1/4–28	75 to 80 (850 to 900)
Remote Sense Terminal or Lamp Driver	M5 x 0.8	25 to 30 (280 to 330)

Table 2, Leece Neville Alternator, Terminal Fastener Torque

Pulley and Mounting Fastener Torque		
Description	**Size**	**Torque: lbf·ft (N·m)**
Pulley Nut Delco Remy	1/2–20	75 (102)
Pulley Nut Leece Neville	5/8–18	75 (102)
Mounting Capscrew	M10 X 1.5	35 (48)

Table 3, Pulley and Mounting Fastener Torque

General Information

The starter is mounted on the forward face of the flywheel housing, on the right-hand side of the engine. Under normal operating conditions, no maintenance will be required between engine overhaul periods. The starter has sealed bearings with lifetime lubrication. At the time of engine overhaul, replace the starter with one that has been remanufactured.

When the starter is engaged, the pinion gear extends outward to mesh with the ring gear on the engine flywheel. An overrunning clutch reduces the likelihood of the engine over driving the starter. Even with this protective feature, always release the keyswitch as soon as the engine starts to avoid overheating the overrunning clutch.

The starter is capable of drawing over 2000 amps and will quickly build up heat that could possibly cause damage. Never crank the starter continuously for more than 30 seconds, and always wait at least 2-minutes between cranking attempts. To prevent the starter from overheating, a thermal management model is incorporated in the starter control electronics. Starting is interrupted and disallowed when the software calculates the starter is too hot. If the starter does not engage after a previous crank attempt, or if cranking is only allowed for a few seconds, wait several minutes for the starter to cool down.

Principles of Operation

When battery power is applied to the magnetic switch activate terminal, cranking will begin. The magnetic switch sends power to the starter solenoid. The solenoid moves a lever which causes the pinion gear to engage with the ring gear on the flywheel. As the gears engage, battery power spins the starter motor.

When diagnosing starting problems, always begin with fully charged batteries, and perform a voltage drop test on the battery cables and magnetic-switch circuit. Once the engine is running, check that the alternator is properly charging the batteries.

A starter that cranks slowly, or just clicks when the keyswitch is turned, typically indicates a problem with supplying adequate power to the starter. Corrosion and loose connections in the battery cables will cause significant voltage drop and may prevent the starter from cranking the engine.

The bulkhead module monitors engine RPM, calculates the starter temperature, and analyzes the specific neutral conditions for the type of transmission. Cranking is not allowed if the engine is running, the transmission is engaged, or if the starter is too hot.

When the keyswitch is in the crank position, it supplies battery power to connector B6, pin A5 of the bulkhead module. This signals the bulkhead module to check for the required starter protection conditions. If these conditions pass, the BHM activates the starter output on connector B4, pin B. See **Fig. 1** for a mechanization diagram of the starter control circuitry.

General Information

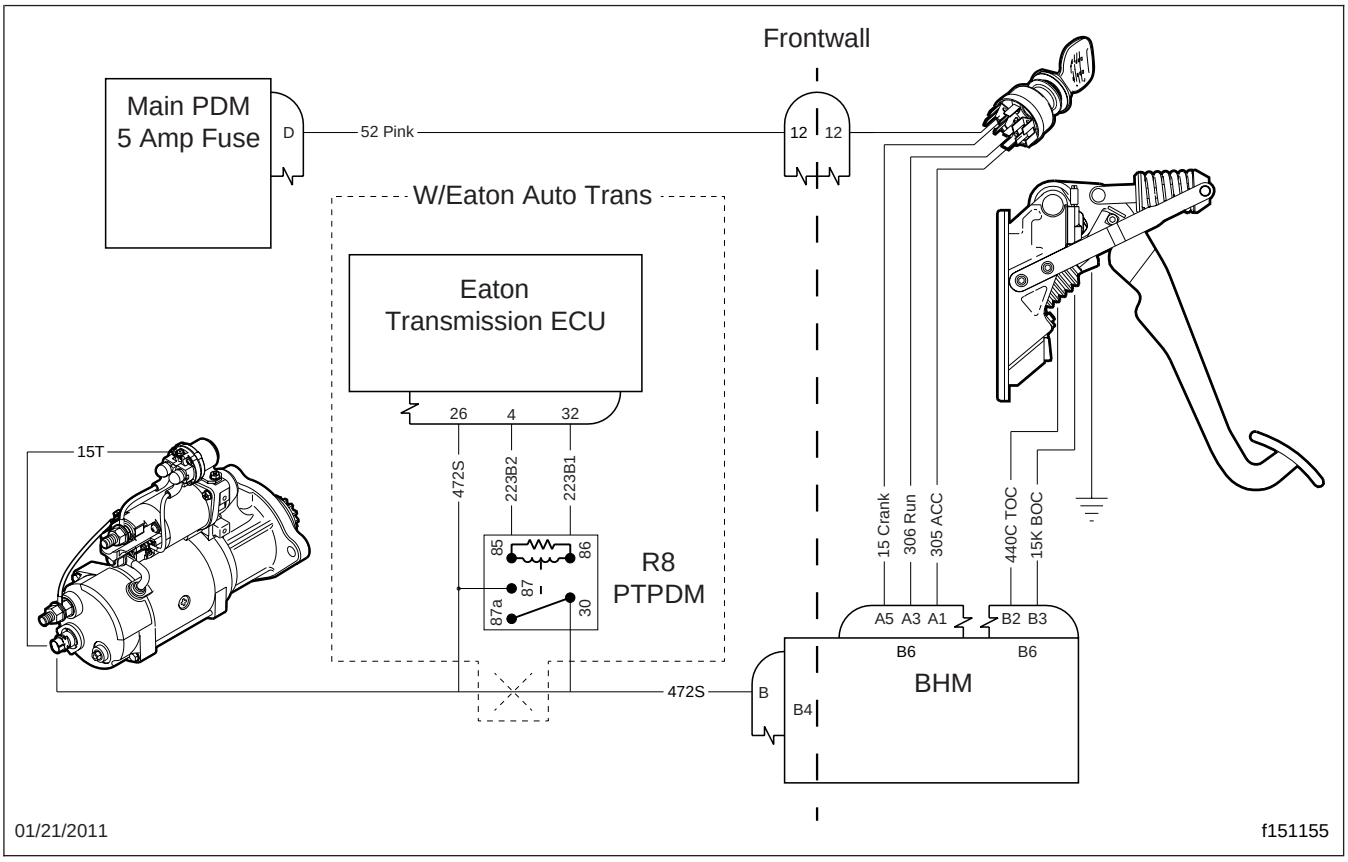
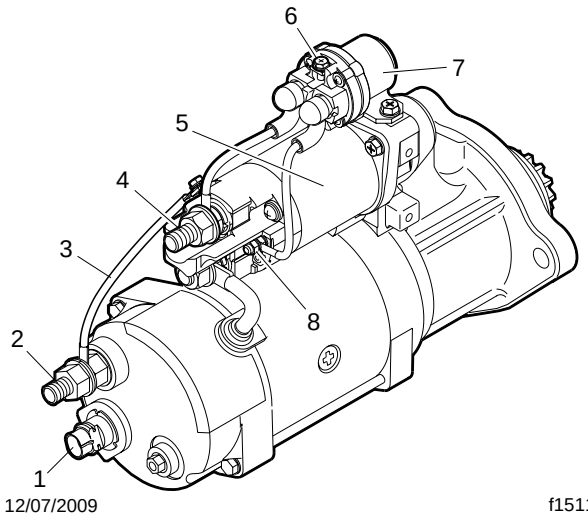


Fig. 1, Starter Control Circuitry

Removal

Before replacing the starter, perform the checks in **Troubleshooting 300**.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the negative battery cables at the batteries. Open the hood.
3. Disconnect and label the wiring that connects to the starter. See **Fig. 1**.



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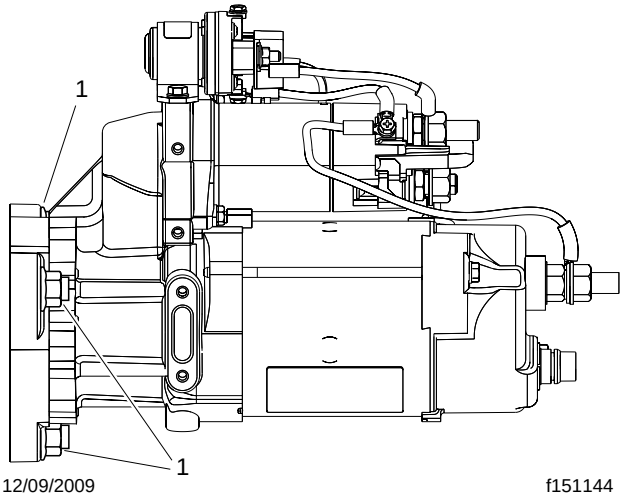
1. Over-Crank Protection Switch Terminal
2. Battery Ground Terminal
3. Ground Circuit to Starter Solenoid
4. Battery Positive Terminal
5. Solenoid
6. Magnetic Switch Activate Terminal
7. Magnetic Switch
8. Solenoid Activate Terminal

Fig. 1, Starter with Integrated Magnetic Switch (IMS)

4. Support the starter, then remove the bolts that mount it to the flywheel housing. See **Fig. 2**.

Installation

1. Place the starter into the mounting hole in the flywheel housing.
2. Hand start the three mounting bolts, then hand tighten them until snug. Using a torque wrench, tighten them to the values shown in **Specifications 400**.
3. Connect the wiring to the solenoid and starter as previously marked. Tighten the terminals to the torque values shown in **Specifications 400**.
4. Protect all exposed terminal connectors with dielectric red enamel.
5. Connect the batteries.



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1. Mounting Bolts

Fig. 2, Starter Mounting

Troubleshooting Tables

Use troubleshooting tables 1 through 4 for system diagnosis to reduce the likelihood of replacing a starter that is not defective, and to insure the complete starting system is tested.

Check for fault codes from Source Address 33 (BHM) and 3 (Transmission). Perform the recommended action in **Table 1** if fault codes from the BHM are shown. Use the applicable transmission manufacturers troubleshooting material if fault codes from the transmission control system are shown.

If the vehicle is equipped with an automated or automatic transmission, also check for any SA 03 fault codes with gear position selection and control. If the transmission is not confirmed to be in neutral, the transmission controller will not allow the engine to be started.

See **Table 2** for troubleshooting related to the starter cranking slowly, or making repeated clicking sounds.

See **Table 3** for troubleshooting problems relating to the starter doing nothing, or making only a single click.

See **Table 4** for troubleshooting relating to the starter making spinning or grinding sounds.

Starting System Faults from SA 33					
SPN	**FMI**	**Conn/Pin**	**Description**	**Behavior**	**Action**
598	7	B6, pins B2 & B3	Clutch switch fault	The bottom of clutch switch and the top of clutch switch are both closed at the same time.	Check the clutch switch for an open or short in circuits 15K and 440C, between the BHM and the clutch switch.
6983	6	B4, pin B	Starter relay output circuit	Current too high when cranking is attempted.	Check for a short to ground on circuits 472S and 15T, between the BHM and the magnetic switch on the starter.
6986	7	B6, pins A1, A3, & A5	Ignition switch inputs fault	The ignition switch input circuits are in a combination of states that is not expected. E.G: • Pin A5 is at battery voltage but pin A3 is not. • Pin A3 is at battery voltage but pin A1 is not. • Pin A5 and A1 are at battery voltage.	Check for open circuit or short in circuits 305, 306, and 15, between the ignition switch and the BHM. Also check the ignition switch.

Table 1, Starting System Faults from SA 33

Slow Cranking or Repeated Clicking Sound but the Engine Does Not Start			
This symptom often indicates low voltage at the starter, or worn and binding starter components.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	Check the ambient temperature. Is the temperature extremely cold?	Yes	Slow cranking due to extreme cold is a normal condition. Do not mistake slow cranking due to cold for slow cranking due to equipment malfunction. Go to step 2.
		No	Go to step 2.

Troubleshooting

Slow Cranking or Repeated Clicking Sound but the Engine Does Not Start			
This symptom often indicates low voltage at the starter, or worn and binding starter components.			
Step	**Test Procedure**	**Test Result**	**Action**
2.	With the keyswitch in the ON position, and the engine not running, measure the voltage at the batteries. Is the voltage below 12 volts?	Yes	Charge the batteries then go to step 3. Perform an alternator test when the vehicle is able to start.
		No	Go to step 3.
3.	Test the batteries individually with the battery tester. Are any batteries defective?	Yes	Replace any batteries that tested defective.
		No	Go to step 4.
4.	Perform a voltage drop test on the starter cables. Is excessive voltage drop present?	Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel.
		Ok	Go to step 5.
5.	Turning the keyswitch to START (cranking), measure the voltage at the magnetic switch activate terminal. Is battery voltage present?	No voltage, or intermittent voltage	Use the troubleshooting procedures in the table titled Starter Does Nothing, or Makes Only a Single Click.
		Ok	Replace the starter.

Table 2, Slow Cranking or Repeated Clicking Sound but the Engine Does Not Start

Starter Does Nothing or Makes Only a Single Click.			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	With the keyswitch in the START (crank) position, measure the voltage at the magnetic switch activate terminal. Is battery voltage present?	Yes	Go to step 2.
		No	Go to step 3.
2.	Perform a voltage drop test on the starter cables. Is excessive voltage drop present?	Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel.
		No	Replace the starter.
3.	With the keyswitch in the START (crank) position, measure the voltage on connector 6, pin A5 of the bulkhead module Is battery voltage present?	Yes	Go to step 5.
		No	Go to step 4.

Starter Does Nothing or Makes Only a Single Click.			
This symptom often indicates a problem with the magnetic switch or starter solenoid circuit. Worn components in the starter or engine can also create binding and result in this symptom.			
Step	**Test Procedure**	**Test Result**	**Action**
4.	Measure the voltage on circuit 52 at the keyswitch. Is battery voltage present?	Yes	Troubleshoot for an open in circuit 15 between the keyswitch and the BHM, and for an open keyswitch.
		No	Check for an open 5 amp fuse (F5) in the main PDM. Test for a wiring fault in circuit 52 between the PDM and the keyswitch and in circuits 15, 305, and 306 between the keyswitch and the BHM.
5.	With the keyswitch in the START (crank) position, measure the voltage on connector B4, pin B of the bulkhead module. Is battery voltage present?	Yes	Go to step 6.
		No	Allow time for the starter protection temperature model to calculate that the starter has cooled off. Troubleshoot for a wiring fault in the bottom of the clutch switch circuit on connector B6, pin B3. If the vehicle has an automated transmission, troubleshoot for faults with gear position and control circuits, otherwise replace the bulkhead module.
6.	Does the vehicle have an Eaton automated transmission?	Yes	Ensure the transmission is in neutral. Test for a wiring fault in circuit 472S between the bulkhead module and relay R8 in the PTPDM. Test for a fault with the transmission control of R8 and repair if necessary. If R8 testing passes, test circuit 472S to the overcrank protection switch in the starter, and circuit 15T to the magnetic switch.
		No	Test for a wiring fault in circuit 472S between the bulkhead module and the starter. If the starter uses the internal overcrank protection switch, test circuit 15T from the overcrank protection switch to the magnetic switch.

Table 3, Starter Does Nothing or Makes Only a Single Click

Starter Makes Spinning or Grinding Sounds but the Engine Does Not Crank.			
This symptom often indicates a mechanical problem with the starter or the ring gear.			
Step	**Test Procedure**	**Test Result**	**Action**
1.	With the keyswitch in the START (crank) position, test the voltage at the starter battery cable connections. Is battery voltage present?	Low or No	Go to step 2.
		Yes	Go to step 3.
2.	With the keyswitch in the START (crank) position, perform a voltage drop test on the positive and negative battery cables, from the starter to the batteries. Is excessive voltage drop present?	No	Go to step 3.
		Excessive voltage drop	Inspect for corroded and loose connections. Clean, tighten and repair all connections, then protect all exposed terminal connectors with dielectric red enamel

Troubleshooting

Starter Makes Spinning or Grinding Sounds but the Engine Does Not Crank.			
This symptom often indicates a mechanical problem with the starter or the ring gear.			
Step	**Test Procedure**	**Test Result**	**Action**
3.	Remove the starter and inspect the starter pinion gear for milling. Test the overrunning clutch in the starter by turning the pinion gear. It can be turned by hand in the clockwise direction but will be extremely difficult or impossible to turn in the counterclockwise direction.	Ok	Go to step 4.
		Defective	Replace the starter.
4.	Bar the engine over to inspect the 3 positions on the ring gear where the starter engages.	Damaged	Replace the ring gear.

Table 4, Starter Makes Spinning or Grinding Sounds but the Engine Does Not Crank

Specifications

Torque Values, Starter-Motor to Flywheel-Housing Bolts		
Fastener Description	**Size**	**Torque Value: lbf·ft (N·m)**
Cummins ISB	M10 x 1.5	38±5 (51±7)
Cummins ISC/ISL	M12 x 1.5	58±5 (78±7)
DD13	M12 x 1.5	58±5 (78±7)

Table 1, Torque Values, Starter-Motor to Flywheel-Housing Bolts

Torque Values, Starter Connections		
Magnetic Switch (+)	**Solenoid Battery (+)**	**Starter Ground (–)**
18 to 21 lbf·in (200 to 250 N·cm)	18 to 20 lbf·ft (24 to 28 N·m)	18 to 20 lbf·ft (24 to 28 N·m)

Table 2, Torque Values, Starter Connections

Troubleshooting Tables

Possible causes of hot or cold engine coolant temperatures are listed below. For repairs, refer to the applicable service group in this manual, or to the engine and component manufacturers' service publications.

Problem—Coolant Temperature Above Normal

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Coolant leakage (see possible sources below) is causing a low coolant level. External Leakage: hoses and hose connections, radiator seams, core, draincock and cap, block core and drain plugs, water pump thermostat housing(s), overflow and surge tank, heater hoses and core, temperature sending unit(s), cylinder head(s) mating (gasket) surfaces, coolant filter, oil cooler(s). Internal Leakage: EGR cooler, cylinder head gasket, warped head or block surfaces, cracked cylinder head or block, cylinder head capscrews loose, missing, or tightened unevenly; oil cooler, air compressor cylinder head and gasket cylinder liners, liner seals aftercooler.	Perform the repairs necessary to stop leakage. Fill to the bottom of the radiator fill neck with the correct mixture of antifreeze and water.
The temperature gauge is not working.	Check the gauge circuit wires, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check temperature gauge operation.
The radiator fins, the aftercooler, or the air conditioner condenser fins are clogged.	Clean the outside of the core, the aftercooler, and the condenser with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
A radiator hose is collapsed or plugged.	Check the vacuum relief valve in the pressure cap. Replace if defective. Replace damaged hoses.
A fan drive belt or the water pump belt is loose.	Adjust belt tension following the instructions for inspection and repair in **Section 01.02**.
The cooling fan shroud is damaged.	Check the radiator for blockage. Repair or replace the shroud.
The radiator cap is incorrect or malfunctioning.	Make sure the correct radiator cap is installed. If the cap does not hold the correct pressure, replace it.
The on-off fan clutch is not working.	Check the solenoid valve in the fan clutch air supply line, the sending unit for the valve, and the operating air pressure to the valve. If valve operation and air pressure are okay, repair or replace the fan clutch. If the valve doesn't work or if air pressure is low, make repairs and then check fan clutch operation.
The engine oil level is incorrect.	Fill to the high (H) mark on the dipstick.
There is too much antifreeze or coolant additive in the system.	Clean and flush the cooling system. Refill the system with the correct mixture of antifreeze and water, and install the correct additive and filter, or treatment filter.

Troubleshooting

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
One or both of the thermostats is incorrect or inoperative.	Make sure the correct thermostat is installed. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.
The water pump is not working correctly.	Repair or replace the water pump.
The radiator core is internally plugged or damaged.	To check for blockages, warm the engine to normal operating temperature. Turn off the engine, and run your hand over the finned surface of the radiator. If there is a blockage in the radiator, it should cause an obvious temperature difference from one area of the core to another. An obvious difference between inlet and outlet temperature is normal. If blockage is suspected, clean and flush the cooling system. Repair or replace a damaged core.
Air or combustion gases are entering the cooling system.	Check the EGR cooler, cylinder head(s), head gasket(s), cylinder liners, aftercooler, air compressor cylinder head, and fan/shutter air control valve (if applicable) for leaks. Repair or replace parts, as necessary.
The aftercooler is plugged or damaged.	Repair or replace the aftercooler.
The oil cooler is plugged or damaged.	Repair or replace the oil cooler.
The engine is receiving too much fuel.	Refer to the engine manufacturer's fuel delivery system adjustment procedures.
The wrong fan (replacement unit) is installed.	Install the correct fan.
The wrong radiator (replacement unit) is installed.	Install the correct radiator.
There is exhaust blockage.	Repair the exhaust system.
There is frozen coolant in the radiator.	Use the proper antifreeze-to-water ratio needed for winter temperatures.

Problem—Coolant Temperature Below Normal

Problem—Coolant Temperature Below Normal	
Possible Cause	**Remedy**
The temperature gauge is not working.	Check the gauge circuit wires, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check temperature gauge operation.
The on-off fan clutch operates continuously.	Check the solenoid valve in the fan clutch air supply line, the sending unit for the valve, and the operating air pressure to the valve. If valve operation and air pressure are okay, repair or replace the fan clutch. If the valve doesn't work or if air pressure is low, make repairs and then check fan clutch operation.
One or both thermostats are incorrect or inoperative.	Make sure the correct thermostat is installed. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.

General Information

The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film.

The central component of the cooling system, the radiator assembly, includes the surge tank (remote mounted on the firewall), the radiator, and the surge tank pressure relief cap.

The surge tank provides storage space for reserve coolant, expansion space for heated coolant, and deaeration space. When coolant in the radiator runs low, reserve coolant stored in the surge tank flows from the tank through the fill hose to the water pump. As the coolant heats and expands beyond radiator capacity, excess coolant travels back through the fill hose from the water pump to the surge tank. Any air trapped in the engine block or radiator rises to the top of the engine or radiator and escapes through the vent hoses to the surge tank.

The coolant level sensor in the surge tank sends a signal to the driver display screen to warn the driver of a low coolant condition. The coolant level sensor in the surge tank warns the driver when coolant is running low. The Gentech coolant level sensor is located in the coolant surge tank on EPA07 and later vehicles. A float with an embedded magnet operates a switch in the sensor body to signal low or normal levels of coolant. The surge tank is translucent polypropylene so you can see the coolant level and compare it to the maximum and minimum levels marked on the tank.

When the engine is running, some of the reserve coolant in the surge tank is drawn into the engine. A coolant level that appears acceptable when the engine is off may fall below the acceptable level when the engine is running at high speed. Many engine systems need the coolant level in the surge tank to be filled to the upper fill mark.

These vehicles use full-flow (or high-flow) radiators. With full-flow radiators, the coolant flows into the radiator at the top of the left side tank and flows out of the radiator at the bottom of the right side tank. Most of the engine coolant is routed through the radiator, and it moves relatively quickly in a single pass.

The surge tank cap limits system pressure to about 11 to 12 psi (76 to 83 kPa), which raises the boiling point of the coolant. If the cooling system overheats, excess coolant is released through the overflow tube.

For more general information about the radiator and surge tank, and for cooling system troubleshooting procedures, refer to **Section 20.00**.

Radiator Removal and Installation

NOTICE

If the radiator is being replaced due to a failure of the transmission cooler, cleaning contamination from the transmission is necessary. Failure to do so can lead to a transmission failure.

Allison automatic transmissions: It is required to test the transmission fluid for contamination. The presence of water and/or any trace of ethylene glycol coolant mixtures in the transmission oil in an Allison transmission is detrimental to the internal components. Refer to the Allison service literature for more information and proper procedures, or contact an authorized Allison service facility.

Standard transmissions: The presence of water and/or ethylene glycol coolant mixtures in the lubricant in standard transmissions decreases the effectiveness of the lubricant and causes rust and wear to internal parts. If contamination is detected, refer to the transmission manufacturer's service literature for proper procedures.

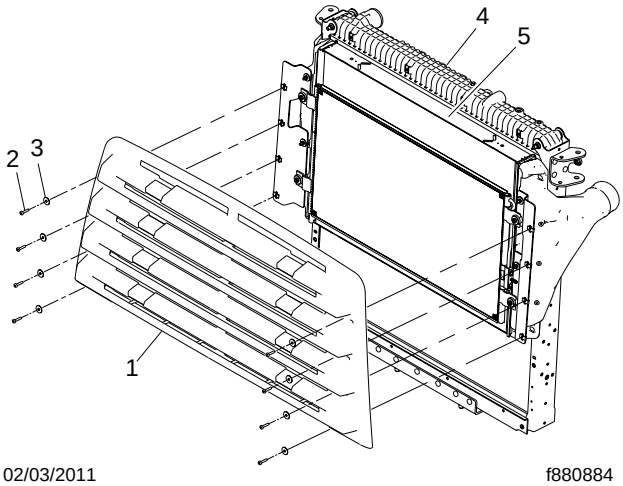
Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.

WARNING

Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

3. Drain the engine coolant system as follows.
   - 3.1 Remove the surge tank cap.
   - 3.2 Place a clean 14-gallon (53-liter) container under the radiator drain.
   - 3.3 Connect a 1/2-inch hose to the drain fitting on the radiator and place the other end in the container.
   - 3.4 Drain the radiator into the container.
4. Remove the bumper. See **Section 31.01, Subject 100** for detailed instructions.
5. Remove the hood. See **Section 88.00, Subject 100** for detailed instructions.
6. Remove the grille. See **Fig. 1**. See **Section 88.00, Subject 110** for detailed instructions.



1. Grille
2. Screw, M6
3. Washer
4. Radiator
5. Charge Air Cooler

Fig. 1, Grille Installation

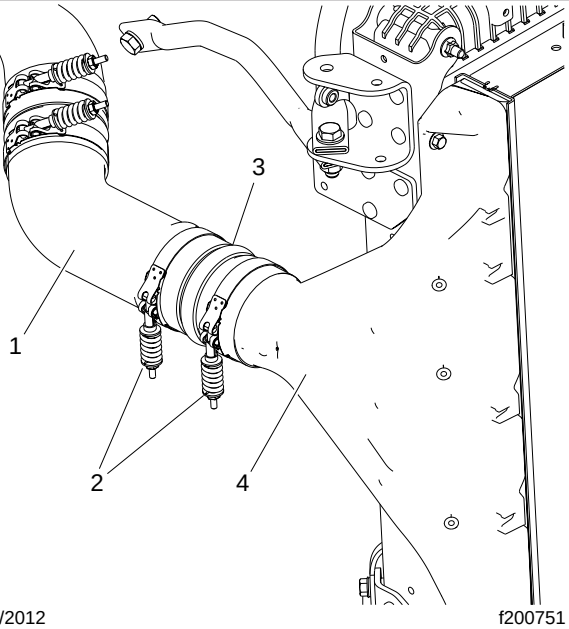
7. Remove the CAC inlet and outlet hoses. See **Fig. 2** and **Fig. 3**.
8. Disconnect the surge tank vent line from the top of the radiator, and free the retaining clamps. See **Fig. 4**.
9. Disconnect the upper radiator hose. See **Fig. 5**.
10. Remove the three radiator strut rods.
11. Remove the upper fan shroud. See **Fig. 6**.
12. Remove the fasteners that hold the fan to the fan clutch, then remove the fan.

WARNING

Do not kink or bend any of the A/C lines or put excessive pressure on any of the joints or connections while moving the condenser. The lines could be damaged and cause the system to discharge, which may lead to environmental damage and personal injury.

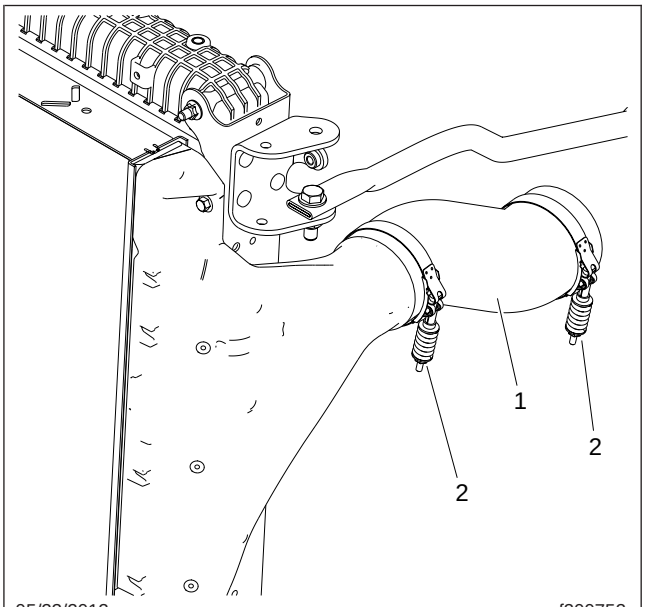
13. Loosen the condenser and move it out of the way as follows.

Radiator Removal and Installation



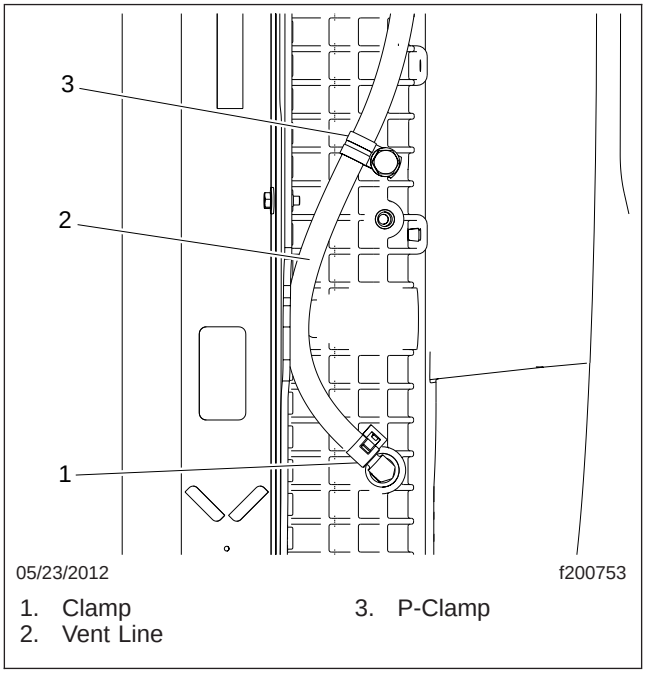
1. Turbo Inlet Tube
2. Clamp
3. CAC Outlet Hose
4. CAC

Fig. 2, CAC Hose, Right Side



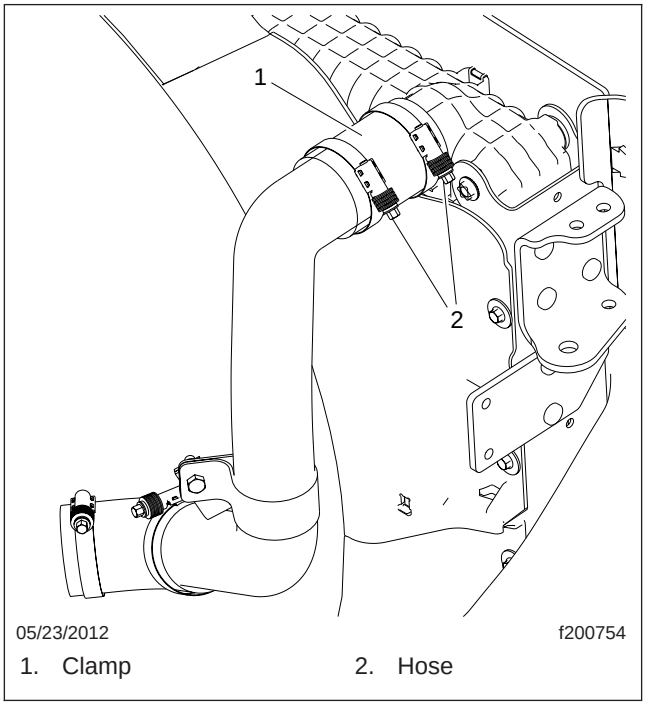
1. CAC Inlet Hose
2. Clamp

Fig. 3, CAC Hose, Left Side



1. Clamp
2. Vent Line
3. P-Clamp

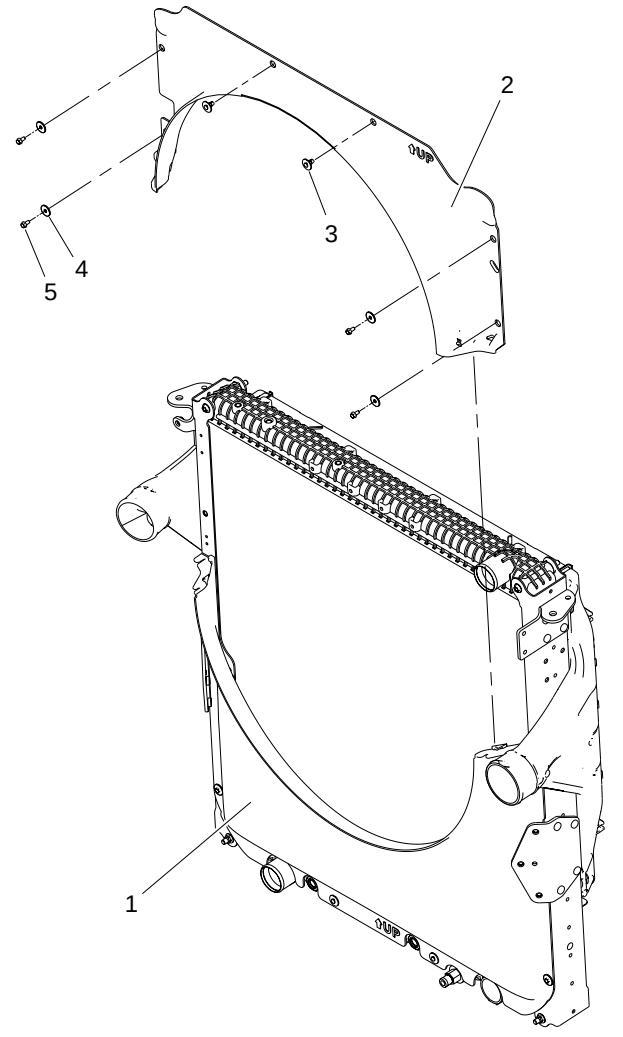
Fig. 4, Surge Tank Vent Line



1. Clamp
2. Hose

Fig. 5, Upper Radiator Hose

Radiator Removal and Installation



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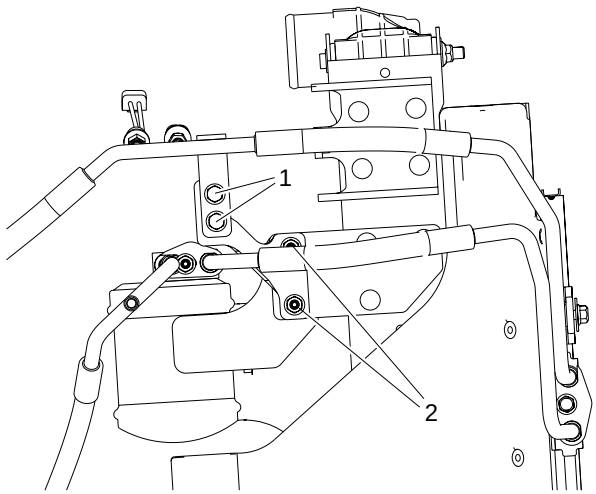
1. Lower Fan Shroud
2. Upper Fan Shroud
3. Fastener
4. Washer
5. Screw

Fig. 6, Fan Shroud Installation

13.1 Remove the receiver-drier and upper A/C hose mounting nuts, then free the receiver-drier. See **Fig. 7**.

13.2 Remove the radiator baffle from the right side of the radiator. See **Fig. 8**.

13.3 Unbolt the A/C condenser from the CAC. See **Fig. 9**.



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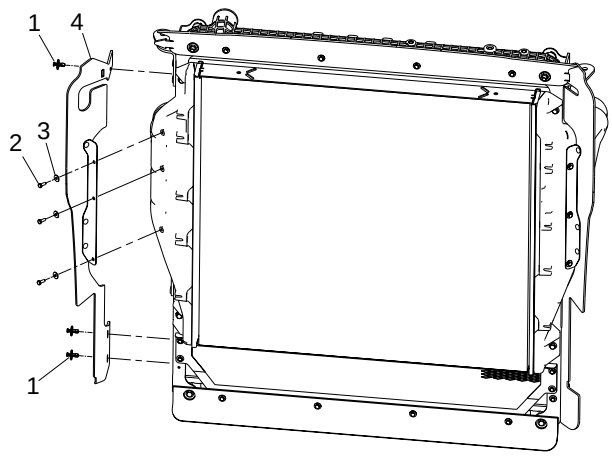
1. Upper Condenser Line Mounting Nuts
2. Receiver-Drier Mounting Nuts

Fig. 7, Receiver-Drier Installation



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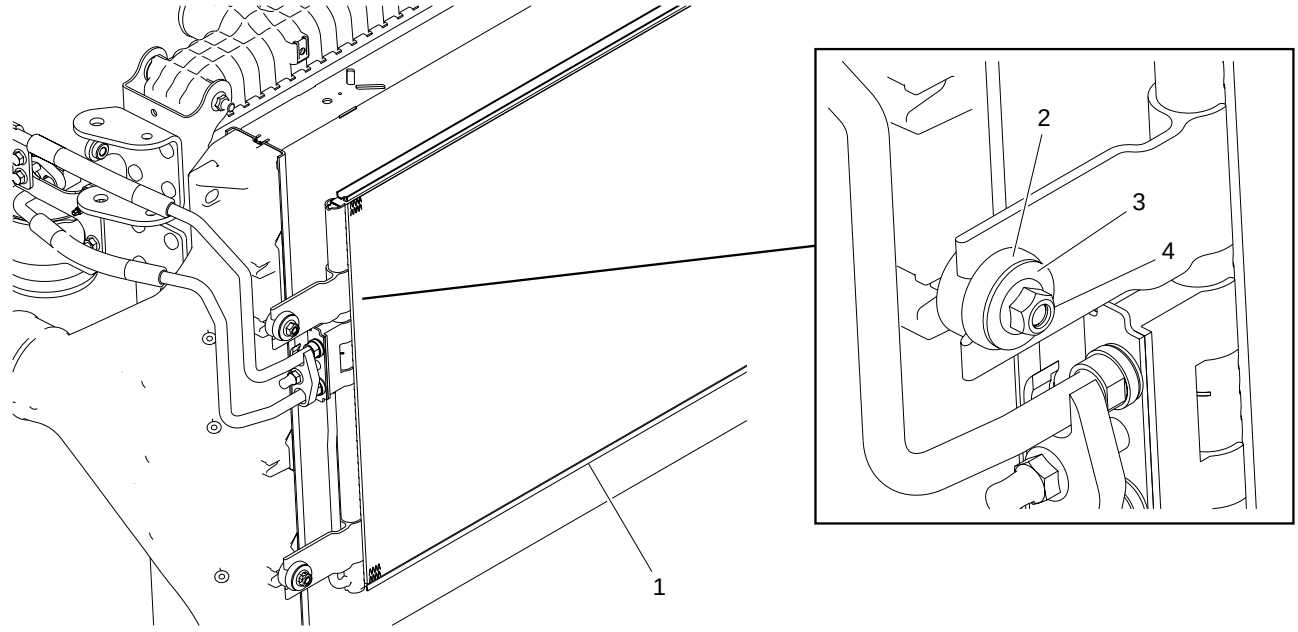
1. Push Fastener
2. Screw
3. Washer
4. Baffle

Fig. 8, Radiator Baffle, Right Side

NOTE: Wrap the condenser in cardboard to protect it while moving it.

13.4 Carefully swing the condenser around and set it on right front tire. Secure it as needed. See **Fig. 10**.

Radiator Removal and Installation



1. A/C Condenser
2. Isolator
3. Washer
4. Nut

Fig. 9, A/C Condenser Installation

14. Unbolt the radiator from the lower mounts. See **Fig. 11**.
15. Remove lower radiator hose. See **Fig. 12**.
16. Using the lifting device, remove the radiator from the truck.
17. Remove lower fan shroud. See **Fig. 6**.
18. Remove CAC from the radiator. See **Fig. 13**.

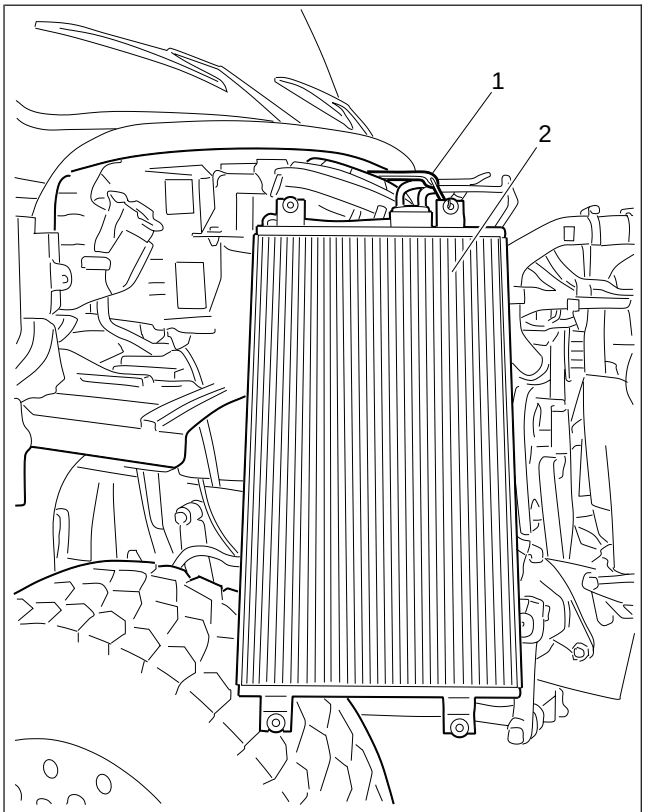
Installation

1. Install the CAC on the new radiator. Tighten 23 to 27 lbf·ft (31 to 37 N·m). See **Fig. 13**.
2. Install the lower fan shroud on the new radiator. See **Fig. 6**.
3. Position the radiator in truck.
4. Tighten the radiator mounting nuts 182 to 223 lbf·ft (247 to 302 N·m).
5. Install the AC condenser as follows.
   - 5.1 Swing the condenser into position and secure it temporarily. See **Fig. 9**.
   - 5.2 Position the receiver-drier and upper A/C line on their respective brackets and install the mounting nuts. See **Fig. 7**. Tighten the nuts 14 to 16 lbf·ft (19 to 22 N·m).
   - 5.3 Install the right-side radiator baffles. See **Fig. 8**.
   - 5.4 Tighten the condenser mounting bolts 7 to 9 lbf·ft (9 to 12 N·m).
6. Apply sealant 48-00094-141 to the threads of the fasteners, then install the fan. Tighten 30 lbf·ft (41 N·m).
7. Install the upper fan shroud. See **Fig. 6**.

NOTICE

Radiator alignment is critical. Make sure that the radiator package does not have to be pushed, pulled, or pried into position to get the strut rod holes to line up. Misalignment of the radiator package may result in damage to the radiator.

8. Install the radiator strut rods and check the alignment as follows.



1. Bungie Cord
2. Condenser

Fig. 10, Securing the A/C Condenser

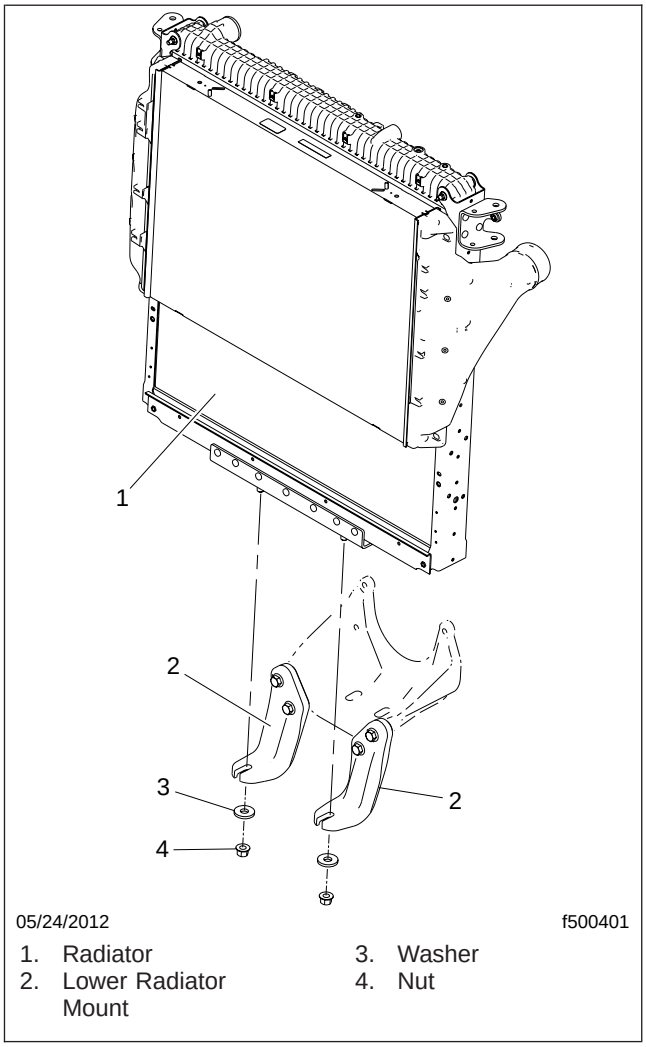
8.1 Position the radiator strut rods, and check the alignment of the mounting holes.

If there is any misalignment, loosen all of the radiator attaching fasteners and reposition all of the mounting parts to align without applying any pre-stress to the radiator.

If all the mounting holes align without issue, install the strut rod mounting bolts and nuts.

8.2 Tighten any loosened radiator mounting fasteners.

8.3 Tighten the strut rod mounting bolts and nuts at the radiator 112 to 125 lbf·ft (152 to 169 N·m) and at the engine 125 to 139 lbf·ft (171 to 188 N·m).



1. Radiator
2. Lower Radiator Mount
3. Washer
4. Nut

Fig. 11, Radiator Lower Mount

9. Install the surge tank vent line and clamps on the top of the radiator. See **Fig. 4**.
10. Install the upper and lower radiator hoses. See **Fig. 5**.
11. Install the CAC inlet and outlet hoses. Tighten the clamps 88 to 108 lbf·in (994 to 1220 N·cm). See **Fig. 2**.
12. Install the grille. Tighten 50 to 55 lbf·in (565 to 622 N·cm). See **Fig. 1**.
13. Install the hood. See **Section 88.00, Subject 100** for detailed instructions.

Radiator Removal and Installation

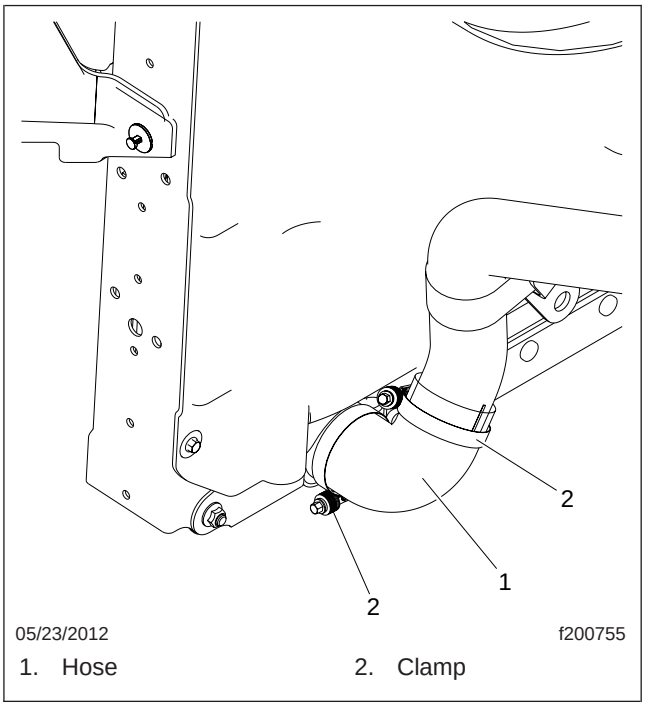


Fig. 12, Lower Radiator Hose

14. Install the bumper. See **Section 31.01, Subject 100** for detailed instructions.
15. Fill the cooling system with coolant.
16. Start the engine, and check the cooling system for leaks. Repair as needed.

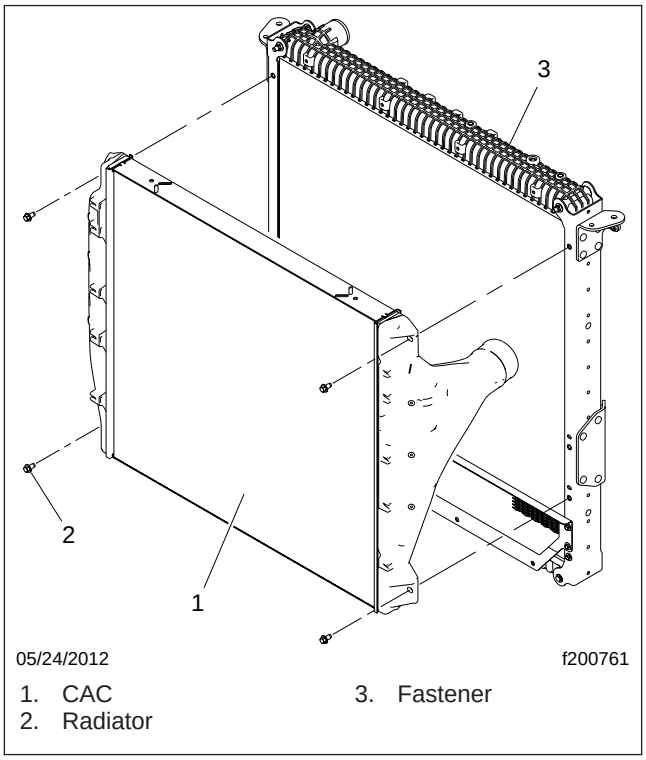
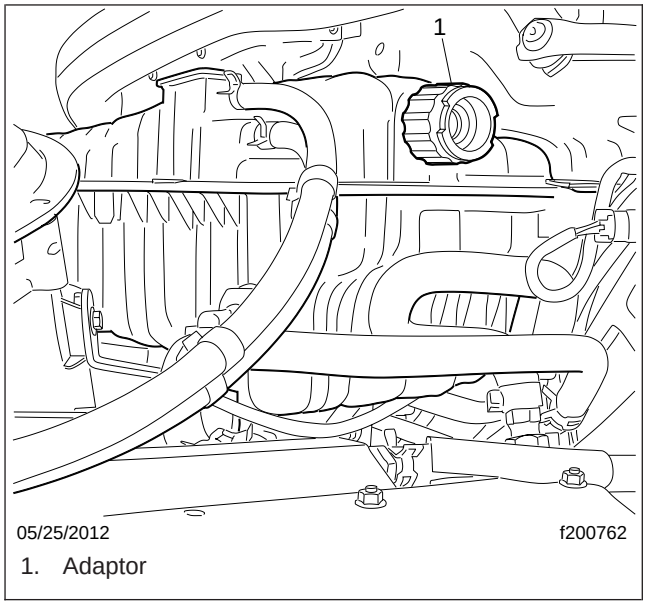


Fig. 13, CAC Installation

Frontwall Mounted Surge Tank, Cooling System Pressure Testing

1. Remove the pressure cap and attach the appropriate adaptor tool (J-42401-3 or J-42401-1A) to the surge tank. See **Fig. 1**.

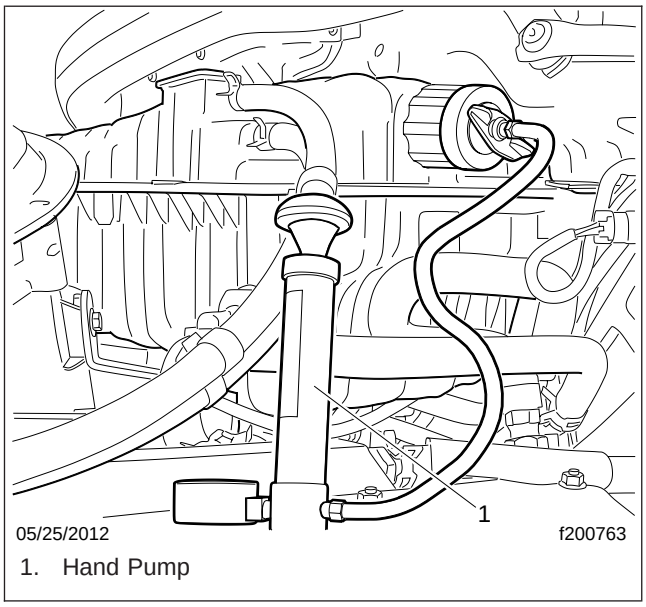


1. Adaptor

Fig. 1, Adaptor Installation

NOTE: These are Kent-Moore/SPX part numbers. Other companies sell these adaptors, such as Snap-On, Mac, Cornwell, etc. These are the same adaptors that are used on cars.

2. Attach a radiator-pressure hand pump, and apply no more than 20 psi (138 kPa) of pressure to the cooling system. See **Fig. 2**.
3. Check for leaks. Repair as needed.
4. Remove the pump and adaptor tool, and install the radiator cap.



1. Hand Pump

Fig. 2, Hand Pump Installation

Surge Tank Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Tilt the hood.

⚠ WARNING

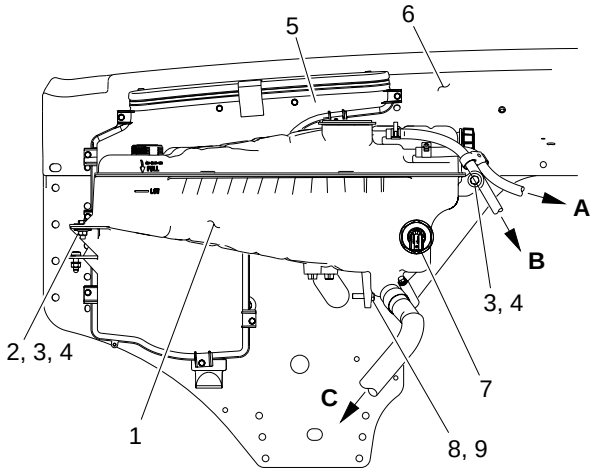
Drain the coolant only when the coolant and engine are cool. Draining it when these are hot could cause severe personal injury due to scalding.

3. Drain the radiator.
   - 3.1 Remove the surge tank cap.
   - 3.2 Open the draincock on the bottom of the radiator to drain the engine coolant. Drain only enough coolant to empty the surge tank.
4. Remove the surge tank.

   NOTE: Cap all the disconnected hoses to prevent the remaining coolant from spilling.
   - 4.1 Mark and disconnect the engine and radiator vent hoses from the front of the surge tank. There are three hoses. See **Fig. 1**.
   - 4.2 Disconnect the wire harness from the low temperature sensor.
   - 4.3 Remove the fasteners holding the right side of the surge tank to the air cleaner bracket. See **Fig. 1**.
   - 4.4 Remove the fasteners holding the left side of the surge tank to the frontwall and the HVAC air plenum.
   - 4.5 Remove the surge tank from the vehicle.
5. If replacing the surge tank, remove the overflow hose from the bottom.
6. If removing the coolant level sensor, see **Subject 130**.

Installation

1. If it was removed, install the overflow hose to the bottom of the surge tank.
2. Position the surge tank onto the air cleaner bracket, then install the fasteners. See **Fig. 1**. Tighten just enough to hold the surge tank in place.
3. Using the fasteners previously removed, attach the surge tank to the HVAC air plenum and the frontwall.
4. Tighten all the fasteners 18 lbf·ft (24 N·m).
5. As previously marked, connect the engine and radiator hoses to the surge tank.
6. Connect the harness to the low coolant sensor.
7. Fill the coolant system through the surge tank.
8. Install the surge tank cap.
9. Start the engine and check for coolant leaks. Repair any leaks.



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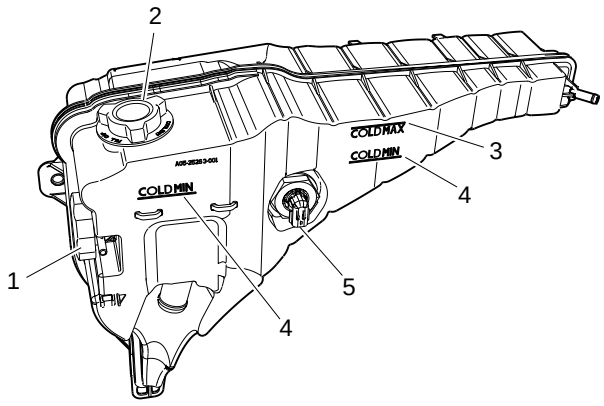
A. To Radiator	C. To Engine Shunt Port
B. To Engine Vent Port	
1. Surge Tank	6. Frontwall
2. Capscrew	7. Coolant Level Sensor
3. Washer (2)	8. Capscrew
4. Flanged Nut	9. Washer
5. HVAC Air Plenum	

Fig. 1, Surge Tank Installation

Coolant Level Sensor Removal and Installation

Removal

Complete the following instructions to remove the coolant level sensor. Refer to **Fig. 1** for sensor location.



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1. Surge Tank Vent Outlet
2. Surge Tank Filler Cap
3. Cold Maximum Coolant Level
4. Cold Minimum Coolant Level
5. Coolant Level Sensor

Fig. 1, Surge Tank

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Allow the engine to cool down to ambient temperature.
3. Drain the coolant below the sensor if needed.
4. Disconnect the electrical sensor by releasing the locking tab, then pressing on the retaining tab.
5. Twist the large, black locknut in the counterclockwise direction until it disengages from the reservoir.
6. Remove the sensor.

Installation

Complete the following instructions to install the coolant level sensor.

1. Lubricate the O-ring of the new sensor using a small amount of light silicone grease, or a bit of coolant.
2. Align the new sensor. Make sure the tabs are aligned at tangent to the surge tank neck.
3. Twist the large, black locknut in the clockwise direction until the sensor securely engages into the reservoir.
4. Connect the eletrical connector to the sensor.
5. Add coolant as needed.

General Information

The fan clutch is a temperature-controlled, air-operated clutch for the engine cooling fan. It is spring engaged, and controls the engine temperature by engaging or disengaging the fan.

When the coolant temperature is below a specified range, air pressure keeps the fan disengaged to save engine power. When the coolant temperature rises above the specified range, air pressure to the fan clutch is cut off and internal spring pressure engages the fan.

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch installed in the thermostat housing. The temperature switch is connected to the engine MCM, which controls the solenoid valve. When you start a cold engine, the solenoid valve allows air pressure to the fan clutch and the clutch remains disengaged. When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve cuts off compressed air to engage the fan.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-drier. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which cuts off air to the fan clutch, engaging the fan.

Fan Clutch Removal and Installation

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.

⚠ WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt and sludge could fly out at high speeds. Don't direct the airstreams at anyone. Do not disconnect pressurized air lines, as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

3. Drain the air tanks.
4. Disconnect the air line from the fan clutch.
5. Remove the upper fan shroud as follows.
   - 5.1 Place alignment marks on the upper and lower fan shrouds, and mark the shroud-to-channel positions, so the shroud can be installed in the same position on the radiator.
   - 5.2 Remove the four fasteners that connect the upper and lower fan shrouds.
   - 5.3 Remove the fasteners that hold the upper fan shrouds to the radiator.
   - 5.4 Remove the upper fan shroud from the vehicle.
6. Remove the fasteners that hold the fan to the fan clutch, then remove the fan.

⚠ WARNING

If the fan clutch engages during the next step, it could cause personal injury. Keep the fan clutch disengaged throughout this procedure by maintaining between 90 and 120 psi (620 and 827 kPa) of air pressure.

7. Align the access holes in the fan clutch with the allen screws on the fan hub. See **Fig. 1**.
   - 7.1 Using shop air and a suitable nozzle attachment, apply between 90 and 120 psi (620 and 827 kPa) of air pressure to the fan clutch to disengage the clutch.
   - 7.2 Line up the access holes.

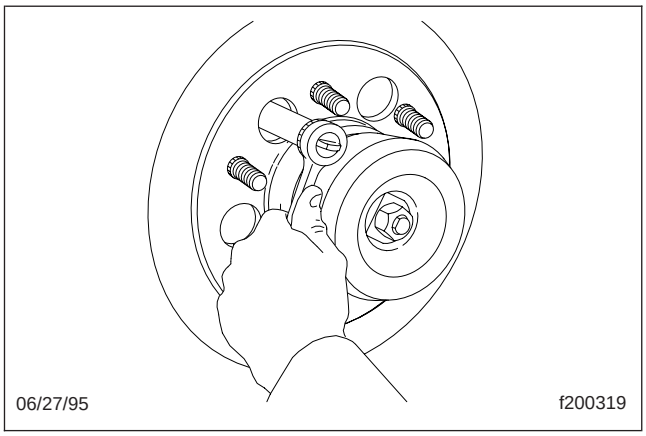


Fig. 1, Line Up the Access Holes

8. Remove the air pressure from the fan clutch, and allow the fan to engage.
9. Remove the allen screws holding the fan clutch to the fan hub.
10. Remove the fan clutch from the fan clutch hub. It may be necessary to gently pry the clutch from the hub.

Installation

IMPORTANT: A new coupler must be used when installing the clutch onto the hub.

1. Install the fan clutch onto the fan clutch hub.
   - 1.1 Install a new coupler onto the fan hub.
   - 1.2 Position the fan clutch onto the fan hub, then push it toward the rear of the vehicle and rotate the clutch until the flats of the coupler engage the fan clutch.
   - 1.3 Line up the access holes in the clutch with the holes for the allen screws in the clutch hub.
   - 1.4 Install the allen screws, and tighten them 45 lbf·ft (61 N·m).
2. Install the fan.
3. Connect the air line to the fan clutch.
4. Position the upper fan shroud on the radiator; align the marks, then install the fasteners that hold it to the radiator and the lower fan shroud.

Fan Clutch Removal and Installation

5. Connect the left-side hose to the charge air cooler.

Special Tools

IMPORTANT: Special tools are are recommended, but not required for this procedure. See **Table 1** for the special tool set.

Special Tools		
Description	**Part Number**	**Order From**
Support and Compressor (see **Fig. 1**)	1090-00000-02	Wright Brothers Enterprises 8171 Hibma Marion, MI 49665 Telephone: 231-825-2939

Table 1, Special Tools

Rebuild

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Remove the fan clutch from the vehicle. For instructions, refer to **Subject 100**.

NOTICE

When caging and compressing the engagement spring of the fan clutch, depress the clutch shaft only enough to relieve the pressure on the retaining plates (about 1/16-inch, or 1.5 mm). Applying additional force after the clutch shaft bottoms in the housing will damage the housing and render it unserviceable.

NOTE: There are two methods of caging the engagement spring. One uses the special tools and a press. The other uses carriage bolts, washers, and wingnuts. Either method is effective.

3. Cage the engagement spring.

   If using the special support and compressor tools, place the fan clutch in a press to cage the engagement spring. See **Fig. 2**.

   If using the optional method of caging the engagement spring, do the following:

   3.1 With the access holes in the housing assembly aligned with those in the shaft assembly, install two 3-1/2-inch (89-mm) long carriage bolts and suitable washers on opposite sides of the clutch assembly.

   3.2 On the shaft assembly side, install about a 1/2-inch (13-mm) thickness of washers onto each carriage bolt.

   3.3 Install a wingnut on the end of each carriage bolt and tighten the wingnuts evenly until the engagement spring is caged.

4. Remove the lining retaining plates and the lining. See **Fig. 2** and **Fig. 3**.

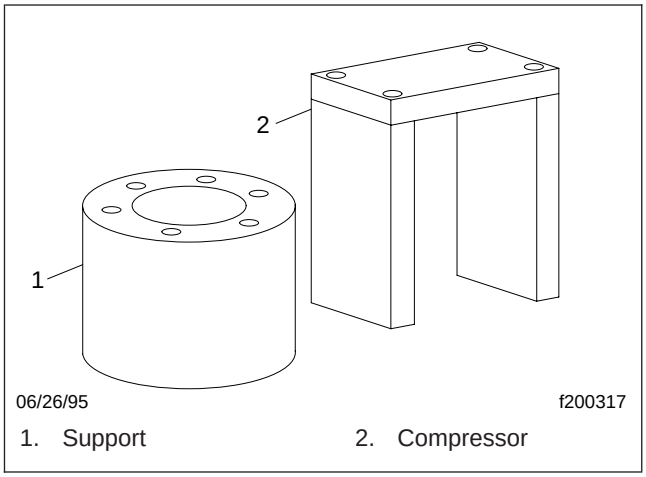


Fig. 1, Special Tools

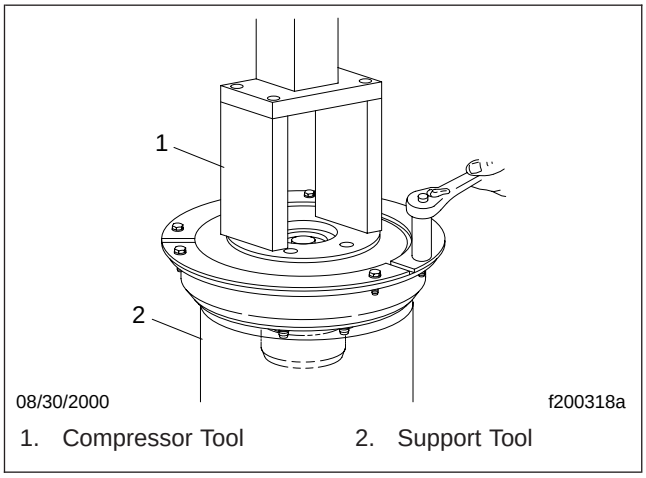
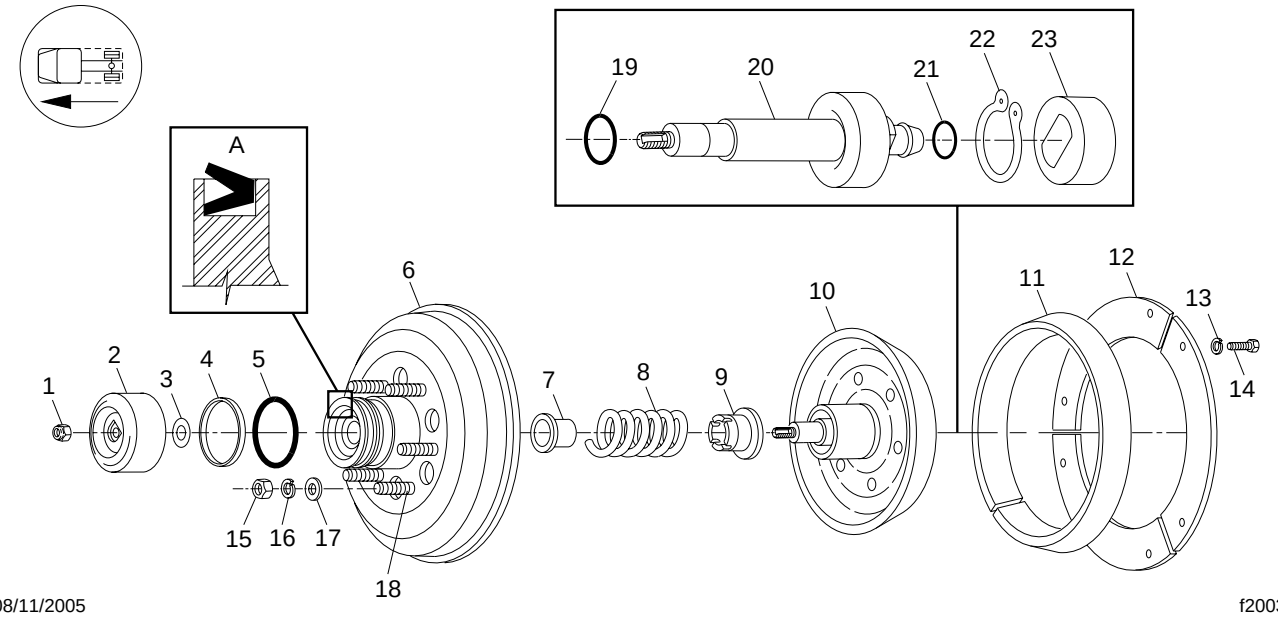


Fig. 2, Caging the Engagement Spring and Removing the Lining Retaining Plates

Fan Clutch Minor Rebuild



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 3, Kysor K26RA Fan Clutch (exploded view)

NOTICE

Do not press on the cylinder during this step, or the cylinder will be damaged. Use a 5/8-inch wrench as shown in Fig. 4 on the piston rod flats.

5. If applicable, turn the clutch over in the press, and use the special compressor tool to cage the engagement spring while removing the cylinder nut and cylinder. See **Fig. 4**.
6. Inspect the fan clutch. See **Fig. 3**
   - 6.1 Inspect the two surfaces where the lining rides.
   - 6.2 Inspect the needle bearing race on the shaft.
   - 6.3 Inspect the needle bearings inside the clutch housing.

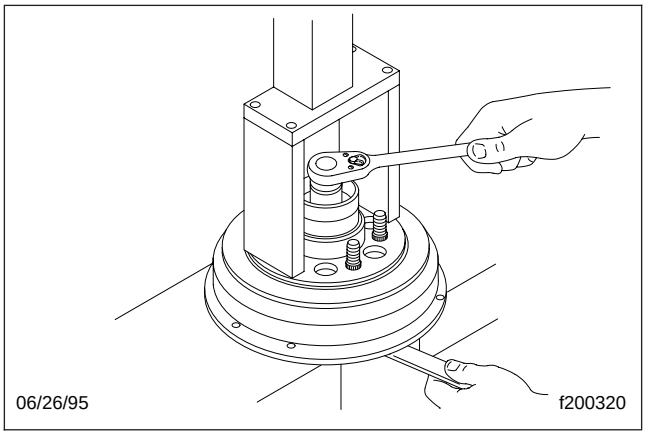


Fig. 4, Removing the Cylinder Nut and Cylinder

- 6.4 Inspect the piston bearing by rotating the piston.

7. If you find cracking or scoring on any surface, or if the bearings are rough, loose, or missing, replace the fan clutch.

NOTE: If you find metal particles in the existing grease, replace the fan clutch or contact Kysor for the training needed to perform a major fan clutch rebuild. Kysor will not provide parts for a major rebuild until the technician has completed rebuild training provided by Kysor.

IMPORTANT: Do not wash the clutch parts in solvent.

8. Using **Fig. 3** as a reference, lubricate the following rebuild parts with lubricant supplied with the rebuild kit (if the lubricant is unavailable, use one of the approved lubricants listed in **Specifications, 400)** :
    - The piston seal (pack the seal groove also)
    - The dust seal (pack the seal groove also)
    - The needle bearings inside the housing
    - The inside of the engagement spring
    - The outside of the piston rod assembly
    - The inside of the piston rod assembly
    - The inside of the cylinder assembly
    - Pack the lip of the grease seal

NOTICE

When caging and compressing the engagement spring of the fan clutch, depress the clutch shaft only enough to relieve the pressure on the retaining plates (about 1/16-inch, or 1.5 mm). Applying additional force after the clutch shaft bottoms in the housing will damage the housing and render it unserviceable.

IMPORTANT: When caging the engagment spring, compress the clutch shaft only 1/16-inch (1.5 mm).

9. Assemble the fan clutch parts according to **Fig. 3**. Using either the special tools and a press, or carriage bolts, washers, and wingnuts, cage the engagement spring when installing the cylinder and lining. Be careful to depress the clutch shaft only 1/16-inch (1.5 mm).

    The piston rod seal washer is the last item to install before the cylinder goes on. See **Fig. 5**.

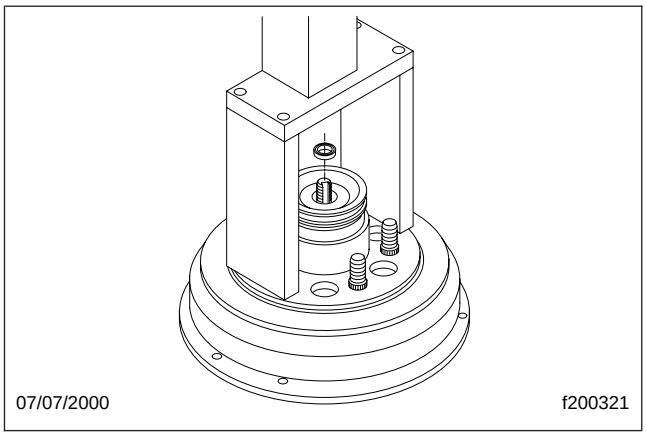


Fig. 5, Installing the Piston Rod Seal Washer

10. Tighten the cylinder nut 84 lbf·in (940 N·cm).
11. Tighten the lining screws 30 lbf·in (340 N·cm).
12. As applicable, remove the fan clutch from the press or remove the carriage bolts, washers, and wing nuts.
13. Check the front-to-rear travel of the fan clutch. For instructions, refer to **Group 20** in the *108SD and 114SD Maintenance Manual*.
14. Install the fan clutch on the engine. For instructions, refer to **Subject 100**.

Relining

IMPORTANT: Premature wearing of the fan clutch lining is due to either insufficient air pressure necessary to fully disengage the clutch (allowing the clutch to remain partially engaged, thus increasing wear), or a problem in the control circuit for the fan. Before putting the fan clutch back in service, check the fan control and air supply systems and make any necessary repairs.

1. Park the vehicle on a level surface, apply the parking brake, and shut down the engine. Chock the tires.

⚠ WARNING

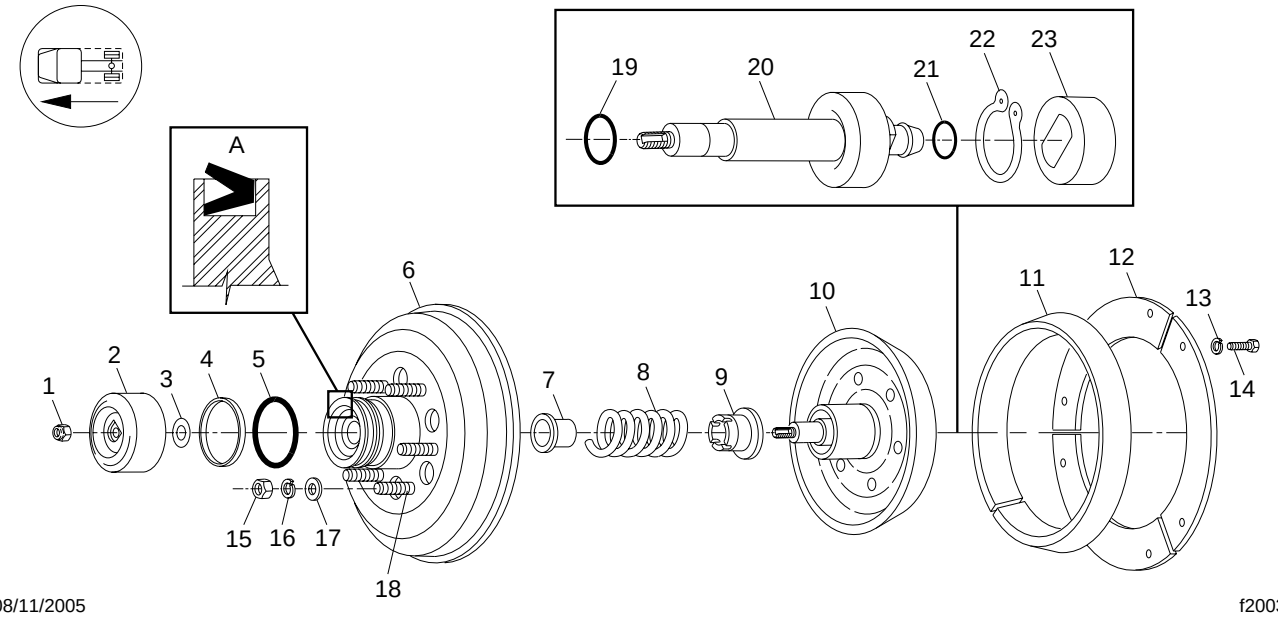
If the fan clutch engages during the next step, it could cause personal injury. Keep the fan clutch disengaged throughout this procedure by maintaining between 90 and 120 psi (620 and 827 kPa) of air pressure.

2. Bleed all the air from the primary and secondary tanks.
3. Disconnect the air line from the fan drive, and apply 90 to 110 psi (620 to 760 kPa) shop air pressure to the fan drive.
4. Remove the six lining plate screws, and remove the three lining plates. See **Fig. 1**.
5. Remove the old lining. If the lining sticks, use a hammer and a screwdriver to free it by tapping on the dividing cut in the lining.
6. Inspect the clutch shaft. If lining residue is present, or if the surface appears glazed over (non-metallic), temporarily release the air pressure from the clutch to allow shaft to protrude, and use a ScotchBrite to break the glaze.

NOTE: Some applications may be too tight to spread the lining and slip it over the pulley. If necessary, the lining can be cut in half with a hacksaw for installation.

7. Apply air pressure to the clutch again, and install the new lining. See **Fig. 2**.
8. Install the new lining plates. Tighten the screws 30 lbf·in (340 N·cm).
9. Remove the air pressure from the fan clutch, and allow the fan to engage.
10. Disconnect the shop air, and connect the air line to the fan drive.

Fan Clutch Relining



A. If a lip seal is used, install it so that it faces away from the fan studs.

1. Cylinder Nut
2. Cylinder Assembly
3. Piston Rod Seal Washer
4. Lip Seal (may be O-Ring)
5. Dust Seal
6. Housing Assembly
7. Engagement Spring End Cap
8. Engagement Spring
9. Engagement Spring Carrier
10. Shaft Assembly
11. Lining
12. Lining Retaining Plates
13. Lockwasher
14. Screw
15. Fan Nut
16. Lockwasher
17. Flatwasher
18. Fan Stud
19. O-Ring
20. Piston Rod Assembly
21. O-Ring
22. Snap Ring
23. Coupling

Fig. 1, Kysor K26RA Fan Clutch (exploded view)

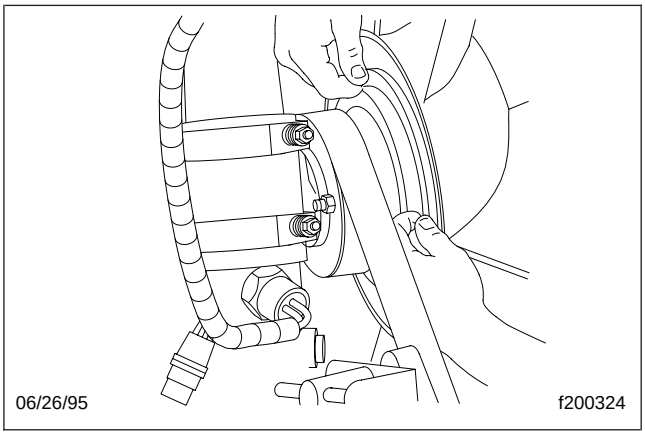
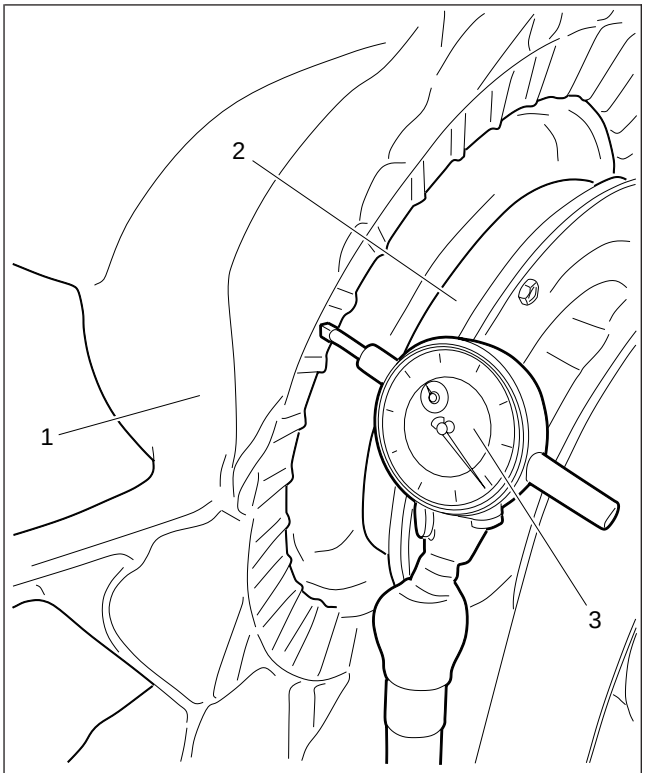


Fig. 2, Removing the Lining Plates

Fan Clutch Rock Runout Measurement

NOTE: Do not try to measure the fan rock runout at the end of the fan blade. An inaccurate reading will result.

1. Park the vehicle on a level surface, shut down the engine, and set parking brake. Chock the tires.
2. Position the indicator on a flat surface near the outside diameter (OD) of the clutch hub section of the fan as shown in **Fig. 1**.



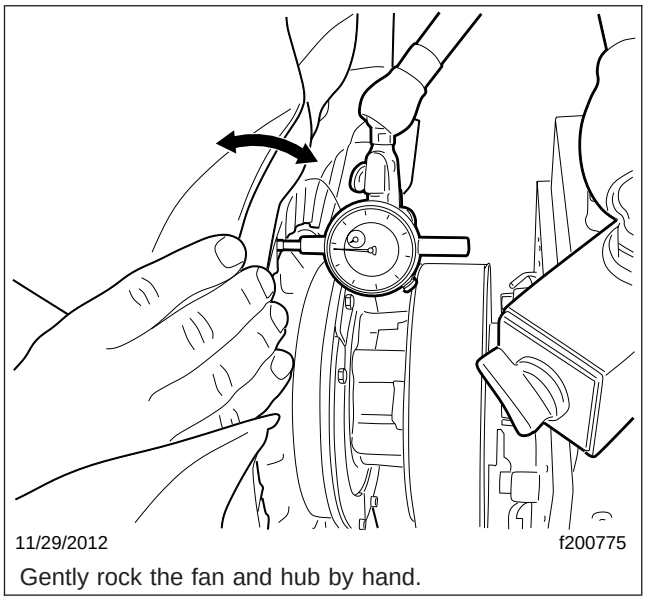
1. Fan
2. Fan Clutch
3. Indicator

Fig. 1, Positioning the Indicator

3. Drain the air from the air system.
4. Disconnect the air line to the fan clutch.
5. Disengage the clutch. Apply, and maintain, 90 to 120 psi (620 to 830 kPa) shop air to the fan clutch for the test.
6. Grasp the fan at the hub and gently rock the fan fore and aft. See **Fig. 2**.

   The total indicator reading should not exceed 0.050 in (1.27 mm).

   If reading is greater than 0.050 in (1.27 mm), replace the fan clutch. For instructions, see **Subject 100**.



Gently rock the fan and hub by hand.

Fig. 2, Checking the Rock Runout Measurement

7. Remove the indicator.
8. Connect the air line to the fan clutch.
9. Pressurize the system, and check for leaks. Repair as needed.

Specifications

If the lubricant that comes with the rebuild kit for the Kysor K26RA fan clutch is unavailable, use one of the following approved lubricants:

- Aeroshell 5
- Shell Alvania R3
- Chevron SR12
- Amoco Rykon Premium #2EP
- Texaco RB Premium

Kysor K26RA Fan Clutch Torques		
Description	**Torque**	
	lbf·ft (N·m)	**lbf·in (N·cm)**
Clutch-to-Hub Fasteners	45 (61)	—
Fan-to-Clutch Fasteners	26 (35)	—
Front Piston Nut	—	84 (950)
Lining Plate Screws	—	30 (340)

Table 1, Kysor K26RA Fan Clutch Torques

General Information

The fan clutch is a temperature-controlled, air-operated clutch for the engine cooling fan. It is spring engaged, and controls the engine temperature by engaging or disengaging the fan.

When the coolant temperature is below a specified range, air pressure keeps the fan disengaged to save engine power. When the coolant temperature rises above the specified range, air pressure to the fan clutch is cut off and internal spring pressure engages the fan.

Air pressure to the fan clutch is controlled by a solenoid valve; the solenoid valve is controlled by a temperature switch installed in the thermostat housing. The temperature switch is connected to the engine MCM, which controls the solenoid valve. When you start a cold engine, the solenoid valve allows air pressure to the fan clutch and the clutch remains disengaged. When the coolant temperature rises to the temperature switch setting, the switch provides power to the solenoid valve and the valve cuts off compressed air to engage the fan.

On vehicles with air conditioning, the fan clutch solenoid valve is connected to a fan cycling switch at the receiver-drier. If the refrigerant pressure exceeds the setting of the fan cycling switch, the switch supplies power to the solenoid valve, which cuts off air to the fan clutch, engaging the fan.

Fan Clutch Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.

⚠ WARNING

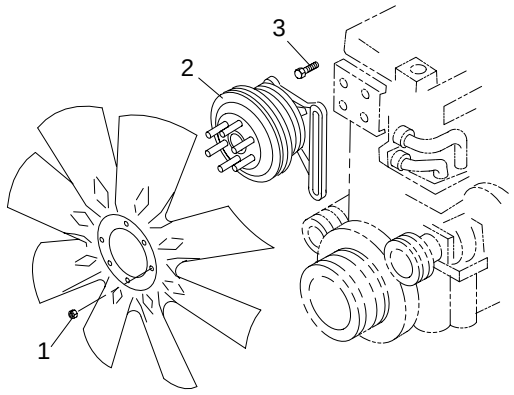
Wear safety goggles when draining the air system or disconnecting an air line because dirt and sludge could fly out at high speeds. Don't direct the airstreams at anyone. Do not disconnect pressurized air lines, as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

2. Drain the air tanks.
3. Open the hood.
4. Disconnect the left-side hose from the charge air cooler.
5. Remove the surge tank as follows.
   - 5.1 Drain coolant from the radiator drain, until no coolant shows in the surge tank. For instructions, refer to **Section 20.01, Subject 100**.
   - 5.2 Disconnect the hoses from the surge tank, being careful to avoid spills.
   - 5.3 Remove the fasteners that hold the surge tank to the radiator assembly. Set the surge tank aside.
6. Remove the upper fan shroud as follows.
   - 6.1 Place alignment marks on the upper and lower fan shrouds, and mark the shroud-to-channel positions, so the shroud can be installed in the same position on the radiator.
   - 6.2 Remove the four fasteners that connect the upper and lower fan shrouds.
   - 6.3 Remove the fasteners that hold the upper fan shrouds to the radiator.
   - 6.4 Remove the upper fan shroud from the vehicle.
7. Remove the drive belts from the engine.
8. Disconnect the air line from the fan hub.
9. Remove the fan.

⚠ CAUTION

The fan clutch assembly may weigh up to 55 lb (25 kg). Be careful when lifting it. Use a helper or a hoist, if necessary. Failure to use care when lifting the fan clutch could cause the assembly to fall, which could result in injury or component damage.

10. Remove the fasteners holding the fan clutch mounting bracket to the front of the engine. Then remove the fan clutch assembly from the vehicle. See **Fig. 1**.



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1. Hexnut
2. Fan Clutch Assembly
3. Hexbolt

Fig. 1, Fan Clutch Removal (typical)

Installation

1. Using either a helper or a hoist, position the fan clutch assembly on the front of the engine, aligning the holes in the mounting bracket with those in the front of the engine. Install the fasteners.
2. Install the drive belts.
3. Connect the air line to the fan clutch.
4. Apply sealant Loctite 242 to the threads of the fasteners, then attach the fan. Tighten the fasteners 30 lbf·ft (40 N·m).
5. Tighten the fan-clutch mounting fasteners 75 to 93 lbf·ft (100 to 125 N·m).

Fan Clutch Removal and Installation

6. Position the upper fan shroud on the radiator; align the marks, then install the fasteners that hold it to the radiator and the lower fan shroud.
7. Position the surge tank on the radiator assembly, and install the fasteners.
8. Connect the hoses to the surge tank.
9. Fill the cooling system. For instructions, refer to **Section 20.01, Subject 100**.
10. Connect the left-side hose to the charge air cooler.
11. Start the engine and check for coolant leaks. Repair as needed.

Disassembly

NOTE: This procedure involves a major rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Super Kit. If you are replacing just the seals or the air cartridge, see **Subject 120** for the minor rebuild procedure.

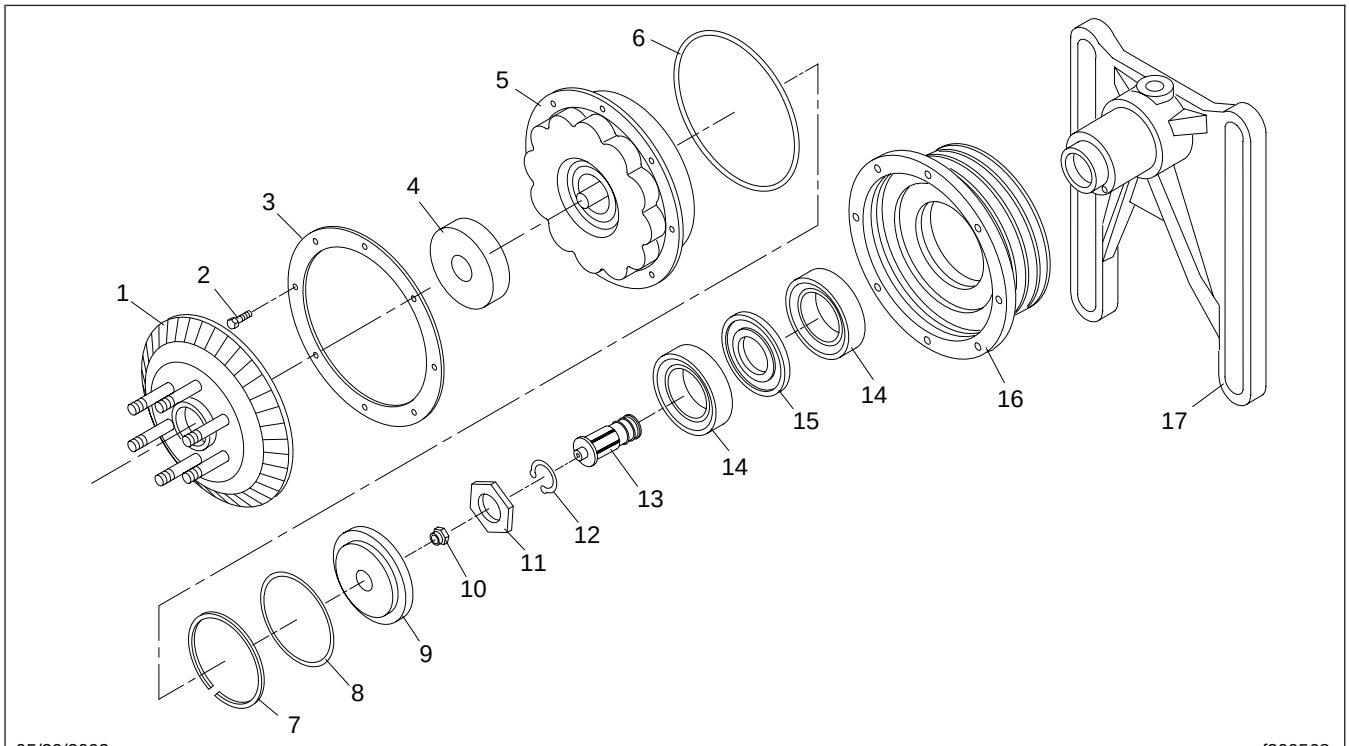
Refer to **Fig. 1** for this procedure.

1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

NOTICE

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

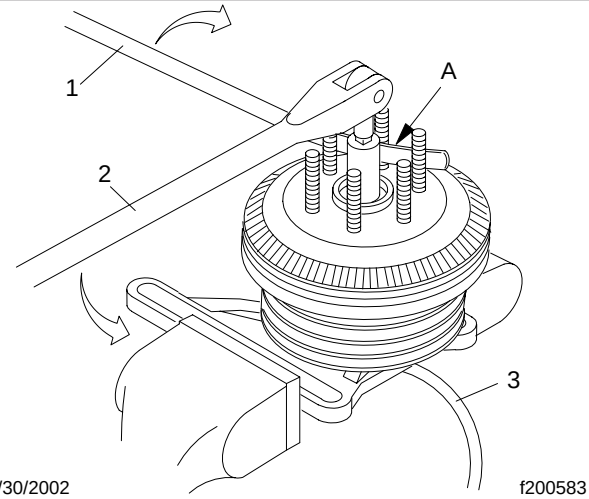
5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 2**.



1. Fan Mounting Disc
2. Torx®-Head Screw (8 qty.)
3. Friction Lining
4. Cage Nut (supplied with repair kit)
5. Spring Housing/Piston Assembly
6. Air Chamber Seal
7. Air Chamber Cap Retaining Ring
8. O-Ring
9. Air Chamber Cap
10. Face Seal
11. Bearing Nut
12. Air Cartridge Retaining Ring
13. Air Cartridge Assembly
14. Sheave Bearings
15. Bearing Spacer
16. Sheave
17. Journal Bracket

Fig. 1, Horton DriveMaster Fan Clutch

Fan Clutch Major Rebuild

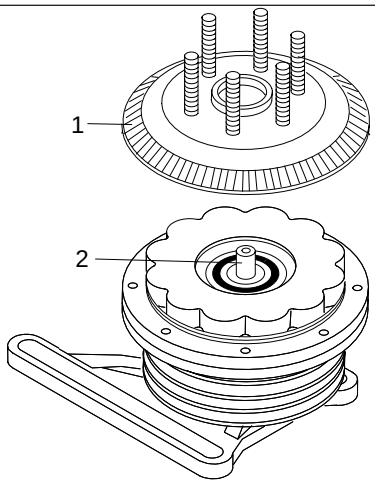


A. Place the pry bar here.

1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 2, Loosening the Jack Bolt

6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 3**.
7. Inspect the fan mounting disc for wear or damage.



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

Fig. 3, Fan Mounting Disc Removal and Installation

WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

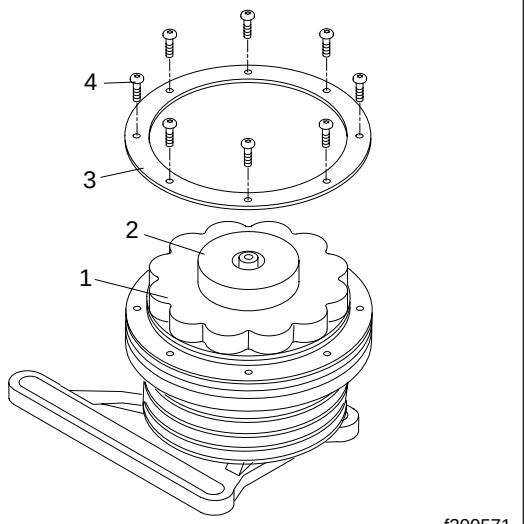
8. Using a wrench and a T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.
9. Release the air pressure from the fan clutch.

WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 4**.
12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 5**.
13. Remove the air chamber seal. See **Fig. 6**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 6**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.
17. Remove the O-ring seal from the air chamber cap. See **Fig. 6**.
18. Remove the face seal. See **Fig. 6**.
19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system



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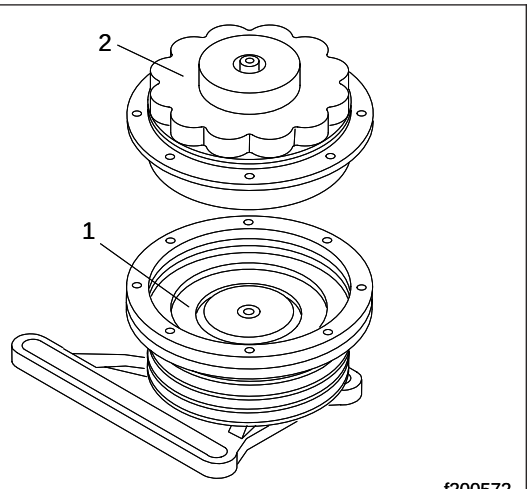
1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

Fig. 4, Friction Lining Removal and Installation



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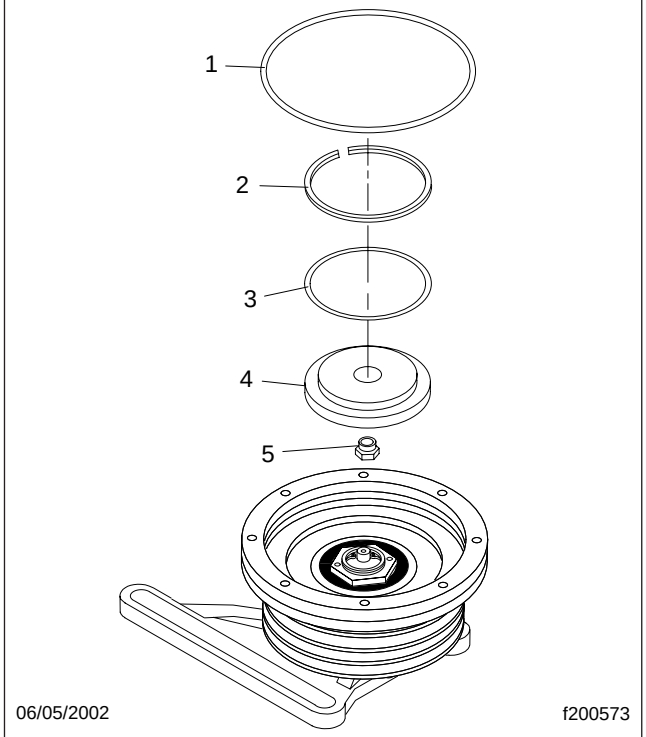
1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

Fig. 5, Spring Housing/Piston Assembly Removal and Installation

20. Remove the bearing nut from the mounting bracket. See **Fig. 7**.



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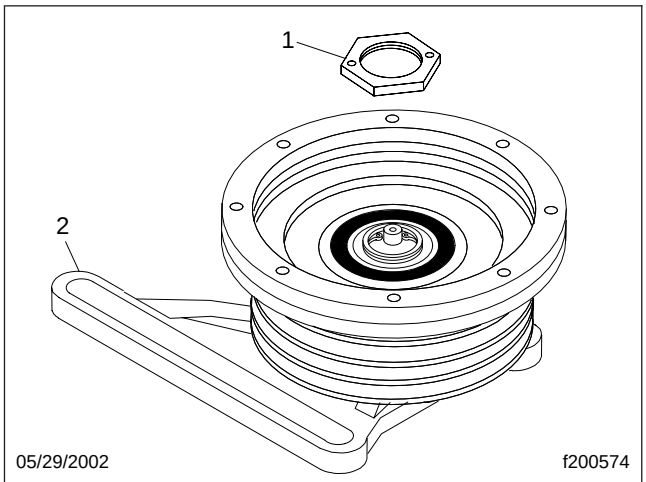
1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 6, Air Chamber Seal Removal and Installation



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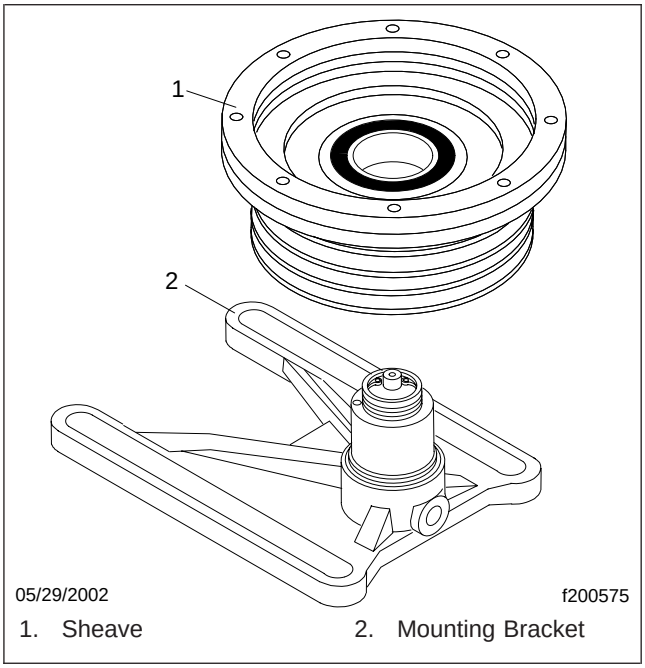
1. Bearing Nut
2. Mounting Bracket

Fig. 7, Bearing Nut Removal and Installation

Fan Clutch Major Rebuild

21. Remove the sheave from the mounting bracket. See **Fig. 8**.



1. Sheave 2. Mounting Bracket

Fig. 8, Removing the Sheave

22. If replacing the bearings, support the sheave and press them out.
23. Clean and remove any dirt, debris, or corrosion that may be present.
24. Remove the air cartridge.
    - 24.1 Remove the retaining ring. See **Fig. 9**.
    - 24.2 Remove the air cartridge assembly. See **Fig. 10**.

Assembly

1. If necessary, clean the air cartridge bore in the mounting bracket.

NOTE: The sheave bearings do not require lubrication.

2. If replacing the sheave bearings, do the following:
    - 2.1 If equipped with two bearings, assemble the bearings so the markings on their edges line up to form an arrow. See **Fig. 11**. It doesn't matter which way the arrow faces when the bearings are installed.

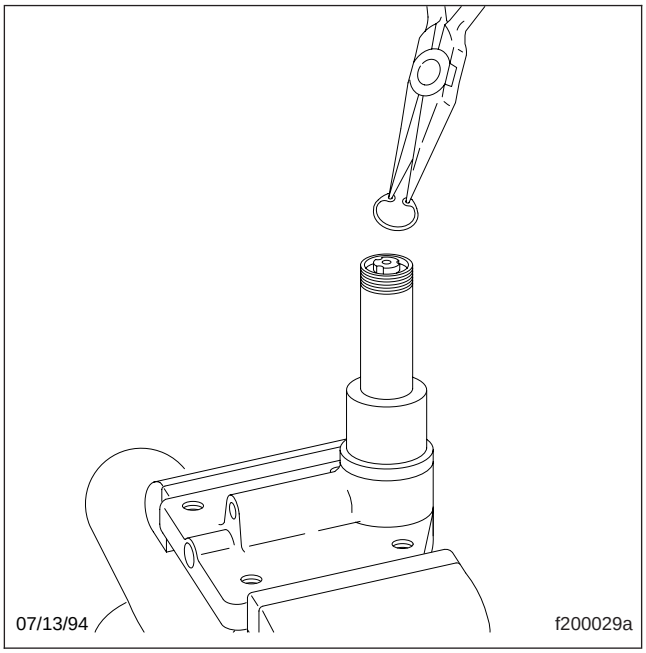
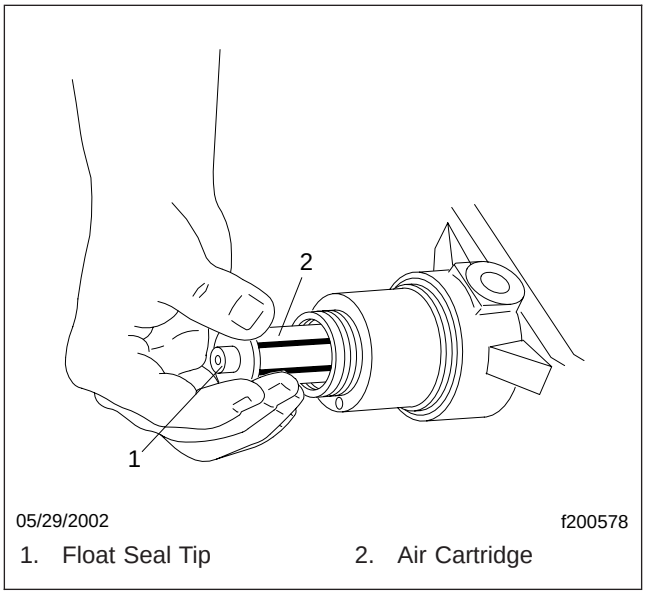
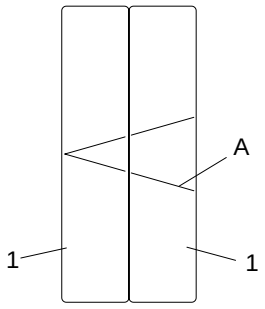


Fig. 9, Retaining Ring Removal and Installation



1. Float Seal Tip 2. Air Cartridge

Fig. 10, Removing the Air Cartridge



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A. Align the markings to form an arrow.

1. Sheave Bearing

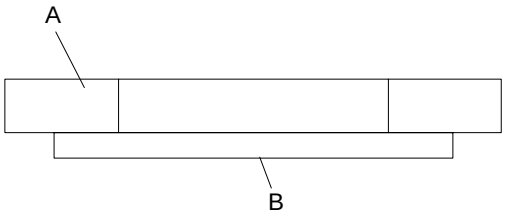
Fig. 11, Aligning the Bearings

IMPORTANT: If the fan clutch uses spacers, be sure to install them between the bearings.

2.2 Supporting the sheave, press the new sheave bearings, and spacers, if applicable, into place. Note the position of the lip inside the sheave.

2.3 Slide the sheave onto the mounting bracket. See **Fig. 8**.

2.4 Making sure that the bearing nut hex is facing up, install the bearing nut. See **Fig. 12**. Tighten 130 lbf·ft (176 N·m). See **Fig. 7**.



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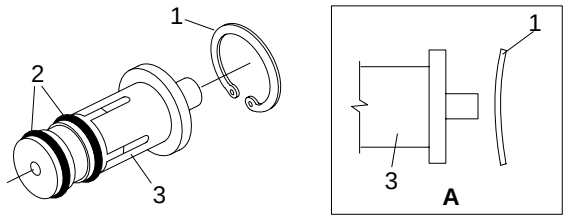
A. Hex faces up.
B. Relief faces toward mounting bracket and bearings.

Fig. 12, Correct Bearing Nut Orientation

3. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See **Fig. 13**.



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A. Convex surface of the retaining ring goes toward the air cartridge.

1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 13, Installing the Air Cartridge Retaining Ring

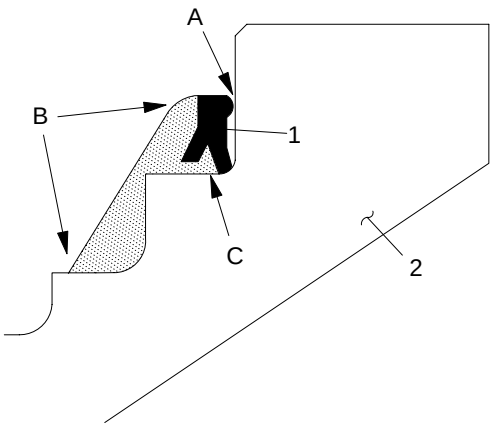
4. Install the new air cartridge assembly into the mounting bracket.
5. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See **Fig. 13**.
6. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.
7. Assemble the air chamber cap and face seal. See **Fig. 6**.

   Tighten the face seal 75 to 100 lbf·in (850 to 1130 N·cm).
8. Lubricate the O-ring seal with the fresh lubricant from the kit.
9. Install the O-ring seal on the air chamber cap. See **Fig. 6**.
10. Carefully set the air chamber cap into the sheave. See **Fig. 6**.
11. Install the retaining ring. See **Fig. 6**.
12. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side and bottom of the groove surfaces, and the "V" of the seal is facing down. See **Fig. 14**.
13. Lubricate contact surfaces with the fresh lubricant from the kit.

⚠ WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring

Fan Clutch Major Rebuild



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A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down

1. Air Chamber Seal 2. Sheave

Fig. 14, Correct Installation of Air Chamber Seal (cross-section view)

housing to be forcibly ejected from the piston assembly, which could result in serious injury.

14. Carefully set the new spring housing/piston assembly into position. See **Fig. 5**. Note that the new assembly has a cage nut installed on it.
15. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.

IMPORTANT: Handle the new friction liner by the edges to avoid contamination.

16. Set the new friction liner from the kit into place, being careful to touch only the edges.
17. Using a T27 Torx bit, install the eight Torx-head screws. See **Fig. 4**. Tighten alternately 80 lbf·in (900 N·cm).
18. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
19. Remove the cage nut from the spring housing/piston assembly.
20. Install the new fan mounting disc from kit.

NOTICE

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

21. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and push the pry bar counterclockwise.
22. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
23. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
24. Install the fan clutch assembly onto the engine. See **Subject 100** for instructions.

Disassembly

NOTE: This procedure involves a minor rebuild of the Horton DriveMaster® fan clutch, using parts from the manufacturer's Seal Kit. If a major rebuild of the fan clutch is needed, see **Subject 110**.

1. Remove the fan clutch assembly from the vehicle. For instructions, see **Subject 100**.
2. Put the fan clutch assembly in a vise.
3. Connect a shop air hose to the fan clutch air inlet.
4. Apply 80 to 120 psi (552 to 827 kPa) to the fan clutch to lift the fan mounting disc off the spring housing/piston assembly.

NOTICE

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

5. Using a pry bar, wrench, and a T55 Torx® bit, loosen the jack bolt (left-hand thread) by turning it counterclockwise. See **Fig. 1**.
6. Unscrew the fan mounting disc from the jack bolt. See **Fig. 2**.
7. Inspect the fan mounting disc for wear or damage.

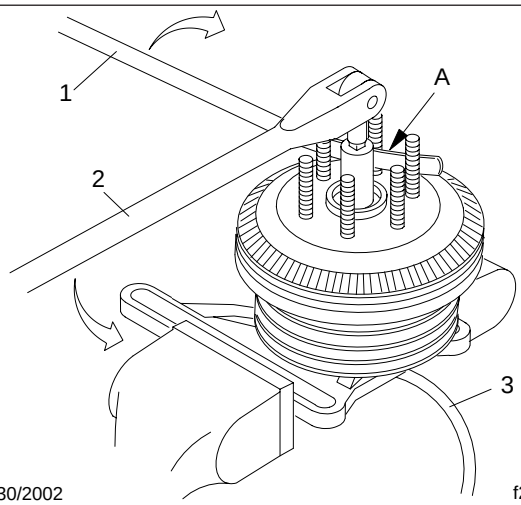
⚠ WARNING

Do not disassemble the spring housing from the piston. The interior springs are very strong, and if released could eject the housing with considerable force, possibly resulting in serious injury. Always use the cage nut to hold the spring housing and the piston together.

8. Using a wrench and T55 Torx bit to hold the jack bolt, install the cage nut from the kit onto the jack bolt (left-hand thread). Hand tighten it onto the spring housing.

   The cage nut will keep the spring housing and piston together as an assembly. It will also maintain pressure on the internal springs after the Torx-head screws holding the friction lining in place are removed.

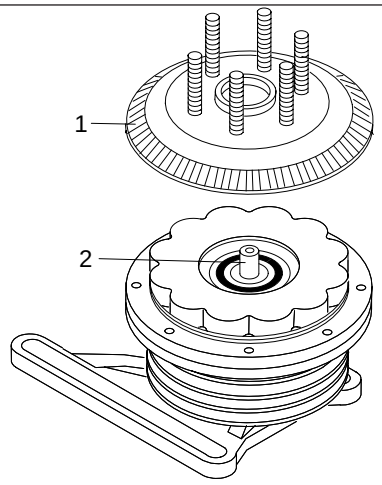
9. Release the air pressure from the fan clutch.



A. Place the pry bar here.

1. Pry Bar (push clockwise)
2. Torx Bit and Wrench (turn counterclockwise)
3. Shop Air Hose (connected to the inlet port)

Fig. 1, Loosening the Jack Bolt



1. Fan Mounting Disc
2. Jack Bolt (left-hand thread)

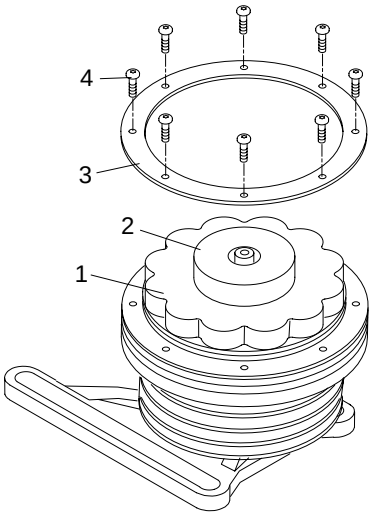
Fig. 2, Fan Mounting Disc Removal and Installation

Fan Clutch Minor Rebuild

WARNING

Release the air pressure from the fan clutch before removing the friction lining Torx-head screws. Failure to release the air pressure could result in the spring housing/piston assembly being ejected with force, which could result in personal injury.

10. Using a T27 Torx bit, remove the eight Torx-head screws holding the friction lining in place.
11. Remove the friction lining. See **Fig. 3**.



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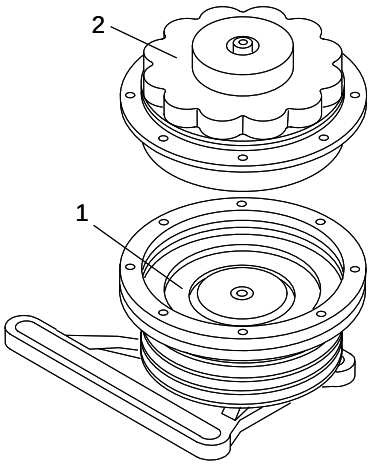
1. Spring Housing/Piston Assembly
2. Cage Nut
3. Friction Lining
4. Torx-Head Screws

Fig. 3, Friction Lining Removal and Installation

12. *Keeping the cage nut installed and tightened,* remove the spring housing/piston assembly. See **Fig. 4**.
13. Remove the air chamber seal. See **Fig. 5**.
14. Examine the inside of the air chamber for signs of moisture and/or contaminants.
15. Remove the air chamber cap retaining ring. See **Fig. 5**.
16. Using two small screwdrivers placed 180 degrees apart, gently and evenly pry the air chamber cap out of the sheave.



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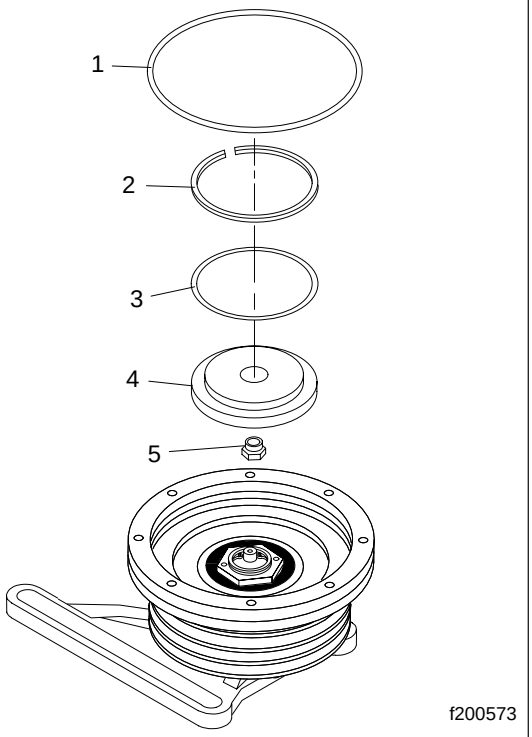
1. Air Chamber
2. Spring Housing/Piston Assembly (with cage nut installed)

Fig. 4, Spring Housing/Piston Assembly Removal and Installation

17. Remove the O-ring seal from the air chamber cap. See **Fig. 5**.
18. Remove the face seal. See **Fig. 5**.
19. Inspect the face seal for signs of wear. Wear indicates that dirt may exist in the air system.
20. Remove the air cartridge.
    - 20.1 Remove the retaining ring. See **Fig. 6**.
    - 20.2 Remove the air cartridge assembly. See **Fig. 7**.

Assembly

1. Clean the mounting bracket bore if necessary.
2. Apply O-ring lubricant from the kit to the outside O-rings of the new air cartridge assembly. See **Fig. 8**.
3. Install the new air cartridge assembly into the mounting bracket.
4. Install the retaining ring, making sure the convex surface of the ring is toward the air cartridge. See **Fig. 8**.
5. Using a clean, dry cloth, clean both the float seal tip of the air cartridge and the face seal of the air chamber cap.



1. Air Chamber Seal
2. Retaining Ring
3. O-Ring Seal
4. Air Chamber Cap
5. Face Seal

Fig. 5, Air Chamber Seal Removal and Installation

6. Assemble the air chamber cap and face seal. See **Fig. 5**.

   Tighten the face seal 75 to 100 lbf·in (850 to 1130 N·cm).

7. Lubricate the O-ring seal with the fresh lubricant from the kit.
8. Install the O-ring seal on the air chamber cap. See **Fig. 5**.
9. Carefully set the air chamber cap into the sheave. See **Fig. 5**.
10. Install the retaining ring. See **Fig. 5**.
11. Install the air chamber seal into the sheave. Be sure the seal is evenly seated against the side and bottom of the groove surfaces, and the "V" of the seal is facing down. See **Fig. 9**.
12. Lubricate contact surfaces with the fresh lubricant from the kit.

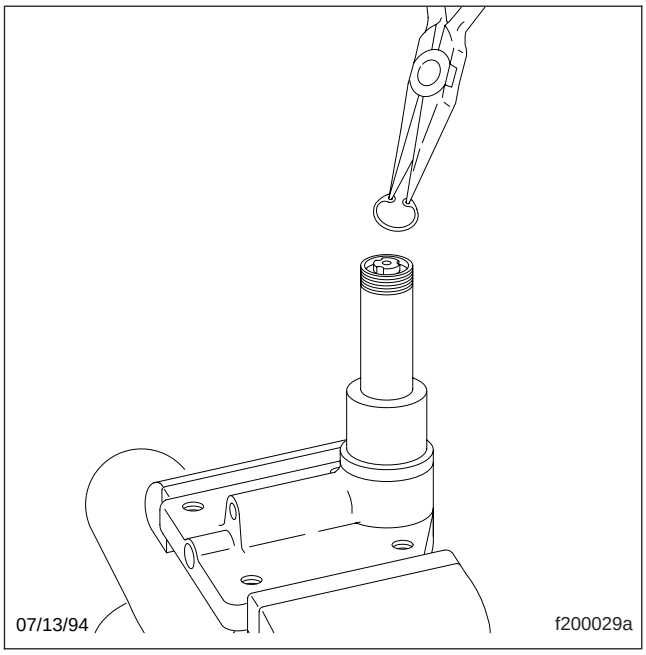
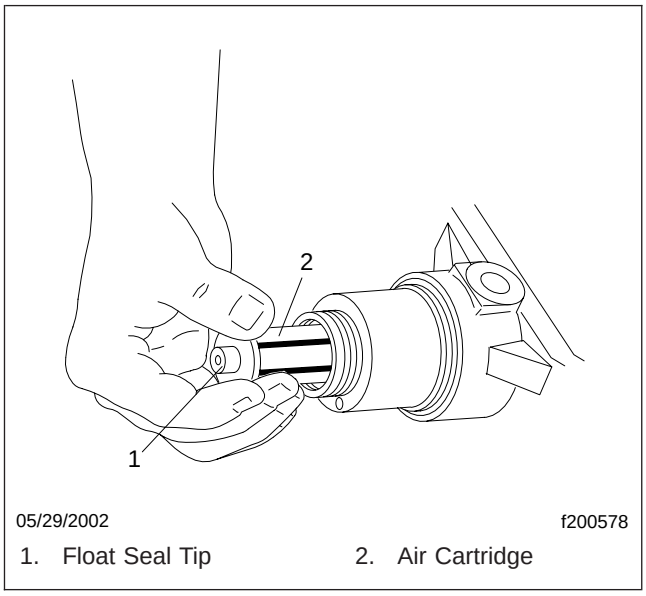


Fig. 6, Retaining Ring Removal and Installation (sheave not shown)



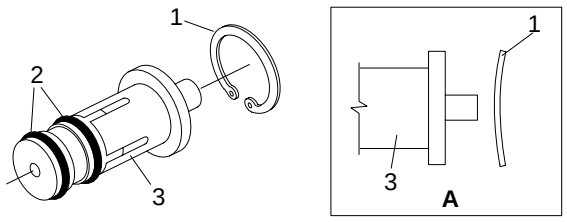
1. Float Seal Tip
2. Air Cartridge

Fig. 7, Removing the Air Cartridge (sheave not shown)

WARNING

The new spring housing/piston assembly from the kit has a cage nut installed on it. Do not remove the cage nut. This will cause the spring

Fan Clutch Minor Rebuild



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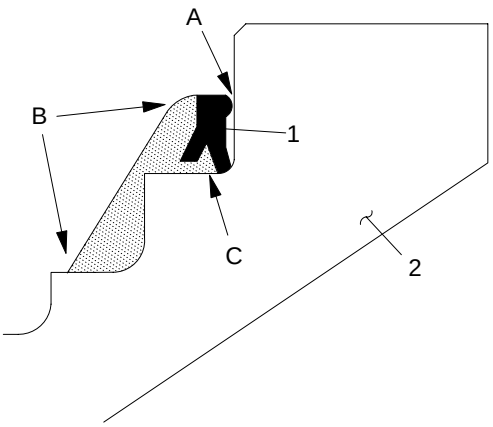
A. Convex surface of the retaining ring goes toward the air cartridge.

1. Retaining Ring
2. O-Rings
3. Air Cartridge

Fig. 8, Installing the Air Cartridge Retaining Ring



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A. Seal is seated evenly against side and bottom of groove.
B. Apply grease only between these areas.
C. "V" of Seal Facing Down

1. Air Chamber Seal
2. Sheave

Fig. 9, Correct Installation of Air Chamber Seal (cross-section view)

housing to be forcibly ejected from the piston assembly, which could result in serious injury.

13. Carefully set the new spring housing/piston assembly into position. See **Fig. 4**. Note that the new assembly has a cage nut installed on it.
14. Rotate the new spring housing/piston assembly to align the mounting holes with those of the sheave.
15. Set the friction liner from the kit into place, being careful to touch only the edges.
16. Using a T27 Torx bit, install the eight Torx-head screws. See **Fig. 3**. Tighten alternately 80 lbf·in (900 N·cm).
17. Apply a minimum of 80 psi (552 kPa) of clean air to the air inlet.
18. Remove the cage nut from the spring housing/piston assembly.

NOTICE

Use care when placing the pry bar onto the fan mounting disc. Make sure it is secure and flat on the surface. Failure to do so may cause the pry bar to slip, which could result in damage to studs or the fan mounting disc.

19. Using a suitable wrench, a T55 Torx bit, and a pry bar, tighten the jack bolt (left-hand thread) 100 lbf·ft (136 N·m). Turn the wrench clockwise and the pry bar counterclockwise.
20. Using shop air, actuate the fan clutch and check for correct engagement and disengagement of the fan mounting disc. If there is a problem, it must be corrected before installing the fan clutch onto the engine.
21. Check for air leaks at the bleed hole and around the spring housing/piston assembly.
22. Install the fan clutch assembly onto the engine. See **Subject 100** for instructions.

Troubleshooting Tables

Problem—Air Is Leaking from the Fan Clutch

Problem—Air Is Leaking from the Fan Clutch	
Possible Cause	**Remedy**
The face seal or air cartridge is damaged or worn.	Install a new seal kit.
The O-ring seals are damaged or worn.	Install a new seal kit.

Problem—The Fan Clutch Fails to Engage

Problem—The Fan Clutch Fails to Engage	
Possible Cause	**Remedy**
There's no power to the fan clutch control circuit.	Check all electrical connections, and repair or replace wiring as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
The solenoid valve is malfunctioning.	Replace the solenoid valve.
The solenoid is not exhausting.	Make sure the solenoid exhaust port is not plugged.

Problem—The Fan Clutch Does Not Disengage

Problem—The Fan Clutch Does Not Disengage	
Possible Cause	**Remedy**
The engine temperature switch is damaged or an incorrect sensor has been installed.	Make sure the switch is normally open, not normally closed. Replace the switch if it is damaged or if the switch is the wrong type.
A restricted air line doesn't allow air supply to the clutch.	Make sure the air lines are not pinched or plugged. Repair the air lines as needed.
The fan clutch is leaking.	Install a new seal kit.
The air supply to the fan clutch is restricted.	Make sure the fan clutch air lines are not leaking or pinched. Repair the lines as needed.
The piston is seized due to contamination or dry seals.	Clean the air supply. Do a major rebuild.

Problem—The Fan Clutch Cycles Frequently

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan clutch control circuit has a loose connection or is poorly grounded.	Check all wiring connections, and repair the circuit as needed. Check the circuit breaker for the engine fan and repair or replace as needed.
The temperature control settings are incorrect.	Check the fan clutch control setting of the temperature switch, according to the engine installed in the vehicle. Repair or replace the temperature switch as needed.

Troubleshooting

Problem—The Fan Clutch Cycles Frequently	
Possible Cause	**Remedy**
The fan cycling switch at the receiver-drier is set too low.	Check the switch at the receiver-drier, and if needed, replace the switch with a switch with a higher setting. Check the ACPU switch and unit.
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
The engine temperature is too high.	Check the programmable engine control parameters, and reprogram as needed.
The temperature switch is malfunctioning.	Replace the temperature switch.

Problem—The Fan Clutch Engages, But the Engine Still Overheats

Problem—The Fan Clutch Engages, But the Engine Still Overheats	
Possible Cause	**Remedy**
There is an air restriction in front of the fan clutch.	Check for incorrect radiator shutter operation, winterfronts, or any other air restrictions.
There is a problem somewhere else in the cooling system.	Refer to the cooling system troubleshooting section, **Section 20.00**.

Specifications

Horton DriveMaster® Repair Kits		
Kit Description *	**Part Number**	**When Used**
Super Kit	HOR994985	Fan Clutch Major Rebuild
Seal Kit	HOR994346	Replacing Seals and Air Cartridge
Friction Disc Kit	HOR994348	Replacing Fan Mounting Disc and Friction Lining
Friction Liner Kit	HOR994349	Replacing Friction Lining Only

* All kits are available from the PDCs.

Table 1, Horton DriveMaster Repair Kits

Torque Values		
Description	**Torque**	
	lbf·in (N·cm)	**lbf·ft (N·m)**
Friction Lining Screws	80 (900)	—
Face Seal	75 to 100 (850 to 1130)	—
Bearing Nut	—	130 (176)
Jack Bolt	—	100 (136)

Table 2, Torque Values

Eaton® Fuller® Easy Pedal™ and Solo™ clutches are pull-type clutches of a dry-disc design. See **Fig. 1** and **Fig. 2**.

Easy Pedal

Easy Pedal clutches are available in 15.5-inch dual-disc assemblies. These clutches are adjustable using the Kwik-Adjust™ mechanism. See **Fig. 1**.

Easy Pedal clutch discs are available in a standard configuration of seven spring dampers with four ceramic facings and an optional VCT™plus design that has seven spring dampers with six ceramic facings. See **Fig. 3** and **Fig. 4**.

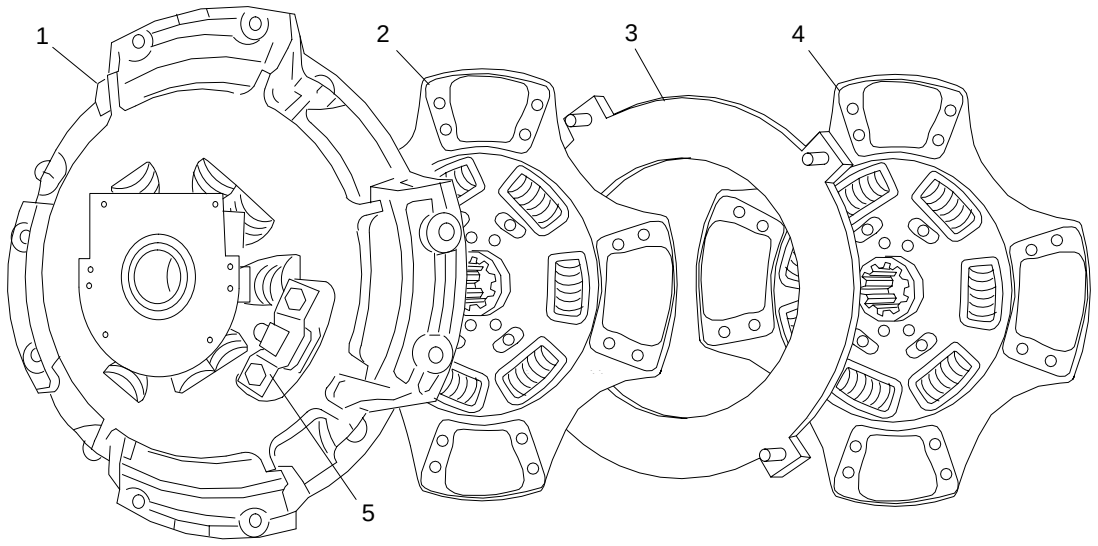
Solo

Eaton Fuller Solo clutches are available in 14-inch and 15.5-inch dual-disc assemblies. See **Fig. 2**.

Solo clutches are adjustment-free: as the clutch wears, its wear-adjusting technology monitors clutch components and makes necessary adjustments. The wear-adjusting technology comes from two sliding cams, which rotate to maintain the proper adjustment. Atop the upper cam, a wear indicating tab mirrors the cam movement to let you know when it's time to replace the clutch. See **Fig. 5**. The wear indicating tab cannot be used as a mechanism for adjusting the clutch.

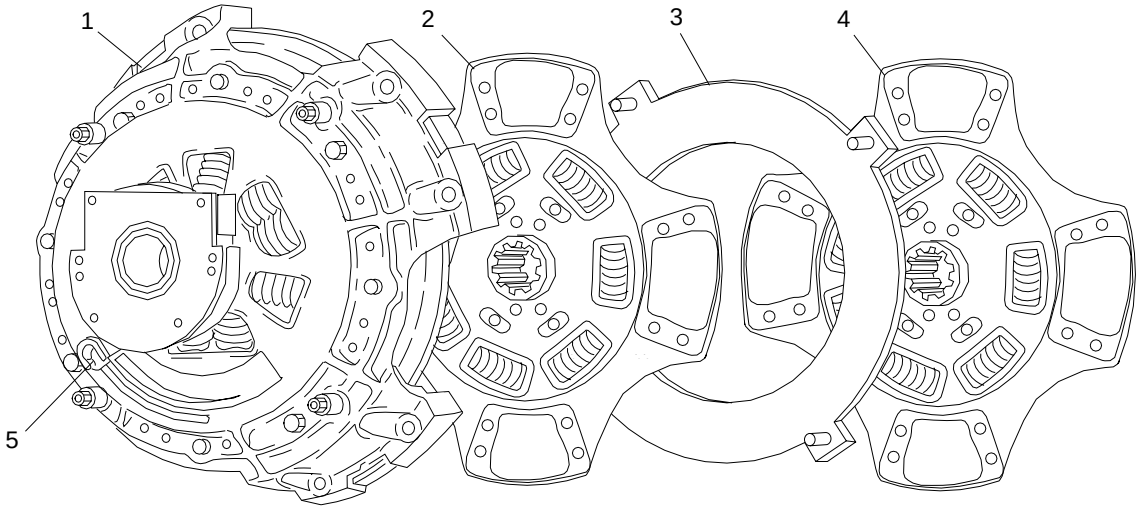
The intermediate plate separating the driven discs is mounted directly to the flywheel. Four separator pins ensure an equal gap on all sides of the intermediate plate and increase the life of the clutch.

General Information



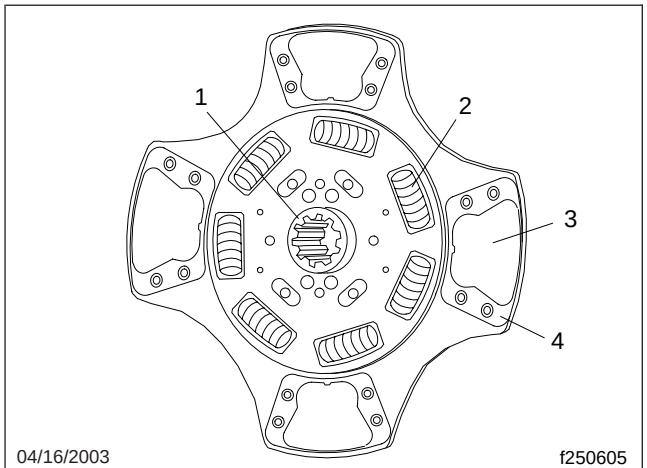
1. Clutch Cover
2. Rear Driven Disc
3. Intermediate Plate
4. Front Driven Disc
5. Kwik-Adjust Mechanism

Fig. 1, Easy Pedal Heavy-Duty Clutch



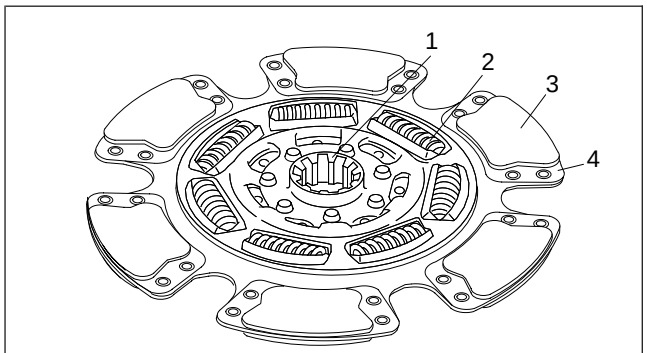
1. Clutch Cover
2. Rear Driven Disc
3. Intermediate Plate
4. Front Driven Disc
5. Wear Indicator

Fig. 2, Solo Heavy Duty Clutch



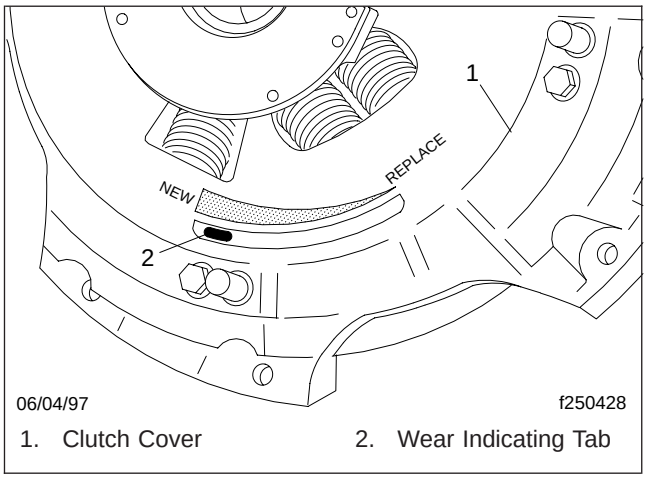
1. Hub
2. Damper
3. Facing
4. Paddle

Fig. 3, Driven Disc With Four Ceramic Facings



1. Hub
2. Damper
3. Facing
4. Paddle

Fig. 4, Driven Disc With Six Ceramic Facings



1. Clutch Cover
2. Wear Indicating Tab

Fig. 5, Wear Indicator

Solo Heavy-Duty Clutch

Use the following procedure if you need to temporarily remove and then reinstall an Eaton Fuller Solo Heavy-Duty 15.5" clutch. Failure to follow these steps could cause the Solo clutch to drag or not release upon installation.

IMPORTANT: Check the position of the wear indicating tab on the clutch cover. If the wear indicating tab is near the REPLACE position on the indicator, it is time to replace the clutch.

NOTICE

For proper installation of the Solo clutch, the wear indicating tab must be reset. Failure to reset this tab will prevent clutch release and result in possible clutch damage.

NOTE: This step requires two persons: one under the vehicle with access to the wear indicating tab, and the other in the vehicle to press the clutch pedal.

1. Reset the wear indicating tab with the clutch in the vehicle, as follows.

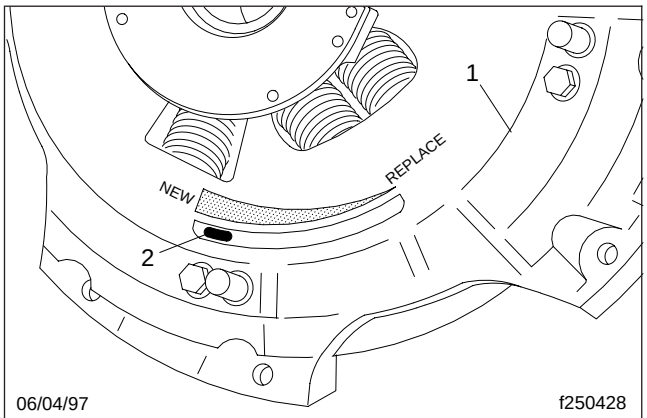
   1.1 From inside the cab, press the clutch pedal all the way down. Hold the clutch pedal down until the wear indicating tab is reset.

   1.2 Through the clutch inspection cover, slide the wear indicating tab to the left until it is at the NEW position on the indicator. See **Fig. 1**.

   1.3 From inside the cab, release the clutch pedal. Check to be sure the wear indicating tab stays at the NEW position on the indicator.

NOTE: Before pulling the transmission from the bell housing, disconnect the external clutch linkage and rotate the release yoke so the yoke will clear the release bearing when it is removed.

2. Remove the transmission. See **Section 26.00**.



With the clutch pedal down, set the tab to the NEW position on the indicator.

1. Clutch Cover
2. Wear Indicating Tab

Fig. 1, Resetting the Wear Indicating Tab

NOTICE

Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch discs. Taking these precautions will prevent bending and distortion of the clutch discs.

3. Remove the clutch brake from the transmission input shaft. See **Fig. 2**.

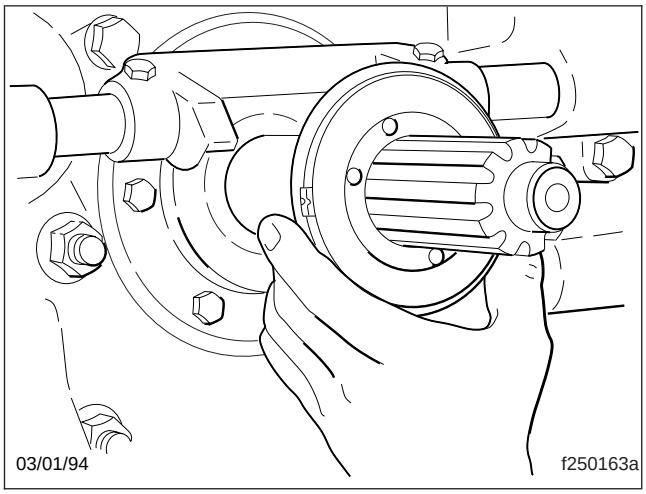


Fig. 2, Clutch Brake Removal

4. Install a spline aligning tool into the release bearing assembly, and through the driven discs. See

Clutch Removal

Fig. 3. An old transmission input shaft may be used for this purpose.

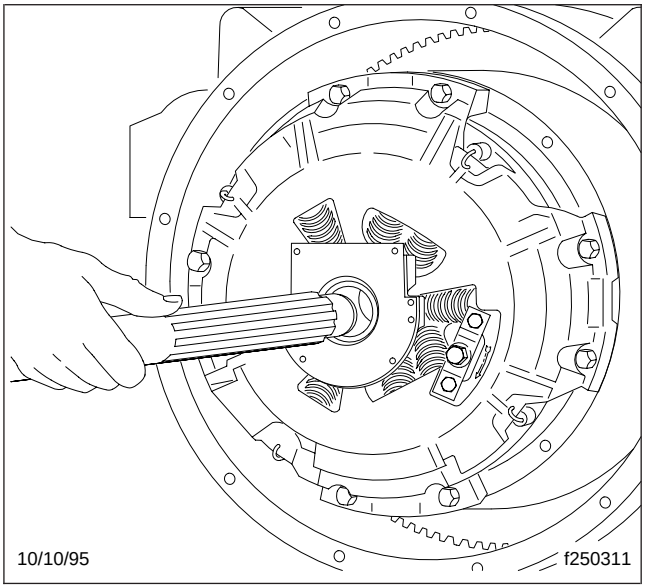


Fig. 3, Installing a Spline Aligning Tool

NOTE: Shipping bolts are installed on the clutch cover prior to installation to prevent the clutch adjustment mechanism from unloading.

5. Install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn. See **Fig. 4**.

   These bolts will cage the pressure plate, preventing the four plate spacers from moving out of position when the clutch is removed from the flywheel.

6. Progressively loosen each of the mounting capscrews in the pattern shown in **Fig. 5**. This will prevent warping or bending within the clutch, and will ease removal of the clutch mounting capscrews.

7. Remove the two top mounting capscrews from the cover assembly. Install two 7/16–14 x 5 guide studs in the open holes to help support the clutch assembly during removal. See **Fig. 6**.

NOTE: Mark the positions of the clutch components so they can be properly oriented during installation.

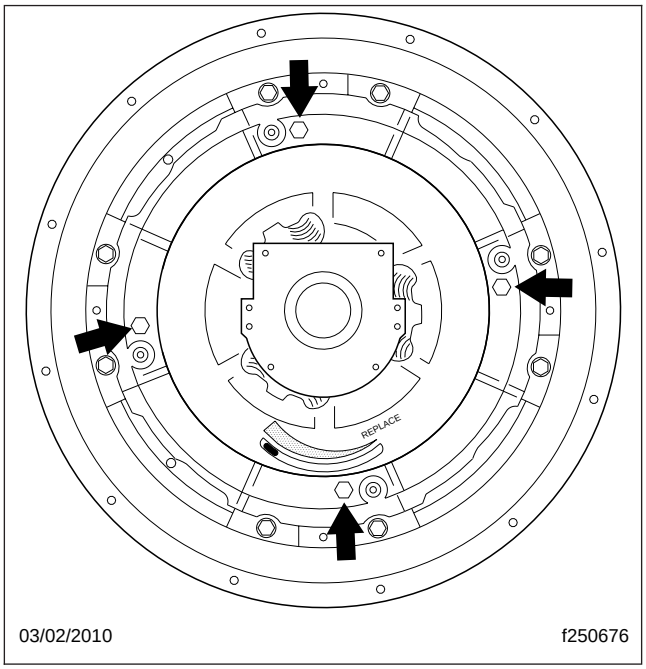


Fig. 4, Installed Shipping Bolts

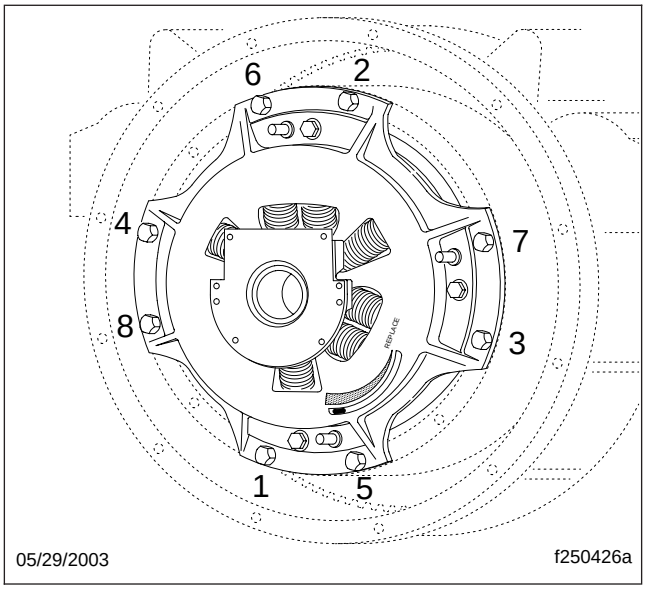


Fig. 5, Loosening Sequence

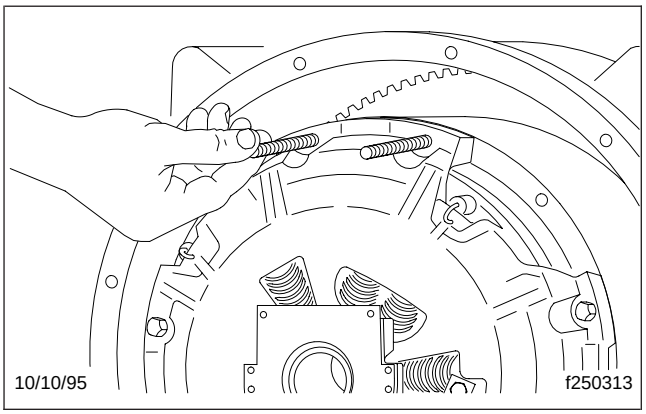
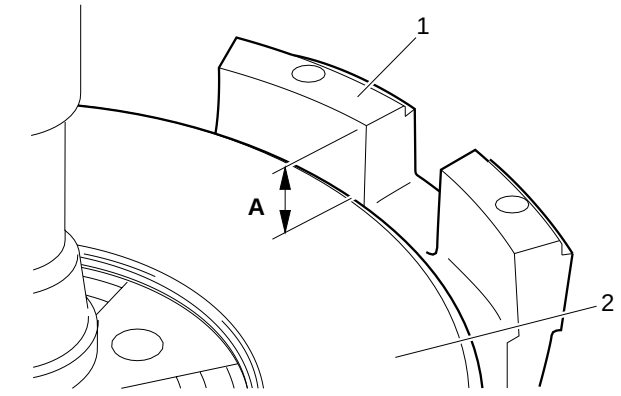


Fig. 6, Installing the Guide Studs

WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

8. Remove the mounting capscrews, and carefully remove the clutch assembly together with the spline aligning tool.
9. Reset the pressure plate, as follows. See **Fig. 7**.



NOTE: The pressure plate will be reset when it is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover.

A. 1.75 to 1.78 inches (44.4 to 45.2 mm)

1. Mounting Surface
2. Pressure Plate

Fig. 7, Reset Pressure Plate

9.1 Progressively tighten the four shipping bolts in a crisscross pattern.

9.2 Measure the depth of the pressure plate. When the face of the pressure plate is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover, the pressure plate is reset.

NOTE: Resetting the pressure plate will allow the clutch to release after installation.

10. Use an appropriate puller to remove the pilot bearing. Inspect the old pilot bearing for any unusual wear or damage. Discard the pilot bearing.

Easy Pedal Clutch

NOTE: Before pulling the transmission from the bell housing, disconnect the external clutch linkage and rotate the release yoke so the yoke will clear the release bearing when it is removed.

1. Remove the transmission. See **Section 26.00**.

NOTICE

Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch discs. Taking these precautions will prevent bending and distortion of the clutch discs.

2. Remove the clutch brake from the transmission input shaft. See **Fig. 2**.
3. Install a spline aligning tool into the release bearing assembly, and through the driven discs. See **Fig. 3**. An old transmission input shaft may be used for this purpose.
4. Use a release tool and two 5/8-inch (16-mm) spacer blocks to pull the bearing back. See **Fig. 8**. The spacer blocks relieve the internal spring load in the clutch assembly, and facilitate clutch removal.
5. Remove the two top mounting bolts from the cover assembly. Install 7/16–14 x 5 guide studs in the open holes to help support the clutch assembly during removal. See **Fig. 6**.
6. Progressively loosen each of the mounting bolts in the pattern shown in **Fig. 9**. This will prevent warping or bending within the clutch, and will ease removal of the clutch mounting bolts.

Clutch Removal

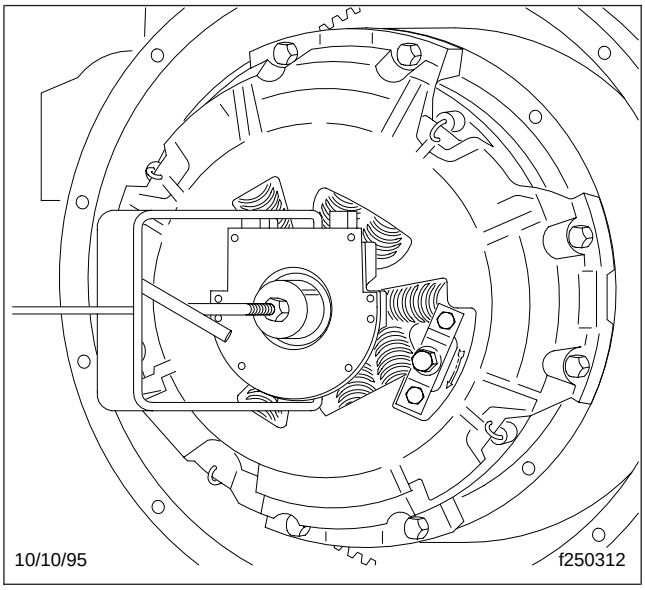


Fig. 8, Pulling the Bearing

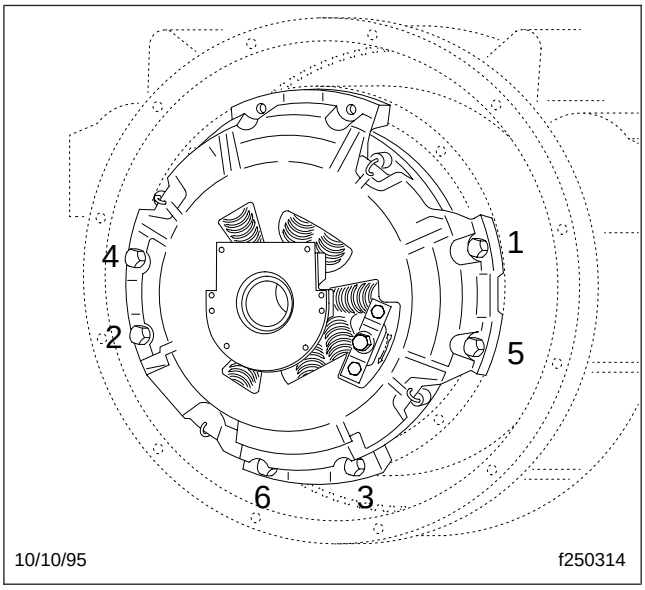


Fig. 9, Loosening Sequence, Easy Pedal

⚠ WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

7. Remove the mounting bolts, and carefully remove the clutch assembly.

   Be careful to keep the spline aligning tool in place to retain the discs and intermediate plate. Remove the spline aligning tool, the rear driven disc, the intermediate plate, and the front driven disc.

8. Use an appropriate puller to remove the pilot bearing. Inspect the old pilot bearing. Correct the cause of any unusual wear or damage. Discard the bearing.

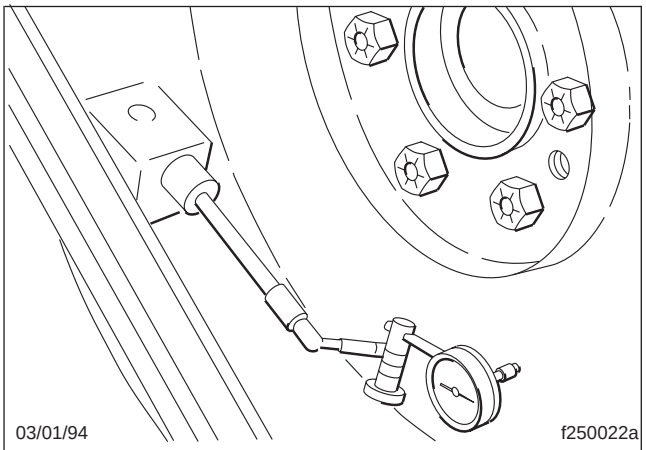
Inspection

NOTICE

Misalignment of any parts described in these procedures will cause premature wear of drivetrain components.

IMPORTANT: When taking the following readings, rotate the engine by hand; do not crank the engine with the starter. The engine may be rotated by the pulley nut at the front of the crankshaft, the flywheel mounting bolts, or the starter ring-gear on the flywheel.

1. Clean the surfaces being measured to ensure accurate measurements.
2. Measure the runout of the flywheel face (friction surface), as follows. See **Fig. 1** for the correct setup.



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Secure the dial indicator to the flywheel housing, with the gauge finger against the flywheel face, and near the outer edge.

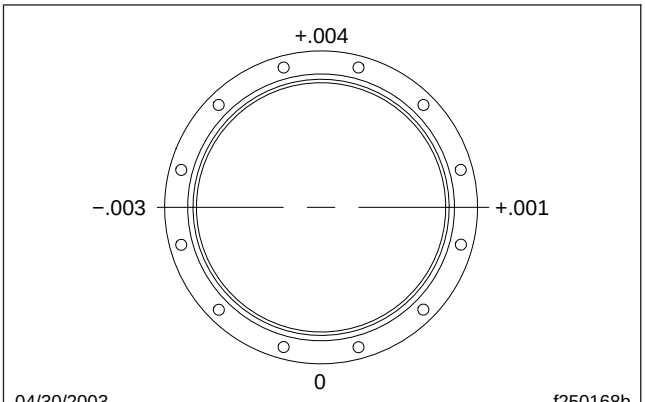
Fig. 1, Measuring the Flywheel Face

2.1 Secure the dial indicator to the flywheel housing, with the gauge finger against the face of the flywheel near the outer edge.

2.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the flywheel face.

2.3 The total runout will be the difference between the highest plus and lowest minus readings. To calculate the runout, see **Fig. 2**.

Example: The highest reading is +0.004 at 12 o'clock. The lowest reading is –0.003 at 9 o'clock. Therefore the total runout is 0.007 inch.



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Take four readings, starting with zero at the 6 o'clock position, and going on to 9, 12, and 3 o'clock. Make sure the dial returns to zero at the original start position.

Fig. 2, Calculating the Runout

2.4 The SAE maximum total runout for the flywheel face is 0.008 inch (0.20 mm). If the readings are higher, see the engine manufacturer's manual for instructions.

3. Measure the runout of the pilot-bearing bore in the flywheel, as follows. See **Fig. 3** for the correct setup.

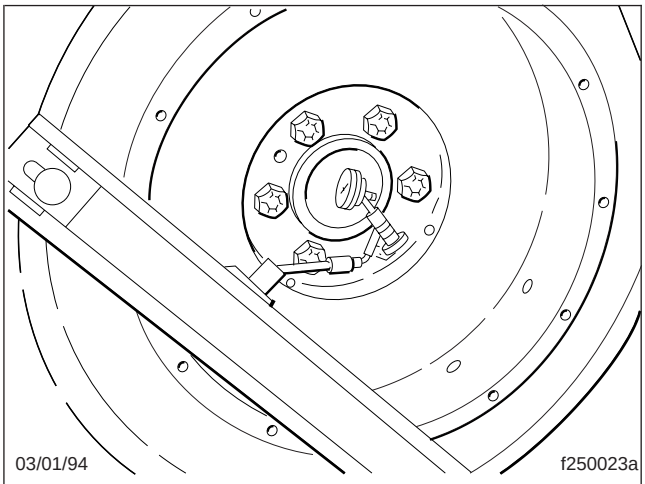
3.1 With the indicator still secured to the flywheel housing, move the gauge finger to contact the surface of the pilot-bearing bore.

3.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the bore of the pilot bearing.

3.3 Calculate the runout as before.

3.4 The SAE maximum total runout for the pilot-bearing bore is 0.005 inch (0.13 mm). If the readings are higher, see the engine manufacturer's manual for instructions.

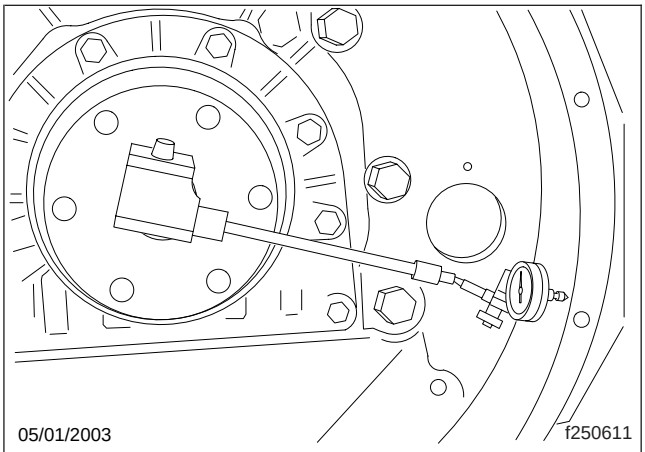
Clutch Inspection and Pre-Installation Procedures



Secure the dial indicator to the flywheel housing, with the gauge finger on the surface of the pilot-bearing bore.

Fig. 3, Measuring the Pilot-Bearing Bore

4. Measure the runout of the flywheel housing bore, as follows. See **Fig. 4** for the correct setup.



Secure the dial indicator to the crankshaft, with the gauge finger against the side of the flywheel housing.

Fig. 4, Measuring the Flywheel Housing Bore

4.1 Secure the dial indicator to the crankshaft, with the gauge finger against the side of the flywheel housing.

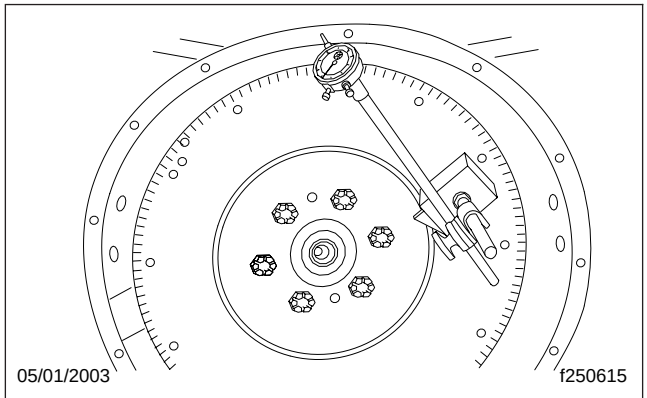
4.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the side of the flywheel housing.

4.3 Calculate the runout as before.

NOTE: Only if you have to reposition the flywheel housing is it necessary to mark the high and low runout readings in clock positions.

4.4 The SAE maximum total runout for the flywheel-housing bore is 0.008 inch (0.20 mm). If readings are higher, replace the flywheel housing. For instructions, see the engine manufacturer's manual.

5. Measure the runout of the face of the flywheel housing, as follows. See **Fig. 5** for the correct setup.



Secure the dial indicator to the outer diameter of the flywheel, with the gauge finger against the face of the flywheel housing.

Fig. 5, Measuring the Flywheel Housing Face

5.1 With the dial indicator secured to the outer diameter of the flywheel, move the gauge finger to contact the face of the flywheel housing.

5.2 Turn the flywheel through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the flywheel housing.

5.3 Calculate the runout as before.

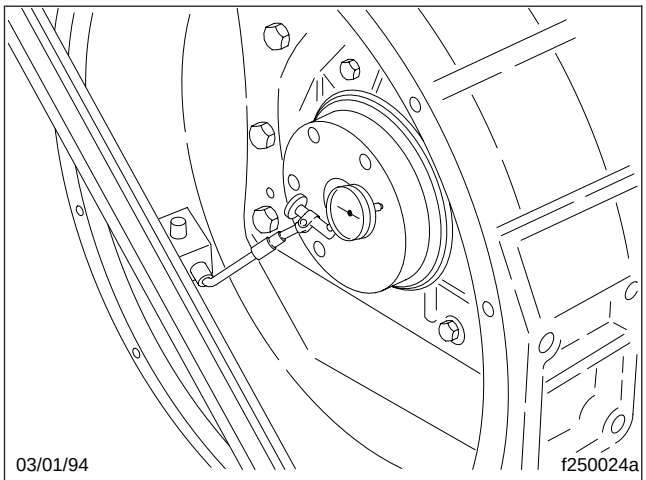
NOTE: Only if you have to reposition the flywheel housing is it necessary to mark the high and low runout readings in clock positions.

5.4 The SAE maximum total runout for the flywheel-housing face is 0.007 inch (0.18 mm) for a 14-inch clutch, and 0.008 inch

(0.20 mm) for a 15.5-inch clutch. If the readings are higher, replace the housing. For instructions, see the engine manufacturer's manual.

NOTE: Use a case-bore plug and shaft set to measure the bell-housing face and pilot. Case-bore plugs are tapped into the front and rear bores of the transmission case, and have very close tolerances. The shaft runs through the center of the plugs, and extends to the front far enough to secure a dial indicator and obtain a reading on the bell housing.

6. Measure the runout of the bell housing face and pilot, as follows.
   - 6.1 Secure the dial indicator to the case-bore shaft, with the gauge finger against the face of the bell housing.
   - 6.2 Turn the case-bore shaft through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the bell housing.
   - 6.3 Calculate the runout as before.
   - 6.4 The SAE maximum total runout for the bell-housing face is 0.008 inch (0.20 mm). If the readings are higher, replace the bell housing. See the transmission manufacturer's service manual for instructions.
7. Remove the flywheel (see the engine manufacturer's manual), and measure the runout of the flywheel crankshaft face. See **Fig. 6**.
   - 7.1 Secure the dial indicator to the flywheel housing, with the gauge finger against the crankshaft face, and near the outer edge.
   - 7.2 Turn the crankshaft through one complete revolution. With chalk or soapstone, mark the high and low points on the face of the crankshaft.
   - 7.3 Calculate the runout as before.
   - 7.4 See the engine manufacturer's manual for maximum runout, corrective measures, and flywheel installation instructions.



Secure the dial indicator to the flywheel housing, with the gauge finger against the crankshaft face, and near the outer edge.

Fig. 6, Measuring the Crankshaft Face Runout

Resetting a Solo Clutch (clutch out of vehicle)

NOTICE

Use this procedure if a Solo clutch was removed without caging the pressure plate. Resetting the pressure plate allows a Solo clutch to release after installation and prevents possible clutch damage.

1. Remove the four shipping bolts if they have been installed. See **Fig. 7**.
2. Support the clutch cover in an arbor press with the release bearing facing down. When setting up the arbor press, allow at least 1 inch (25 mm) clearance for both movement of the release bearing and access to install shipping bolts. See **Fig. 8**.
3. Center the ram and press downward on the retainer until it comes to a stop. Lock the ram in position.
4. Slide the wear indicating tab to the left until it is at the NEW position of the indicator (**Fig. 9**) and hold it in position with a magnet.

Clutch Inspection and Pre-Installation Procedures

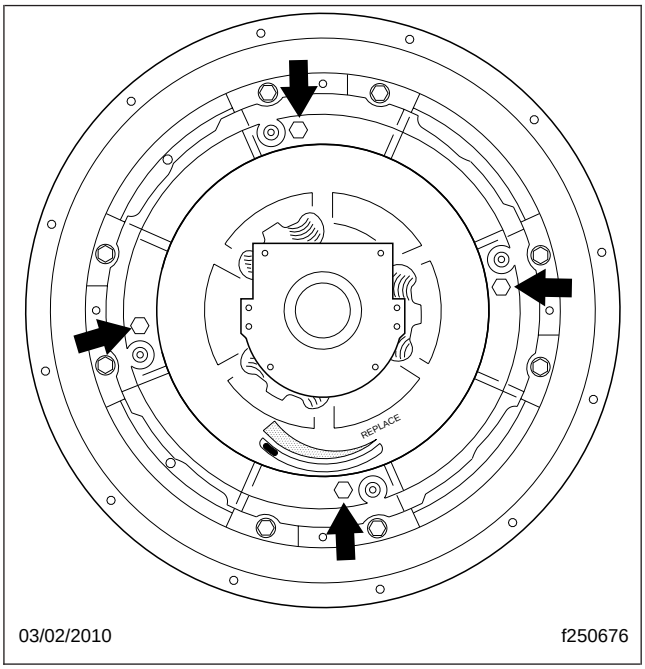


Fig. 7, Installed Shipping Bolts

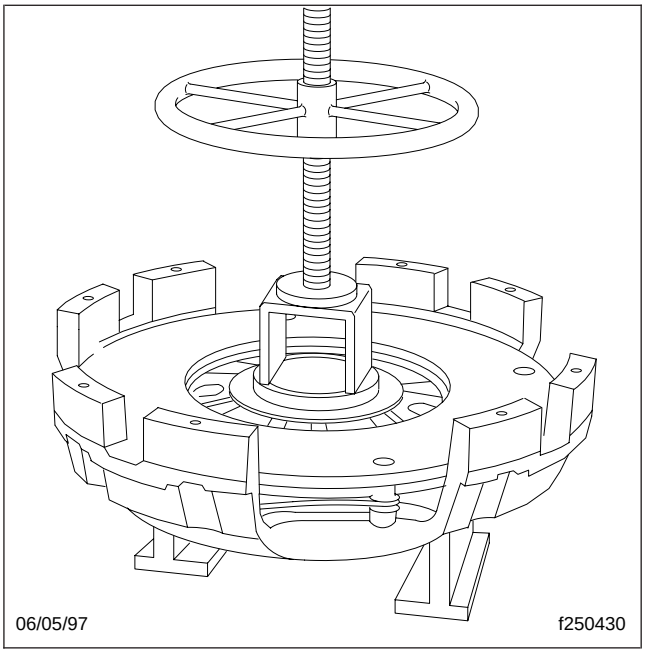


Fig. 8, Arbor Press Setup

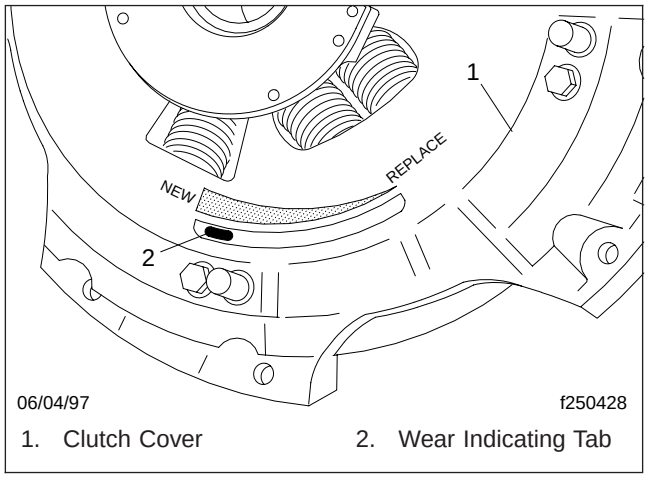


Fig. 9, Resetting the Wear Indicating Tab

NOTE: Shipping bolts are installed on the clutch cover prior to installation to prevent the clutch adjustment mechanism from unloading. See **Fig. 7**.

5. *For 14-inch clutches*, install four 3/8–16 x 1-1/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.

   For 15.5-inch clutches, install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and tighten them finger-tight plus one full turn.

NOTE: You may need to temporarily install slightly longer bolts to allow access of the shipping bolts.

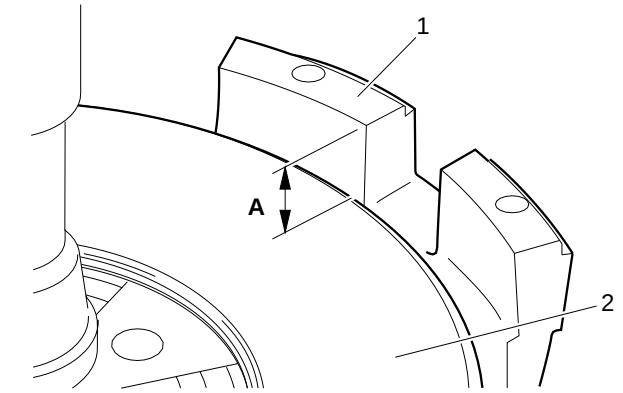
6. Reset the pressure plate, as follows.

   6.1 Progressively tighten the four shipping bolts in a crisscross pattern.

   6.2 Measure the depth of the pressure plate. See **Fig. 10**.

   For 14-inch clutches, the pressure plate is reset when the face of the pressure plate is 0.50 inch (12.7 mm) below the mounting surface of the clutch cover.

   For 15.5-inch clutches, the pressure plate is reset when the face of the pressure plate is 1.75 to 1.78 inches (44.4 to 45.2 mm) below the mounting surface of the clutch cover.



A. 0.50 inch (12.7 mm) for 14-inch clutches; 1.75 to 1.78 inches (44.4 to 45.2 mm) for 15.5-inch clutches

1. Mounting Surface
2. Pressure Plate

Fig. 10, Reset Pressure Plate

Pre-Installation Procedures

Before installing a new, rebuilt, or used clutch, do the following procedures:

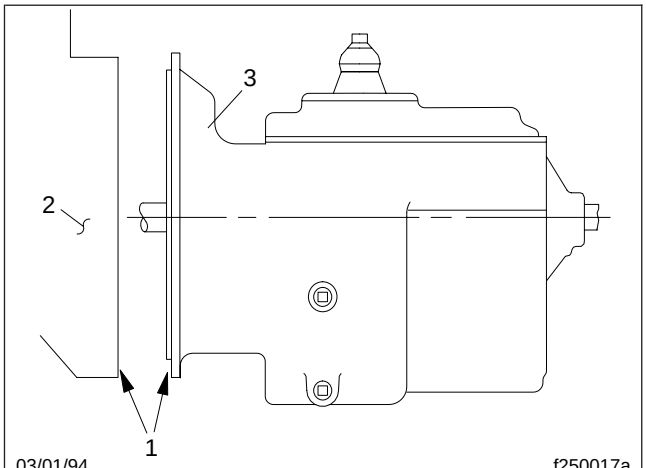
1. Install a new pilot bearing. Be sure that the pilot bearing has a press-fit in the flywheel.

NOTICE

Tap on the outer race only. Tapping on the inner race could damage the pilot bearing.

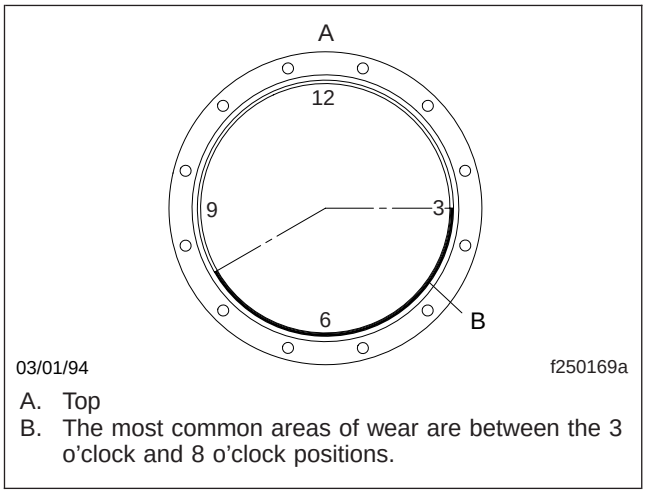
NOTE: To discourage warranty claims for drag or clutch noise, use a premium grade C3/C4 pilot bearing. Due to increased operating temperatures and longer clutch life, the standard pilot bearings and grease are no longer acceptable.

2. Check for wear on the mating surfaces of the flywheel housing and the transmission bell housing. Any noticeable wear on either part causes misalignment. If worn, replace the part. See **Fig. 11**.
3. Check the flywheel housing for wear caused by the bell housing pilot (projecting lip of the bell housing). The correct dimension is 1/8-inch (3.2-mm). Wear is most likely to appear between the 3 o'clock and 8 o'clock positions. See **Fig. 12**.



1. Mating Surfaces
2. Engine Flywheel Housing
3. Transmission Bell Housing

Fig. 11, Inspecting the Mating Surfaces



A. Top
B. The most common areas of wear are between the 3 o'clock and 8 o'clock positions.

Fig. 12, Checking the Flywheel Housing for Wear

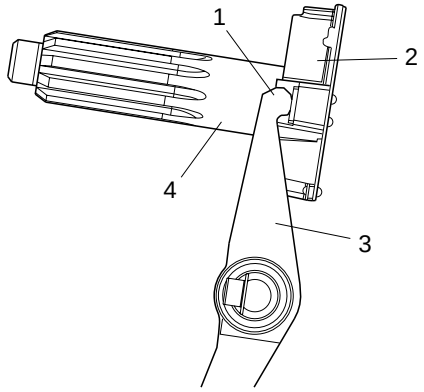
NOTE: The pilot (lip) of the bell housing can wear into the flywheel housing. This can be caused by the transmission loosening up, or by road and engine vibration after high mileage.

4. Inspect the flywheel, as follows. Replace or repair the flywheel if the wear is extreme.
   4.1 Visually inspect the friction surface of the flywheel for heat checks and scoring.

Clutch Inspection and Pre-Installation Procedures

4.2 Measure the friction surface wear with a straightedge and feeler gauge. For instructions, see the engine manufacturer's manual.

5. Inspect the input shaft, both the splined and the smooth area, as follows. See **Fig. 13**.



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1. Release Fork Finger
2. Release Bearing
3. Release Fork
4. Input Shaft

Fig. 13, Input Shaft, Release Bearing, and Release Fork

5.1 Check the fit of the splined hubs of the driven discs by sliding them along the splines of the input shaft. The hubs must slide freely so the clutch will release cleanly. If necessary, use a hand stone to dull the sharp edges of the splines.

5.2 If the input shaft splines are worn or notched, or if the hubs still do not slide freely, replace the input shaft. For instructions, see the transmission manufacturer's service manual.

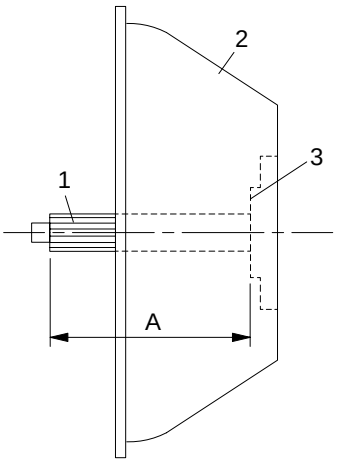
5.3 Inspect the smooth area of the input shaft for wear and/or rough spots. Replace the input shaft if necessary.

6. Check for excessive wear at the fingers of the release fork. See **Fig. 13**.

7. To prevent clutch brake wear, check the input-shaft bearing cap, as follows, and measure it as shown in **Fig. 14**.

7.1 Visually check the bearing cap for excessive wear.

7.2 Measure the distance between the splined end of the input shaft and the bearing cap



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A. Length of Input Shaft, from the Splined End to the Bearing Cap

1. Input Shaft
2. Bell Housing
3. Bearing Cap

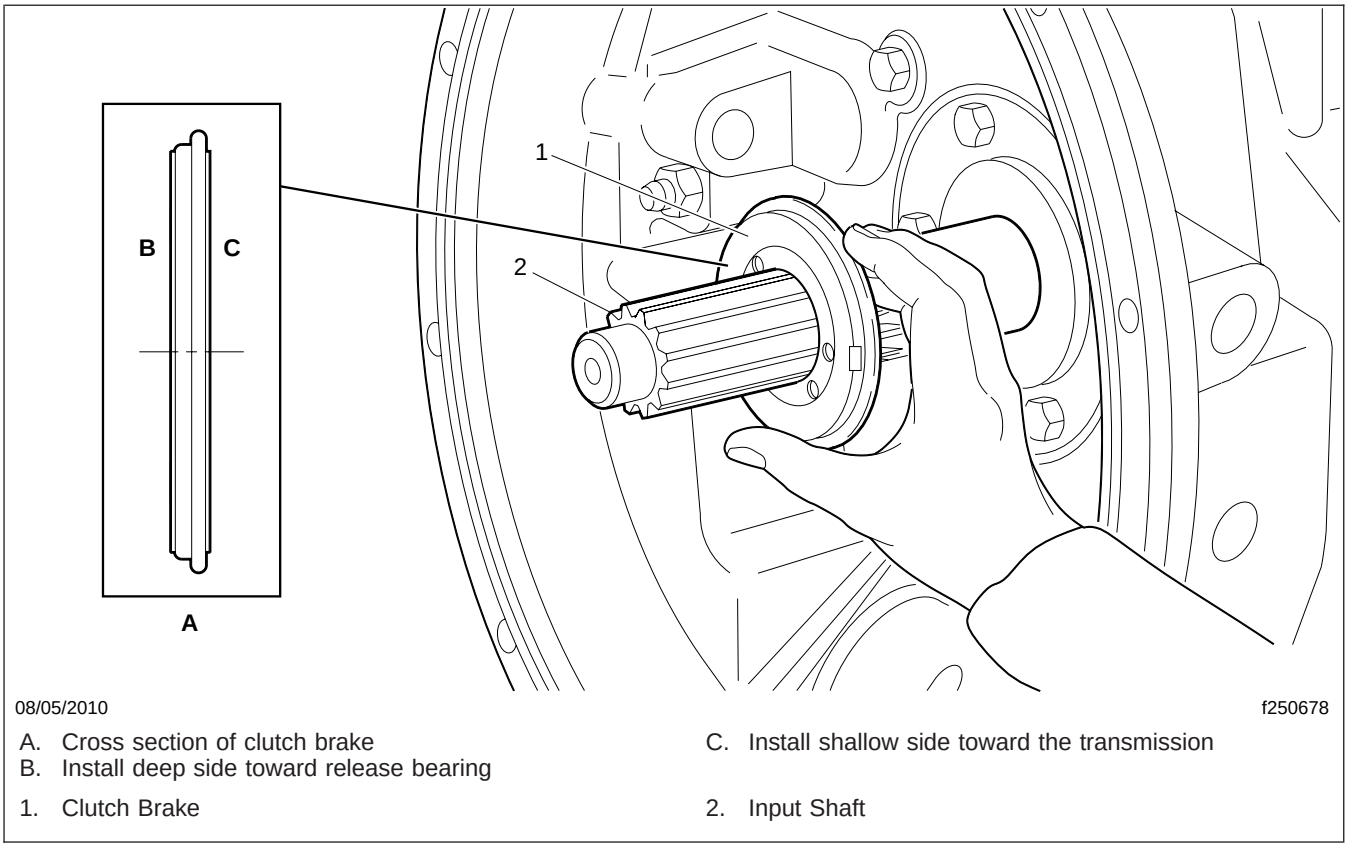
Fig. 14, Measuring the Input Shaft

(dimension A). If dimension A is greater than 8.71 inches (221.5 mm), replace the bearing cap.

NOTE: A torque-limiting clutch brake has facings on both sides. When installing it, orient the shallow side toward the transmission, and the deep side toward the engine to allow clearance for the release bearing.

8. On unsynchronized transmissions, install a new clutch brake on the transmission input shaft, as shown in **Fig. 15**. Slide it tight against the input-shaft bearing cap.

9. Measure the diameter of the flywheel bore opening (this is the recessed area for the flywheel bolt circle). See **Table 1** for minimum flywheel bore diameters for each disc type.



A. Cross section of clutch brake
B. Install deep side toward release bearing
C. Install shallow side toward the transmission
1. Clutch Brake
2. Input Shaft

Fig. 15, Installing the Clutch Brake

Minimum Flywheel Bores	
Disc Type	**Flywheel Bore in inch (mm)**
10-Spring	8.562 (217.48)
9-Spring	9.750 (247.65)
8-Spring	7.250 (184.15)
7-Spring	9.750 (247.65)
6-Spring	9.750 (247.65)

Table 1, Minimum Flywheel Bores

Installation

1. Do the clutch inspection and pre-installation procedures in **Subject 110**.
2. If not already installed, insert two 7/16–14 x 5 guide studs in the upper mounting holes of the flywheel. See **Fig. 1**. Rotate the flywheel to level the guide studs.

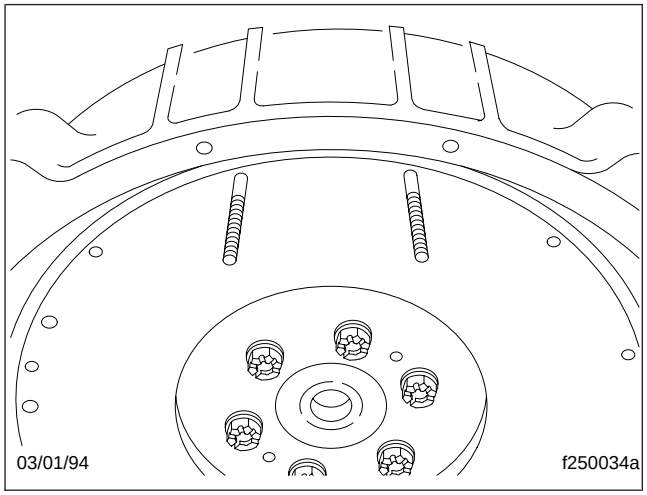


Fig. 1, Install the Guide Studs

3. If the clutch is new, remove the protective coating from the pressure plate and the intermediate plate.
4. Set the clutch cover upright, and insert a spline aligning tool through the release bearing sleeve. See **Fig. 2**.
5. Install the rear driven disc and intermediate plate.
   - 5.1 Install the rear driven disc on the aligning tool. Follow the orientation instructions on the disc. See **Fig. 3**.
   - 5.2 Place the intermediate plate in the clutch cover. Align the drive lugs of the plate with the notches in the cover. See **Fig. 4**.
   - 5.3 Make sure the positive separator pins protrude toward the flywheel side. See **Fig. 4**. The pins should be flush on the pressure-plate side.

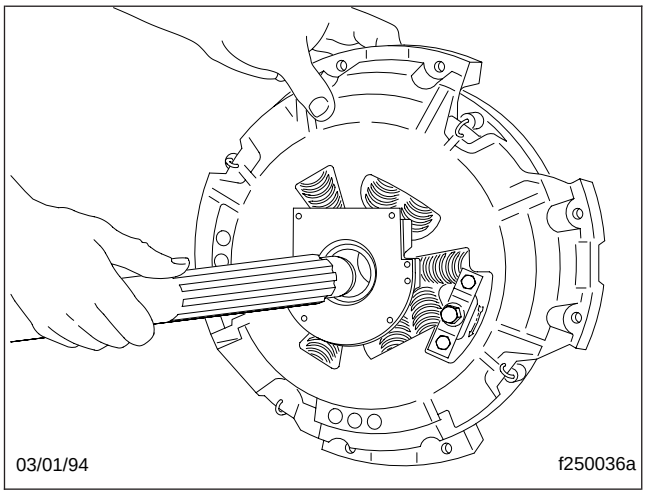


Fig. 2, Inserting an Aligning Tool

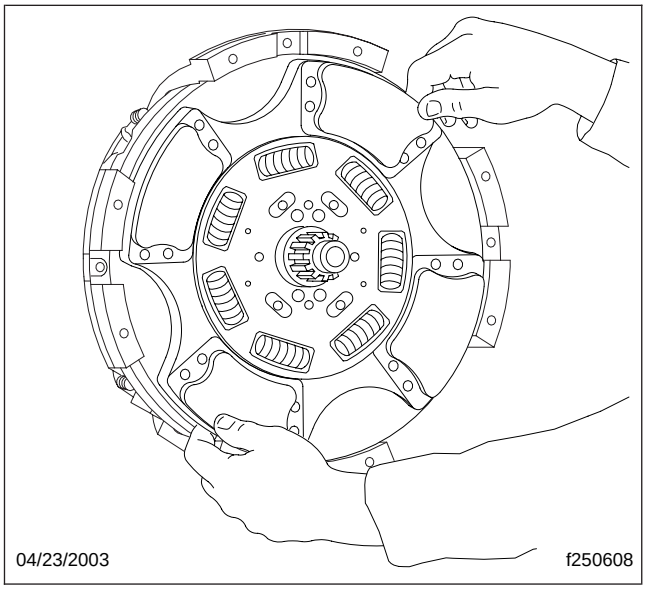


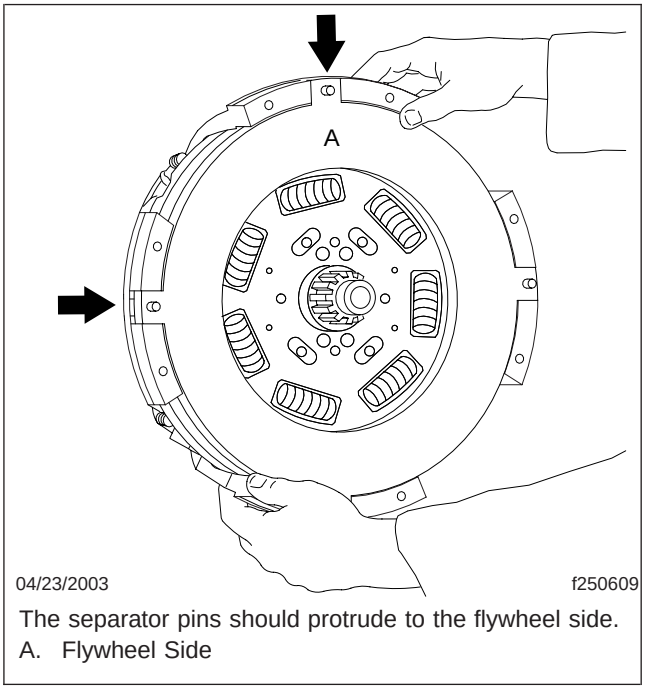
Fig. 3, Installing the Rear Driven Disc

6. Install the front driven disc on the aligning tool. Follow the orientation instruction on the disc. Ensure that both driven discs are aligned as shown in **Fig. 5**.

⚠ WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

Easy Pedal Clutch Installation



The separator pins should protrude to the flywheel side.
A. Flywheel Side

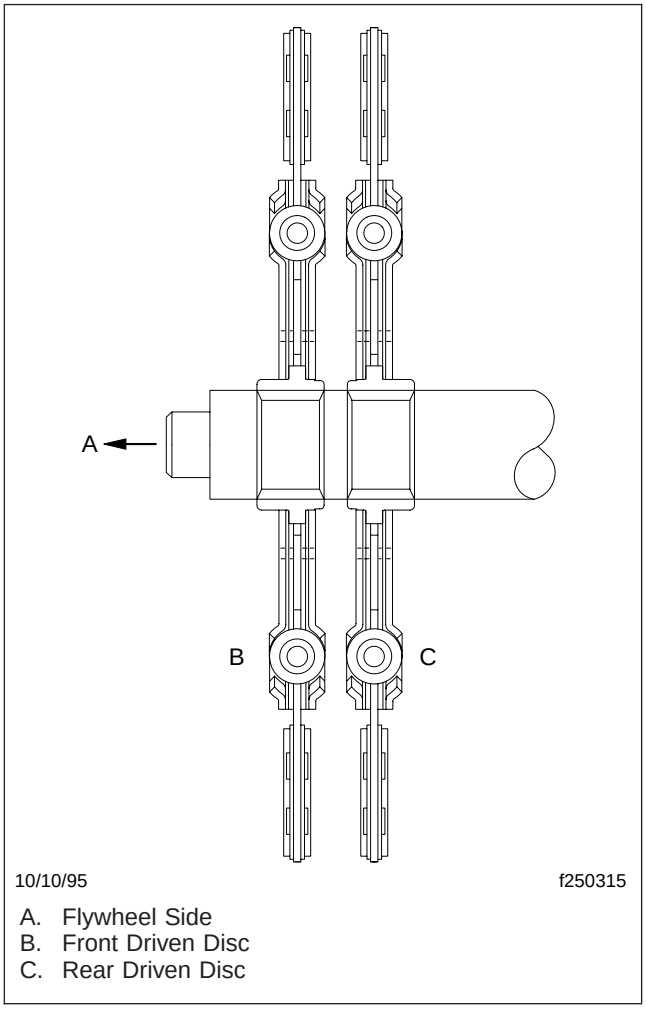
Fig. 4, Positioning the Intermediate Plate

7. Position the clutch over the two guide studs, and slide the assembly forward until it starts in the flywheel pilot. See **Fig. 6**.
8. Start six 7/16–14 x 2-1/4 (grade 5 or better) mounting bolts with lockwashers, and fasten them finger-tight. Tap the aligning tool to make sure it is centered and seated in the pilot bearing, then remove the two guide studs and replace them with 7/16–14 x 2-1/4 bolts and lockwashers.
9. Using the sequence shown in **Fig. 7**, progressively tighten the eight clutch mounting bolts. The final torque is 40 to 50 lbf·ft (54 to 68 N·m).

NOTICE

If the bolts are not tightened in sequence, it may cause permanent damage to the clutch cover and create an out-of-balance condition.

10. As the capscrews are tightened, the release bearing spacers should fall free. If they don't, remove them. This may require light taps with a mallet on the end of the aligning tool.
11. Remove the aligning tool.



A. Flywheel Side
B. Front Driven Disc
C. Rear Driven Disc

Fig. 5, Checking Disc Alignment

12. Set the positive separator pins.
    12.1 Locate the pin access holes. See **Fig. 8**.

WARNING

Wear safety goggles when tapping the pins. If any of the metal parts were to chip, flying pieces of metal could possibly cause eye injury.

    12.2 To ensure that all four separator pins are flush against the flywheel, insert a 1/4-inch (6-mm) diameter flat-nose punch through the access holes and *lightly* tap each of them toward the flywheel. See **Fig. 9**.

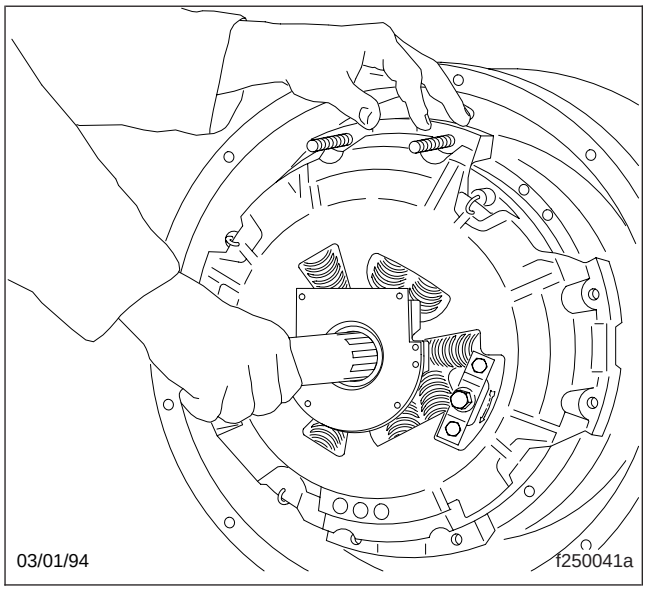


Fig. 6, Positioning an Easy Pedal Clutch

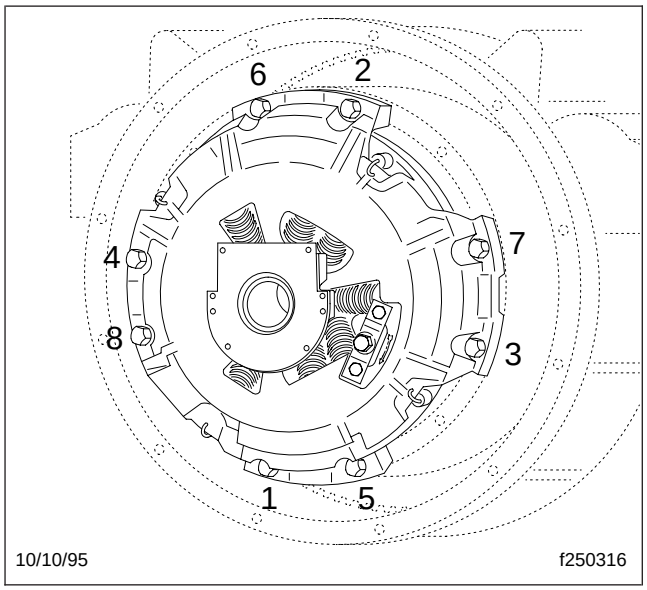


Fig. 7, Easy-Pedal Tightening Sequence

NOTE: Failure to perform this step properly may cause the clutch to drag (clutch does not release). If necessary, after the transmission has been installed, the four pins can be set through the inspection opening of the transmission bell housing.

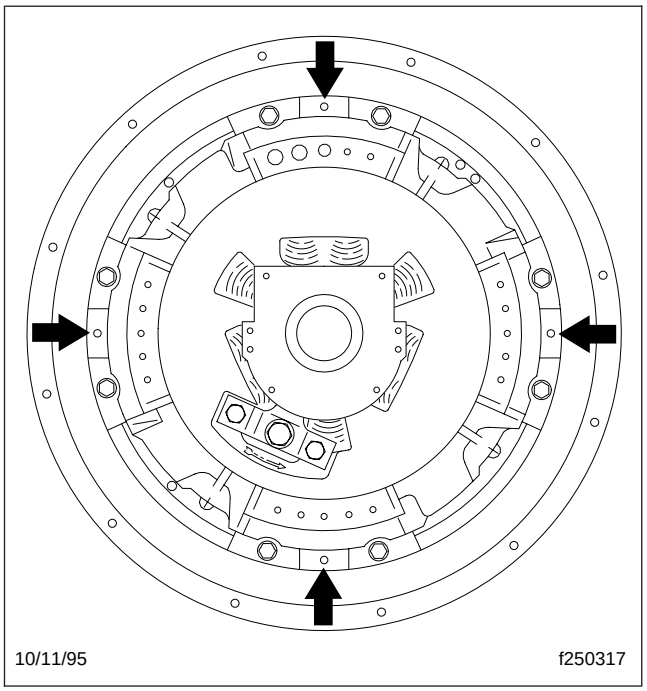
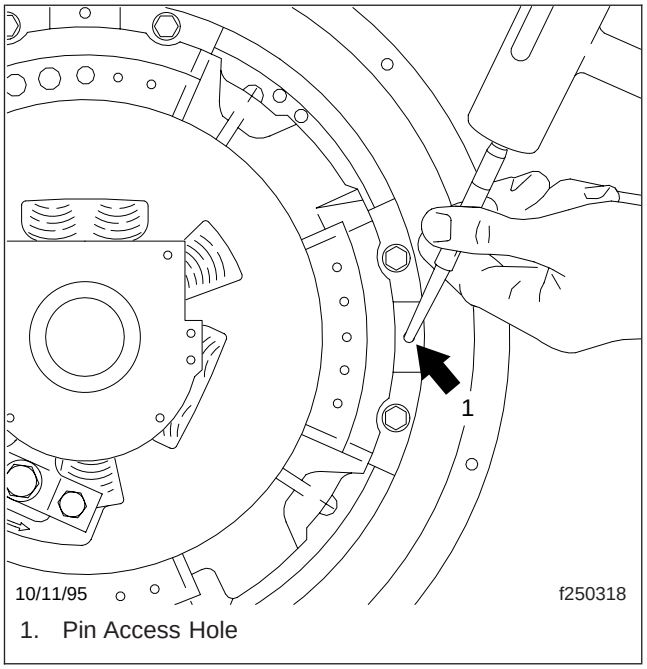


Fig. 8, Pin Access Holes, Easy-Pedal



1. Pin Access Hole

Fig. 9, Tapping the Pin, Easy-Pedal

13. Using a clean cloth, remove all grease from the input shaft.

Easy Pedal Clutch Installation

14. Shift the transmission into gear. Rotate the transmission input shaft to line up with the clutch driven-disc hub splines during assembly.
15. Install the transmission and attach the clutch linkage.

IMPORTANT: On vehicles equipped with a mechanical clutch linkage, ensure the release yoke clears the bearing, and is rotated over the wear pads as the transmission is moved forward. See **Fig. 10**. Align the splines by turning the transmission output shaft.

NOTICE

Do not excessively force the transmission into the clutch assembly or engine housing. If it doesn't enter freely, investigate the cause of the problem and then make any necessary changes. Don't let the transmission drop or hang unsupported in the driven discs. If this should occur, the rear disc will become bent or distorted, causing the clutch to drag (not release).

16. Lubricate the release bearing and release shafts. For instructions and recommended lubricants, see **Group 25** of the *108SD and 114SD Maintenance Manual*.
17. Adjust the clutch according to the procedures in **Subject 150**.

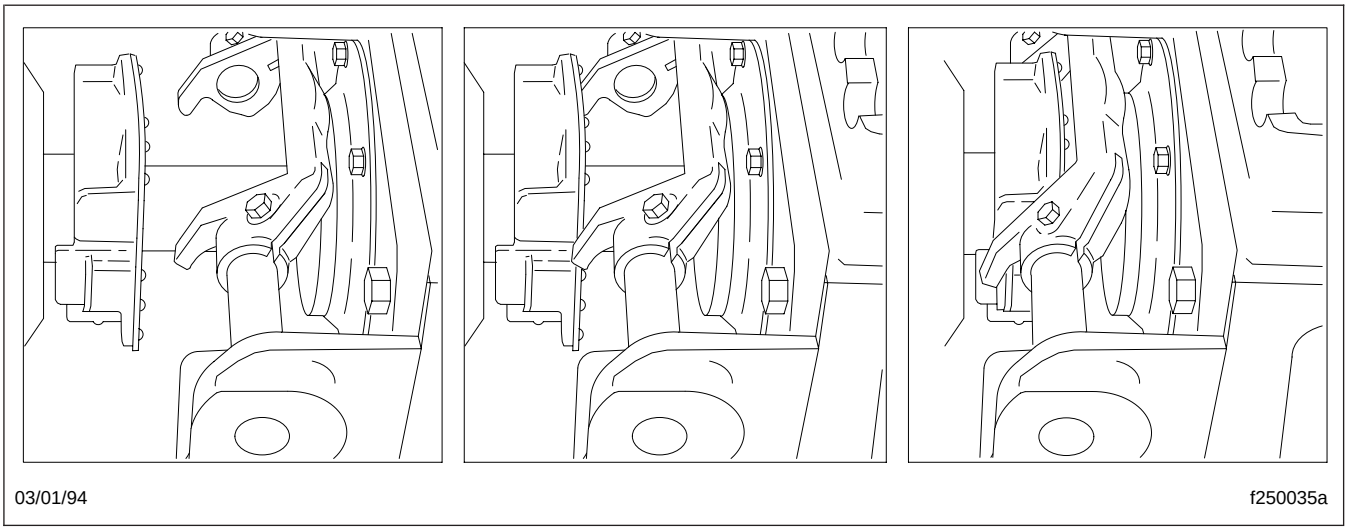


Fig. 10, Make Sure the Release Yoke Clears the Bearing

Installation

1. Do the clutch pre-installation procedures in **Subject 110** before installing the clutch.
2. If not already installed, insert two 7/16–14 x 5 guide studs in the upper mounting holes of the flywheel. See **Fig. 1**. Rotate the flywheel to level the guide studs.

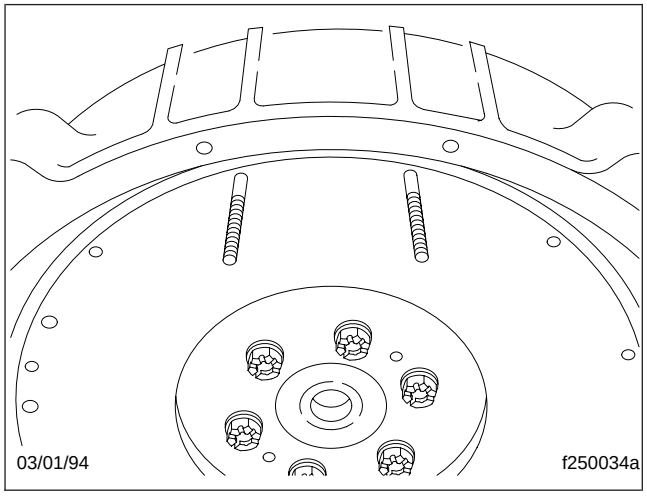


Fig. 1, Installing the Guide Studs

3. If installing a new clutch, remove the protective coating from the pressure plate and the intermediate plate.
4. Set the clutch cover upright, and insert a spline aligning tool through the release bearing sleeve. See **Fig. 2**.
5. Install the rear driven disc and intermediate plate, as follows.

   5.1 Install the rear driven disc on the aligning tool, with the side stamped *INTERMEDIATE PLATE SIDE* facing away from the clutch cover. See **Fig. 3**.

   5.2 Place the intermediate plate in the clutch cover. Align the drive lugs of the plate with the notches in the cover. See **Fig. 4**.

   5.3 Make sure the separator pins protrude toward the flywheel side. See **Fig. 4**. The pins should be flush on the pressure-plate side.

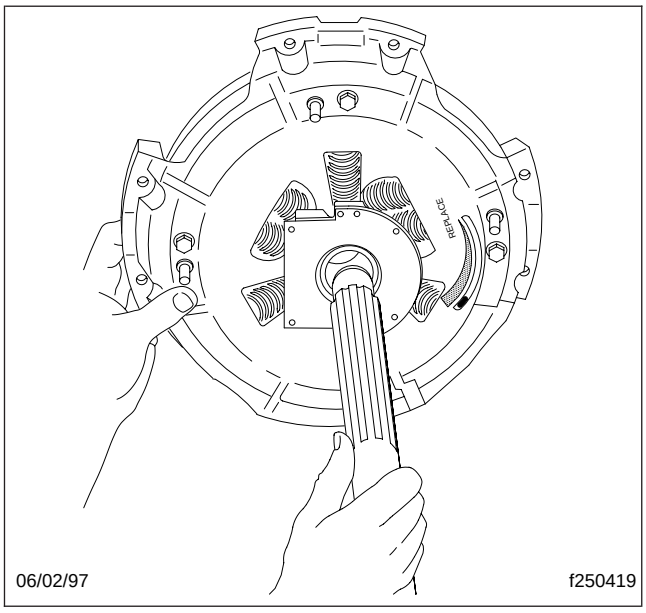


Fig. 2, Inserting an Aligning Tool

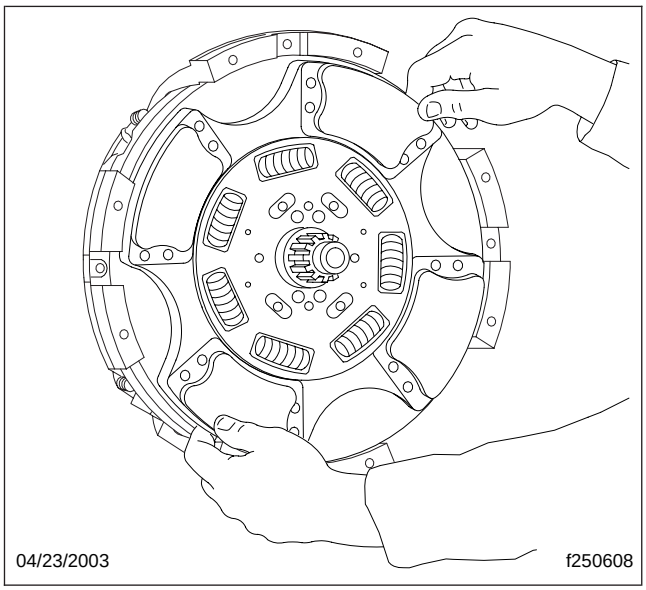
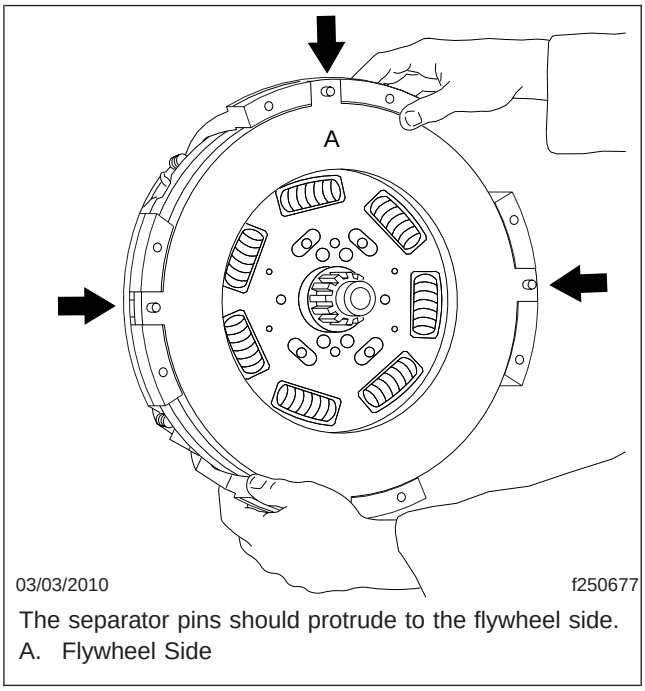


Fig. 3, Installing the Rear Driven Disc

6. Install the front driven disc on the aligning tool, with the side stamped *INTERMEDIATE PLATE SIDE* facing the intermediate plate. See **Fig. 5**.

15.5-Inch Solo Clutch Installation



The separator pins should protrude to the flywheel side.
A. Flywheel Side

Fig. 4, Positioning the Intermediate Plate

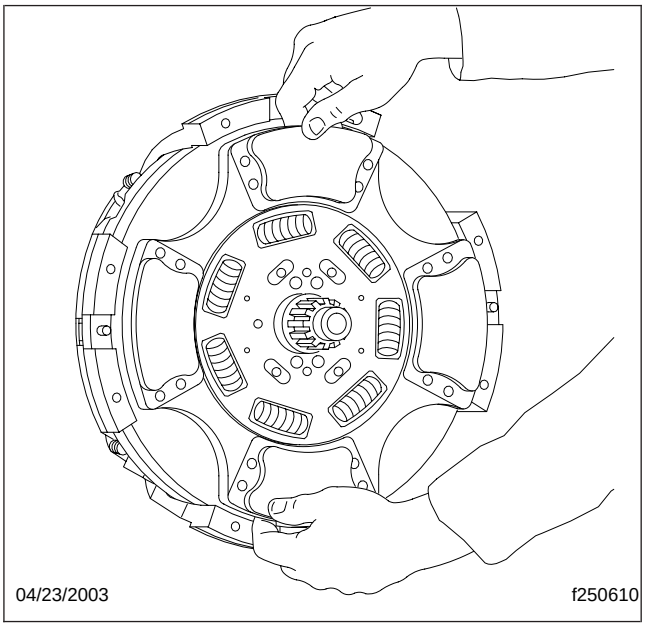


Fig. 5, Installing the Front Driven Disc

WARNING

The clutch assembly is heavy. It should be removed and installed only with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

7. Position the clutch over the two guide studs, and slide the assembly forward until contact is made with the flywheel surface. See **Fig. 6**.

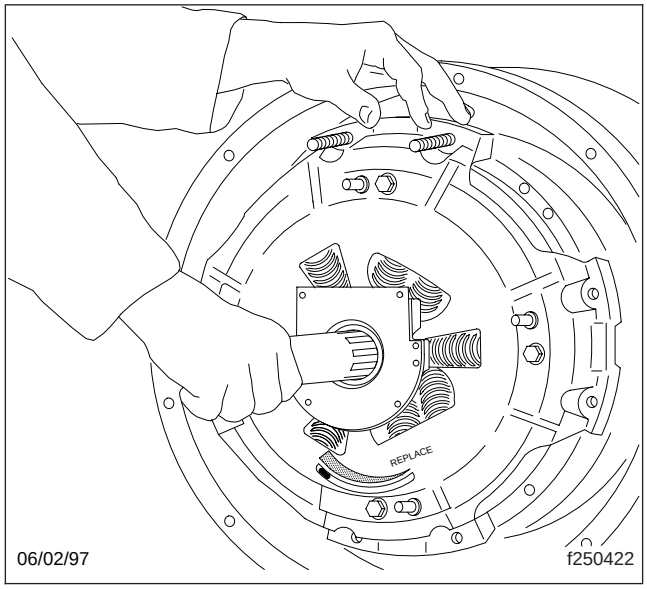


Fig. 6, Positioning the Clutch Cover

8. Install the mounting capscrews, as follows.
   - 8.1 Start six 7/16–14 x 2-1/4 (grade 5 or better) mounting capscrews with lockwashers, and tighten them finger-tight.
   - 8.2 Tap the aligning tool to make sure it is centered and seated in the pilot bearing. See **Fig. 7**.
   - 8.3 Remove the two guide studs and replace them with the two remaining 7/16–14 x 2-1/4 mounting capscrews and lockwashers.
9. Tighten the eight mounting capscrews progressively, in a crisscross pattern as shown in **Fig. 8**. Final torque is 40 to 50 lbf·ft (54 to 68 N·m).

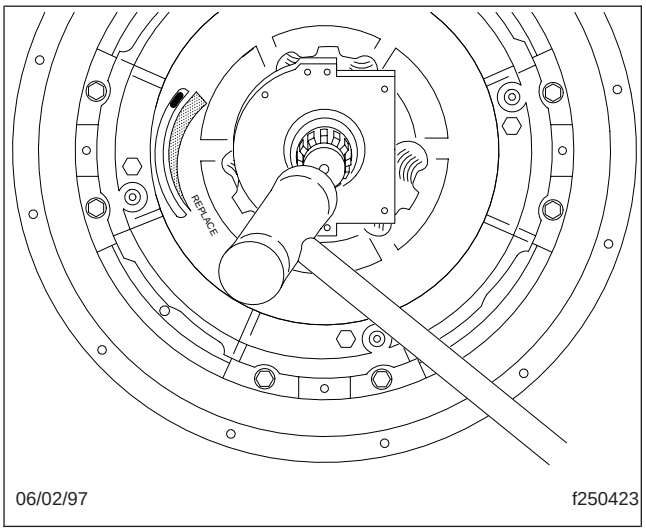


Fig. 7, Tap Aligning Tool

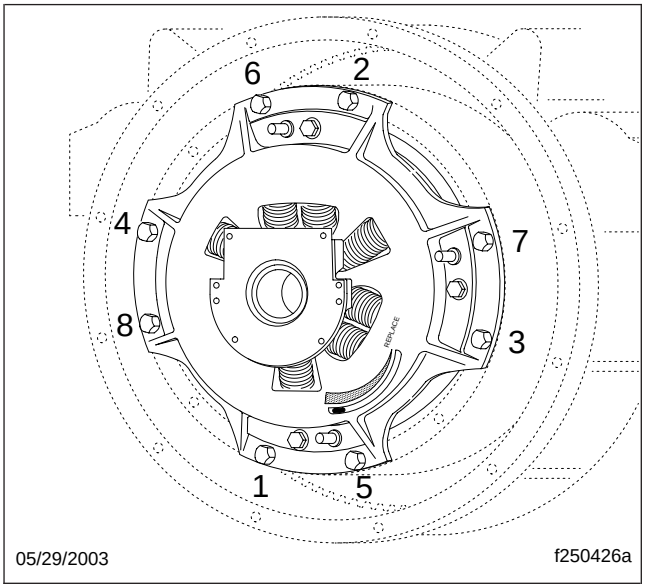


Fig. 8, Tightening Sequence

NOTICE

Failure to tighten the bolts according to this procedure can have the following effects:

- preventing the clutch cover from centering into the pilot area of the flywheel;
- causing the clutch assembly to be out-of-balance with the flywheel;
- causing permanent damage to the clutch cover.

10. Following a crisscross pattern, remove and retain the four shipping bolts from the clutch cover. See **Fig. 9**.

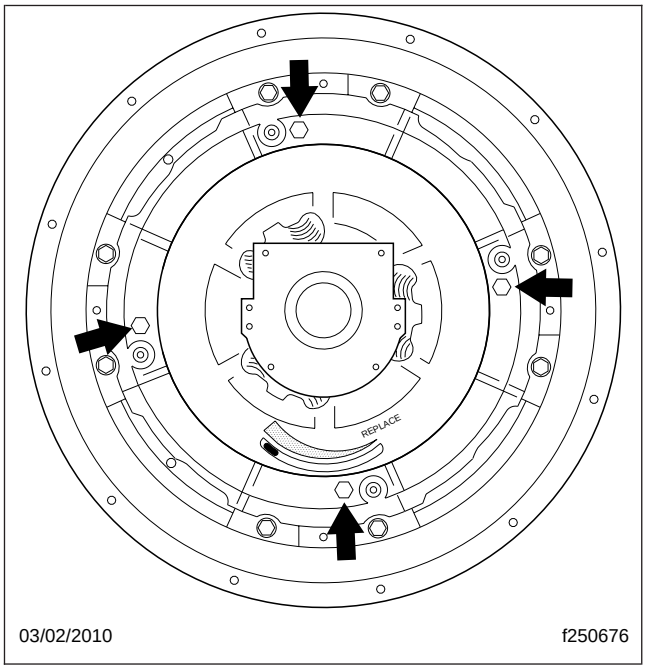


Fig. 9, Installed Shipping Bolts

NOTE: These bolts will be needed to secure future clutch assemblies during removal and installation.

11. Remove the aligning tool.

NOTE: Do not be concerned if the release bearing housing touches the clutch cover.

WARNING

Wear safety goggles when tapping the pins. If any of the metal parts were to chip, flying pieces of metal could cause eye injury.

12. To ensure that all four separator pins are flush against the flywheel, insert a 1/4-inch (6-mm) diameter flat-nose punch through the access holes and *lightly* tap each of them toward the flywheel. See **Fig. 10** and **Fig. 11**.

NOTE: Failure to perform this step properly may cause the clutch to drag or not release.

15.5-Inch Solo Clutch Installation

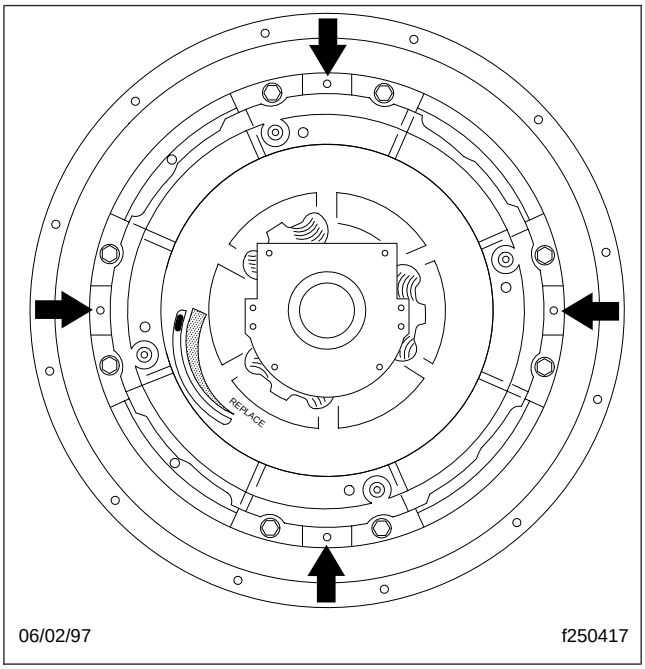


Fig. 10, Separator Pin Access Holes

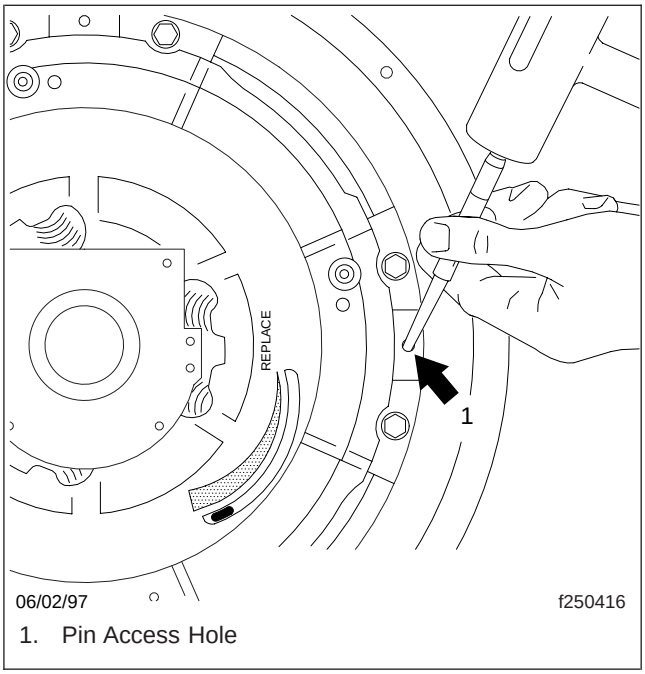


Fig. 11, Tapping A Separator Pin

13. Using a clean cloth, remove all grease from the input shaft.

NOTE: For lubrication of the release fork fingers, Eaton Fuller recommends a lithium-base grease that can operate up to at least 325°F (163°C) and meets the NLGI Grade 1 or 2 specification.

14. Lubricate the release fork fingers. See **Fig. 12**.

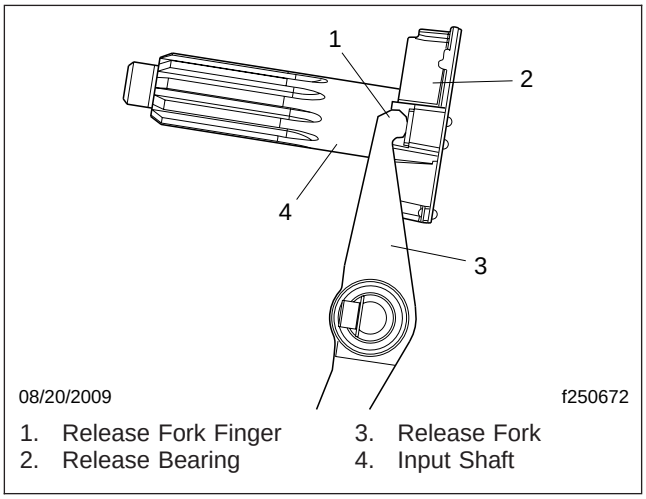


Fig. 12, Release Fork

15. Shift the transmission into gear so that during assembly the transmission input shaft can be rotated into line with the clutch driven-disc hub splines.
16. Install the clutch brake.

NOTICE

Do not excessively force the transmission into the clutch assembly or engine housing. If it doesn't enter freely, investigate the cause of the problem and then make any necessary changes. Don't let the transmission drop or hang unsupported in the driven discs. If this should occur, the rear disc will become bent or distorted, causing the clutch to drag (not release).

17. Install the transmission and attach the clutch linkage.
18. Lubricate the release bearing as needed; for instructions and recommended lubricants, see **Group 25** of the *108SD and 114SD Maintenance Manual*.

Installation

1. Do the clutch pre-installation procedures in **Subject 110**.
2. If not already in place, install two 3/8–16 x 3 guide studs in the two upper mounting holes of the flywheel. See **Fig. 1**.

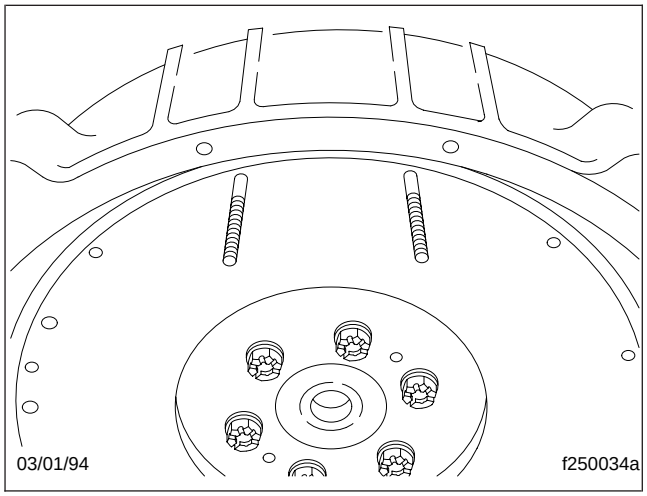


Fig. 1, Guide Studs, Installed

3. If the clutch is new, remove any protective coating applied to the pressure plate and the intermediate plate.
4. Insert an aligning tool through the splines of the front disc and, with the side marked *FLYWHEEL SIDE* facing the flywheel, install the front driven disc on the flywheel.

IMPORTANT: The drivestraps of the intermediate plate must face the pressure plate.

5. Install the intermediate plate assembly over the two guide studs and slide it forward until it touches the flywheel. Make sure the side marked PRESSURE PLATE SIDE faces the pressure plate. See **Fig. 2**.
6. Make sure the separator pins protrude toward the flywheel side. The pins should be flush on the pressure-plate side.
7. Remove the aligning tool.
8. Insert the aligning tool through the splines of the rear driven disc and, with the side of the rear disc marked *PRESSURE PLATE SIDE* facing the pressure plate, install the rear driven disc. See **Fig. 3**.

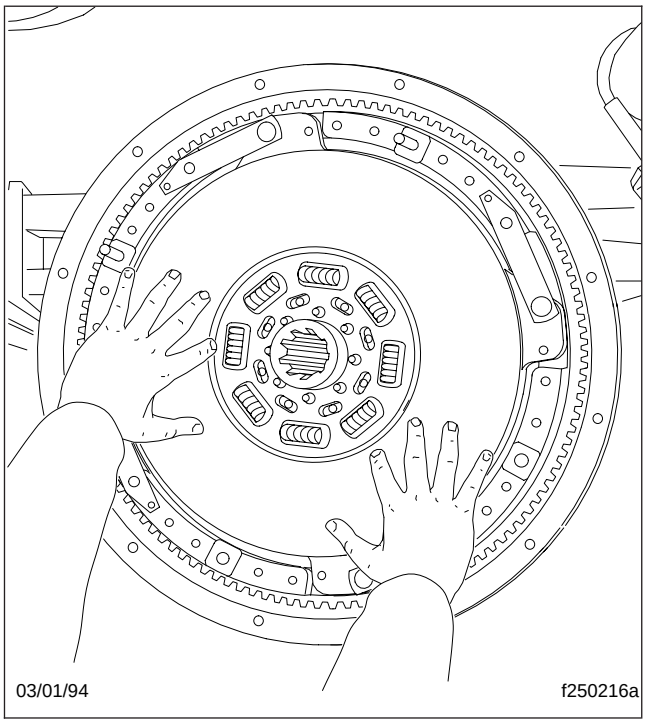


Fig. 2, Install the Intermediate Plate

9. Make sure that the ceramic buttons on each disc are as closely aligned as possible. See **Fig. 4**.

NOTE: Aligning the discs aids the function of the separator pins.

10. With the aligning tool still in place, slide the cover assembly over the aligning tool and the two guide studs until it rests against the intermediate plate assembly.
11. Install the clutch mounting capscrews, as follows. See **Fig. 5** for the tightening sequence.

NOTICE

If the capscrews are not tightened in sequence, it may cause permanent damage to the clutch cover and create an out-of-balance condition.

11.1 Start six 3/8–16 (grade 5 or better) mounting capscrews with lockwashers, and tighten them finger-tight.

14-Inch Dual Disc Solo Clutch Installation

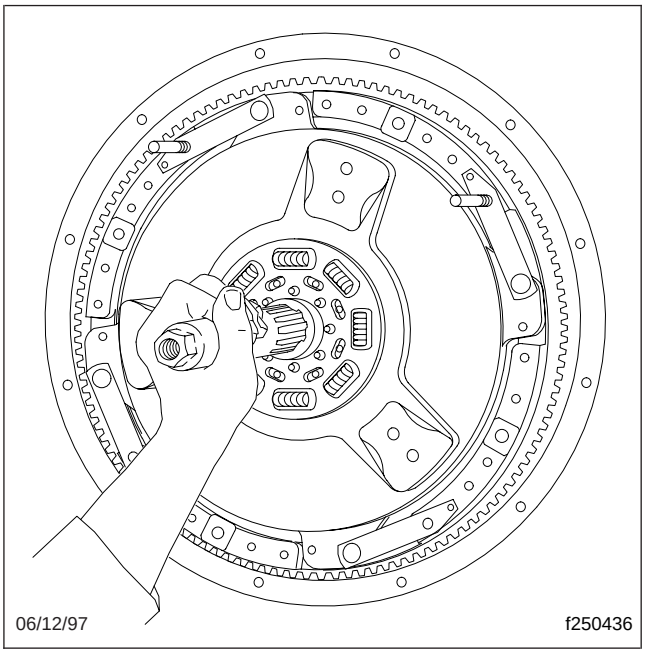
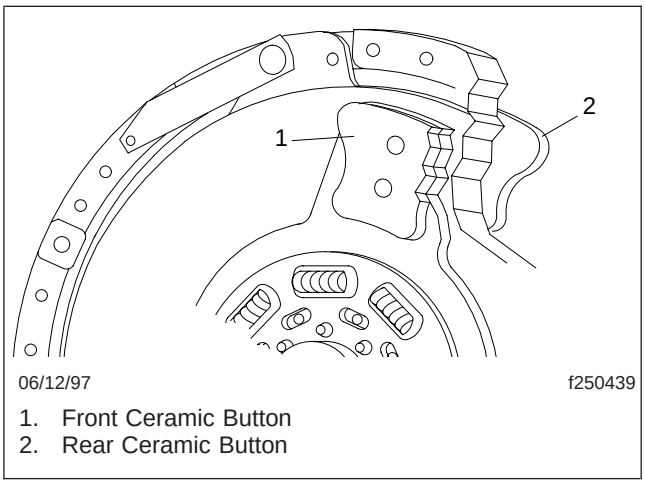


Fig. 3, Position the Rear Disc, Solo



1. Front Ceramic Button
2. Rear Ceramic Button

Fig. 4, Driven Disc Alignment

11.2 Remove the guide studs and replace them with the two remaining mounting capscrews, as above.

11.3 Tighten the eight capscrews progressively. The final torque is 30 to 35 lbf·ft (40 to 47 N·m).

12. Remove the aligning tool.

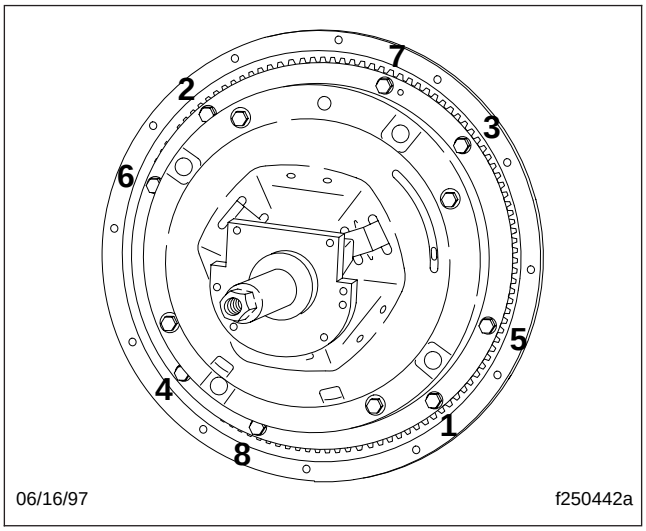


Fig. 5, Tightening Sequence

13. Follow a crisscross pattern to remove the four shipping bolts from the clutch cover. See **Fig. 6**.

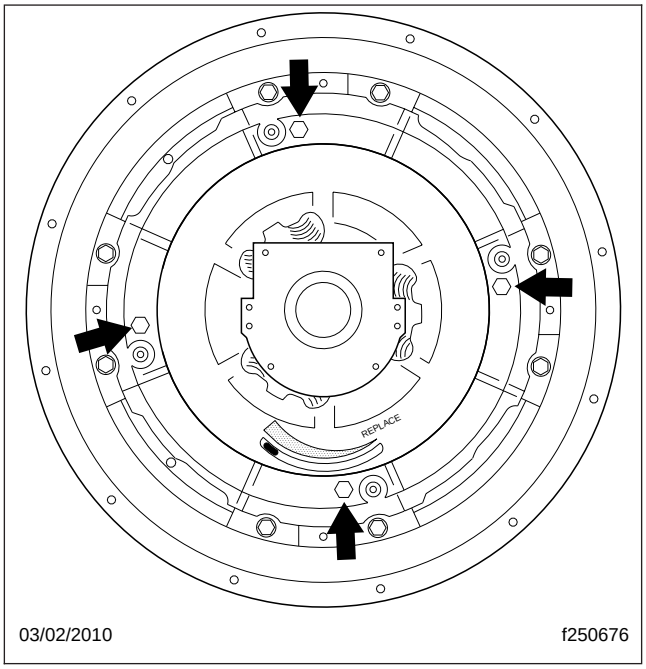


Fig. 6, Installed Shipping Bolts

NOTE: Retain the four shipping bolts. These bolts will be needed in the future to secure the clutch assembly during removal and installation.

WARNING

Wear safety goggles when tapping the pins. If any of the metal parts were to chip, flying pieces of metal could cause eye injury.

NOTE: Only a small portion of each separator pin is visible through the access hole. See **Fig. 7** and **Fig. 8**.

14. To ensure that all four separator pins are flush against the flywheel, insert a 1/4-inch (6-mm) diameter flat-nose punch through the access holes and lightly tap each of them toward the flywheel. See **Fig. 9**.

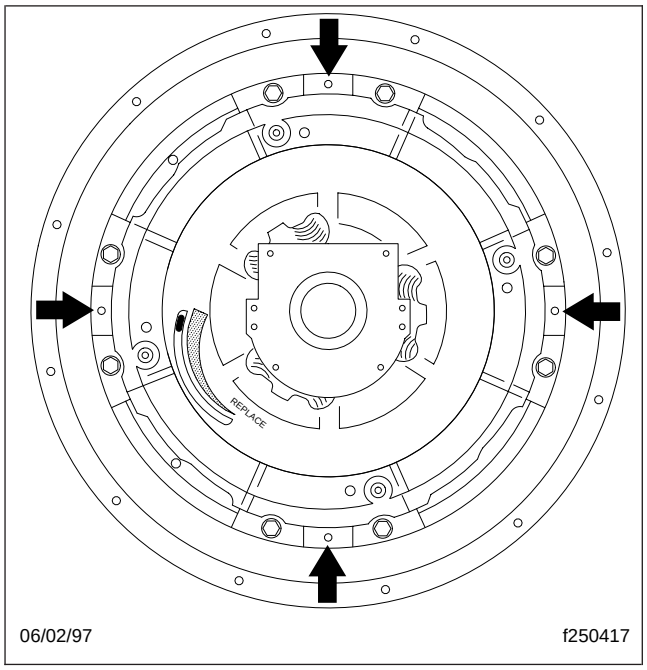
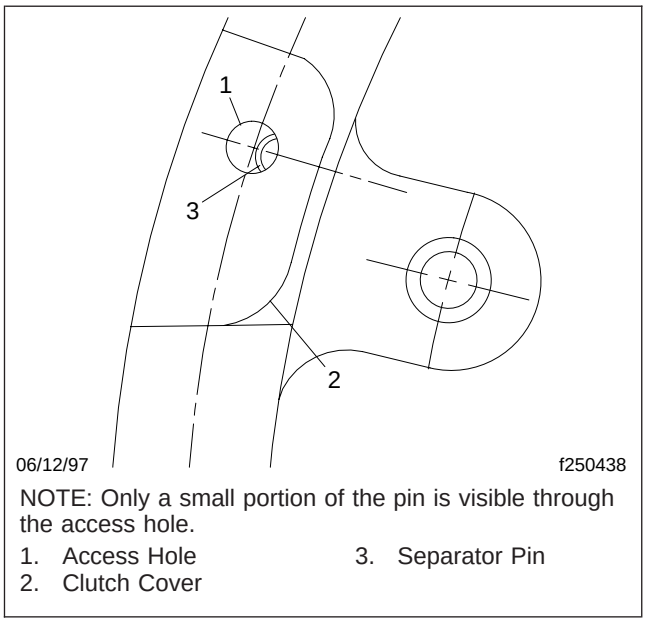


Fig. 7, Separator Pin Access Holes

NOTE: Do this step to ensure that all four pins are flush against the flywheel. This allows an equal gap on all sides of the intermediate plate during clutch disengagement.

15. Using a clean cloth, remove all grease from the input shaft.

16. Lubricate the release fork fingers. See **Fig. 10**.



NOTE: Only a small portion of the pin is visible through the access hole.

1. Access Hole
2. Clutch Cover
3. Separator Pin

Fig. 8, Separator Pin Access

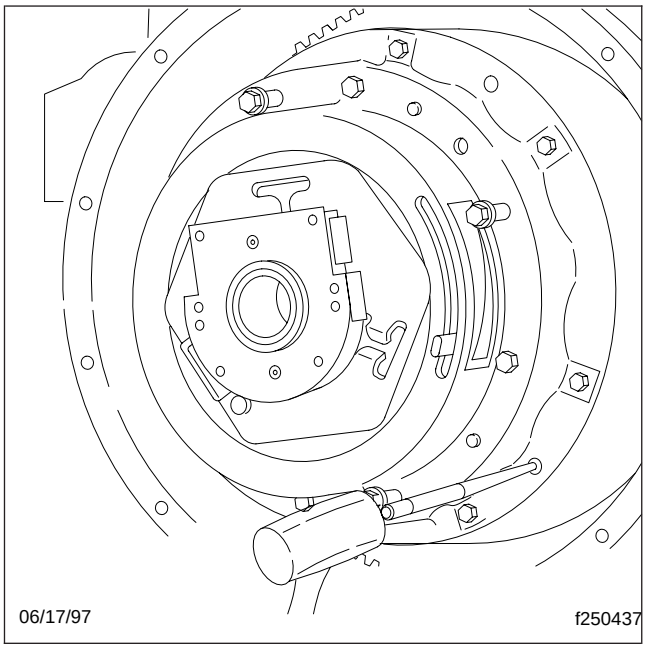
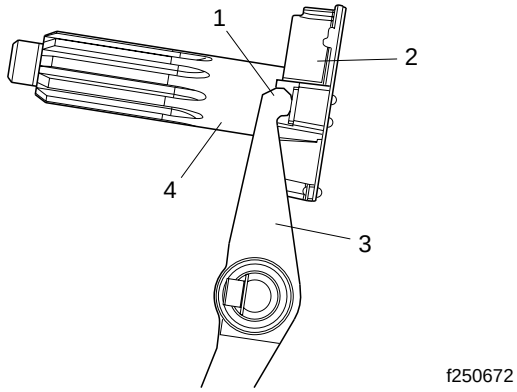


Fig. 9, Setting the Separator Pins

17. Shift the transmission into gear so that during assembly the transmission input shaft can be rotated into line with the clutch driven-disc hub splines.

18. Install the clutch brake, if equipped.

14-Inch Dual Disc Solo Clutch Installation



1. Release Fork Finger
2. Release Bearing
3. Release Fork
4. Input Shaft

Fig. 10, Release Fork

NOTICE

Do not excessively force the transmission into the clutch assembly or engine housing. If it does not enter freely, investigate the cause of the problem and then make any necessary changes. Do not let the transmission drop or hang unsupported in the driven discs. If this should occur, the rear disc will become bent or distorted, causing the clutch to drag (not release).

19. Install the transmission and attach the clutch linkage. For instructions, see **Group 26**.
20. Lubricate the release bearing as needed; for instructions and recommended lubricants, see **Group 25** of the *108SD and 114SD Maintenance Manual*.

NOTE: The following procedures apply only to Eaton Fuller Easy Pedal clutches. Eaton Fuller Solo clutches are adjustment-free.

Release bearing travel is the clearance between the aft end of the release bearing housing and the forward surface of the clutch brake disc. For the clutch to release properly, the release bearing travel measurement must be between 1/2 and 9/16 inch (12.7 to 14.3 mm).

As the clutch wears, the release bearing moves towards the engine flywheel, reducing release yoke free-travel and increasing release bearing travel. If internal clutch adjustments are not made, the release yoke fingers will eventually ride against the wear pads. This could cause the following problems:

- Worn bearing wear pads and release yoke
- Damaged release bearing and housing
- Eventual clutch slippage and burn-up

Release yoke free-travel is the distance between the release bearing wear pads and the release yoke. At the factory, the release yoke free-travel is set to 0.105 to 0.145 inch (2.7 to 3.7 mm). This setting produces approximately two inches (51 mm) of clutch free-pedal.

IMPORTANT: When clutch free pedal is less than about 3/4 inch (19 mm), adjust the clutch internally according to the procedures in this subject. Take care to do all procedures in the proper order.

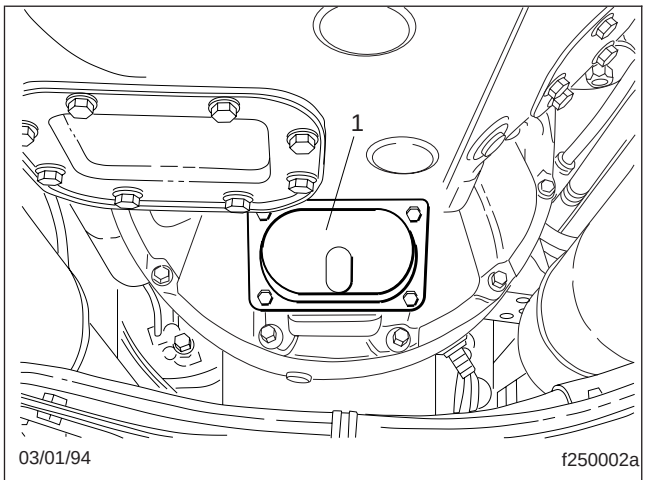
Release Bearing Travel

Measurement

NOTICE

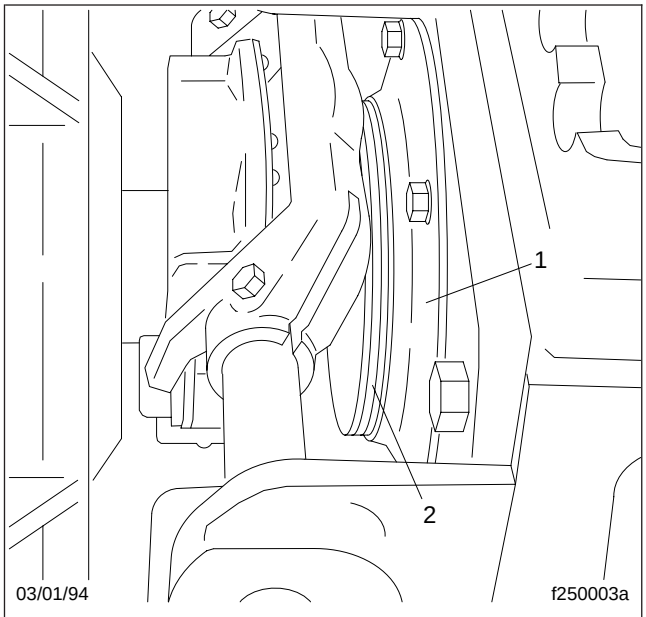
Make sure the internal adjustment is correct before making any linkage adjustments. Incorrect adjustments can cause transmission gear clash, slipping, and burning of clutch components.

1. Apply the parking brakes and chock all the tires.
2. Remove the clutch inspection cover from the bottom of the bell housing. See **Fig. 1**.
3. Slide the clutch brake (either the one-piece torque-limiting clutch brake, or the two-piece disc-type clutch brake with washer) tight against the transmission input-shaft bearing cap. See **Fig. 2**. Also, slide the release bearing as far as possible towards the transmission.



1. Clutch Inspection Cover

Fig. 1, Remove the Clutch Inspection Cover



1. Transmission Input-Shaft Bearing Cap
2. Clutch Brake

Fig. 2, Position the Clutch Brake

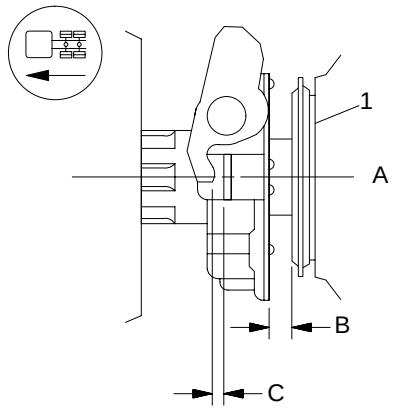
IMPORTANT: Release bearing travel tool A02–12419 is available through the PDCs. One end of the tool has green tape on it and is 0.50 inch

Easy Pedal Clutch Adjustments

(12.7 mm) in diameter; the other end has blue tape on it and is 0.56 inch (14.3 mm) in diameter.

4. Measure the release bearing travel. See **Fig. 3** for the correct dimension to measure. Using both ends of the release bearing travel tool (**Fig. 4**), check this gap as follows:

   4.1 Position the tool so that the legs straddle the transmission input shaft.



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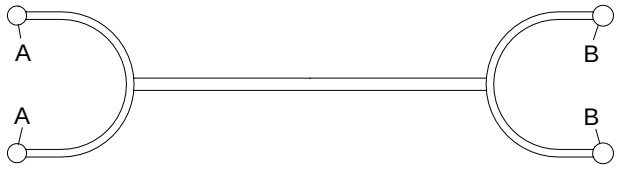
A. Check both dimensions: release bearing travel (B) and release yoke free-travel (C).
B. Release bearing travel: 1/2 to 9/16 inch (12.7 to 14.3 mm) between release bearing housing and clutch brake.
C. Release yoke free-travel: approximately 0.105 to 0.145 inch (2.7 to 3.7 mm) between yoke and wear pads.

1. Torque-Limiting Clutch Brake

Fig. 3, Clutch Dimensions



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A. 0.50 inch (12.7 mm) B. 0.56 inch (14.3 mm)

Fig. 4, Release Bearing Travel Tool A02-12419

   4.2 Insert the blue 0.56-inch (14.3-mm) end. If it fits loosely, the gap is too wide and adjustment is needed. See "Adjustment."

   4.3 If the blue 0.56-inch (14.3-mm) end can't be inserted in the gap, then try to insert the green 0.50-inch (12.7-mm) end. If the green end of the tool fits, snug or loose, then no adjustment is needed.

   4.4 If the green end of the tool can't be inserted in the gap, adjustment is needed. See "Adjustment."

5. If no internal clutch adjustment is necessary, go to "Release Yoke Free-Travel."

Adjustment

To adjust Easy-Pedal clutches, use the Eaton Fuller Kwik-Adjust® mechanism (see **Fig. 5**).

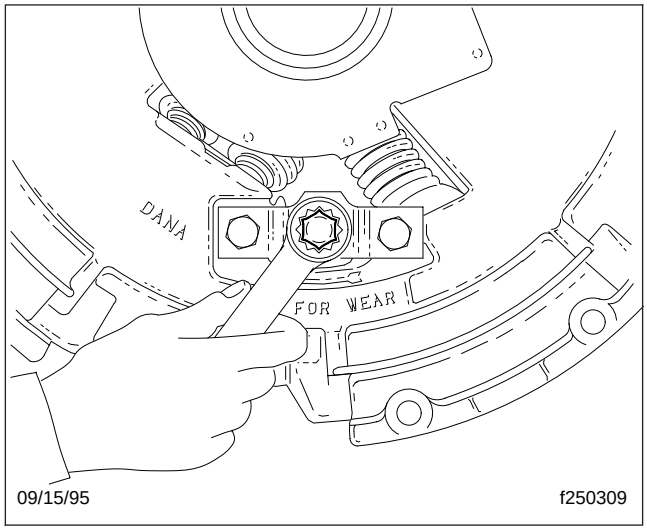

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Fig. 5, Adjustment with Kwik-Adjust

1. Turn the engine flywheel until the lockstrap is aligned with the clutch inspection-cover opening. See **Fig. 1**.
2. Release the clutch by depressing the pedal. Block the pedal in the released position, or have someone assist you by holding the pedal down during the adjustment procedure.

NOTE: An open-end wrench is not recommended for the following step.

3. Adjust the clutch, using a 5/8-inch box-end or socket wrench on the adjustment bolt.

3.1 Insert the 5/8-inch box-end or socket wrench through the inspection cover opening.

3.2 To begin the adjustment, release the adjustment bolt by pressing down on the bolt head.

NOTE: Normal wear increases the gap between the release bearing and the transmission.

3.3 *To decrease the gap*: If clearance between the release bearing housing and the clutch brake is *more than* 9/16-inch (14.3 mm), turn the adjustment bolt clockwise (the release bearing moves toward the transmission).

To increase the gap: If clearance between the release bearing housing and the clutch brake is *less than* 1/2-inch (12.7 mm), turn the adjustment bolt counterclockwise (the release bearing moves toward the engine).

3.4 When the adjustment is complete, make sure the adjustment bolt is locked (pulled up flush with the mounting bolts).

4. After adjusting, release the pedal and check the clearance between the release bearing housing and the clutch brake. When the clearance is 1/2 to 9/16 inch (12.7 to 14.3 mm), the adjustment is complete.

Release Yoke Free-Travel

IMPORTANT: Release yoke free-travel tool A02–12254 is available through the PDCs. The legs on one end of the tool have green tape on them and are 0.105 inch (2.7 mm) thick; the legs on the other end have blue tape on them and are 0.145 inch (3.7 mm) thick.

1. Measure the release yoke free-travel. See **Fig. 3** for the correct dimension to measure. Using both ends of the free-travel tool (**Fig. 6**), check the gap as follows.
2. Position the tool so that the legs straddle the release yoke.

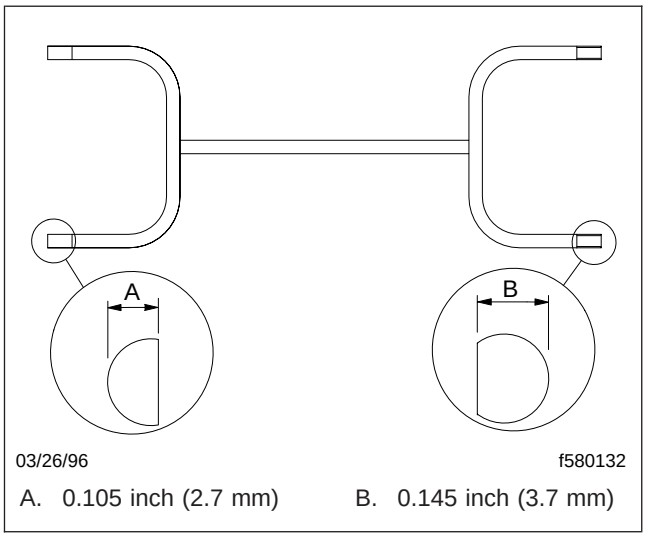


Fig. 6, Release Yoke Free-Travel Tool A02-12254

3. Insert the blue 0.145-inch (3.7-mm) end. If it fits loosely, the gap is too wide and linkage adjustment is needed.
4. If the blue 0.145-inch (3.7-mm) end can't be inserted in the gap, then try to insert the green 0.105-inch (2.7-mm) end. If the green end of the tool fits, snug or loose, then no adjustment is needed.
5. If the green end of the tool can't be inserted in the gap, linkage adjustment is needed.

Clutch Brake Squeeze

NOTE: This procedure requires two persons: one under the vehicle with access to the release bearing, and the other in the vehicle to depress the clutch pedal and measure the pedal travel.

The distance the pedal moves (from the fully depressed position) to free the feeler gauge is the clutch brake squeeze measurement.

1. Apply the parking brakes and chock all the tires.
2. Remove the clutch inspection cover from the bottom of the bell housing. See **Fig. 1**.
3. Insert a 0.010 inch (0.25 mm) feeler gauge (a business card works well if a feeler gauge is not available) between the release bearing and clutch brake.
4. Depress the clutch pedal to the end of its stroke.

Easy Pedal Clutch Adjustments

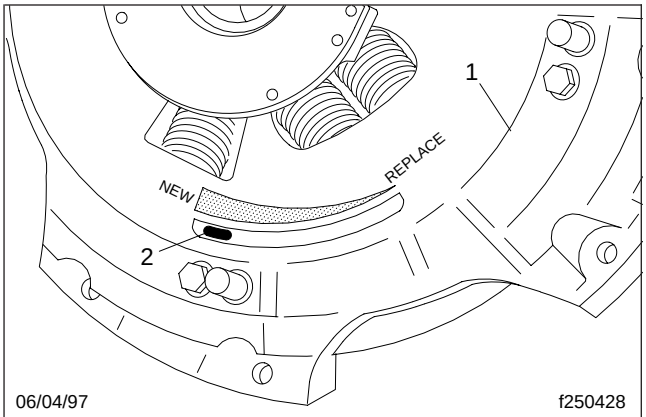
5. Slowly let the pedal up. Stop when the feeler gauge can be pulled out. The pedal should be 1/2 to 1 inch (12.7 to 25.4 mm) from the end of the stroke.
6. If necessary to obtain proper clutch brake squeeze, check the linkage for worn or damaged components. Repair or replace components as necessary.

For vehicles equipped with a Solo clutch, when there is excessive free pedal, try resetting the clutch.

Resetting

NOTE: This procedure requires two persons; one under the vehicle with access to the wear indicating tab, and the other in the vehicle to operate the clutch pedal.

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the tires.
2. Inside the cab, press the clutch pedal all the way down, and hold it there until instructed to release it later in this procedure.
3. Through the clutch cover inspection panel, use moderate force to slide the wear indicating tab leftward until it is at the NEW position on the indicator. See **Fig. 1**. If the tab does not move, use the clutch reset tool as described later in this subject.



With the clutch pedal down, set the tab to the "NEW" position on the indicator.

1. Clutch Cover
2. Wear Indicating Tab

Fig. 1, Resetting the Wear Indicating Tab

4. Release the clutch pedal.
5. Through the clutch inspection cover, remove the gap between the sleeve and the pin, as follows. See **Fig. 2**.

   For a 14-inch clutch, install four 3/8–16 x 1-1/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and use a hand tool to tighten them until the gap is removed and the bolts are snug.

   For a 15.5-inch clutch, install four 7/16–14 x 1-3/4 shipping bolts (if available) or hexhead machine screws into the four clutch cover holes, and use a hand tool to tighten them until the gap is removed and the bolts are snug.
6. Remove the bolts.
7. Press the clutch pedal all the way down, and squeeze the clutch brake five times to reposition the bearing.

NOTE: The release bearing travel tool A02–12419 may be used in the following step. This tool is available through the PDCs.

8. Measure the distance between the clutch brake and the release bearing. It should be between 0.49 and 0.56 inch (12.5 to 14.2 mm). If it is not within this range, refer to the literature available on the Roadranger website, **www.roadranger-.com**.

   If you are using the release bearing travel tool A02–12419 (see **Fig. 3**) for this measurement, position it so that the legs at the blue 0.56-inch (14.3-mm) end straddle the transmission input shaft. If it fits loosely, the gap is too wide. If it does not fit in the gap, try inserting the green 0.50-inch (12.7-mm) end. If the green end of the tool fits, snug or loose, then no adjustment is needed. If the gap is too wide or the green end does not fit in the gap, refer to literature available on the Roadranger website, **www.roadranger-.com**.

Using the Clutch Reset Tool

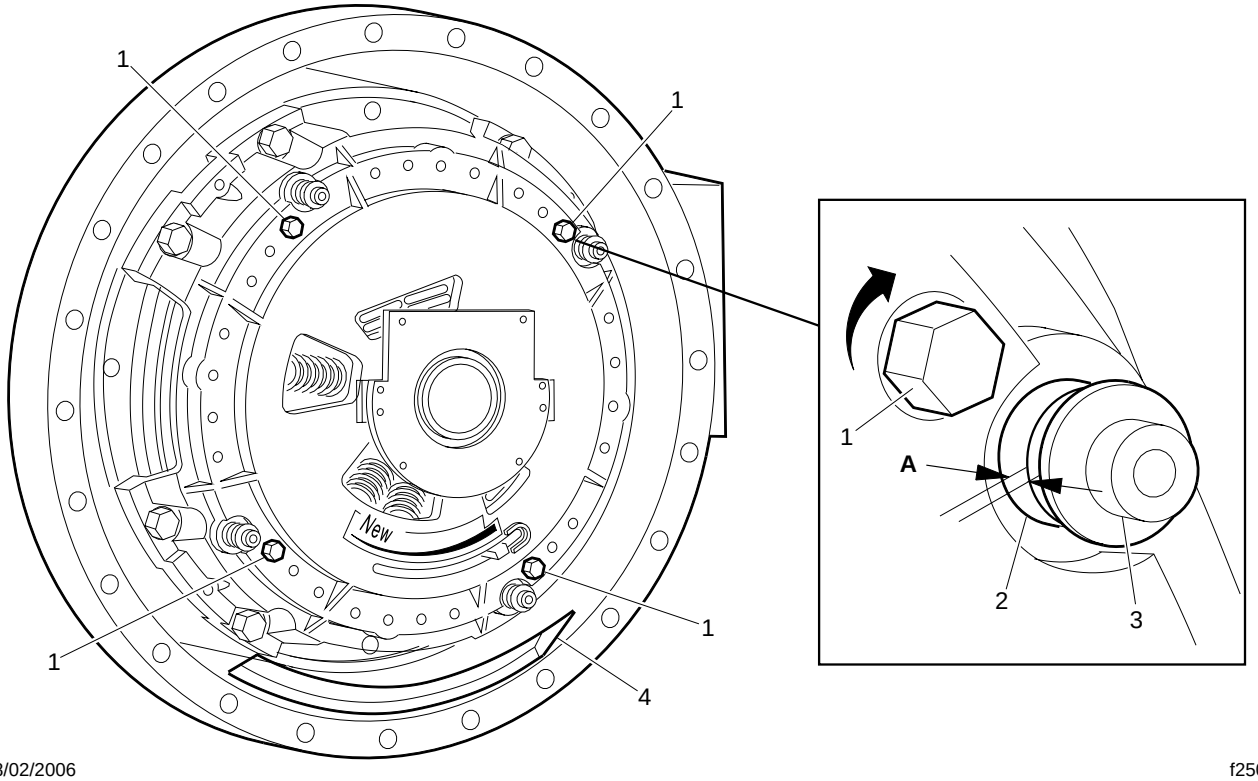
See **Table 1** for more information about the clutch reset tool.

1. While an assistant holds down the clutch pedal, insert the tip of the clutch reset tool through the access panel and position it under the bearing. Align the tool so that the threaded bolt extends into the slot in the cam. See **Fig. 4**.

NOTICE

Use the clutch reset tool carefully. Do not use heavy force on it; heavy force can break the cam.

Resetting a Solo Clutch



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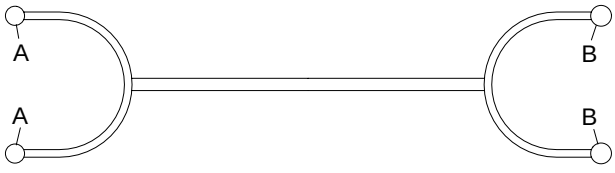
NOTE: The bell housing is shown transparent to provide a clear view of clutch components.

A. Gap Between the Sleeve and the Pin

1. Bolt
2. Sleeve
3. Pin
4. Access Panel

Fig. 2, Removing the Gap Between the Sleeve and the Pin



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A. 0.50 inch (12.7 mm) B. 0.56 inch (14.3 mm)

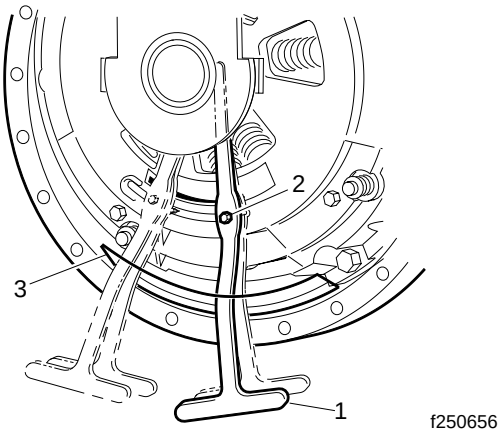
Fig. 3, Release Bearing Travel Tool A02–12419

2. Using the tool, carefully try to move the cam toward the NEW position.

   If the cam moves easily, resume the resetting procedure.

   If the cam does not move, go to the next step.

3. Loosen the transmission, and install 1/4" spacers between the flywheel housing and bell housing.
4. While an assistant holds down the clutch pedal, use the clutch reset tool to move the tab to the NEW position.
5. Once the tab is in the NEW position, release the clutch pedal and remove the spacers.
6. Tighten the transmission mounting bolts; see **Group 26** for torque values.
7. Resume the resetting procedure.



1. Clutch Reset Tool
2. Threaded Bolt
3. Access Panel

Fig. 4, Resetting the Clutch with the Clutch Reset Tool

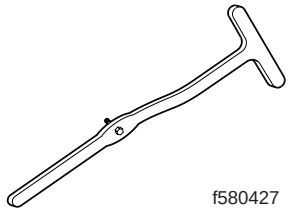
Clutch Reset Tool		
Tool	**Description**	**Eaton Tool Part Code**
 f580427	Clutch Reset Tool	CLPI-SOLOTOOL

Table 1, Clutch Reset Tool

Troubleshooting Tables

Problem—The Clutch Does Not Release Completely

Problem—The Clutch Does Not Release Completely	
Possible Cause	**Remedy**
The clutch pedal height is incorrect.	Make adjustments to obtain the following settings: • 1/2 to 9/16 inch (12.7 to 14.3 mm) release bearing travel; • 1/2 to 1 inch (12.7 to 25.4 mm) clutch brake squeeze. For clutches with mechanical linkage, also make adjustments to obtain 0.105 to 0.145 inch (2.7 to 3.7 mm) release yoke free-travel. (Clutches with hydraulic linkage will have constant contact between the yoke and clutch bearing pads.)
The bushing in the release bearing sleeve assembly is damaged.	Replace the clutch cover.
The clutch cover assembly is not properly seated into the flywheel.	Re-seat the clutch cover assembly into the flywheel. Use a crisscross pattern when tightening the mounting bolts.
The intermediate plate and/or pressure plate is cracked or broken.	Replace any damaged parts.
The cross shafts protrude through the release yoke (a side-loading condition exists).	Check for protruding cross shafts. Repair or replace as necessary.
The release yoke fingers are bent or worn (a side-loading condition exists).	Install a new release yoke.
The engine housing and bell housing are misaligned (a side-loading condition exists).	Check for loose transmission mounting bolts. Tighten the transmission mounting bolts to the proper torque.
The clutch linkage is set up improperly (a side-loading condition exists).	Thoroughly examine the clutch linkage and adjust as necessary.
The driven discs are distorted or warped.	Replace any distorted or warped driven discs. If the transmission is allowed to hang unsupported during clutch installation, the driven discs may become distorted.
The driven discs are installed backwards, or the front and rear driven discs were switched with each other.	Install new driven discs. Also, check the clutch cover for any damage. Replace the clutch cover if damaged.
The input shaft spline is worn.	Replace the input shaft. Also, check the driven disc hubs for wear. Replace the driven discs if worn.
The input shaft spline is coated with grease, anti-seize compound, etc.	Clean and dry the input shaft spline before installation.
The input shaft splines are twisted.	Select a new driven disc and slide it along the full length of the splines. If the disc does not slide freely, replace the input shaft.
The input-shaft bearing cap is worn.	Replace the input-shaft bearing.
The flywheel pilot bearing fits either too tight or too loose in the flywheel and/or end of input shaft.	Check the pilot bearing for proper fit and replace it if worn.
The pilot bearing is dry or damaged.	Replace the pilot bearing.

Troubleshooting

Problem—The Clutch Does Not Release Completely	
Possible Cause	**Remedy**
The separator pins are bent, damaged or incorrectly set.	Be sure to use the proper tool when setting the separator pins. Also, take great care when handling the intermediate plate. For procedures, see the appropriate clutch installation subject.
The clutch brake is damaged and/or not functioning.	Install a new clutch brake.
The driven disc faces are coated with oil or grease.	Replace the driven disc assemblies. Cleaning the old driven discs is not recommended.
There is foreign material (dirt, chaff, salt, etc.) inside the clutch cover.	Remove the foreign material and make sure the clutch inspection cover is installed.
The drive pins are cocked, causing the intermediate plate to stick on the drive lugs (Easy Pedal only).	The drive pins must be ninety degrees square to the flywheel surface with a 0.006-inch (0.15-mm) minimum clearance between drive pins and intermediate plate slots. Repair or replace as necessary.
The pressure plate is not fully retracting (Easy Pedal only).	Check the pressure plate return springs through the clutch inspection cover. If any are bent, stretched, or broken, replace them as necessary.
The release bearing travel is excessive and is causing the lever to contact the pressure plate (Easy Pedal only).	Adjust the release bearing travel from 1/2 to 9/16 inch (12.7 to 14.3 mm).
The three anti-rattle springs were installed backwards (Easy Pedal only).	Install the anti-rattle springs so the rounded sections are pointed toward the flywheel/engine.

Problem—The Clutch Rattles or Is Noisy

Problem—The Clutch Rattles or Is Noisy	
Possible Cause	**Remedy**
There is excessive flywheel runout.	Repair or replace the flywheel. For procedures, see the engine manufacturer's manual.
There is corrosion between the input shaft spline and the driven disc hubs.	Clean the mating parts between the input shaft and driven discs to ensure that the discs slide freely over the input shaft spline.
The engine idle is too fast.	Readjust engine idle to proper idling speed.
The clutch release bearing is dry or damaged.	Lubricate the clutch release bearing. If the noise persists, install a new clutch cover.
The flywheel pilot bearing is dry or damaged.	Replace the flywheel pilot bearing.
The bridge of the release yoke is hitting the clutch cover (an over-stroking condition exists).	Check for a worn, broken or missing clutch brake. Also, check the release yoke and input-shaft bearing cap for wear. Replace any worn parts.
The release yoke fingers are hitting the clutch cover.	Check if the release bearing, clutch cover, or release yoke fingers are worn or broken. Replace worn parts.
The clutch inspection cover is not installed.	Re-install the clutch inspection cover.
The sleeve bushings are worn.	Investigate for any side-loading conditions on the release bearing housing. If there is a side-loading condition, determine its cause. Also, before installing the new clutch, make sure that the side-loading condition has been corrected.
The clutch linkage is rattling excessively.	Clean, lubricate and reassemble or replace missing/worn parts.

Problem—The Clutch Rattles or Is Noisy	
Possible Cause	**Remedy**
An idle gear rattle is coming from the transmission.	Specify low-vibration driven discs. Check the engine for correct idle speed. For procedures, consult the engine manufacturer's manual.
The damper spring cover of the driven disc assembly is interfering with the flywheel.	Install the correct clutch assembly.
The rivets of the rear driven disc are interfering with the retainer assembly (Easy Pedal only).	Adjust the clutch internally (via the adjustment bolt). For procedures, see **Subject 150**.

Problem—The Clutch Vibrates

Problem—The Clutch Vibrates	
Possible Cause	**Remedy**
The flywheel is loose.	Retighten the flywheel mounting bolts to the proper specifications.
The universal joints are worn.	Replace the worn parts.
The driveshaft is not properly phased.	Investigate and correct the phasing of the driveshaft.
The driveshaft is not balanced.	Balance and straighten the driveshaft.
The driveline angles are incorrect.	Shim the drivetrain components to equalize universal joint angles.
The flywheel is not balanced.	Balance the flywheel.
The pilot area of the clutch is not completely seated into the flywheel.	Ensure that no dirt, burrs, etc., are preventing the clutch cover from completely seating into the flywheel mounting surface.
The engine mounts are loose, damaged, or worn out.	Replace any worn or damaged parts. Retighten all bolts to proper specifications.
The engine is misfiring.	The engine is not in tune. To correct the problem, see the engine manufacturer's manual.
There is excessive flywheel runout.	Repair or replace the flywheel. For procedures, see the engine manufacturer's manual.
The rivets of the rear driven disc are interfering with the retainer assembly (Easy Pedal only).	Adjust the clutch internally (via the adjustment bolt). For procedures, see **Subject 150**.

Problem—The Clutch Needs Frequent Adjustments

Problem—The Clutch Needs Frequent Adjustments	
Possible Cause	**Remedy**
The clutch specification is incorrect.	Check the clutch specifications in **Subject 400**. Install a new clutch with the proper specifications, if necessary.
The cross shafts and/or clutch linkage system is worn.	Investigate the entire clutch linkage system to determine if it is binding or operating sporadically and/or worn excessively.
The clutch driven discs are worn down to the rivets.	Install a new clutch.
The crankshaft has excessive end play.	Repair or replace the crankshaft. Consult the engine manufacturer's manual for procedures.

Troubleshooting

Problem—The Clutch Slips

Problem—The Clutch Slips	
Possible Cause	**Remedy**
The clutch is overloaded.	Verify that the proper clutch has been specified for the particular vehicle application.
The release mechanism is binding.	Free up the release mechanism and linkage. Also, check the clutch linkage adjustment.
The driven disc faces are coated with oil or grease.	Replace the driven disc assembly.
The driver is riding the clutch pedal.	Use correct driving procedures.
The input shaft spline is worn.	Replace the input shaft.

Problem—The Clutch Grabs or Chatters

Problem—The Clutch Grabs or Chatters	
Possible Cause	**Remedy**
The clutch is worn out.	Replace the clutch and all worn components.
The linkage system is not operating freely.	Check the clutch linkage for binding or excessive wear. Replace all worn parts.
The driven disc faces are coated with oil or grease.	Replace the driven disc assembly.
The engine mounts are loose.	Retighten the engine mounts to manufacturer’s specifications.
The release yoke fingers and/or the release bearing wear pads are worn excessively.	Replace all the worn parts.

Clutch Torque Values			
Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Mounting Bolts, Clutch Cover to Flywheel on 14-inch clutch	3/8–16 x 1-1/4	5	30–35 (40–47)
Mounting Bolts, Clutch Cover to Flywheel on 15.5-inch clutch	7/16–14 x 2-1/4	5	40–50 (54–68)

Table 1, Clutch Torque Values

Minimum Flywheel Bores	
Disc Type	**Minimum Flywheel Bore in inch (mm)**
10-Spring	8.562 (217.48)
9-Spring	9.750 (247.65)
8-Spring	7.250 (184.15)
7-Spring	9.750 (247.65)
6-Spring	9.750 (247.65)

Table 2, Minimum Flywheel Bores

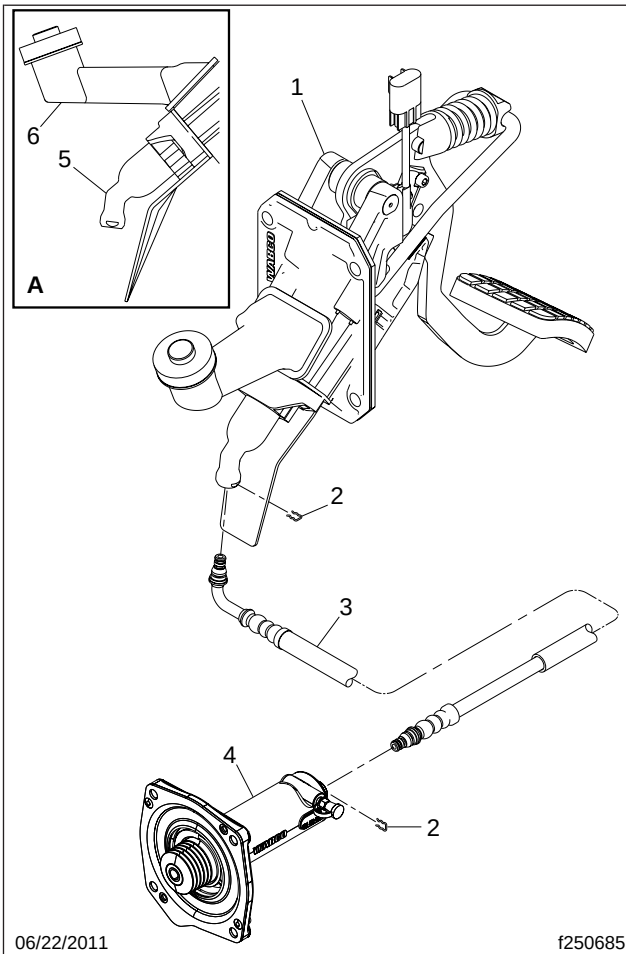
General Information

The hydraulic clutch control system consists of a pedal unit and a slave cylinder, connected by a hydraulic hose that is fastened with quick-disconnect clips. See **Fig. 1**. The hydraulic system is self-adjusting, and it uses DOT 4 brake fluid.

The pedal unit includes a hydraulic subassembly (composed of the master cylinder and reservoir) that can be removed from the pedal unit for service purposes; see **Subject 110** for instructions.

Principles of Operation

When the clutch pedal is pressed, the fluid in the master cylinder is forced through a hydraulic line to the slave cylinder. The fluid pressure moves the slave cylinder piston, pushing the plunger rod and clutch release lever, which disengages the clutch.



A. Hydraulic Subassembly

1. Pedal Unit
2. Clip
3. Hydraulic Hose
4. Slave Cylinder
5. Master Cylinder
6. Reservoir

Fig. 1, Components, Hydraulic Clutch Control

Pedal Unit Removal and Installation

Removal

⚠ WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.
3. As needed, cut zip ties to allow the hydraulic hose to move freely when the pedal unit is removed.

⚠ WARNING

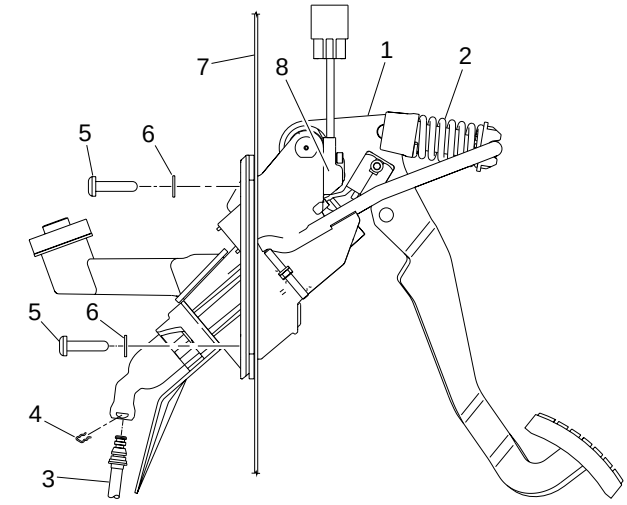
Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.

4. Remove the fasteners that attach the pedal unit to the frontwall, and withdraw the unit until you can access the clutch control switch. Retain the fasteners for later installation. See **Fig. 1**.
5. Disconnect the clutch control switch, as follows.
   - 5.1 Retract the secondary lock. See **Fig. 2**.
   - 5.2 Depress the latch to unlock the switch connector, then separate the clutch control switch from the wire harness.
6. Remove the pedal unit through the frontwall and into the engine compartment.

IMPORTANT: To avoid spilling fluid when the hose is removed from the master cylinder, turn the pedal unit upside down so that the fluid drains into the master cylinder and reservoir.

NOTE: When removing the quick-disconnect clip, note the position of the clip for later installation.

7. Use a flat-tip screwdriver to remove the quick-disconnect clip that locks the hydraulic hose into the master cylinder. See **Fig. 3**. Remove the hose, and with the end pointing upwards to prevent fluid spillage, secure it temporarily to a safe point on the vehicle. Retain the clip for later installation.



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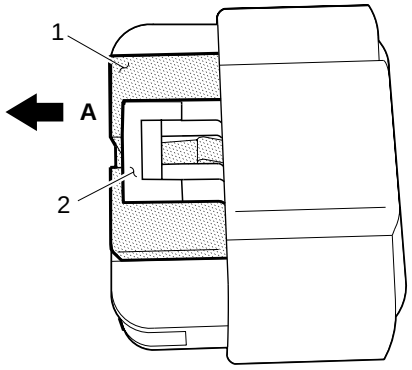
1. Pedal Unit
2. Assist Spring
3. Hydraulic Hose
4. Clip
5. Bolt
6. Washer
7. Frontwall
8. Clutch Control Switch

Fig. 1, Pedal Unit Installation



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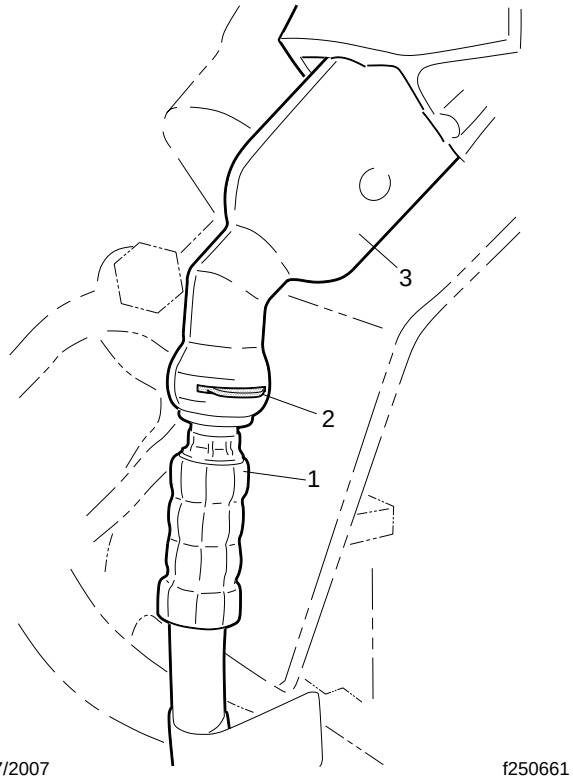
A. Retract the secondary lock, then depress the latch to release the connector.

1. Secondary Lock
2. Latch

Fig. 2, Clutch Control Switch Connector

Pedal Unit Removal and Installation



1. Hydraulic Hose
2. Quick-Disconnect Clip
3. Master Cylinder

Fig. 3, Quick-Disconnect Clip at the Master Cylinder

Installation

1. Install the pedal unit, and tighten the four mounting plate capscrews 11 lbf·ft (15 N·m).
2. Install the quick-disconnect clip and hydraulic hose, as follows.
   - 2.1 Insert the clip arms into the recessed areas on the nozzle of the master cylinder.
   - 2.2 Snap the hydraulic hose into place.
   - 2.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.

   IMPORTANT: Do not force the hose into the master cylinder. If the clip is incorrectly installed, the hose will not snap into place.
3. As removed, brace the hydraulic hose with zip ties.
4. Connect the clutch control switch.

⚠ WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

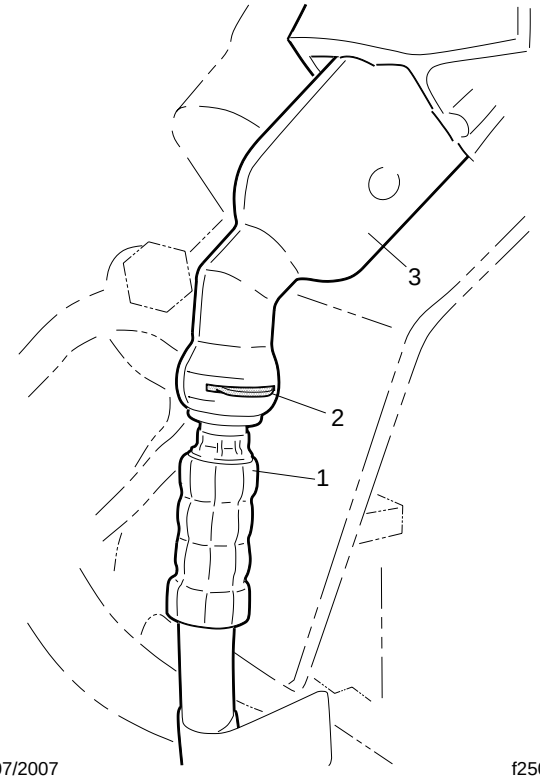
5. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system as instructed in **Subject 130**.
6. Check the function of the clutch actuation system as instructed in **Subject 300**.

Replacement

1. Place a suitable container under the master cylinder to collect the fluid that will drain as the hose is removed from the master cylinder.

NOTE: When removing the quick-disconnect clip, note the position of the clip for later installation.

2. Use a flat-tip screwdriver to remove the quick-disconnect clip that locks the hydraulic hose into the master cylinder. See **Fig. 1**. Remove the hose, and with the end pointing upwards to prevent fluid spillage, secure it temporarily to a safe point on the vehicle. Retain the clip for later installation.



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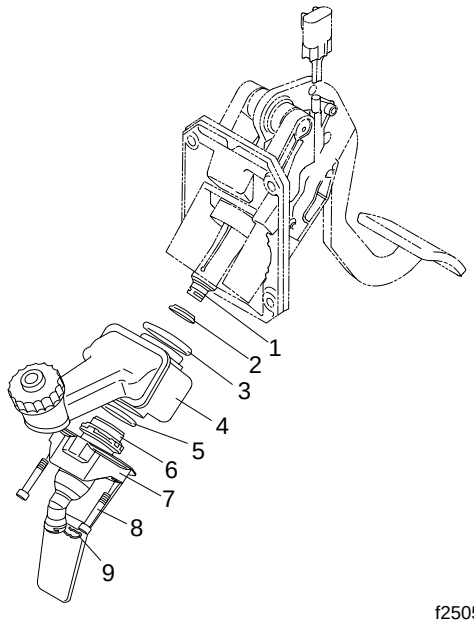
1. Hydraulic Hose
2. Quick-Disconnect Clip
3. Master Cylinder

Fig. 1, Quick-Disconnect Clip at the Master Cylinder

3. Drain the fluid from the master cylinder.

4. Remove the two screws that attach the hydraulic subassembly to the mounting plate. See **Fig. 2**.



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1. Piston
2. Lip Seal
3. Reservoir O-Ring
4. Reservoir
5. Body O-Ring
6. Hydraulic Body
7. Base
8. Screw
9. Clip

Fig. 2, Hydraulic Subassembly

5. Pull carefully on the hydraulic subassembly until it comes loose from the pedal unit. Discard the old hydraulic subassembly.

NOTICE

Be careful when removing the lip seal. Avoid damaging the sealing surfaces of the plastic piston.

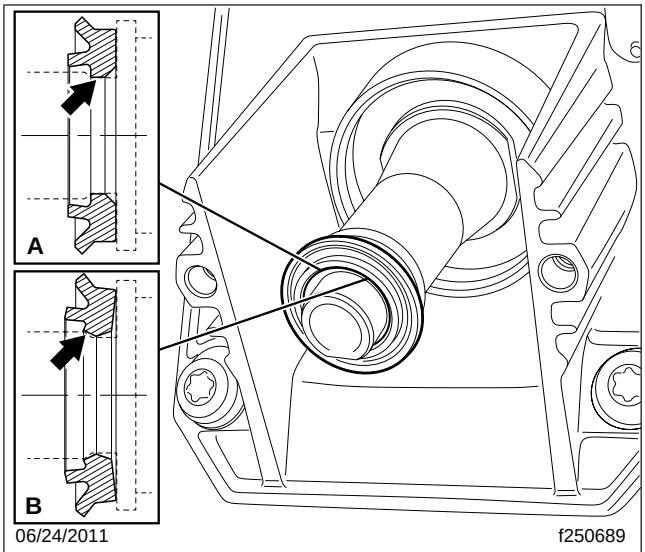
6. Carefully remove the lip seal from the piston of the master cylinder. Discard the lip seal.

NOTICE

Use only the special grease provided in the assembly kit. Do not use mineral oil or any other lubricant which could damage the seals and cause loss of clutch function.

Hydraulic Subassembly Replacement

7. Using the grease included in the kit, lubricate a new lip seal and mount it on the piston. See **Fig. 3**.



A. Correct Installation
B. Incorrect Installation

Fig. 3, Lip Seal Installation

8. Using the grease included in the kit, lubricate the new O-rings and the O-ring seats in the new reservoir and hydraulic body.
9. Put the reservoir and hydraulic body together with the O-rings properly seated and lubricated.
10. While holding the reservoir and hydraulic body together, insert the base over the hydraulic body.
11. Install the screws, and tighten them 44 lbf·in (500 N·cm).
12. Install the quick-disconnect clip and hydraulic hose, as follows.
    - 12.1 Insert the clip arms into the recessed areas on the nozzle of the master cylinder.
    - 12.2 Snap the hydraulic hose into place.
    - 12.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.

    IMPORTANT: Do not force the hose into the master cylinder. If the clip is incorrectly installed, the hose will not snap into place.

WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

13. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system as instructed in **Subject 130**.
14. Check the function of the clutch actuation system as instructed in **Subject 300**.

Replacement

⚠ WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.
3. Place a suitable container under the slave cylinder to collect the fluid that will drain as the hose is removed from the slave cylinder.
4. Using a flat-tip screwdriver, remove the quick-disconnect clip that attaches the hydraulic hose to the slave cylinder. See **Fig. 1**. Retain the clip for later installation.

⚠ WARNING

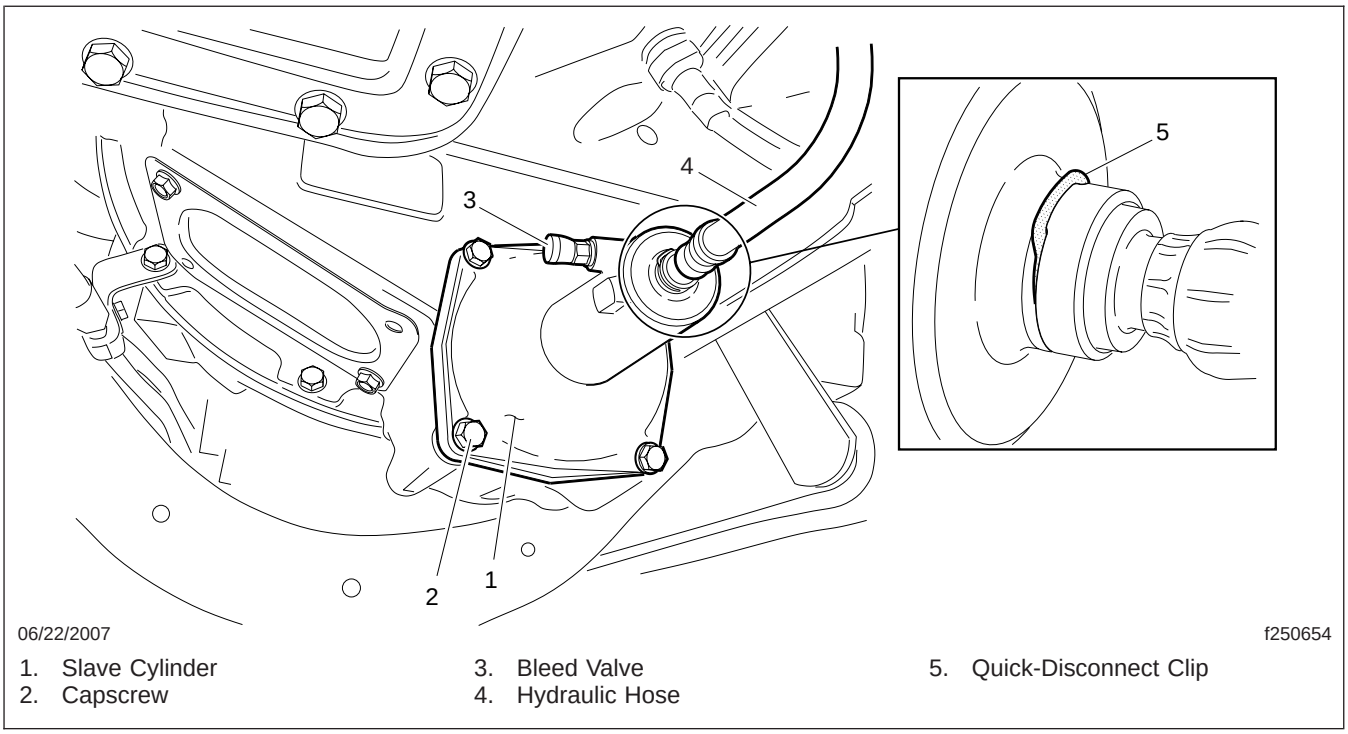
Do not depress the clutch pedal while the slave cylinder is removed from the clutch housing. The slave cylinder piston could be ejected, causing component damage or serious personal injury.

5. Drain the hydraulic fluid from the entire system.
6. Loosen the four slave cylinder mounting capscrews that attach the slave cylinder to the clutch housing.
7. After bracing the slave cylinder so that it does not fall, remove and save the four slave cylinder mounting capscrews.

IMPORTANT: Handle the slave cylinder carefully to prevent spillage.

IMPORTANT: Be sure to mount the slave cylinder with the bleed valve on top of the unit and horizontal to the ground, as shown in **Fig. 1**.

8. Mount a new slave cylinder on the clutch housing, as follows.



1. Slave Cylinder
2. Capscrew
3. Bleed Valve
4. Hydraulic Hose
5. Quick-Disconnect Clip

Fig. 1, Clutch Slave Cylinder

Slave Cylinder Replacement

8.1 Make sure that the pushrod is attached to the clutch fork and inserted into the push-rod bore in the slave cylinder.

8.2 Push the slave cylinder against the clutch housing to compress the internal spring.

9. Install the four slave cylinder mounting cap-screws and tighten them 13 lbf·ft (18 N·m).
10. Install the quick-disconnect clip and hydraulic hose, as follows.

10.1 Insert the clip arms into the recessed areas on the nozzle of the slave cylinder.

10.2 Snap the hydraulic hose into place.

10.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.

IMPORTANT: Do not force the hose into the slave cylinder. If the clip is incorrectly installed, the hose will not snap into place.

⚠ WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

11. Fill the reservoir with approved DOT 4 hydraulic brake fluid, and bleed the system as instructed in **Subject 130**.
12. Check the function of the clutch actuation system as instructed in **Subject 300**.

⚠ WARNING

Hydraulic clutch control fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling it or bleeding hydraulic lines. If you get it on your skin, wash it off as soon as possible.

NOTICE

Do not spill hydraulic clutch control fluid on the cab paint. Clean it off immediately if any is spilled. Brake fluid can damage paint.

Filling

The hydraulic system holds approximately 0.5 quart (0.5 liter) of fluid. Use new DOT 4 brake fluid from a tightly sealed container to fill the system until the fluid level is between the MIN and MAX lines marked on the side of the reservoir. See **Fig. 1**.

Bleeding

IMPORTANT: The pressure line must slope continuously downward between the master and slave cylinders. On some vehicles, the securing clamps may need to be removed to achieve this and allow the air to be purged.

The hydraulic clutch control can be bled by using a pressure bleeder or manual bleeding. Pressure bleeding can be done by one person and manual bleeding requires two.

Pressure Bleeding

NOTE: A bleeder system (J-29532) and a bleed adaptor (J-35798) for the fluid reservoir are available through SPX Kent-Moore Tools and may be used to complete the following procedure. To order these parts, call Kent-Moore at 1-800-328-6657.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires and open the hood.
2. Prepare the pressure bleeding equipment according to the manufacturer's instructions. Use new DOT 4 brake fluid from a tightly sealed container. Pressurize the bleed adaptor to 15 psi (103 kPa).
3. Remove the reservoir lid, and install the pressure bleed adaptor on the reservoir. See **Fig. 1**.

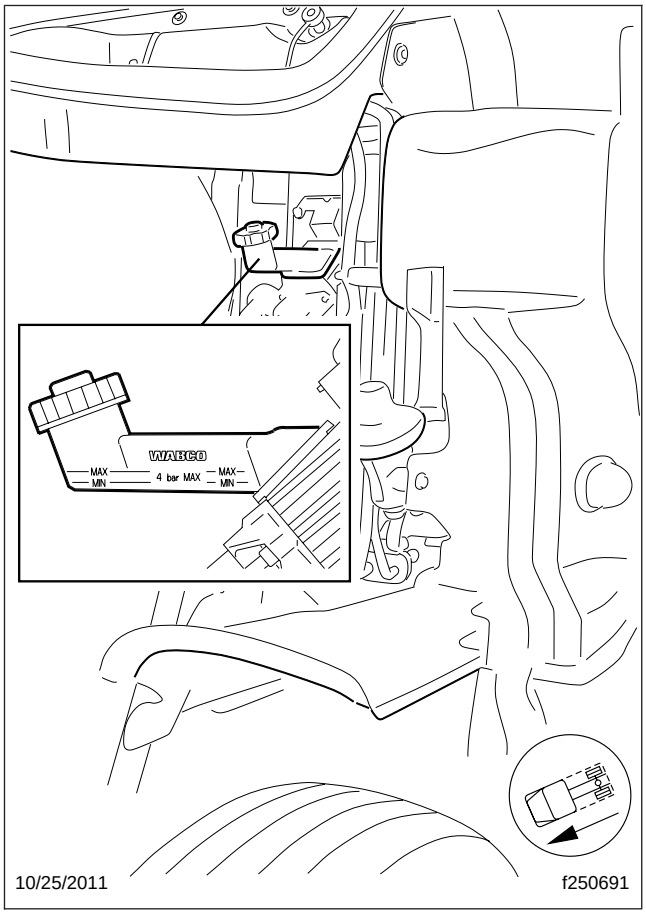
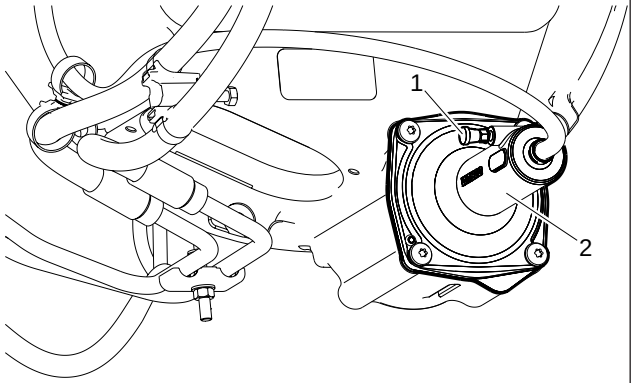


Fig. 1, Reservoir, Hydraulic Clutch Control

4. Bleed the hydraulic system, as follows.
   - 4.1 Open the bleed valve on the bleed tank to pressurize the reservoir.
   - 4.2 Remove the cap from the bleed valve of the slave cylinder. See **Fig. 2**. On the valve, install a transparent drain hose connected to a catch bottle. The hose needs to fit the bleed valve tight enough so it does not fall off when fluid is pumped out.
   - 4.3 Open the bleed valve on the slave cylinder.

Fluid Filling and Bleeding



1. Bleed Valve
2. Slave Cylinder

Fig. 2, Slave Cylinder, Hydraulic Clutch Control

4.4 When the draining fluid is clear and free of air bubbles, close the bleed valve.

5. Check the fluid level in the reservoir. If necessary, add or drain fluid to bring the fluid level to between the MIN and MAX lines marked on the side of the reservoir. Install the reservoir lid.
6. Disconnect the transparent hose. Tighten the bleed valve 88 lbf·in (1000 N·cm) and install the cap on the slave cylinder bleed valve.
7. Depress the clutch pedal a few times. There should be resistance over the full pedal stroke.

Manual Bleeding

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires and open the hood.

NOTE: The hydraulic system holds approximately 0.5 quart (0.5 liter) of fluid. It may need to be refilled during the bleeding process to prevent air from re-entering the system.

2. Remove the reservoir lid and fill the reservoir (see **Fig. 1**) with new DOT 4 brake fluid from a tightly sealed container.
3. Remove the cap from the bleed valve of the slave cylinder. See **Fig. 2**. On the valve, install a transparent drain hose connected to a catch bottle. The hose needs to fit the bleed valve tight enough so it does not fall off when fluid is pumped out.

NOTE: The following steps require two people – one in the cab to work the clutch pedal, and one to open and close the bleed valve and watch the fluid.

4. Bleed the system, as follows.
   - 4.1 Open the bleed valve.
   - 4.2 Depress the clutch pedal until it stops.
   - 4.3 Close the bleed valve.
   - 4.4 Return the pedal to the upper position.
   - 4.5 Repeat the previous steps until the fluid is clear and free of air bubbles.
   - 4.6 Depress the clutch pedal. There should be resistance over the full pedal stroke.
5. Check the fluid level in the reservoir. If necessary, add or drain fluid to bring the fluid level to between the MIN and MAX lines marked on the side of the reservoir. Install the reservoir lid.
6. Disconnect the transparent hose. Tighten the bleed valve 88 lbf·in (1000 N·cm) and install the cap on the slave cylinder bleed valve.

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.

⚠ WARNING

Clutch hydraulic fluid (DOT 4 brake fluid) is hazardous. It may be a skin irritant and can cause blindness if it gets in your eyes. Always wear safety glasses when handling clutch hydraulic fluid or bleeding hydraulic lines. If you get clutch hydraulic fluid on your skin, wash it off as soon as possible.

3. Using a flat-tip screwdriver, remove the quick-disconnect clip that attaches the hydraulic hose to the slave cylinder. Retain the clip. See **Fig. 1**.
4. Drain the hydraulic fluid from the entire system.

NOTE: When removing the quick-disconnect clip at the master cylinder, note the position of the clip for later installation.

5. Using a flat-tip screwdriver, remove the quick-disconnect clip that attaches the hydraulic hose to the master cylinder. Retain the clip. See **Fig. 2**.
6. Route the new hydraulic hose between the slave cylinder and the master cylinder.

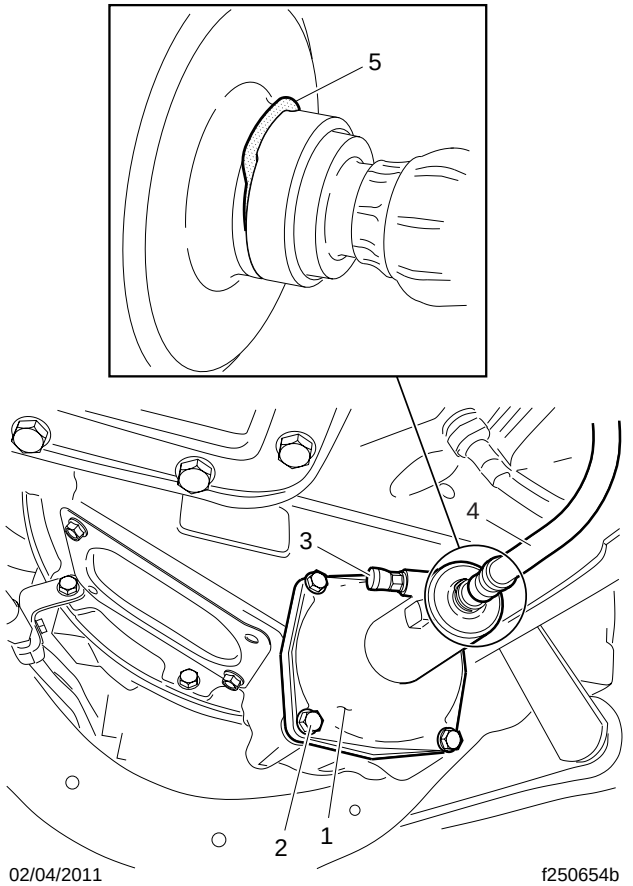
IMPORTANT: Do not force the hose into the master or slave cylinders. If a clip is incorrectly installed, the hose will not snap into place.

7. Install the quick-disconnect clips and hydraulic hose, as follows.
   - 7.1 Insert the clip arms into the recessed areas on the nozzle of the master cylinder.
   - 7.2 Snap the hydraulic hose into place.
   - 7.3 Tug on the hose to make sure it is installed correctly. The hose should not pull out.
   - 7.4 Insert the clip at the slave cylinder, and install the hose as described above.

⚠ WARNING

Use only approved clutch hydraulic fluid (DOT 4 brake fluid). Do not mix different types of brake fluid. The wrong fluid will damage the rubber parts of the system, causing loss of clutch function and the risk of serious personal injury.

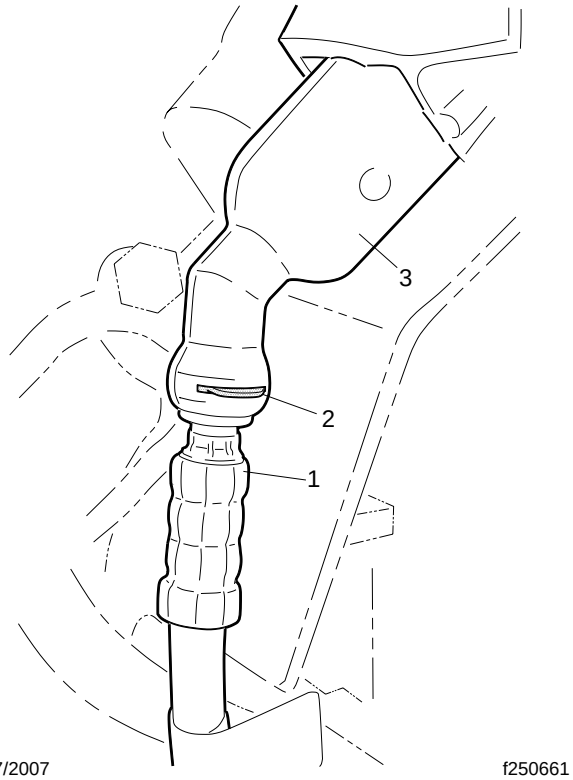
8. Fill the reservoir with approved DOT 4 hydraulic brake fluid and bleed the system as instructed in **Subject 130**.
9. Check the function of the clutch actuation system as instructed in **Subject 300**.



1. Slave Cylinder
2. Capscrew
3. Bleed Valve
4. Hydraulic Hose
5. Quick-Disconnect Clip

Fig. 1, Clutch Slave Cylinder

Hydraulic Hose Replacement

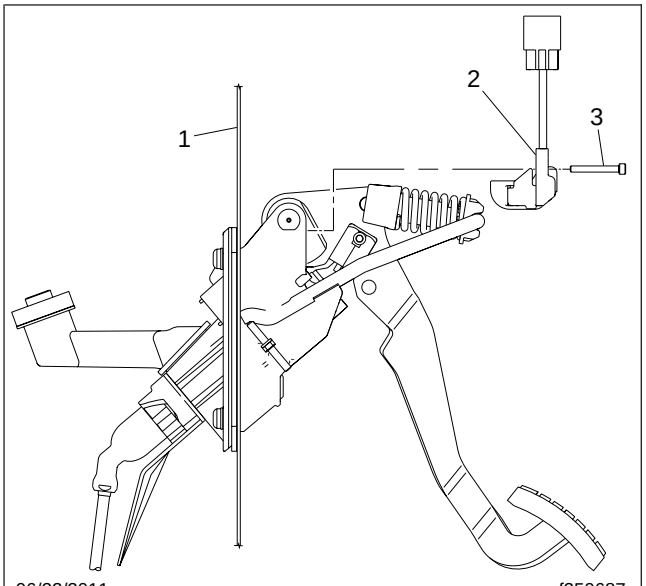


1. Hydraulic Hose
2. Quick-Disconnect Clip
3. Master Cylinder

Fig. 2, Quick-Disconnect Clip at the Master Cylinder

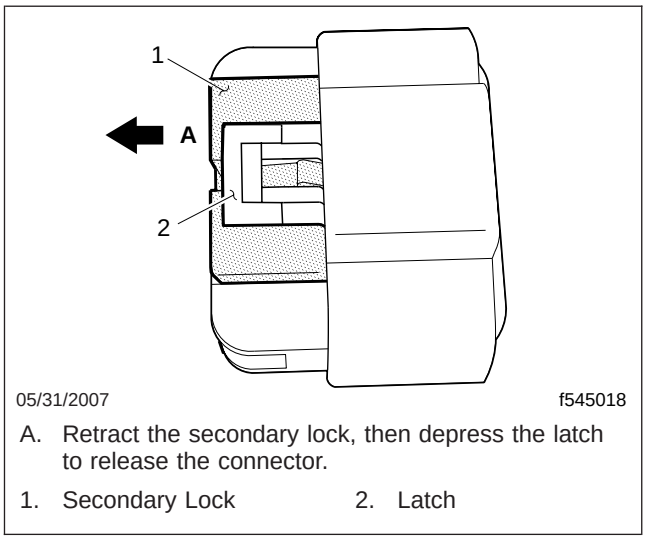
Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the hood.
3. Disconnect the clutch control switch located under the dash and above the clutch pedal, as follows. See **Fig. 1**.
   - 3.1 Retract the secondary lock. See **Fig. 2**.
   - 3.2 Depress the latch to unlock the switch connector, then separate the clutch control switch from the wire harness.
4. Remove the screw that holds the switch assembly to the pedal unit, and remove the switch.
5. Mount the new switch assembly on the connector and tighten the M5 screw 23 lbf·in (260 N·cm).
6. Check the function of the clutch actuation system as instructed in **Subject 300**.



1. Frontwall
2. Clutch Control Switch
3. Screw

Fig. 1, Clutch Control Switch



A. Retract the secondary lock, then depress the latch to release the connector.

1. Secondary Lock
2. Latch

Fig. 2, Clutch Control Switch Connector

Diagnostic Checks

IMPORTANT: If any problems are noticed during these diagnostic checks, take corrective action using the information under the heading "Troubleshooting Tables."

When repairing any components, bleed the clutch hydraulic system before restoring the vehicle to service. This will prevent air from remaining in the system.

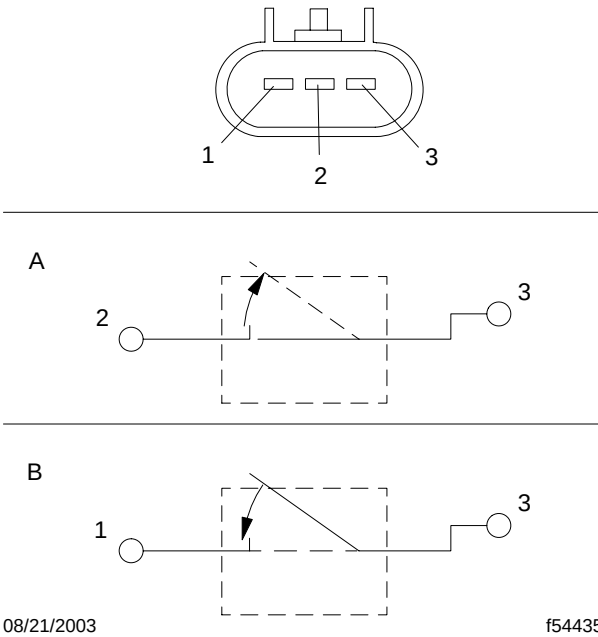
Clutch Switch Check

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.
3. Disconnect the clutch control switch connector located under the dash just above the clutch pedal.
4. To check the upper position switch, do a continuity check between pin 2 and pin 3 of the connector. See **Fig. 1**.
   - 4.1 With the pedal not pressed, the circuit should be closed (continuity should be present).
   - 4.2 With the pedal pressed down about 4 inches (10 cm), the circuit should be open (no indication of continuity).
5. To check the lower position switch, do a continuity check between pin 1 and pin 3 of the connector.
   - 5.1 With the pedal not pressed, the circuit should be open (no indication of continuity).
   - 5.2 With the pedal pressed down all the way to the floor, the circuit should be closed (continuity should be present).
6. If either check gives an incorrect result, replace the clutch switch.

Clutch Actuation System Check

⚠ WARNING

Air in the clutch hydraulic system can prevent the gears from engaging properly, and cause a serious accident resulting in personal injury.



A. Upper Position Switch–The switch is open when the pedal is pressed down about four inches (10 cm).
B. Lower Position Switch–The switch closes when the pedal is pressed down to the floor.

1. Pin 1
2. Pin 2
3. Pin 3

Fig. 1, Clutch Switch

1. Shut down the engine.
2. Apply the parking brakes and chock the front and rear tires.
3. Do the "Clutch Actuation System Leak Check."
4. Press the pedal all the way to the floor several times and check the action of the pedal. The pedal should be easy to operate and return without difficulty to its original position. It should feel firm and responsive, not soft or spongy.
5. With both the brake and the clutch pedals pressed down, start the engine.
   - If the engine does not start, take corrective action using the information under the heading "Troubleshooting Tables."
   - If the clutch does not disengage properly, take corrective action using the information under the heading "Troubleshooting Tables."

6. Remove the chocks from the front and rear tires.
7. Test drive the vehicle.
   - 7.1 Check for proper clutch functioning while shifting gears.
   - 7.2 If the clutch makes noise when shifting out of neutral into another gear, do the "Clutch Incomplete Disengagement Check."
   - 7.3 With cruise control on, press the clutch pedal down. If cruise control does not deactivate, take corrective action using the information under the heading "Troubleshooting Tables."

Clutch Actuation System Leak Check

1. Shut down the engine.
2. Apply the parking brakes, chock the front and rear tires, and open the hood.

NOTE: This step requires two persons.

3. Have one person press down on the clutch pedal while the other person checks the clutch hydraulic system for signs of leakage.

Clutch Incomplete Disengagement Check

NOTE: Do this check only on vehicles with synchronized transmissions.

1. Chock the front tires and apply the parking brake.
2. Put the gear shift lever in neutral.
3. Start the engine.
4. Press the clutch pedal all the way to the floor.
5. Shift the transmission into 1st gear.
6. With the clutch pedal still on the floor, shift into 2nd gear.
7. Listen for noise and feel for difficult shifting. If there is noise or difficulty in getting the gears to shift, the clutch is not completely disengaged. Take corrective action using the information under the heading "Troubleshooting Tables."

Troubleshooting Tables

Problem–The Clutch Pedal Feels Soft or Spongy

Problem–The Clutch Pedal Feels Soft or Spongy	
Possible Cause	**Remedy**
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 130** for instructions.
There is a hydraulic fluid leak.	Check the fluid level. Check for leakage and replace any components found to be leaking. Fill and bleed the hydraulic system.

Problem–The Clutch Pedal Is Unusually Hard To Operate

Problem–The Clutch Pedal Is Unusually Hard To Operate	
Possible Cause	**Remedy**
The clutch is damaged.	Remove the clutch and inspect it for damage. Replace the clutch if damaged, or make any necessary repairs.
The clutch is not functioning properly.	Check clutch function and make any necessary repairs. See the instructions under the heading "Clutch Actuation System Check."

Problem–The Clutch Pedal Is Unusually Hard To Operate	
Possible Cause	**Remedy**
The return or assist spring is broken.	Replace the pedal unit. See **Subject 100** for instructions. **WARNING** **Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.**
The pedal assembly is worn or jammed.	Replace the pedal unit. See **Subject 100** for instructions.
The master cylinder has components that are jammed or broken.	Replace the hydraulic subassembly. See **Subject 110** for instructions.

Problem–The Clutch Does Not Completely Disengage; Shifting Is Difficult and Noisy

Problem–The Clutch Does Not Completely Disengage; Shifting Is Difficult and Noisy	
Possible Cause	**Remedy**
There is air in the hydraulic system.	Bleed the hydraulic system. See **Subject 130** for instructions.
There is a hydraulic fluid leak.	Check the fluid level. Check for leakage and replace any components found to be leaking. Fill and bleed the hydraulic system.
Components of the pedal unit are defective.	Replace the pedal unit. See **Subject 100** for instructions.
The slave cylinder is defective.	Replace the slave cylinder. See **Subject 120** for instructions.
The slave cylinder is loose.	Tighten the slave cylinder mounting capscrews 13 lbf·ft (18 N·m).
The wrong type of brake fluid was used.	Replace the complete system. Fill only with approved DOT 4 brake fluid.

Problem–The Clutch Is Slipping

Problem–The Clutch Is Slipping	
Possible Cause	**Remedy**
The clutch is worn.	Replace the clutch.
Contamination (e.g. oil, grease, etc.).	Replace the clutch.
The clutch actuation system is "preloading."	Check the clutch actuation system. See the procedures under the heading "Clutch Actuation System Check."

Problem–The Clutch Switch Does Not Activate

Problem–The Clutch Switch Does Not Activate	
Possible Cause	**Remedy**
The switch contacts are damaged or worn.	Replace the clutch switch assembly. See **Subject 150** for instructions.
The switch wiring is damaged.	Repair the wiring. See **Section 54.00**.
The switch cam is damaged.	Replace the pedal unit. See **Subject 100** for instructions.

Troubleshooting

Problem–The Clutch Pedal Does Not Return

Problem–The Clutch Pedal Does Not Return	
Possible Cause	**Remedy**
The return or assist spring is broken.	Replace the pedal unit. See **Subject 100** for instructions. **WARNING** **Do not attempt to disassemble the preloaded assist spring. Sudden release of the assist spring could cause property damage and serious personal injury.**

Problem–Cruise Control or Engine Brake Does Not Deactivate When the Clutch Pedal Is Pressed Down

Problem–Cruise Control or Engine Brake Does Not Deactivate When the Clutch Pedal Is Pressed Down	
Possible Cause	**Remedy**
The upper position switch is damaged.	Check switch function and make any necessary repairs. See the instructions under the heading "Clutch Switch Check."

Problem–Starter Does Not Operate

Problem–Starter Does Not Operate	
Possible Cause	**Remedy**
The lower position switch is damaged.	Check switch function and make any necessary repairs. See the instructions under the heading "Clutch Switch Check."

Specifications

Torque Values				
Description	**Size**	**Grade/Class**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
Bleed Valve	M7	—	—	88 (1000)
Clutch Switch Mounting Screw	M5	—	—	23 (260)
Hydraulic Sub-Assembly Retainer	—	—	—	44 (500)
Pedal Unit Mounting Plate Capscrews	M8	8.8	13 (18)	—
Slave Cylinder Mounting Capscrews	M8	10.9	13 (18)	—
Standoff Bracket Mounting Capscrews	1/4–20	8	10 (14)	—

Table 1, Torque Values

Removal

1. Apply the parking brakes, chock the tires, put the transmission into high gear, and open the hood.
2. Disconnect the batteries.
3. Drain the air system.
4. Remove the air reservoirs, as needed. For instructions, see **Section 42.06, Subject 120**.
5. If needed, remove the aftertreatment device (ATD). For instructions, see **Section 49.00**.
6. Disconnect the transmission cooler lines from the transmission.
7. As needed, remove the DEF (Diesel Exhaust Fluid) lines. For instructions, see **Section 49.01, Subject 120**.
8. Disconnect the driveline from the transmission output yoke. For instructions, see **Section 41.00**.
9. Disconnect the driveline midship bearing from the midship bearing bracket, and set the driveline out of the way. For instructions, see **Section 41.00**.
10. Remove or disconnect the manual shift linkage, as follows.
    - 10.1 Remove the shift tower boot and air lines.
    - 10.2 Remove the shift tower from inside the cab, and cover the shift tower hole in the top of the transmission to prevent dirt from entering the transmission.

⚠ WARNING

Do not depress the clutch pedal while the slave cylinder is removed from the clutch housing. The slave cylinder piston could be ejected, causing component damage or serious personal injury.

11. Remove the slave cylinder. For instructions, see **Section 25.01, Subject 120**.
12. Disconnect all wiring at the transmission, and mark wires for reassembly.
13. Disconnect all air lines from the transmission, and mark those lines for reassembly. Plug all air lines, and cap all transmission air fittings.
14. Remove any remaining cables, brackets, and lines as needed to remove the transmission.
15. Adjust a transmission jack until it fits securely against the bottom of the transmission, then secure the transmission to the jack with a chain.
16. Remove the flywheel-housing-to-clutch-housing attachment bolts. Keep the flange of the clutch housing parallel (all the way around) to the flange of the flywheel housing, until the input shaft is clear of the clutch.

NOTICE

Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch discs. Taking these precautions will prevent damage to the clutch discs.

17. Pull the transmission and jack straight back, until the transmission input shaft is clear of the clutch and the engine flywheel housing. Lower the transmission. See **Fig. 1**.

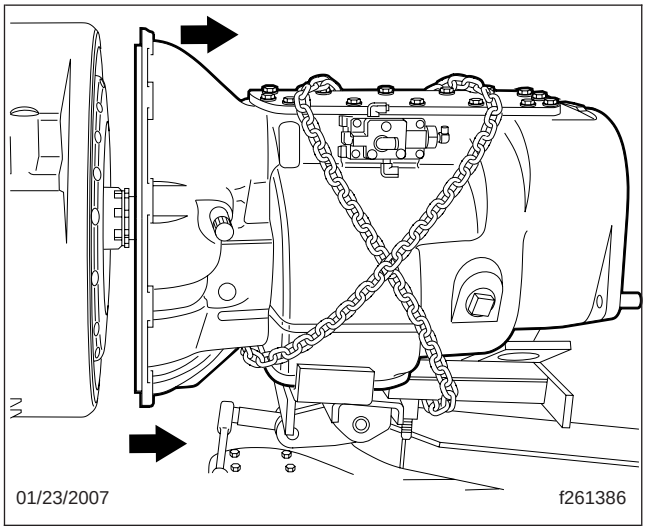


Fig. 1, Transmission Removal

⚠ WARNING

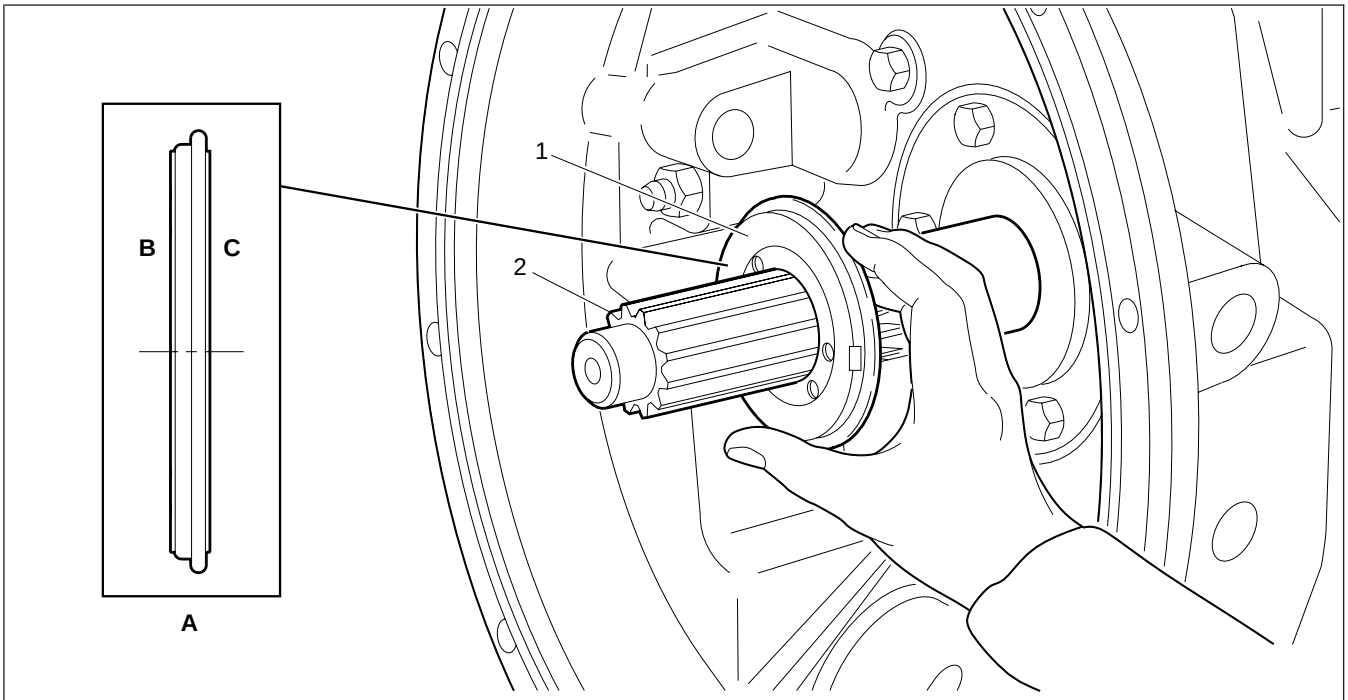
If the front of the vehicle needs to be raised, do not get under the vehicle until it is securely supported by vehicle stands. If the vehicle is supported only by an axle jack, the vehicle can fall, resulting in personal injury or property damage.

18. If needed, raise the front axle of the vehicle until you can remove the transmission by rolling it out behind the front tire.

Removal and Installation

Installation

1. If the clutch brake was removed, install the clutch brake on the transmission input shaft. See **Fig. 2**. Slide it tight against the input shaft bearing cap.
3. Shift the transmission into gear so that the transmission input shaft can be rotated during assembly to line it up with the clutch driven disc hub splines.
4. Roll the transmission and jack into alignment behind the engine. Raise the transmission jack support plate until the flange of the clutch housing is parallel (all the way around) to the flange of the flywheel housing. Align the transmission input shaft with the hole in the release bearing sleeve.



A. Cross section of clutch brake
B. Install deep side toward release bearing
C. Install shallow side toward the transmission

1. Clutch Brake
2. Input Shaft

Fig. 2, Clutch Brake Installation

IMPORTANT: Torque-limiting clutch brakes are a one-piece assembly with a thicker and a thinner face. When installing a torque-limiting clutch brake on an Eaton Fuller transmission, install the *thinner* face toward the transmission.

2. Check for wear on the fingers of the clutch release yoke, release shafts, and the release shaft bushings. Replace worn parts as necessary.

NOTE: If necessary, wipe the input shaft clean with a clean, dry cloth. It is not necessary to lubricate the input shaft.

5. While making sure the flanges remain parallel, push the transmission and jack straight forward until the transmission input shaft begins to enter the clutch release bearing.

6. Rotate the clutch release yoke fingers forward, and rotate the release bearing so the release yoke fingers align with the release bearing wear pads. Roll the transmission slowly forward. Raise or lower the transmission as needed to maintain alignment.

IMPORTANT: Be sure that the release yoke clears the release bearing, and is rotated under the wear pads as the transmission is moved forward. Align the input shaft splines with the clutch disc splines by turning the transmission output shaft.

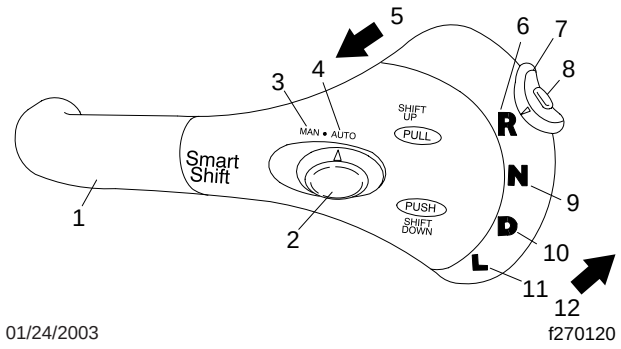
NOTICE

Use care to avoid springing the drive discs when the transmission is being installed. Do not force the transmission into the clutch or flywheel housing if it does not enter freely. Do not let the transmission drop or hang unsupported in the driven discs. These practices can damage the clutch assembly.

7. Push the transmission forward until the clutch housing pilot flange enters the flywheel housing pilot bore. Install the flywheel-housing-to-clutch-housing attachment capscrews, and using a crisscross pattern, tighten them finger-tight. Then, using the same crisscross pattern, tighten the capscrews either 43 to 53 lbf·ft (58 to 72 N·m) for Patch-Lok capscrews, or 38 to 45 lbf·ft (52 to 61 N·m) for non-locking capscrews with lockwashers.
8. Remove the chain that secures the transmission to the jack, and remove the jack from under the vehicle.
9. Install or connect the shift linkage, as follows.
   - 9.1 Install the shift tower inside the cab.
   - 9.2 Install the air lines and shift boot.
10. If removed, install the ATD. For instructions, see **Section 49.00**.
11. Connect the air lines and wiring to the transmission as previously marked.
12. Connect the clutch release lever to the clutch release shaft. Tighten the nut 26 lbf·ft (35 N·m).
13. Connect the driveline to the transmission output yoke. For instructions, see **Section 41.00**.
14. Connect the midship bearing to the midship bearing bracket. For instructions, see **Section 41.00**.
15. If removed, install the DEF lines. For instructions, see **Section 49.01, Subject 120**.
16. Connect the transmission cooler lines to the transmission.
17. Attach any remaining cables, brackets, and lines, as removed.
18. Install the air reservoirs on the vehicle. For instructions, see **Section 42.06, Subject 120**.
19. Connect the batteries.
20. Grease the clutch release bearing and the release shafts. For instructions, see **Group 25** of the *108SD and 114SD Maintenance Manual*.
21. Check the clutch for proper clutch brake operation. For instructions, refer to the *108SD and 114SD Driver's Manual*.
22. Start the engine and run it until the air system pressurizes to at least 80 psi (550 kPa).

General Information

The SmartShift™ transmission shift control (**Fig. 1**) is an electronic transmission control device. The SmartShift control replaces either the typical floor-mounted shift lever or dash-mounted pushbutton control. It mounts to the right-hand side of the steering column and is operated by the driver's right hand. SmartShift accepts driver requests for transmission functions and transmits them through hard wiring to the transmission control unit (TCU). SmartShift is a true shift-by-wire system.



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To upshift manually, pull the lever up (towards you). To downshift manually, push the lever down (away from you).

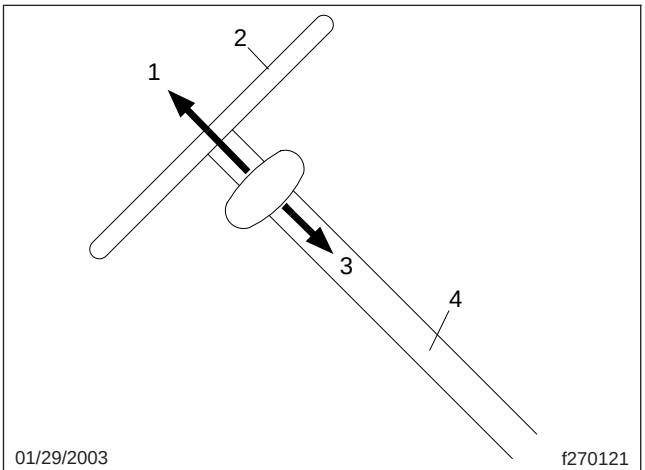
1. SmartShift Control Lever
2. Slide Switch (forward driving mode switch)
3. MAN Mode (of slide switch)
4. AUTO Mode (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Low Position (of selector switch)
12. Downshift Direction

Fig. 1, SmartShift Control

A two-position slide switch allows the driver to choose automatic (AUTO) or manual (MAN) mode. In AUTO mode, gears shift automatically, without driver interaction. In MAN mode, the driver has direct control over gear shifts. Manual gear shifts are accomplished by a momentary pull or push on the control lever in the plane perpendicular to the steering wheel. See **Fig. 2**. All shifts into reverse (R) are done manually.

Pull upward (toward you) on the control lever to upshift and push downward (away from you) to downshift. The lever is spring-loaded and returns to mid-position when released after an upshift or downshift.

The selector switch is located at the end of the control lever. Embedded in the selector switch is a small neutral lock button to prevent accidental shifts into gear from neutral. Any time you shift through N, press down on the neutral lock button to move the switch from neutral (N) to another gear. When shifting to N, it is not necessary to press the neutral lock button.



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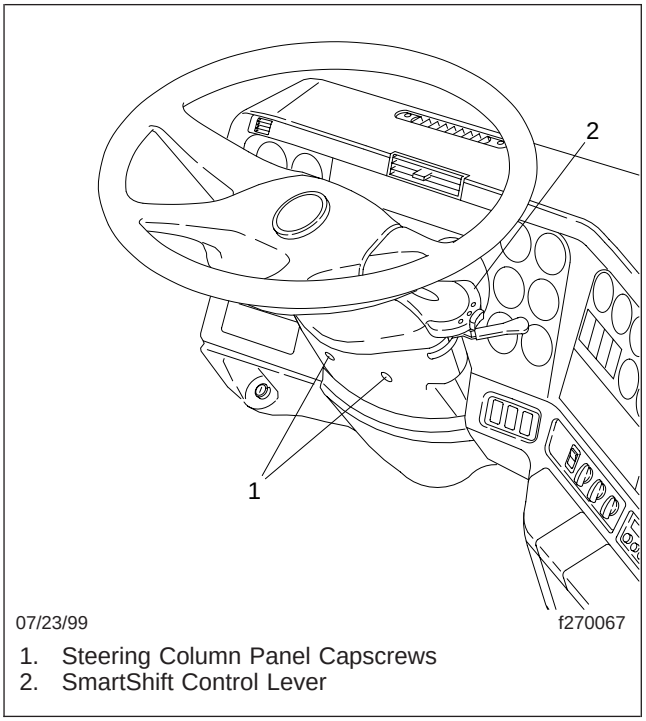
1. Upshift (in manual mode, pull upward)
2. Steering Wheel
3. Downshift (in manual mode, push downward)
4. Steering Column

Fig. 2, SmartShift Control Lever Operation

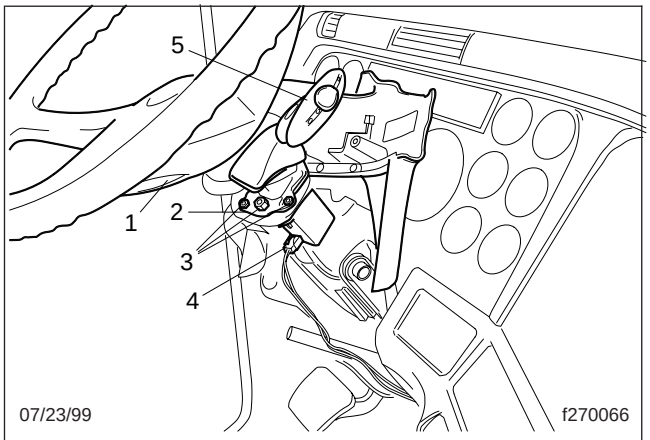
Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the screws that secure the steering column trim panels, and separate the forward and rear panels to access the shift control. See **Fig. 1**.
3. Disconnect the electrical connector from the plug on the shift control unit. See **Fig. 2**.
4. Remove the three bolts that secure the control lever to the bracket on the column.
5. Remove the control lever.
6. Place the new lever into position and secure it using the nuts and bolts previously removed.
7. Connect the electrical connector to the control lever.
8. Using the screws previously removed, fasten the upper and lower column panels.



1. Steering Column Panel Capscrews
2. SmartShift Control Lever

Fig. 1, Steering Column



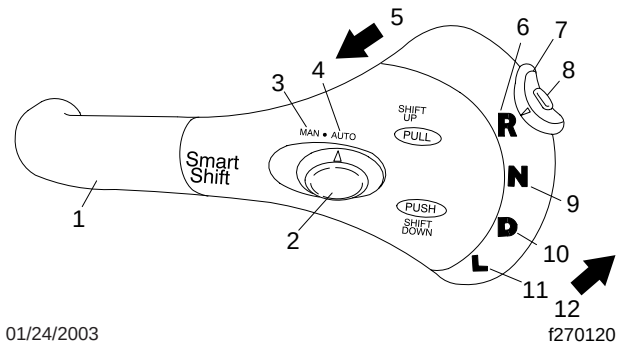
1. Steering Wheel
2. Control Lever Bracket
3. Nuts and Bolts
4. Electrical Connector
5. Control Lever

Fig. 2, SmartShift Control Lever Installation

NOTE: The information in this subject applies to vehicles with Eaton Fuller AutoShift, UltraShift, and UltraShift PLUS transmissions.

General Information

The following information is provided to help determine whether a problem is with the transmission or the SmartShift® Transmission Shift Control (**Fig. 1**).



1. SmartShift Control Lever
2. Slide Switch (forward driving mode switch)
3. MAN Mode (of slide switch)
4. AUTO Mode (of slide switch)
5. Upshift Direction
6. Reverse Position (of selector switch)
7. Selector Switch
8. Neutral Lock Button
9. Neutral Position (of selector switch)
10. Drive Position (of selector switch)
11. Low Position (of selector switch)
12. Downshift Direction

Fig. 1, SmartShift Control

Resistance checks at the SmartShift connector can help determine connection problems.

DataLink Software can be used to test the SmartShift control. The tests require a ServiceLink computer connected to the vehicle. If the tests confirm the shift control is defective, this subject also includes connector resistance checks to rule out wiring issues.

Follow the procedures below for resistance checking and Freightliner SmartShift testing using DataLink Monitor and dash displays.

Shift Control Resistance Checking

Parts

See **Table 1** for parts.

Parts for Wire Extension*		
Part Number	**Description**	**Qty.**
PAC12110847	Metri-Pack Terminal	3
PAC12047767	Connector Terminal	3
48-02493-184	18GA GTX Wire, Yellow	3 ft x 3
PAC12047781	3-Pin Connector	1
PAC12047783	Connector Lock	1

* Parts are available through the PDCs.

Table 1, Parts for Wire Extension

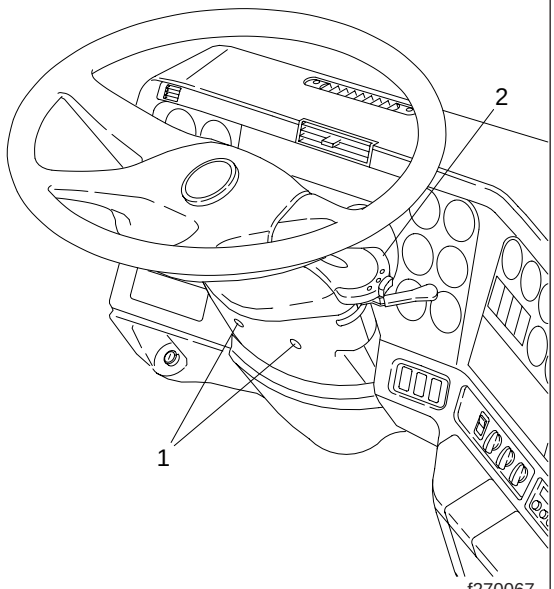
Procedure

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the screws that secure the steering column trim panels, and separate the forward and rear panels to access the shift control. See **Fig. 2**.
3. Disconnect the electrical connector from the plug on the shift control unit. See **Fig. 3**.
4. Assemble the wire extension from the parts in **Table 1** to allow for easy resistance testing, as follows.
   - 4.1 Crimp the connector terminals at the end of each 3-foot (1-meter) wire.
   - 4.2 Assemble the 3-pin connector with the connector terminals and connector lock.
   - 4.3 Crimp the Metri-Pack terminals on the other end of the wires.
5. Plug the wire extension into the plug on the shift control unit. See **Fig. 4** for SmartShift terminal positions.

NOTE: Using this new wire extension prevents the need to remove the shift control.

6. Check the resistance at the other end of the wires. See **Fig. 5**, **Table 2**, and **Table 3**.

Troubleshooting



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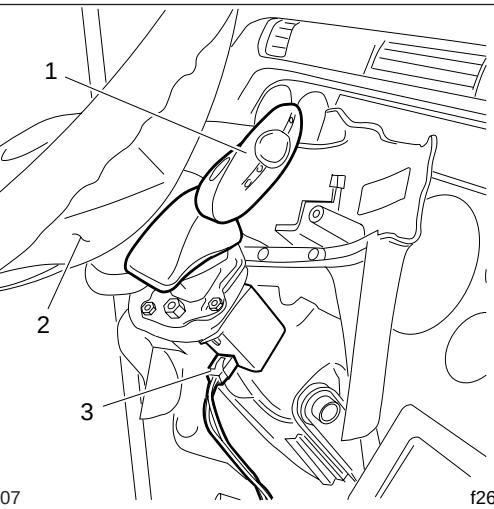
1. Steering Column Panel Capscrews
2. Shift Control

Fig. 2, Steering Column



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1. Shift Control
2. Steering Wheel
3. Electrical Connector

Fig. 3, SmartShift Components

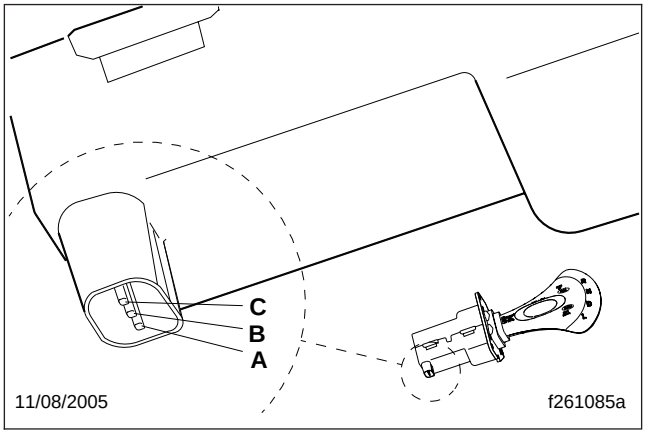

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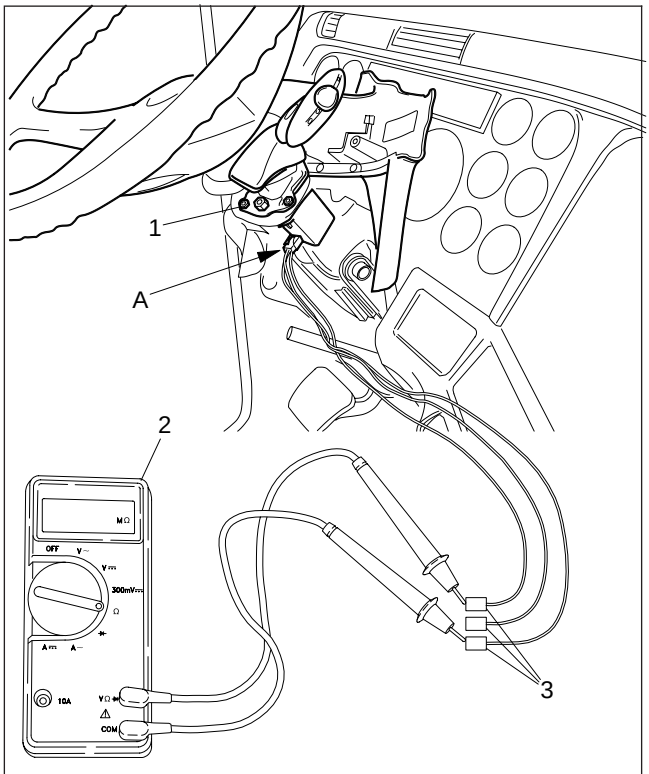
Fig. 4, SmartShift Terminal Positions



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A. Plug the newly assembled wire extension into the plug on the shift control unit.

1. Shift Control Unit
2. Digital Multimeter (set to ohms)
3. Metri-Pack Terminals (at wire ends)

Fig. 5, Resistance Checking at Shift Control

Resistance on SmartShift Controls at B and C	
Selector Switch Position	**Reading: kOhm**
R	2.947–3.067
N	0.347–0.361
D	0.606–0.630
L	1.65–1.72

Table 2, Resistance on SmartShift Controls at B and C

Resistance on SmartShift Controls at A and C	
Slide Switch + Lever Position	**Reading: kOhm**
Manual	2.865–2.981
Manual + Up	0.531–0.553
Manual + Down	1.150–1.197
Auto	11.27–11.73

Table 3, Resistance on SmartShift Controls at A and C

7. After checking the resistance, unplug the wire extension, and reconnect the electrical connector.
8. Install the steering column trim panels.

SmartShift Control Checking Using DataLink Monitor (DLM)

1. With the wheels chocked, start the engine.
2. Connect the service computer to the engine and start ServiceLink.
3. Click on the **Transmission** icon on the left screen.
4. Click on the **Templates** tab. From the pull-down menu, select **Eaton AutoShift**.

   The AutoShift DataLink Monitor template (see **Fig. 6**) will display the current vehicle status and will reflect change in status. Vehicle information is retrieved from the transmission ECU on the datalink. The monitor can also be used to verify readings on the instrument panel.

NOTE: To test the shift control using the datalink, the vehicle can be placed into a mode that allows the gears to be shifted without the engine running. The following step explains how to enter that mode.

5. Turn the ignition OFF, then turn the ignition back ON, but don't start the engine. The transmission controller will still be in the Engine ON mode, thereby allowing the gears to be shifted.
6. Test the operation of the shift control for Reverse (R) and Neutral (N), as follows.

   6.1 Select R on the selector switch. In the *Range Selected* field of the template an R should be displayed.

   6.2 Select N on the selector switch. In the *Range Selected* field of the template an N should be displayed.
7. Test the operation of the shift control for Drive (D), as follows.

   7.1 Select D on the selector switch and move the slide switch (reading "MAN/AUTO") to AUTO. In the *Range Selected* field of the template, a D should be displayed.

   7.2 With the selector switch still on D, toggle the slide switch from AUTO to MAN and back. Confirm that the *Range Selected* field shows a D while in AUTO and an H (High) while in MAN.

   7.3 While in Manual mode, change the selector switch to L (Low) and confirm that the *Range Selected* field changes from H to L.
8. Test upshifting and downshifting, as follows.

   8.1 With the selector switch on D, pull and hold the shift control lever. The *Up-Shift* field will turn green and read ON for 3 seconds.

   8.2 Push and hold the shift control lever. The *Down-Shift* field will turn green and read ON for 3 seconds.

NOTE: A blinking display indicates that the transmission is attempting to shift into the gear position. A solid display shows the current gear position attained.

9. When the selector switch is in any position but N (Neutral), the *Status* field on the Monitor template will read YES.

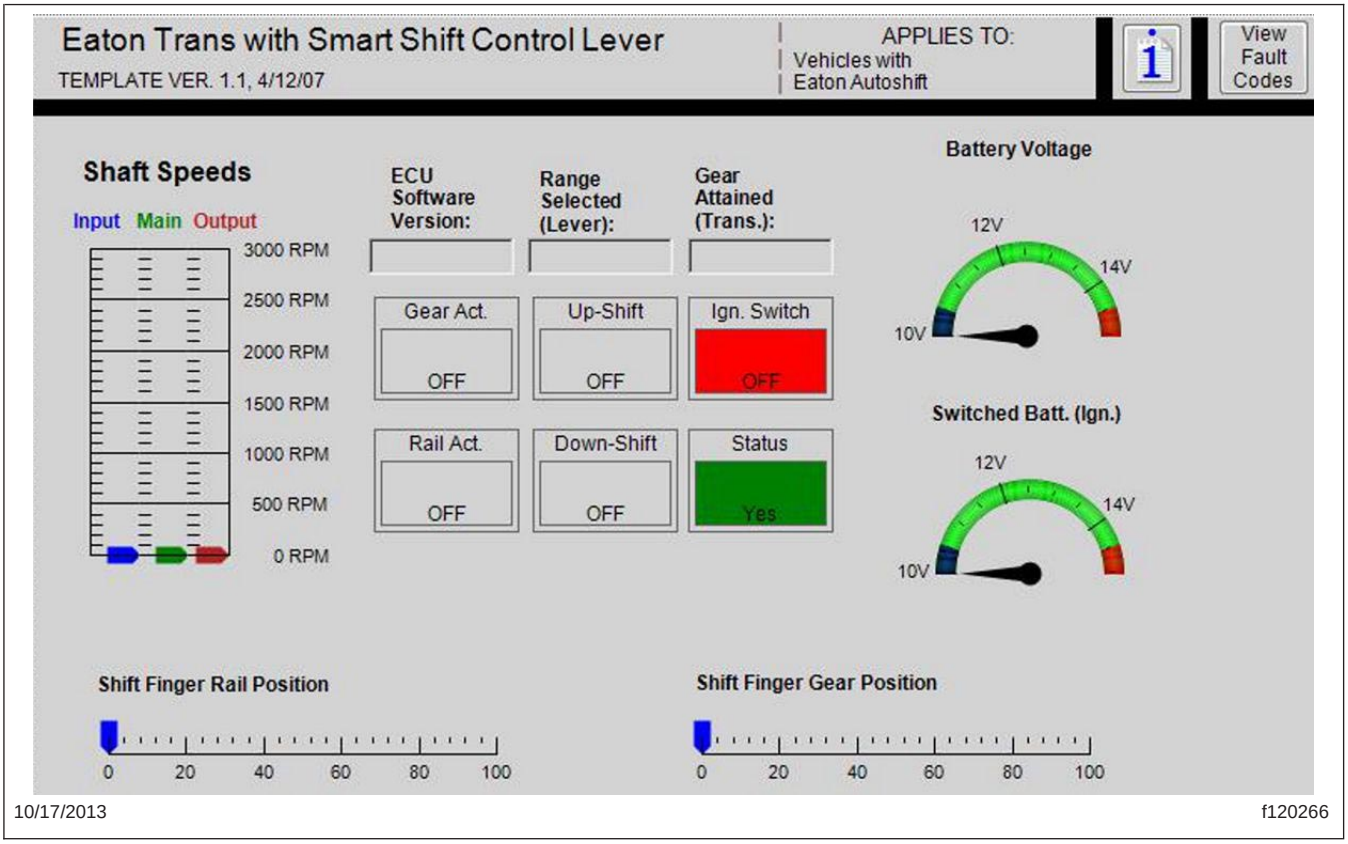

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Fig. 6, DataLink Monitor Template for Eaton AutoShift

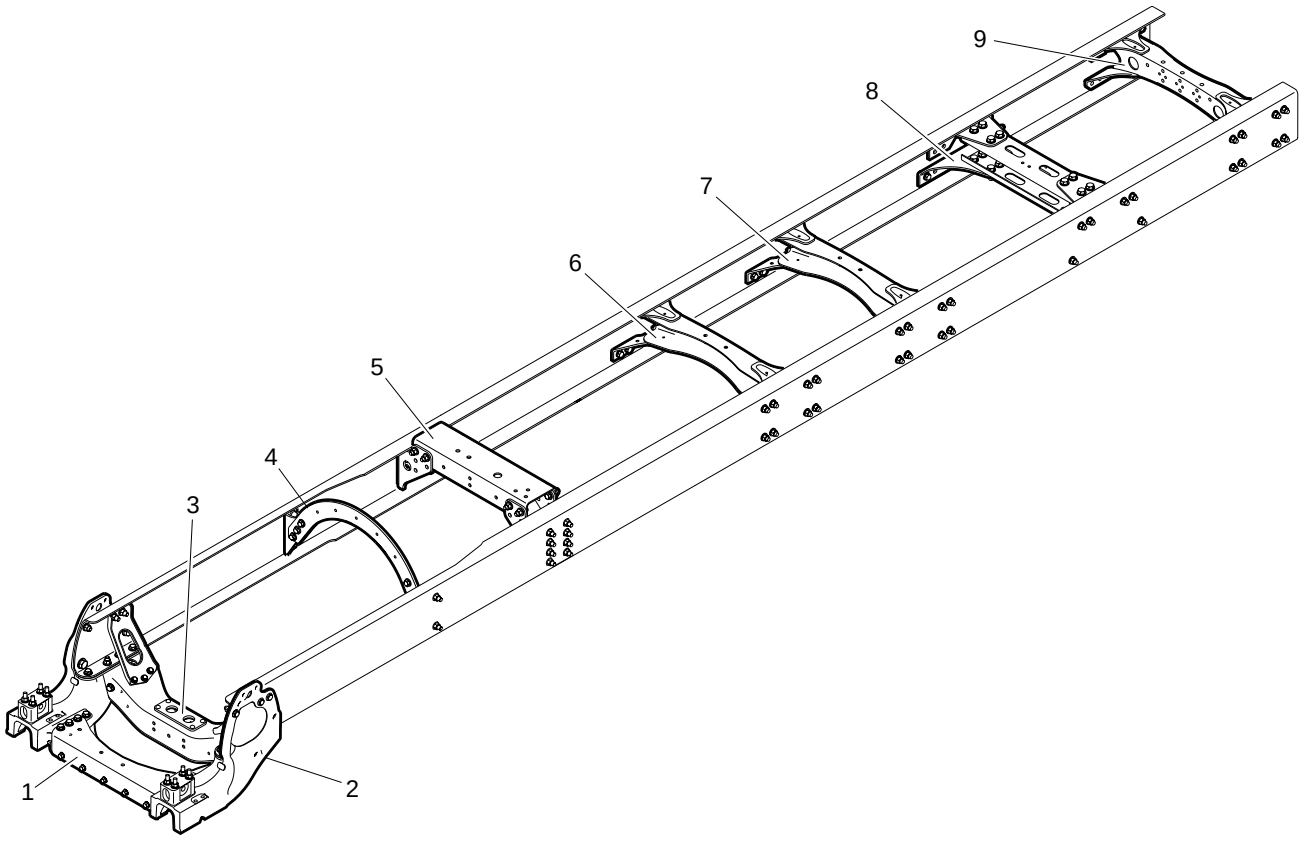
General Description

IMPORTANT: This coverage *does not include* the procedures and calculations necessary to make frame modifications. Consult your regional service representative before making any modification to the frame rails.

The main body of the frame consists of two frame rails connected by a series of crossmembers. See **Fig. 1**. The frame supports the rest of the chassis and body.

The frame rails are made of steel, and both have identical specifications. Each rail has an upper flange, lower flange, and web (the surface area between the flanges). The inside area of the frame rail is called the channel. See **Fig. 2**.

The crossmembers control axial rotation and longitudinal motion of the rails, and reduce torsional stress transmitted from one rail to the other. Crossmembers are also used for vehicle component mounting, and protecting the wires and tubing that are routed from one side of the vehicle to the other.



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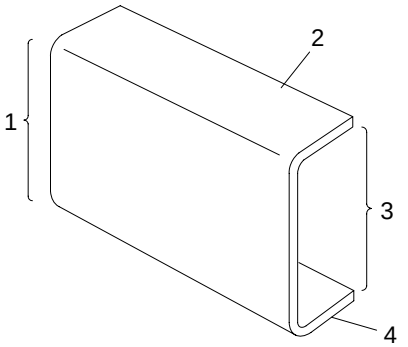
1. Front-Closing Crossmember–Module 550
2. Frame-Extension Bracket – Module 550
3. Engine Crossmember–Module 550
4. Overslung Crossmember–Module 560
5. Back-of-Transmission Crossmember–Module 561
6. Midship Crossmember–Module 562, 563, and 564
7. Forward-Rear-Suspension Crossmember (when shared with suspension bracket)–Module 565
8. Rearmost-Rear-Suspension Crossmember–Module 565
9. Rear-Closing Crossmember–Module 572

Fig. 1, Frame Assembly and Crossmembers

General Information



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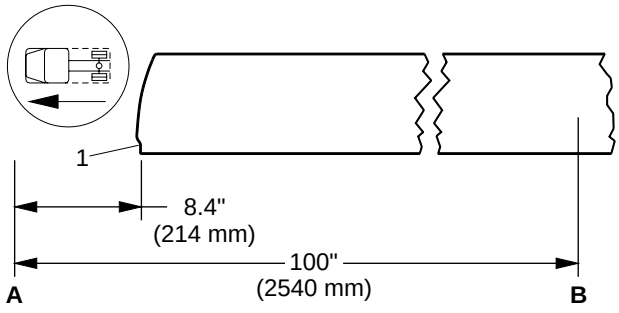
1. Web
2. Upper Flange
3. Channel
4. Lower Flange

Fig. 2, Frame Terminology

Frame Stations

A frame station is a reference point from which the location of each component mounted on the frame rail is measured. There are two frame stations: station zero; and station 2540.

Station zero is located 8.4 inches (214 mm) forward of the most forward edge of the frame rail. See **Fig. 3**.



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A. Station Zero (0.00)
B. Station 2540
1. Front Edge of Frame Rail

Fig. 3, Frame Rail Stations

Station 2540 is located 100 inches (2540 mm) to the rear of station zero. Station 2540 is used when station zero is not accessible because of vehicle assembly. Station 2540 is identified by three vertical center-punch marks on the frame rail web. In some cases, however, these marks may be obscured by a vehicle component.

The vehicle's frame drilling chart lists the location of each frame rail component. For example, if a component is given a location of 3000, then that component is installed on the frame rail 118-1/8 inches (3000 mm) aft of station zero, and 18-1/8 inches (460 mm) aft of station 2540.

Handling

Whenever the frame rails are lifted or moved, take care to avoid anything that may scratch, cut, or damage the exposed frame assembly. Cushion all chain hoists or cable slings with a section of heavy hose. If the frame rail is raised with a jack, place a block of wood between the jack and the frame rail.

NOTICE

Heating the frame rail for straightening purposes will reduce the strength of the rail in localized areas, which can result in structural failure of the frame rail.

Never heat the frame rails for straightening purposes. Such work should be done cold because the frame rails have been heat-treated.

Use pencil lines or soapstone for marking the frame rail. High visibility can be obtained by first chalking the surface of the frame rail, then making the pencil marks.

Welding Precautions

WARNING

Improper welding technique may fatigue the frame and lead to structural failure and serious personal injury. The frame rails are made of heat treated steel. Only experienced, qualified persons using proper equipment should attempt welding the frame rails.

WARNING

Wear protective welding masks and gloves when welding. Failure to do so could result in personal injury, due to the intensity of heat, sparks, and flying debris.

NOTICE

The vehicle is equipped with electronic control units. Serious damage to ECUs and components may result when welding unless the following precautions are taken.

- Never allow an electronic component to be situated between the ground electrode and the weld site.
- Never lay welding cables on, near, or across any electronic component or wiring.
- Protect electronic components and wiring near the weld site from heat and splatter.
- Disconnect the battery power and ground cables.

Before welding, prepare the vehicle as follows.

1. Park the vehicle, shut down the engine, and set the parking brake. Chock the front and rear tires.
2. Disconnect the battery negative cables first, then the positive cables. Take precautions to prevent them from making connection with the frame or any other electrically conductive surface.
3. If a supplemental restraint system (SRS) is installed, disconnect it.
4. Disconnect all wiring from electronic control modules near the weld site.
5. Attach the ground electrode as close as possible to the weld site (within 18 inches).
6. Remove paint, rust, and grease to provide a clean, bare metal connection for the ground electrode. When welding work is completed, apply touch-up paint to protect the frame rail.

Repairing Frame Rail Cracks, Filling Unused Holes, and Drilling Holes

Repairing Cracks

IMPORTANT: Cracked or damaged frame rails should be replaced. However, in some cases it may be necessary to repair minor damage. Before attempting any repairs, contact your regional service representative for approval.

CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 050. Failure to follow the safety precautions can result in personal injury.

NOTICE

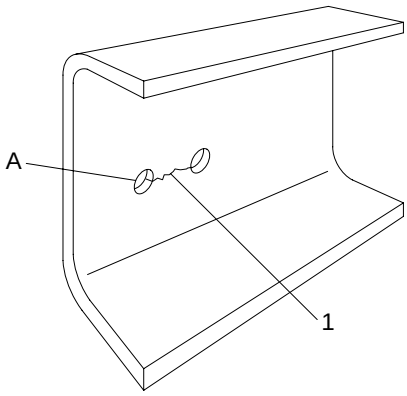
Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs. Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post, or disconnect the main connection at the ECU.

1. Drill a 1/8-inch (3-mm) diameter hole at each end of the crack to prevent further spreading of the crack. See Fig. 1.
2. Grind a V-shaped groove along the crack to a depth of two-thirds of the stock thickness. See Fig. 2.

NOTE: The crack repair includes grinding a groove on each side of the frame rail. If it is not possible to grind both sides of the rail, then grind the groove on one side to the full depth of the stock thickness. See Fig. 3.

3. Clamp a copper or aluminum bar on the opposite side of the groove. The bar will act as a "chill" strip, keeping the heat from spreading to the surrounding area of the frame rail. See Fig. 4.



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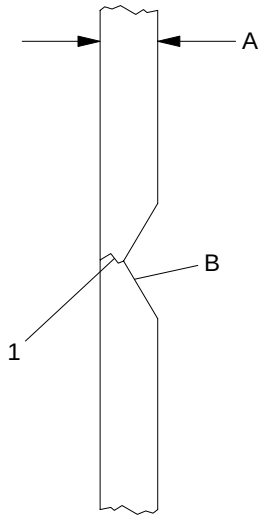
A. 1/8-inch (3-mm) Diameter Hole
1. Crack

Fig. 1, Preventing Cracks from Spreading



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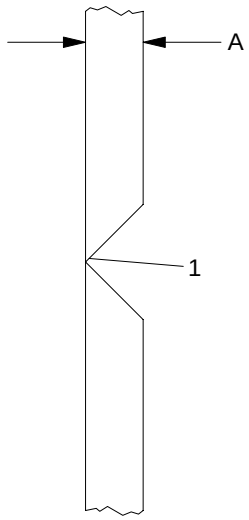
A. Frame Rail Thickness
B. Grind V-groove to 2/3 depth of stock thickness.
1. Crack

Fig. 2, Frame Rail Cross-Section

4. Using the applicable welding method described in Subject 110, deposit the weld material in the groove.
5. Grind the weld flush with the frame rail. See Fig. 5.

Repairing Frame Rail Cracks, Filling Unused Holes, and Drilling Holes



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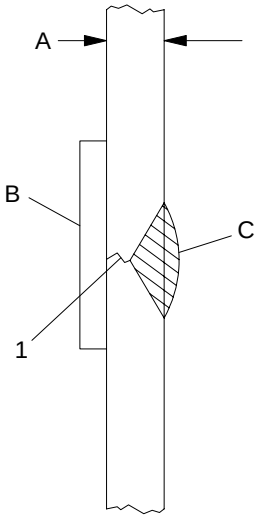
A. Frame Rail Thickness

1. V-Groove (Full Depth)

Fig. 3, Full-Depth Groove



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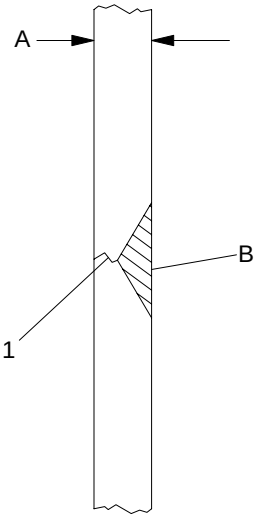
A. Frame Rail Thickness
B. Clamp the "chill" strip on opposite side of groove.
C. Deposit weld material.

1. Crack

Fig. 4, Using a Chill Strip

6. Cut a deep enough V-groove on the opposite side of the frame rail to reach the weld metal. See **Fig. 6**.



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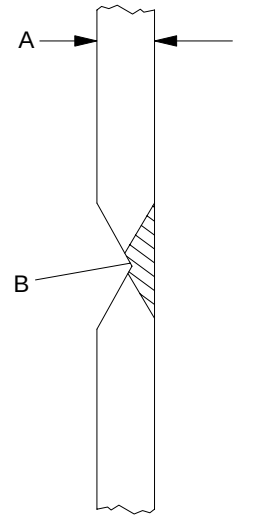
A. Frame Rail Thickness
B. Grind weld flush with frame rail.

1. Crack

Fig. 5, Weld Ground Flush



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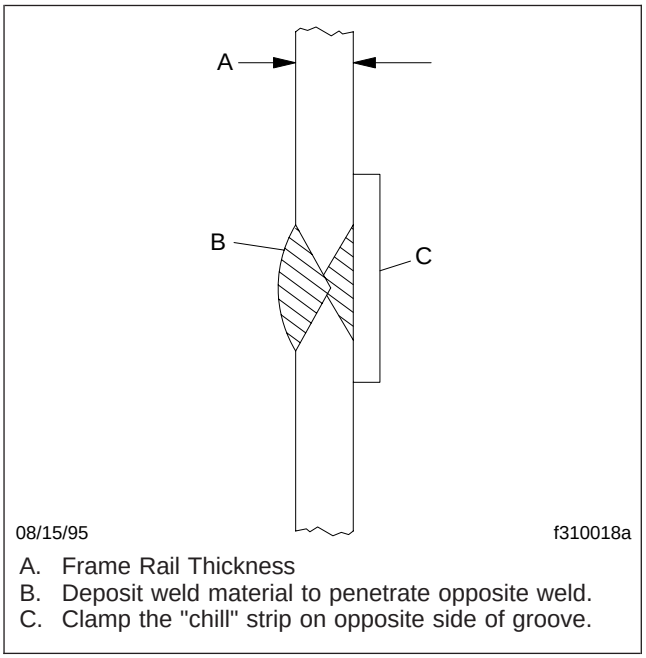
A. Frame Rail Thickness
B. Grind V-groove deep enough to reach weld.

Fig. 6, Cross-Section View

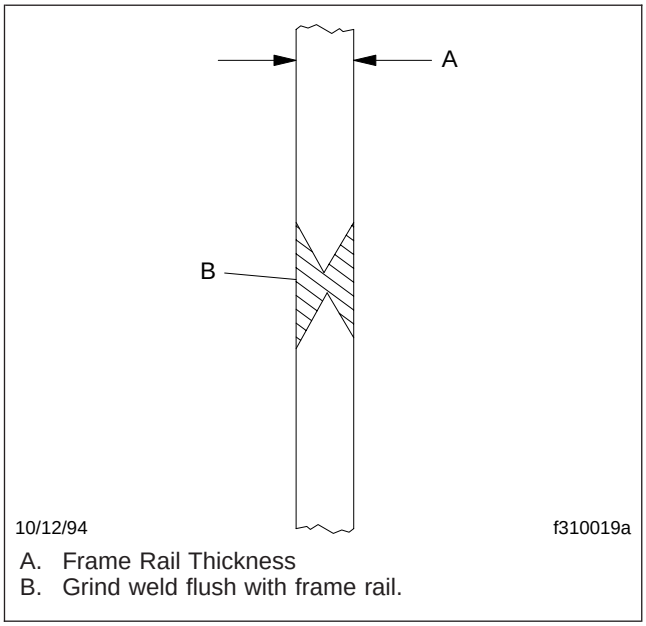
Repairing Frame Rail Cracks, Filling Unused Holes, and Drilling Holes

7. Clamp the "chill" strip on the opposite side of the groove. See **Fig. 7**. Weld the V-groove; make full penetration of the weld.
8. Grind the weld flush with the frame rail. See **Fig. 8**.



A. Frame Rail Thickness
B. Deposit weld material to penetrate opposite weld.
C. Clamp the "chill" strip on opposite side of groove.

Fig. 7, Second Weld



A. Frame Rail Thickness
B. Grind weld flush with frame rail.

Fig. 8, Second Weld Ground Flush

Filling Unused Holes

1. Fill all unused holes in the frame assembly with an applicable nut, washer, and bolt combination.
2. If the diameter of a hole is less than 3/8 inch (9.5 mm), enlarge it to 3/8 inch (9.5 mm) and fill it with an applicable nut, washer, and bolt combination.
3. Tighten the fasteners to the torque value specified for the bolt size. For proper frame fastening instructions, see **Subject 160**.

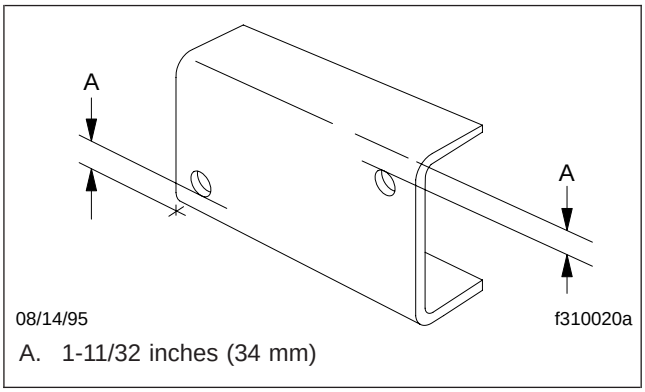
Drilling Holes

During vehicle manufacture, holes are drilled or punched in the frame rail only as specified on the vehicle frame drilling chart. If any additional holes need to be drilled, contact your regional service representative for approval.

A single exception to this rule is that holes may be drilled for tubing clips and the like through the web portion of the channel only, with the following restrictions:

- The *edge* (not the center) of the hole must be no closer than 1-11/32 inches (34 mm) from the outer face of the flange. See **Fig. 9** for the minimum distance to the flanges that holes can be placed on the web.
- Material between the centerline of the hole and the outside of the upper or lower flange must be at least 2-13/32 inches (60 mm).
- Minimum material between hole centerlines must be 2 inches (50 mm).
- All attaching fasteners must be Grade 8. Flat washers must be made with high strength steel.
- The minimum material between the rear suspension bracket and the end of the frame must be at least 2 inches (50 mm).
- Holes between the front frame structure—including front frame bracket—and the rearmost suspension bracket cannot exceed 3/4 inches (19 mm).

Repairing Frame Rail Cracks, Filling Unused Holes, and Drilling Holes



A. 1-11/32 inches (34 mm)

Fig. 9, Minimum Distance for Drilling Holes

Welding Requirements

IMPORTANT: Before welding anything on a frame rail, contact your regional service representative for approval. There are very few cases in which welding a heat-treated frame rail is allowable. If possible, avoid direct welding of the frame rail web.

CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 050. Failure to follow the safety precautions can result in personal injury.

NOTICE

Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs. Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post, or disconnect the main connection at the ECU.

NOTICE

Weld only as instructed in this subject; all precautions and methods must be strictly followed. Failure to do so can reduce the structural strength in the welded area of the frame rail.

Read and comply with the following requirements.

- Do not weld attachments to the frame rail.
- Use only the applicable welding method under "Welding Methods."
- Before welding, clean off any oil, grease, paint, scale, and other contaminants. Wipe dry with a clean cloth.
- Do not weld in an area that allows drafts from any source such as windows, engines, or fans, as it will affect the soft flow of gas from the welding gun.
- Do not weld into the radius of the frame rail flanges or along the edge of the flange.
- Do not weld square with the frame side rail. Make all reinforcing welds at least 30 degrees from square. This will distribute the weld stresses over a larger area.
- Do not notch, undercut, or leave craters during the welding process.
- Keep as close to the weld centerline as possible.

Welding Methods

Gas-metal arc welding is the recommended method. If gas-metal arc welding is not available, coated-electrode arc welding can be used.

For both gas-metal arc welding and coated-electrode arc welding, direct current reverse polarity is recommended; however, alternating current can be used. Use either a short arc beading technique or a narrow weave technique.

Gas-Metal Arc Welding

For the gas-metal arc welding method:

- Use weld wire that meets American Welding Society (AWS) specification A 5.28, Class E110S.
- Use Linde M-5 gas or an equivalent argon-oxygen mixture of 5 percent oxygen.
- For machine settings, see **Specifications 400**.

Coated-Electrode Arc Welding

For the coated-electrode arc welding method:

- Use 1/8-inch-thick AWS-E-11018 type weld rod.
- For amperage and voltage settings of each weld position, see **Specifications, 400**.

NOTE: On 1/4-inch-thick frame rails only, AWS-E-9018 type weld rod can be used, however, AWS-E-11018 type weld rod is recommended.

IMPORTANT: Always keep the weld rod free of moisture. The welding rod should be taken from a hermetically sealed container immediately be-

Welding Frame Rails

fore use, or be dried at least one hour in a 700 to 800°F (371 to 427°C) oven. Immediately after removal from a sealed container or after drying, store the welding rod in an oven at 250°F (121°C). A welding rod that has been exposed to the atmosphere longer than one-half hour must be dried before use.

Lengthening Frame Rails

Steel frame rails can be lengthened by welding an extension onto the rear of the frame rail. The end of the frame rail and the extension piece are cut so that they overlap each other. Obtain approval from your regional service representative before welding and lengthening the frame rail.

CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 050. Failure to follow the safety precautions can result in personal injury.

NOTICE

Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs. Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post, or disconnect the main connection at the ECU.

1. Cut the frame-rail end and extension to the applicable dimensions. See Fig. 1 for truck dimensions, or Fig. 2 for tractor dimensions. Refer only to the figure that relates to the vehicle being modified.

NOTE: If the length of the extension is to be 6 inches (152 mm) or less, straight-cut the frame rail end and extension.

2. Grind the cut ends of the frame rail and extension to the dimensions in Fig. 3.
3. Align the cut ends of the extension piece with the cut ends of the frame rail, so that there is a 1/16- to 1/8-inch (1.5- to 3-mm) gap between them. See Fig. 3. Using a torch, heat the cut ends to 70°F (21°C), if necessary, before welding.

NOTE: A 1/16-inch (1.6-mm) gap is recommended. The ends must not contact each other.

Maintain the joint spacing by placing a short piece of clean, 1/16-inch (1.6-mm) diameter bare steel wire between the extension and frame rail. The wire sections must be short enough to be completely fused by the welding process.

NOTICE

Weld the web area first, making sure that the flanges do not contact each other. Residual stresses will occur in the weld if the web area is not welded first, or if the flanges contact each other when welding the web.

4. Using one of the methods in Subject 110, weld the extension to the frame rail, making full penetration. See Fig. 4. Weld the web area first, then the flange, working from the inside of the channel. When welding the web, make sure that the flanges do not contact each other.

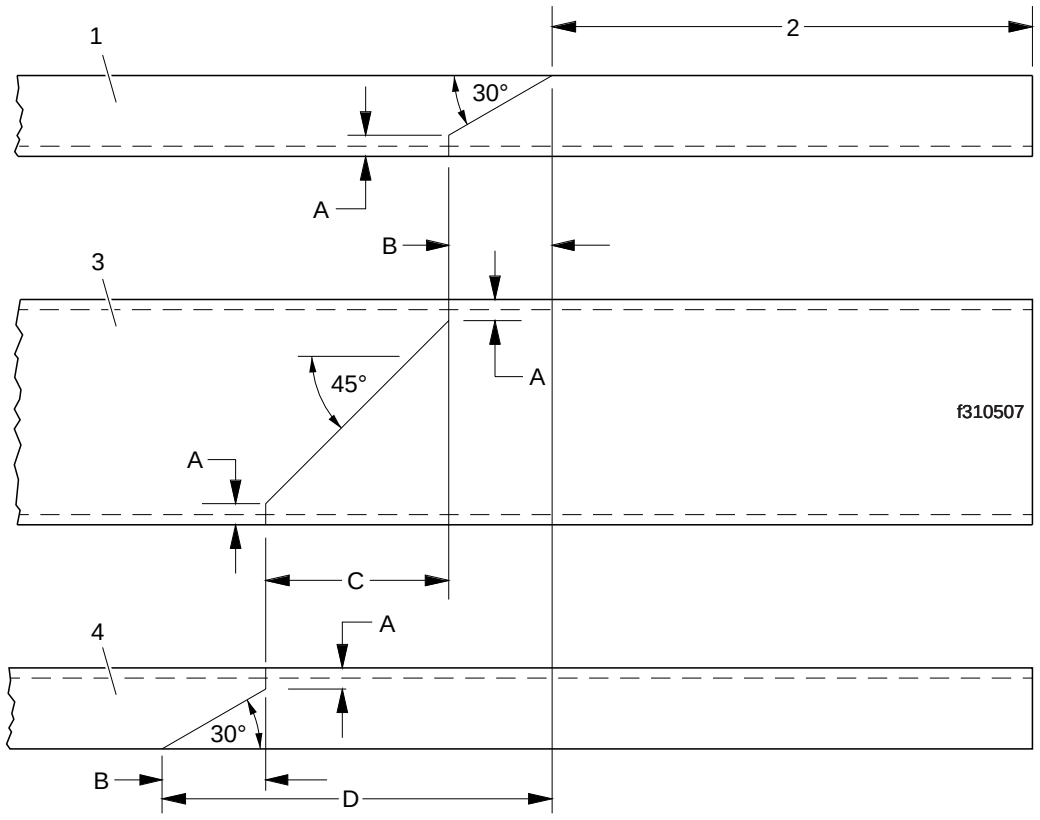
   Remove any slag between passes and back-gouge the root of the first vee before welding the other side.

NOTICE

Do not "hollow grind" the weld. Small depressions from improper grinding of the weld will reduce the strength of the frame rail.

5. When finished welding, sand the joint for appearance. Hold the sander so that the grind runs parallel with the length of the frame rail.

Lengthening Frame Rails



NOTE: Left rail shown; right rail will be opposite dimensions.

FRAME RAIL SIZE inches	DIMENSION			
	A inches (mm)	B inches (mm)	C inches (mm)	D inches (mm)
10.06	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)
10.12	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)

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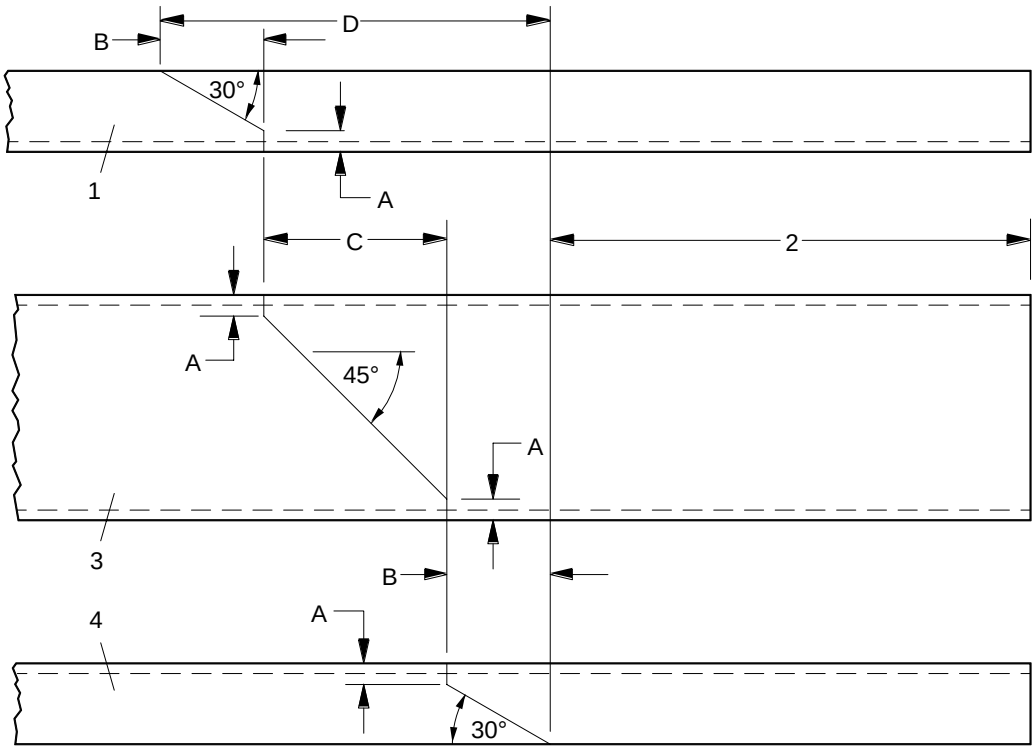
1. Upper Flange
2. Extension Length
3. Web
4. Lower Flange

Fig. 1, Frame Rail and Extension Cutting Dimensions for Truck Vehicles



NOTE: Left rail shown; right rail will be opposite dimensions.

FRAME RAIL SIZE inches	DIMENSION			
	A inches (mm)	B inches (mm)	C inches (mm)	D inches (mm)
10.06	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)
10.12	0.69 (17.5)	5.00 (127.0)	8.75 (222.2)	18.75 (476.2)

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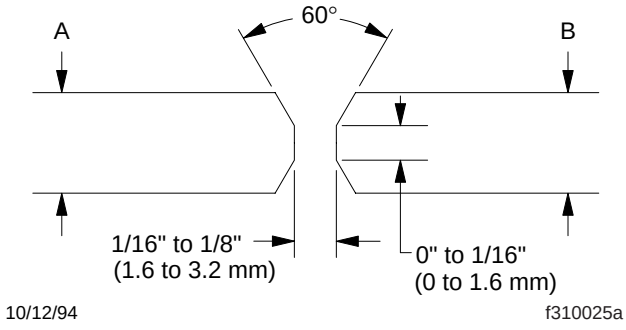
1. Upper Flange
2. Extension Length
3. Web
4. Lower Flange

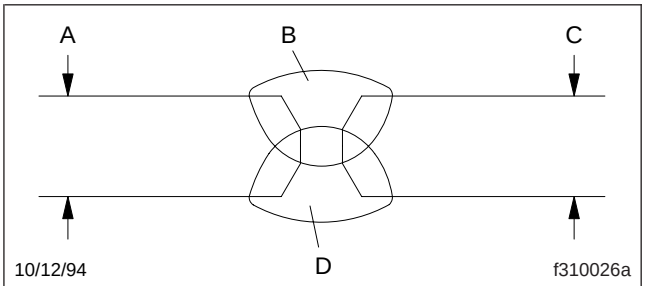
Fig. 2, Frame Rail and Extension Cutting Dimensions for Tractor Vehicles

Lengthening Frame Rails



A. Frame Rail Thickness
B. Extension Thickness

Fig. 3, Grinding Dimensions



A. Frame Rail Thickness
B. First Weld
C. Extension Thickness
D. Second weld penetrates the first weld.

Fig. 4, Correct Weld Penetration

Frame Crossmember Removal and Installation

General Information

The placement of crossmembers affects the overall stability of the frame. If a crossmember is being eliminated, added, or relocated, contact your regional service representative for instructions and approval.

See **Subject 050** for an overview of a typical frame assembly with crossmembers.

Before working on a crossmember that is mounted on the vehicle, park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the front and rear tires.

Where threaded fasteners are used, save them to use with the new crossmember. To aid assembly, note which frame fasteners are installed with the threads facing to the inside of the frame, and which are installed outward facing. Tighten frame fasteners to the torque value shown in **Specifications, 400**, in this section.

Where Huck® fasteners are used, see **Subject 160** in this section, for replacement instructions.

If it is necessary to remove the hood to access a crossmember, see **Section 88.00, Subject 100** in this manual for instructions.

If it is necessary to remove the front bumper to access a crossmember, see **Section 31.01, Subject 100** in this manual for instructions.

Set-Forward Axle, Front-Closing Crossmember and Front-Frame-Extension Bracket

Front-Closing Crossmember

Removal

1. Remove the front bumper.
2. Remove the hood.
3. Remove the fasteners that attach the crossmember to the front-frame-extension brackets, then remove the lower and upper crossmember. See **Fig. 1**.

Installation

1. Set the upper crossmember piece on the frame extension brackets, then position the lower crossmember and install the fasteners, hand tightening them, making any adjustments needed to properly align the components. See **Fig. 1**.
2. Tighten the fasteners to the torque value shown in **Specifications, 400**.
3. Install the hood.
4. Install the bumper.

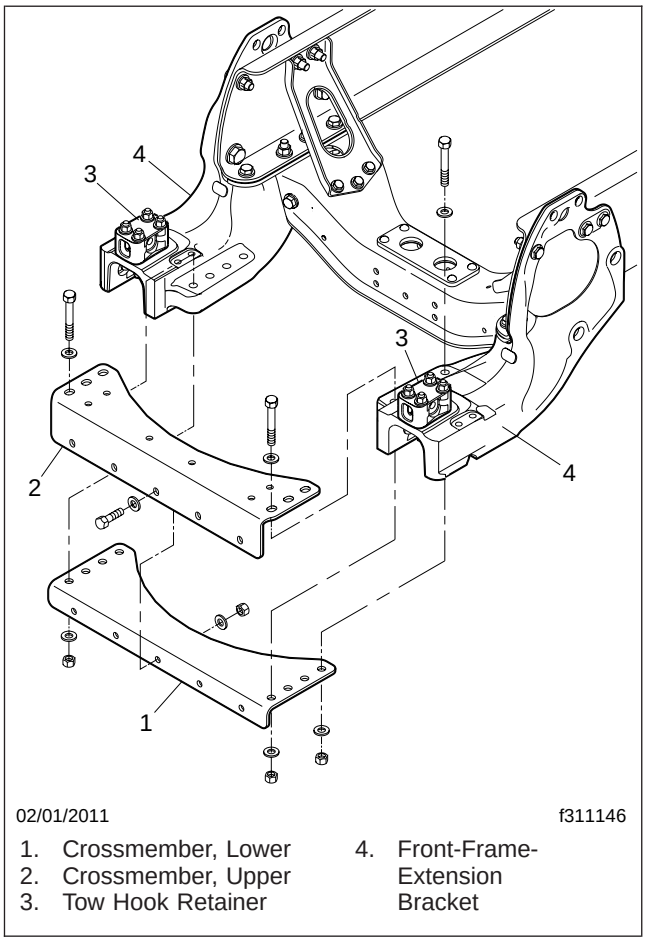


Fig. 1, Front-Closing Crossmember for Set-Forward Axle

Front-Frame-Extension Bracket

Removal

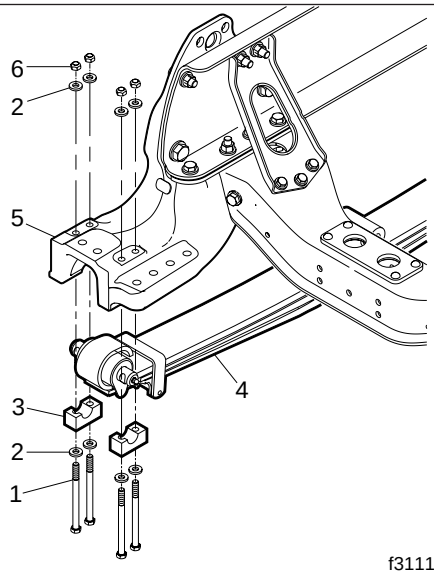
1. Remove the front bumper.
2. Remove the hood.
3. Drain the air system.

Frame Crossmember Removal and Installation

4. Raise the vehicle, so that there is no weight compressing the front suspension, then support the frame with safety stands.
5. Support the front of the engine from the forward-upper hook point.

IMPORTANT: Confirm that the weight of the vehicle is still on the safety stands that support the frame.

6. Remove the front spring assembly from the front-frame-extension bracket.
   - 6.1 Remove the four capscrews.
   - 6.2 Remove the two spring-pin retainers. See **Fig. 2**.



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1. Capscrew
2. Washer
3. Spring-Pin Retainer
4. Front Spring
5. Front-Frame-Extension Bracket
6. Locknut

Fig. 2, Removing the Front of the Spring

7. As required, remove any air hoses or wiring that attach to the front-frame-extension brackets. Detach any equipment that is mounted on the front-frame-extension bracket.

   IMPORTANT: If an air dryer assembly or fuel filter/separator assembly is mounted to the bracket, remove the fasteners, then secure the assembly with tie straps. Do not allow it to dangle.

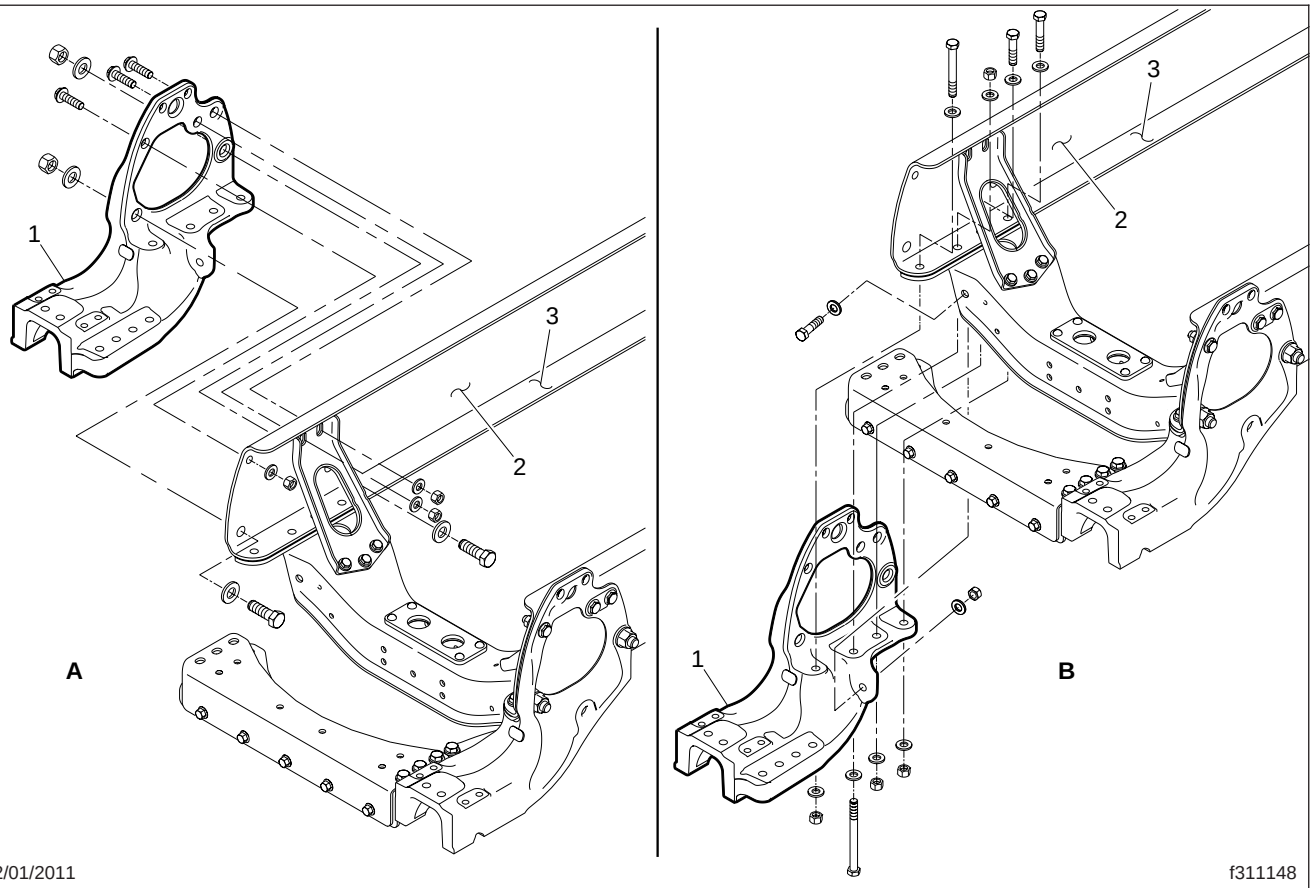
8. Remove the fasteners that attach the front-closing crossmember to the front-frame-extension bracket that is to be replaced, leaving the crossmember attached to the opposite side.
9. Remove the fasteners that attach the front-frame-extension bracket to the frame-rail web. See **Fig. 3**.
10. Remove the fasteners that attach the bracket to the frame-rail flange. See **Fig. 3**.
11. Remove the bracket, leaving the front-closing crossmember attached on the opposite side of the vehicle.

Installation

1. Attach the front-frame-extension bracket to the frame rail. Hand-tighten the fasteners, making any adjustments needed to properly align the components.

NOTE: Hand-tightening the fasteners allows for some play in the brackets, which is helpful when attaching the front-closing crossmember.

2. Attach the front-spring assembly to the front-frame-extension bracket.
   - 2.1 Install the capscrews upward through the retainers and the front-frame-extension bracket.
   - 2.2 Attach the locknuts and tighten them evenly to 68 lbf·ft (92 N·m), maintaining equal clearance between the retainers and the bracket.
3. Install the front-closing crossmember, and tow hooks. Tighten the frame fasteners to the torque value shown in **Specifications, 400**.
4. If harnesses were removed, pass the harnesses through the hole in the front frame-extension bracket and secure them with tie straps.
5. Remove the engine hoist.
6. Remove the safety stands.
7. If an air dryer assembly or fuel filter/separator assembly was removed, install it.
8. Install the hood.
9. Install the bumper.



A. Remove the fasteners from the frame-rail web and the bracket.

B. Remove the fasteners from the frame-rail flange and the bracket

1. Front-Frame-Extension Bracket
2. Frame-Rail Web
3. Frame-Rail Flange

Fig. 3, Front-Frame-Extension Bracket Removal

Setback Axle, Front-Closing Crossmember

Removal

1. Remove any components that are attached to the crossmember channels and brackets.
2. Remove the crossmember channels and brackets from the frame. See **Fig. 4**

Installation

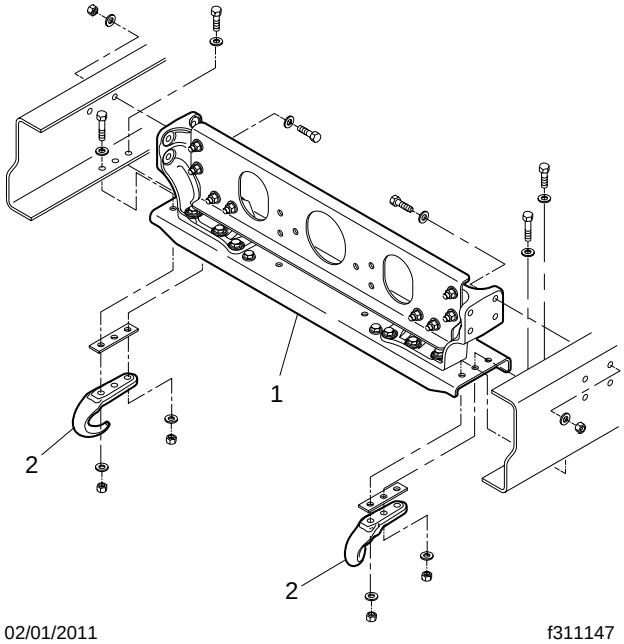
1. Install the crossmember channels and brackets on the frame.
2. Tighten the frame fasteners to the torque value shown in **Specifications, 400**.
3. Install any components that were removed from the crossmember channels and brackets.

Engine Crossmember

Removal

1. Remove the bumper.
2. Remove the hood.
3. Drain the air system.

Frame Crossmember Removal and Installation



1. Closing Crossmember Assembly
2. Tow Hook

Fig. 4, Front-Closing Crossmember, Setback Axle

4. Raise the vehicle, so that there is no weight compressing the front suspension, then support the frame with safety stands.
5. Support the front of the engine from the forward-upper hook point.

IMPORTANT: Confirm that the weight of the vehicle is still on the safety stands that support the frame.

6. Remove any air valves, lines, and hoses that may be attached to the crossmember.
7. Remove the two engine-mount bolts that secure the front engine mount to the crossmember. See **Fig. 5**.
8. Remove the fasteners that attach the engine crossmember to the frame rail, and front frame-extension brackets.
9. On set-forward-axle configurations, follow the instructions previously in this subject to remove the front-frame-extension brackets.

   For set-back axles, remove the fasteners that attach the engine crossmember to the crossmember brackets.
10. Slide the crossmember out from under the vehicle.

Installation

1. Slide the new crossmember into place.
2. Install the engine-mount bolts, but do not tighten them at this time.
3. On set-forward-axle configurations, attach the front-spring assembly to the front frame-extension bracket.

   3.1 Install the retaining bolts up through the front frame-extension bracket and attach the retainers.

   3.2 Tighten the nuts evenly to 68 lbf·ft (92 N·m) maintaining equal clearance between the retainers and the bracket.
4. Install the fasteners that attach the crossmember to the frame and front frame-extension brackets. Tighten the frame fasteners to the torque value shown in **Specifications, 400**.
5. Install any air valves, brackets, air lines, or hoses that were removed.
6. Remove the engine hoist.
7. Remove the safety stands.
8. Install the hood.
9. Install the front bumper.

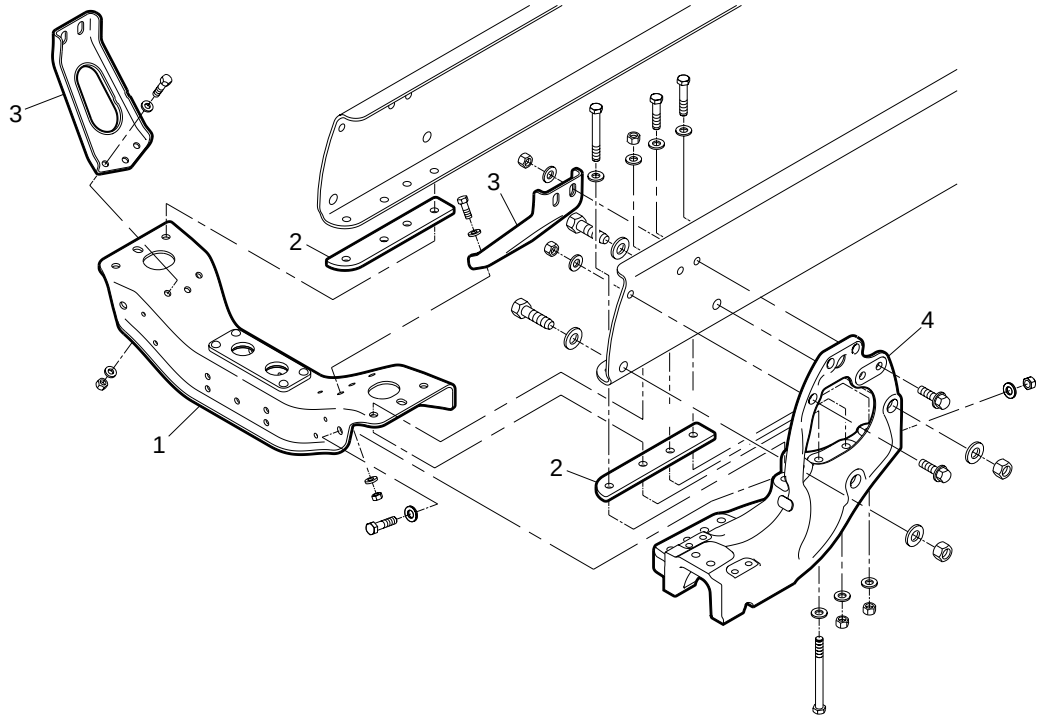
Overslung Crossmember

Removal

1. Remove the fasteners that attach the crossmember to the mounting brackets. See **Fig. 6**.
2. Lower the crossmember to remove it from the vehicle.

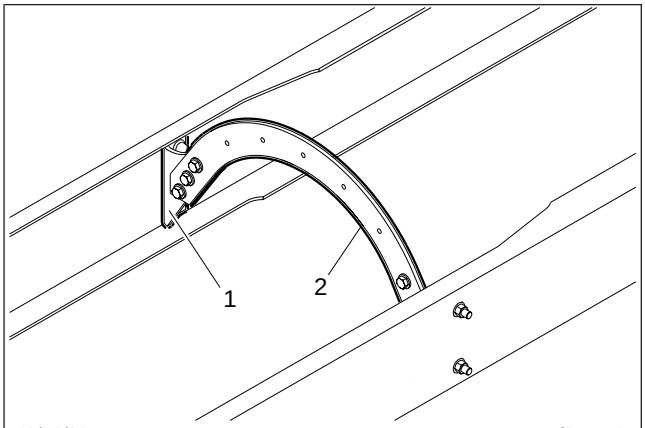
Installation

1. Align the holes in the crossmember with the holes in the mounting brackets.
2. Install the fasteners that attach the crossmember to the mounting brackets.



1. Engine Crossmember
2. Spacer
3. Mounting Bracket
4. LH Front Frame-Extension Bracket

Fig. 5, Front Engine Crossmember Removal



1. Mounting Bracket
2. Overslung Crossmember

Fig. 6, Overslung Crossmember Installation

3. Tighten the 5/8–11 fasteners for the mounting brackets to the torque value shown in **Specifications, 400**.

Back-of-Cab Crossmember

Removal

This style of crossmember is used to the rear of the day cab.

1. Remove the cab suspension from the crossmember.
   - 1.1 Disconnect the cab leveling-valve linkage from the cab.
   - 1.2 Manually operating the leveling valve, fill the air bags to maximum height.
   - 1.3 Support the cab in the raised position.

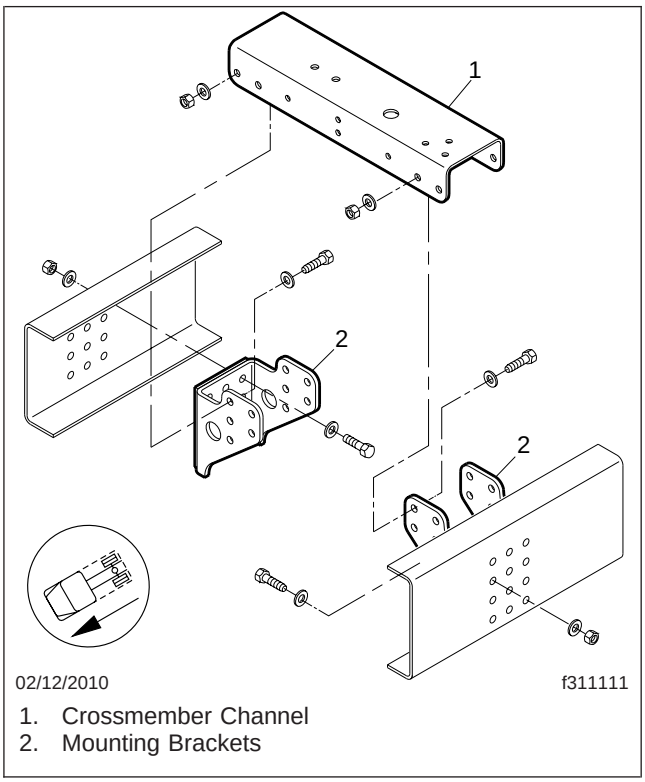
Frame Crossmember Removal and Installation

IMPORTANT: Confirm that there is back-up support, as the cab will remain raised for the remainder of the procedure.

1.4 Manually operating the leveling valve, exhaust the air from the air bags.

1.5 Remove the air bags, cab shock absorbers, hoses, harnesses, and brackets that are attached to the crossmember.

2. Remove the fasteners that attach the crossmember and any mounting brackets that are being replaced, then remove the crossmember. See **Fig. 7**.



1. Crossmember Channel
2. Mounting Brackets

Fig. 7, Back-of-Cab Crossmember (day cabs)

NOTE: It may necessary to remove one or both of the gussets in order to remove the crossmember.

Installation

1. Place the crossmember and gussets in position, then install the fasteners finger tight. After all the fasteners are installed, tighten them 136 lbf·ft (184 N·m).
2. Attach any brackets, hoses, and harnesses that were removed.
3. Attach the cab suspension.

3.1 Install the air bag brackets, air bags, shock absorbers, and any other components that were removed.

3.2 Manually moving the leveling-valve lever arm slightly downward, slowly inflate the air bags until they are completely inflated.

3.3 Connect the leveling-valve linkage.

3.4 Remove the cab supports.

Midship Welded Crossmember

Five- or six-piece welded midship crossmembers are factory installed as midship-bearing crossmembers, or rear suspension crossmembers. See **Fig. 8**. When a five- or six-piece welded crossmember is replaced, a bolted crossmember is installed as a service replacement.

IMPORTANT: See the applicable parts technical bulletin for service replacement part numbers.

The following instructions are for removal of the five-piece welded midship crossmember, then the installation of a five-piece bolted crossmember.

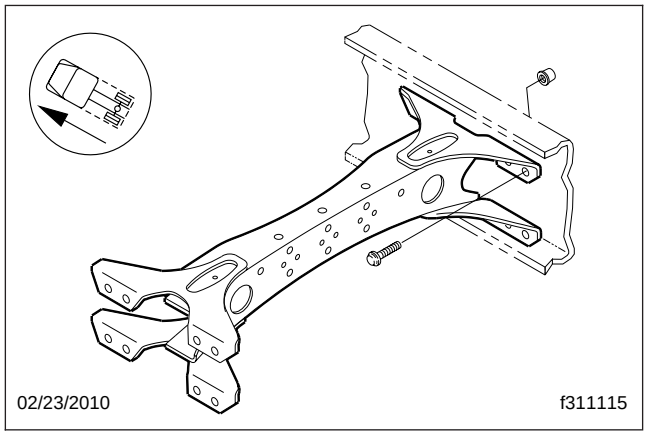


Fig. 8, Midship Five-Piece Welded Crossmember

Frame Crossmember Removal and Installation

Removal

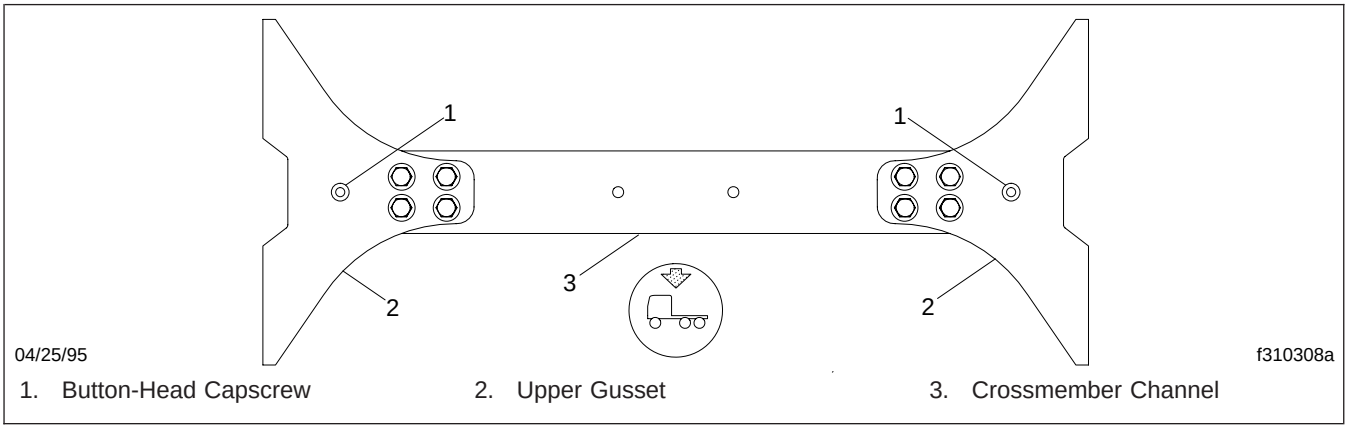
1. If an air brake valve is attached to the crossmember, drain the air reservoirs, then remove the valve from the crossmember.
2. Remove any clamps that attach air lines or wiring to the crossmember, and secure the lines or wiring away from the crossmember.
3. If replacing a forward-rear-suspension crossmember with suspension brackets that share frame fasteners with the crossmember, use safety stands to support the rear of the frame at a height that the tires are just touching the floor, so there is no weight on the suspension.
4. If replacing a midship-bearing crossmember, support the driveline on a safety stand, then remove the the midship-bearing bracket from the crossmember.
5. Using a metal-cutting reciprocating saw or cutting torch, cut the crossmember channel into two pieces. A slightly diagonal cut will make removal of the crossmember pieces easier.
6. Remove the fasteners that attach the crossmember halves to the frame rails, and remove the crossmember.

Installation, Service Crossmember

1. Attach one new upper gusset to the crossmember channel. Tighten the fasteners snugly, but not to final torque value. See **Fig. 9**.
2. Place the crossmember channel and gusset in the frame rails, with the channel opening facing the same direction as the original crossmember. Position the crossmember so the channel is resting on the lower flanges of both frame rails.
3. Slide the other upper gusset into position and attach it to the crossmember channel. Tighten the fasteners snugly, but not to their final torque value.
4. With the crossmember channel resting on the lower flanges of both frame rails, tighten the locknuts on the button-head capscrews at the outboard end of both upper gussets 68 lbf·ft (92 N·m). See **Fig. 9**.

NOTE: The locknuts must be tightened now since, when the crossmember is in place, the frame upper flange blocks access to the capscrews.

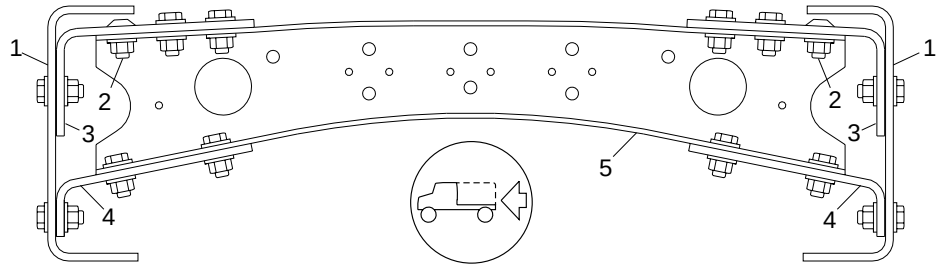
5. Using a dead-blow hammer, tap the crossmember into place. Align the mounting holes of the upper gussets with the holes in the frame rails. Install the fasteners, but do not tighten them. Attach the suspension bracket with the same capscrews, if they were removed.
6. Place the lower gussets in position against the crossmember channel and insert the fasteners that secure the gussets to the channel. See **Fig. 10**.
7. Reposition any frame mounted components such as fuel tank brackets, then install the fasteners that attach the gussets to the frame rails. Attach



1. Button-Head Capscrew 2. Upper Gusset 3. Crossmember Channel

Fig. 9, Five-Piece Bolted Crossmember, Top View

Frame Crossmember Removal and Installation



1. Frame Rail
2. Button-Head Capscrew
3. Upper Gusset
4. Lower Gusset
5. Crossmember Channel

Fig. 10, Five-Piece Bolted Crossmember, Rear View

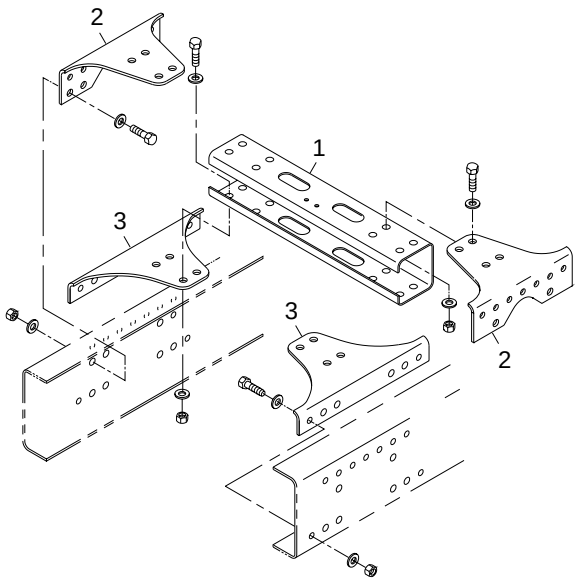
the suspension bracket with the same capscrews, if they were removed.

8. Tighten the fasteners that secure the gussets to the frame rails 136 lbf·ft (184 N·m). Then, tighten the fasteners that secure the gussets to the crossmember 68 lbf·ft (92 N·m).
9. If the driveline was disconnected, attach the midship bearing bracket to the crossmember.
10. Remove the supports.

Rearmost Rear-Suspension (Channel) Crossmember

Removal

1. Use safety stands to support the rear of the frame at a height that the tires are just touching the floor, so there is no weight on the suspension.
2. Disconnect any suspension torque-rod brackets that are attached to the crossmember. Note the number and location of any spacers.
3. If any air valves or components are attached to the crossmember channel, drain the air reservoirs, then remove the valve from the crossmember.
4. Remove all fasteners that attach the crossmember channel to the upper and lower gussets. See **Fig. 11**.
5. Remove any gussets that will interfere with the crossmember center channel removal. Note the direction the fasteners are installed.



1. Crossmember Channel
2. Upper Gusset
3. Lower Gusset

Fig. 11, Rearmost Rear-Suspension Crossmember

6. Work the crossmember out of the top or bottom of the frame rails.

Installation

1. Install the crossmember, gussets, and any frame spacers (if used), in the reverse order in which they were removed. Be sure the spacers are installed in the same location noted during removal.

IMPORTANT: Be sure to install fasteners in the same direction that was noted during removal.

2. Tighten the frame fasteners to the torque value shown in **Specifications, 400**.
3. Attach any air valves or clamps that were removed from the crossmember during disassembly.
4. Attach any suspension torque rods that were disconnected.
5. Remove the supports.

Rear-Closing Crossmember

Five-piece welded midship crossmembers are factory installed as rear-closing crossmembers. When a five-piece welded crossmember is replaced, a bolted crossmember is installed as a service replacement.

IMPORTANT: See the applicable parts technical bulletin for service replacement part numbers.

The following instructions are for removal of the five-piece welded rear-closing crossmember, then the installation of a five-piece bolted service crossmember.

Removal

1. Remove the taillights from the rear-closing crossmember. If equipped, remove the backup alarm.

IMPORTANT: Some mudflap brackets are spring-loaded and may recoil violently when disconnected improperly.

2. Remove the rear mudflap brackets and fasteners. If the mudflap bracket is spring loaded, to prevent the spring from recoiling violently during removal, push downward on the outboard end of the mudflap and insert a screwdriver between the anchor of the spring and the bracket, before removing it. See **Fig. 12**.
3. Remove any components that are attached to the crossmember.
4. Remove the fasteners that attach the crossmember to the frame rails. See **Fig. 13**.
5. Slide the crossmember out through the rear of the frame. The crossmember may need to be cut into two pieces if there is a body or other welded attachment blocking the rear of the frame.

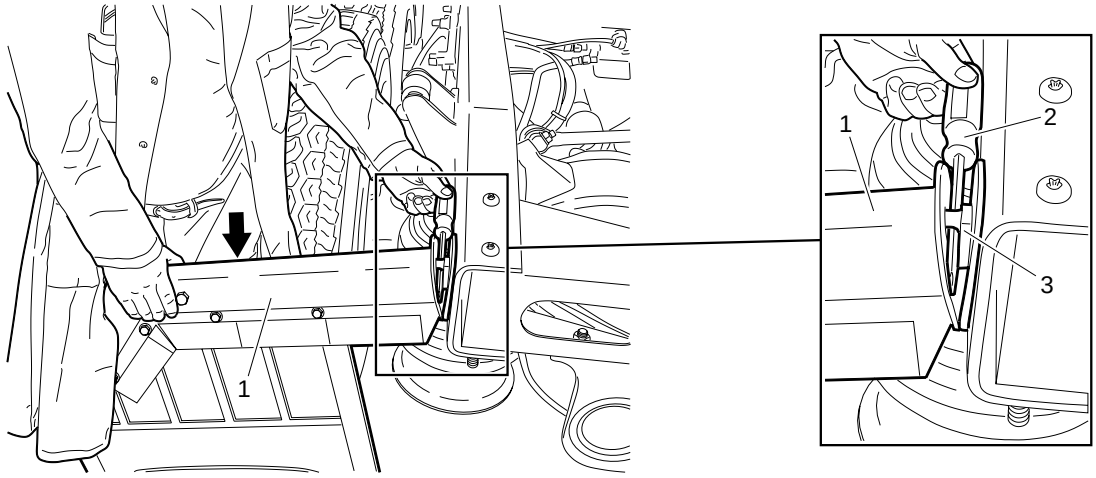
Installation, Service Crossmember

1. Attach one new upper gusset to the crossmember channel. Tighten the fasteners snugly, but not to final torque value. See **Fig. 9**.
2. Place the crossmember channel and gusset in the frame rails, with the channel opening facing the same direction as the original crossmember. Position the crossmember so the channel is resting on the lower flanges of both frame rails.
3. Slide the other upper gusset into position and attach it to the crossmember channel. Tighten the fasteners snugly, but not to their final torque value.
4. With the crossmember channel resting on the lower flanges of both frame rails, tighten the locknuts on the button-head capscrews at the outboard end of both upper gussets 68 lbf·ft (92 N·m). See **Fig. 9**.

NOTE: The locknuts must be tightened in this step because when the crossmember is in place the frame upper flange blocks access to the capscrews.

5. Using a dead-blow hammer, tap the crossmember into place. Align the mounting holes of the upper gussets with the holes in the frame rails. Install the fasteners, but do not tighten them. Attach the suspension bracket with the same capscrews, if they were removed.
6. Place the lower gussets in position against the crossmember channel and insert the fasteners that secure the gussets to the channel. See **Fig. 10**.
7. Reposition any frame mounted components such as mud flaps, then install the fasteners that attach the gussets to the frame rails.
8. Tighten the fasteners that secure the gussets to the frame rails 136 lbf·ft (184 N·m). Then, tighten the fasteners that secure the gussets to the crossmember 68 lbf·ft (92 N·m).
9. Attach the tail lights and any other accessory that was removed.

Frame Crossmember Removal and Installation



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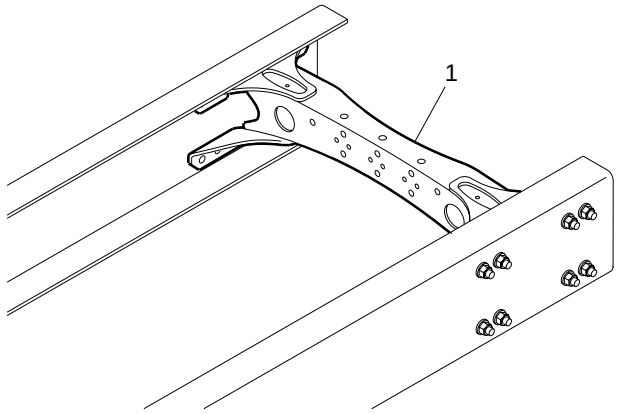
1. Spring-Loaded Mudflap Hanger 2. Screwdriver 3. Anchor

Fig. 12, Spring-Loaded Mudflap Hanger Removal



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1. Rear-Closing Crossmember

Fig. 13, Rear-Closing Crossmember

Frame Rail Alignment

Frame rail alignment is checked by measuring the distances from two sets of points on the upper flanges of the frame rails. The rear set of points must be as far back as possible from the forward set of points. There must be no interference, along or between the frame rails, that would prevent measuring from any one of the four points to the other three points; the fifth wheel and deck plate (as equipped) must be removed.

There are no marks or bolt holes in the top flanges of the frame rails. Therefore, the points must be projected from the frame station marks and from the bolt holes on the frame rail webs.

Measuring Frame Rail Alignment

IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the upper flanges, and to measure inboard from the outside face of the frame rails.

1. For each frame rail, project the exact vertical centerline of the frame station 2540 mark, from the frame web to the top flange, and mark it with a line across the top flange.

   If, because of interference, frame station 2540 cannot be used, choose and mark another matched set of points, as follows:

   1.1 Determine how far forward the upper flanges of both frame rails are clear.

   1.2 Find a matched set of bolt holes on the frame rail webs that are aligned with, or just rearward of, the front of the clear area on the flanges. The bolt holes must be in exactly the same location in each frame rail.

   1.3 Project the exact vertical centerline of each bolt hole, and mark a line across the top flange of its respective frame rail.

2. At identical locations on both frame rails, measure and mark a point 2 inches (5 cm) inboard from the outside face of the frame web.

3. As equipped, remove the fifth wheel and deck plate from the frame. Refer to the applicable fifth wheel section in this manual for instructions.

4. Measure back along each frame rail to find a set of bolt holes *at least* 72 inches (183 cm) rearward from the forward set of points. The bolt holes must be in exactly the same location in each frame rail.

IMPORTANT: If, because of interference, the distance must be less than 72 inches (183 cm), the distance must be the maximum that is possible.

5. Project the exact vertical centerline of each bolt hole, and mark a line across the top flange of its respective frame rail.

6. Along each line, measure and mark a point 2 inches (5 cm) inboard from the outside face of its respective frame rail. The rear points must be in identical locations on both frame rails.

7. At the forward set of points, and again at the rear set of points, measure the distance across the frame, from the inside face of each frame rail web. At both locations, this distance must be 33.62 inches (854 mm) for standard frame rails, or 33.11 inches (841 mm) if an inner liner is present. See **Fig. 1**.

   If the distance at either location is incorrect, check for the correct spacers, and add or remove spacers as needed, using the procedures in **Subject 130**.

8. Measure the distance from the forward point on one frame rail to the rear point on the opposite frame rail. See **Fig. 1**. Then measure the distance from the other forward point to the rear point on its opposite frame rail.

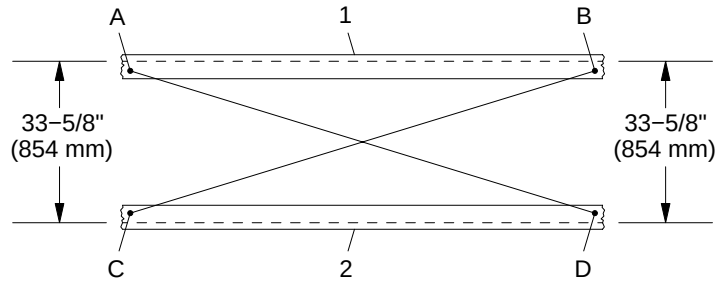
   If the measurements are within 1/8 inch (3 mm) of each other, the frame rails do not need to be aligned.

   If the values differ by more than 1/8 inch (3 mm), align the frame rails.

Aligning Frame Rails

IMPORTANT: To align the frame rails, the frame assembly must be assembled with all of the crossmembers in place, but the attachment fasteners not tightened.

Frame Rail Alignment



A. Right Forward Point
B. Right Rear Point
C. Left Forward Point
D. Left Rear Point
1. Right Frame Rail
2. Left Frame Rail

Fig. 1, Frame Rail Squaring

1. Loosen all of the frame fasteners just enough to allow movement of the parts when force is applied.
2. Place a large wooden block against the rear end of the frame rail that has its rear point the greatest distance from the opposite rail's front point. Then, using a large hammer, tap the block until the measurements are within 1/8 inch (3 mm) of each other.
3. Tighten the fasteners for the front- and rear-closing crossmembers to the applicable torque values. See **Specifications, 400**.
4. Check the frame rail alignment again, and adjust as needed.
5. When the measurements are within specifications, install the fifth wheel and deck plate (as equipped). Refer to the applicable fifth wheel section in this manual for instructions.
6. Tighten all of the frame fasteners, starting at the middle of the frame and working alternately toward both ends. Tighten the fasteners to the applicable torque values. See **Specifications, 400**.
   - 6.1 Tighten the fasteners that attach crossmembers to the frame.
   - 6.2 Tighten the fasteners that attach the upper and lower struts or gussets to the frame.
   - 6.3 Tighten the fasteners that attach the lower struts or gussets to the crossmembers.
7. Check the axle alignment. Refer to **Section 35.00** for instructions.

Frame Shaping

IMPORTANT: Obtain approval from your regional service representative before doing any cutting or frame shaping.

⚠ WARNING

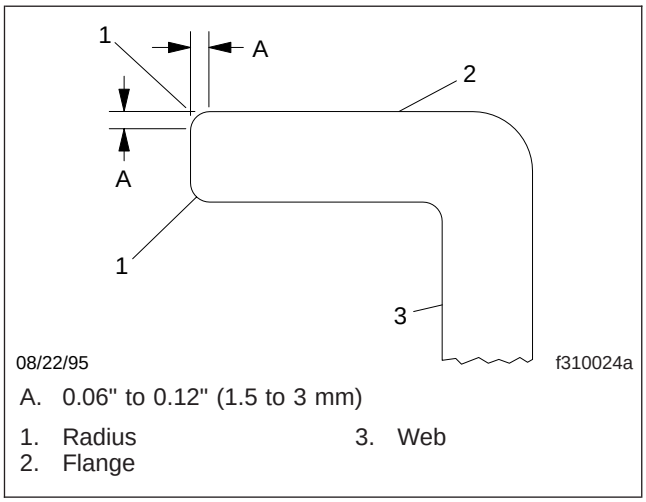
Wear protective eye and facial gear when grinding. Failure to wear this gear can result in personal injury due to flying metal debris from the grinding process.

1. If the flange of a frame rail is cut (for relief cuts or notches), shape the edges of the flange to form a smooth ground radius of 0.06 to 0.12 inch (1.5 to 3.0 mm) over the entire length of the cut. **Figure 1** shows this dimension of the edge radius of the frame rail flanges.

NOTICE

When grinding, apply light pressure only. Heavy pressure can result in harmful overheating and a loss of surface temper. Grind only in the direction of the cut. Grinding across the direction of the cut can reduce the structural strength of the frame rail.

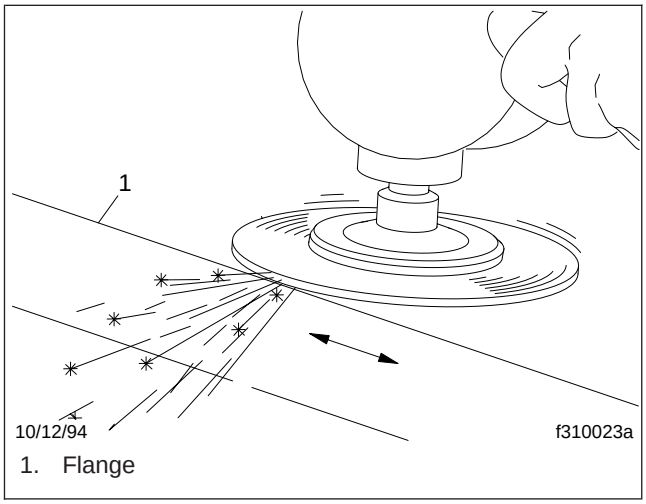
2. Using a clean, sharp, rotary drum grinder or flapper wheel grinder, apply light pressure and grind the cut edges in the direction of the length of the frame rail, to form the radius. See **Fig. 2**. Do not grind across the edges.



A. 0.06" to 0.12" (1.5 to 3 mm)

1. Radius
2. Flange
3. Web

Fig. 1, Radius Dimensions



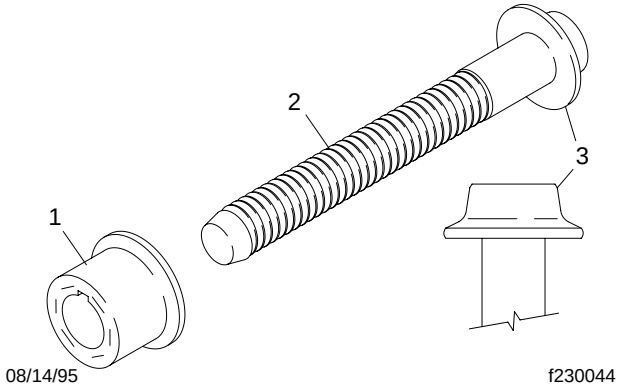
1. Flange

Fig. 2, Direction of Grind

General Information

Either Huck® fasteners or grade 8 hexhead bolts and grade C prevailing torque locknuts are used for frame attachments. See **Fig. 1** and **Fig. 2**. Huck fasteners are used for frame components and cross-member assemblies.

For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. Prevailing torque locknuts of both bolt types have distorted sections of threads to provide torque retention.



1. Spin Collar
2. Lock Pin
3. Round Head

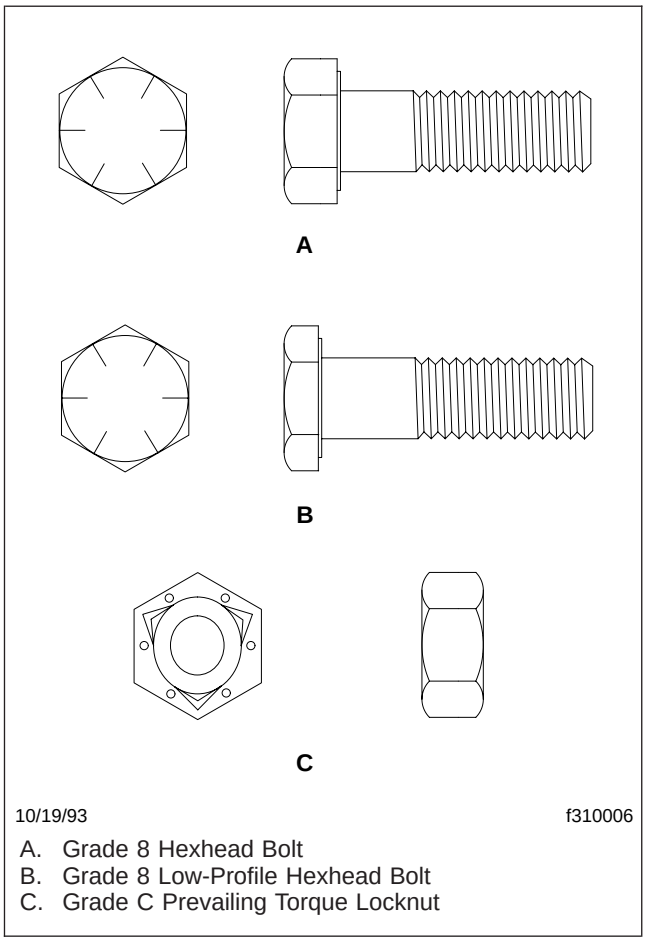
Fig. 1, Huck Fastener

When hexhead bolts and locknuts are used on an attached part, a hardened flatwasher is required to prevent the bolt head or nut from embedding in the part.

In general, hardened washers are used to distribute the load, and to prevent localized overstressing of the frame rails, brackets, and other parts. They are placed directly against the part, under the nut or bolt head. They are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

Huck Fastener Removal

The collar for Huck fasteners is spun on when they are installed, but it cannot be unscrewed. Use the Huck Collar Cutter to remove Huck fasteners. If the Collar Cutter isn't available, split the collar with an air chisel while supporting the opposite side of the collar with an anvil. See **Fig. 3**.



A. Grade 8 Hexhead Bolt
B. Grade 8 Low-Profile Hexhead Bolt
C. Grade C Prevailing Torque Locknut

Fig. 2, Hexhead Fasteners

Then, drive out the lock pin with a punch.

Discard the fastener after removing it. Install standard Grade 8 threaded fasteners to replace the removed Huck fasteners.

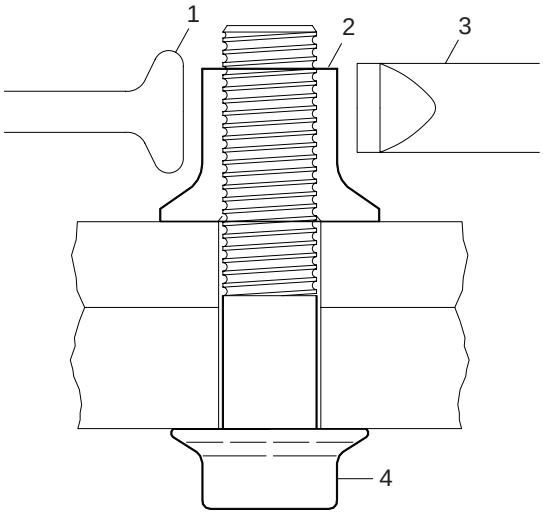
NOTICE

Never attempt to reuse any Huck fastener that has been removed. Reusing any Huck frame fastener can result in damage to the vehicle frame or components attached to the frame.

Hexhead Bolt Replacement

Replace hexhead bolts with identical fasteners.

Frame Fasteners



1. Anvil
2. Spin Collar
3. Chisel
4. Lock Pin

Fig. 3, Huck Fastener Removal

NOTICE

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the frame or parts.

Apply Alumilastic® compound, or an equivalent, to all surfaces where steel and aluminum parts contact each other.

Never hammer or screw bolts into place. Align the holes of the frame and the part being attached to it, so that the nut and bolt surfaces are flush against the frame and the part.

Make sure the length of the bolt threads that extend beyond the tightened locknuts are as specified in **Table 1**.

Thread Extension Specifications		
Bolt Length: in (mm)	**Thread Extension ***	
	Minimum	**Maximum**
4 (102) or Less	1-1/2 Threads	5/8 in (16 mm)
Longer than 4 (102)	3 Threads	3/4 in (19 mm)

* Length of bolt thread extending beyond tightened locknut.

Table 1, Thread Extension Specifications

Frame Fastener Tightening

NOTE: Huck fasteners do not require periodic tightening.

NOTICE

Tighten standard frame fasteners periodically. Continued vehicle operation with loose fasteners could result in component, bracket, and frame damage.

Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating). Refer to the Maintenance Schedule and **Group 31** of the *108SD and 114SD Maintenance Manual* for intervals.

When tightening the fasteners, tighten the nut, not the bolt head. This will give a true torque reading by eliminating bolt body friction. For torque specifications, see **Specifications, 400**.

Specifications

Gas-Metal Arc Welding Machine Settings				
Wire Diameter: inch (mm)	Current: amperes		Wire Extension: inch (mm)	
	Minimum	Maximum	Optimum	Maximum
0.045 (1.14)	160	320	1/2 (13)	3/4 (19)
1/16 (1.6)	300	600	3/4 (19)	1-1/8 (29)
5/64 (2.0)	480	960	1 (25)	1-1/2 (38)

Table 1, Gas-Metal Arc Welding Machine Settings

Coated-Electrode Arc Welding Settings		
Weld Position	Amperes	Volts
Downhand	130–140	21–23
Overhead	130–140	21–23
Vertical Up	110–120	22–24

Table 2, Coated-Electrode Arc Welding Settings

Frame Fastener Torque Specifications *	
Fastener Size	Torque: lbf·ft (N·m)
1/2–13	68 (92)
9/16–12	98 (133)
5/8–11	136 (184)
3/4–10	241 (327)
3/4–16	269 (365)
7/8–9	388 (526)
7/8–14	427 (579)

* Lubricated or plated threads.

Table 3, Frame Fastener Torque Specifications

Removal

See **Fig. 1** for a steel or aluminum bridge formula (mixer) bumper installation, for 114SD set-forward axle with drop casting.

See **Fig. 2** for a steel or aluminum bumper installation, for 114SD set-back axle with a bolt on front crossmember.

See **Fig. 3** for a swept-back bumper installation, for 114SD set-back axle with front frame extension.

See **Fig. 4** for a swept-back 14-Inch bumper installation, for 108SD set-back axle with front frame extension.

1. Park the vehicle, shut down the engine, and set the parking brake. Chock the front and rear tires.
2. Open the hood.
3. Remove the road lights (if equipped) from the bumper.
4. Close the hood.
5. Leaving one set of fasteners on each side to support the front of the bumper, remove the remaining locknuts, washers, and capscrews that attach the bumper to the mounting brackets.

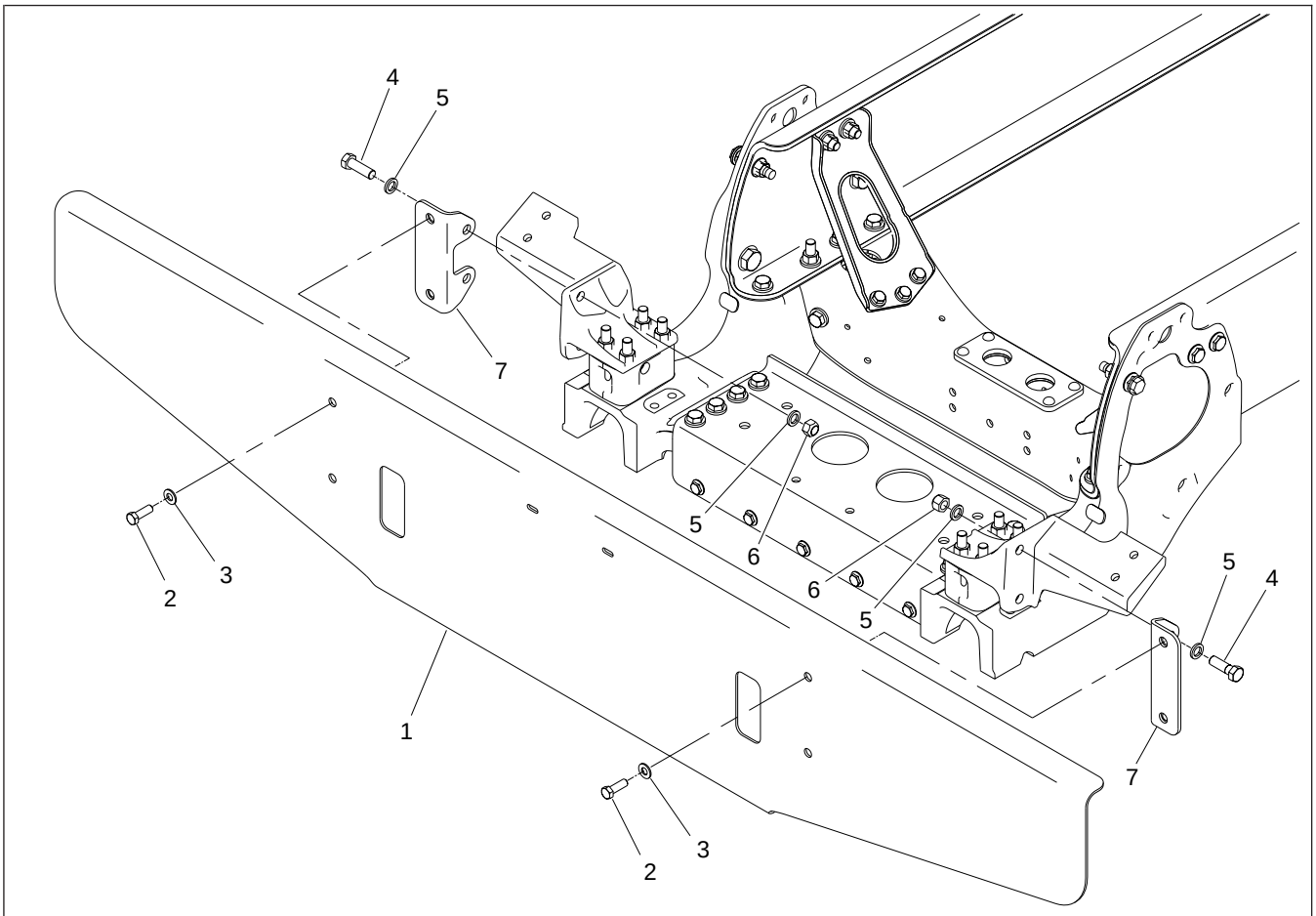
NOTE: The following step requires two persons.

6. With an assistant supporting the bumper, remove the final capscrew, locknut, and washer on each side of the vehicle. Remove the bumper.

Installation

1. Position the bumper so the holes in the bumper align with the holes in the bumper brackets.
2. With an assistant supporting the bumper, install the upper mounting fasteners on each of the bumper mounting brackets. Install the remaining fasteners, tightening the nuts finger-tight.
3. Align the bumper, then tighten the locknuts to 68 lbf·ft (92 N·m).
4. Open the hood, install the roadlights (if equipped), then close the hood.

Bumper Removal and Installation



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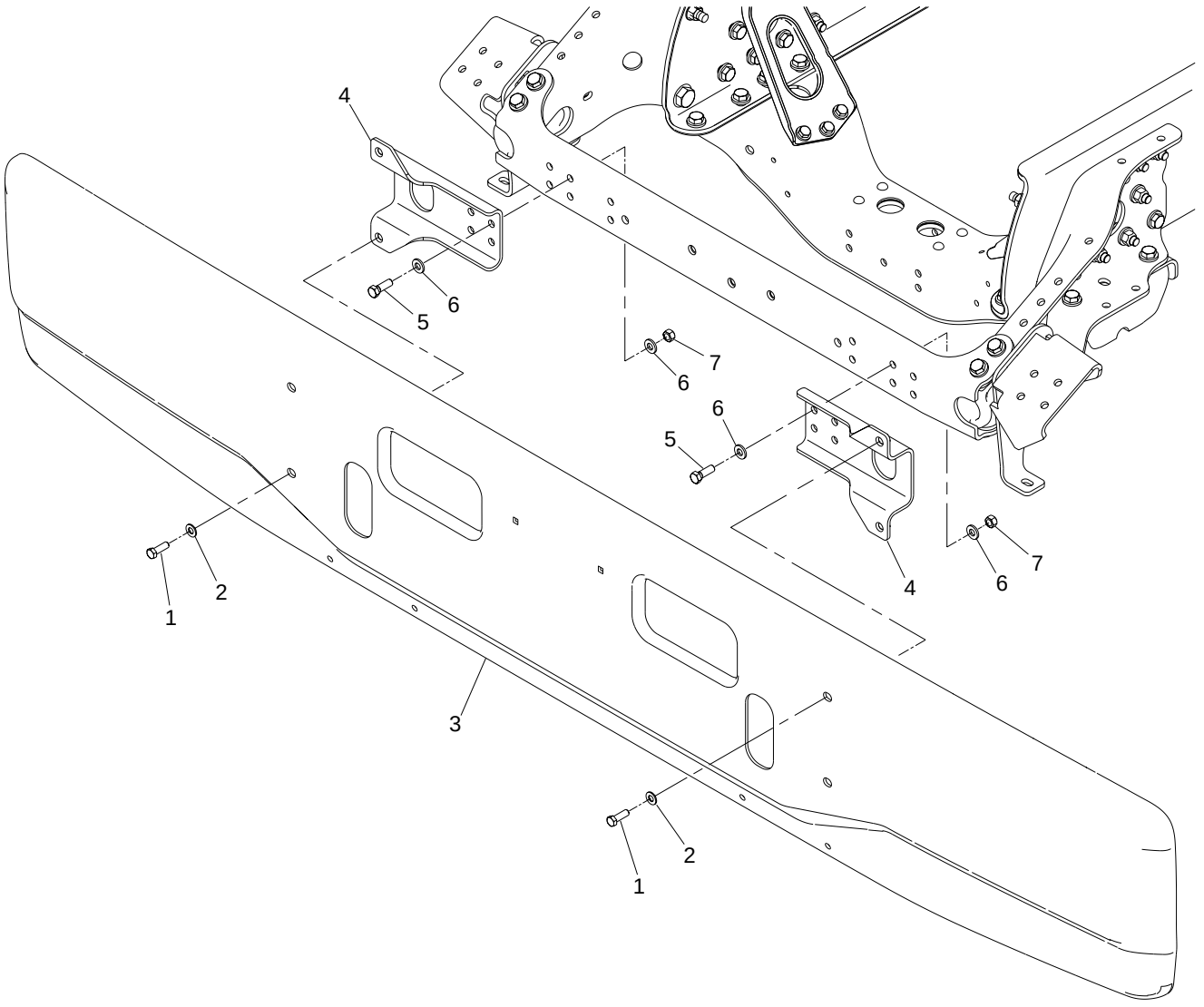
1. Chrome Bumper, Set Forward Axle
2. Capscrew, 1/2–13 UNC
3. Flat Washer, SST 1/2-Inch
4. Bolt, 5/8–11 x 2.00
5. Hardened Washer, 0.53 x 1.06x 0.177 ZN
6. Hex Nut, 5/8
7. Bumper Mounting Bracket

Fig. 1, Bumper Installation, Bridge Formula (mixer), 114SD Set-Forward Axle with Drop Casting

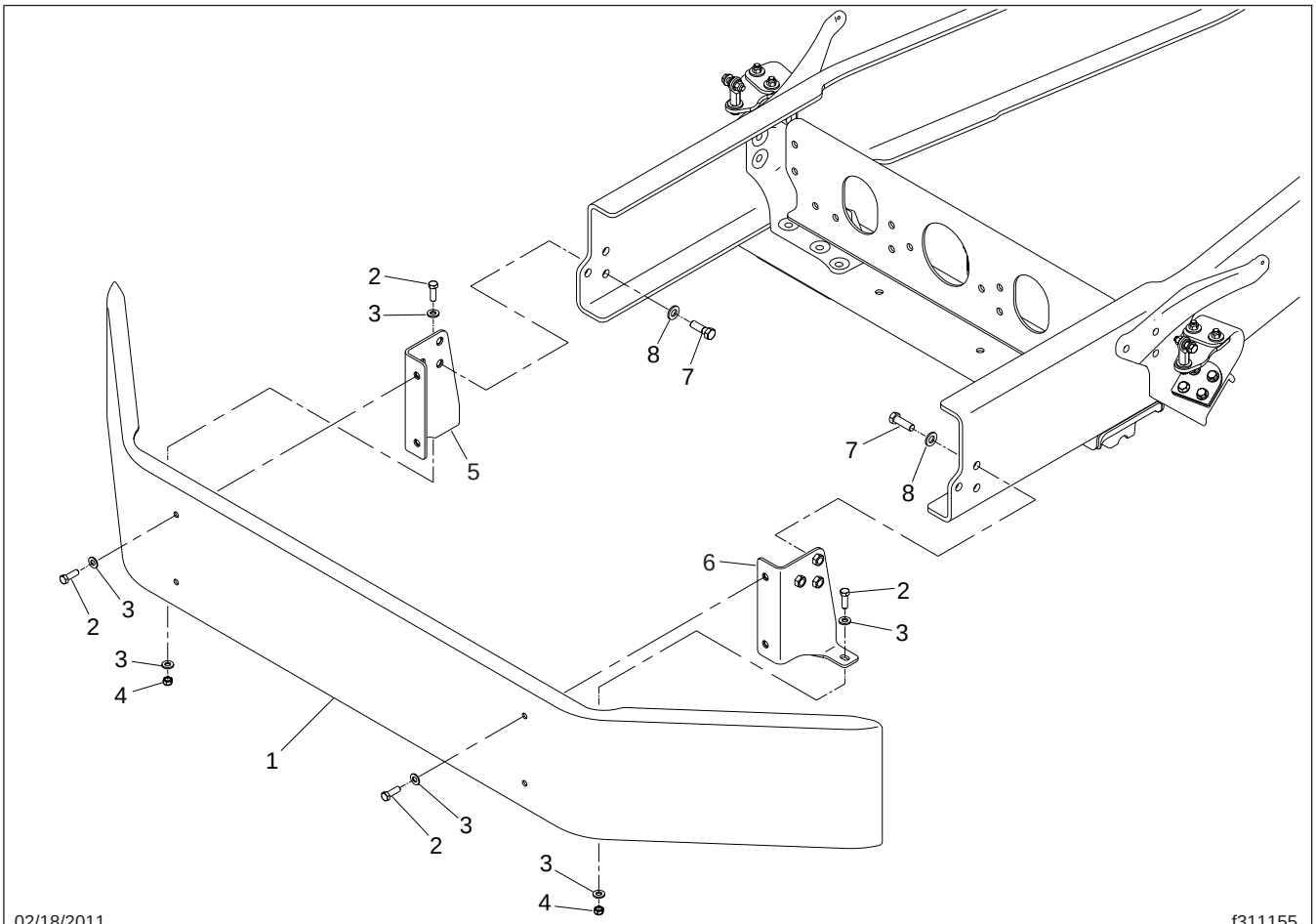
Bumper Removal and Installation



1. Capscrew, SST 1/2–13
2. Flat Washer, SSt, 1/2-Inch
3. Bumper, Setback Axle
4. Bracket, Bumper Front
5. Bolt, 5/8–11 x 2.0
6. Hardened Washer, 0.53 x 1.06 x 0.177 ZN
7. Hex Nut, 5/8

Fig. 2, Bumper Installation, 114SD Set-Back Axle with Bolt on Front Crossmember

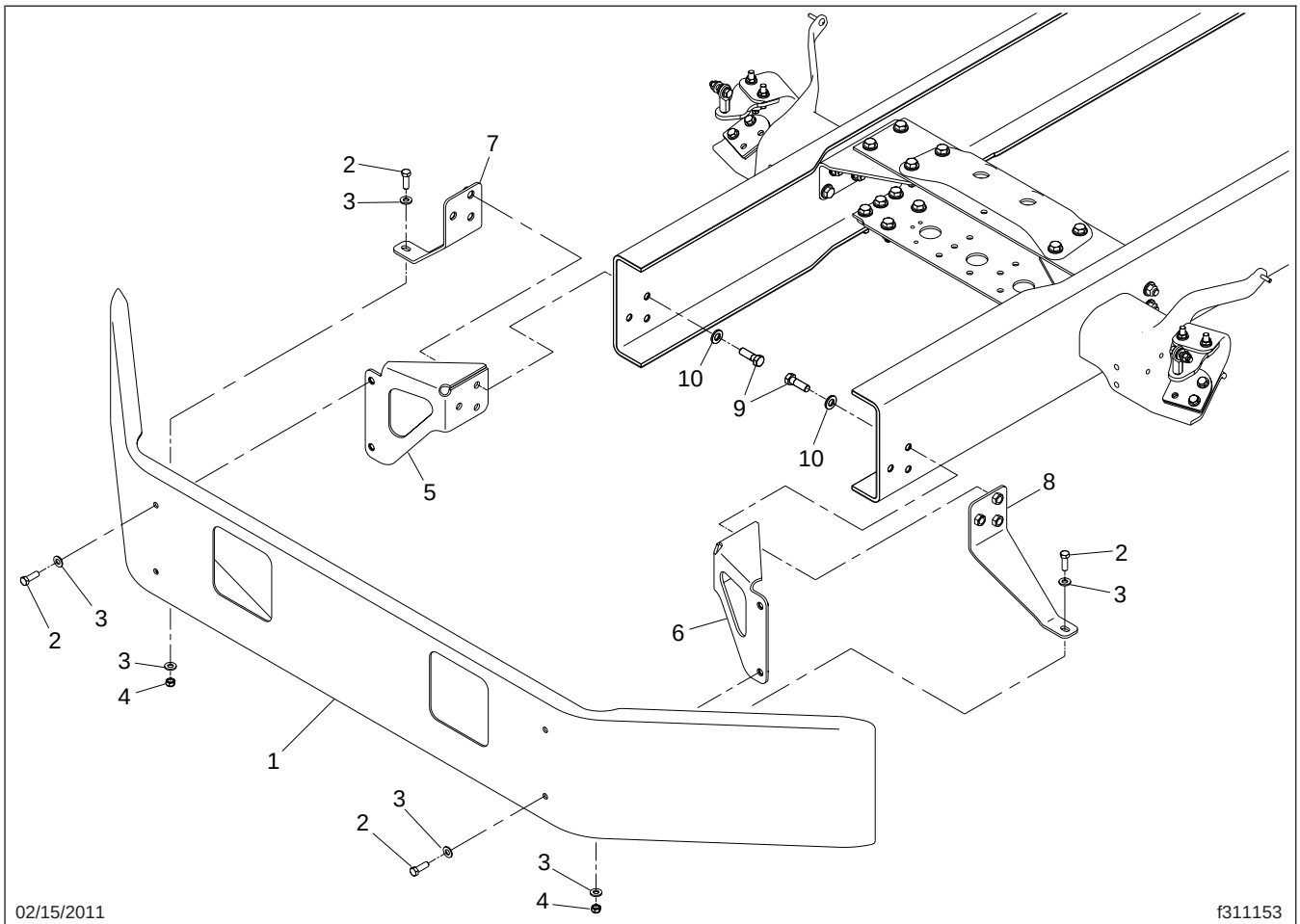
Bumper Removal and Installation



1. Bumper, Setback Axle
2. Capscrew, SST 1/2–13
3. Flat Washer, SSt, 1/2-Inch
4. Nut, 1/2–13
5. Bracket, Bumper Front, RH
6. Bracket, Bumper Front, LH
7. Bolt, 5/8–11 x 2.0
8. Hardened Washer, 0.69 x 1.31 x 0.177

Fig. 3, Swept-Back Bumper Installation, 114SD Set-Back Axle with Front Frame Extension

Bumper Removal and Installation



1. Bumper, Setback Axle
2. Capscrew, SST 1/2–13
3. Flat Washer, SSt, 1/2-Inch
4. Nut, 1/2–13
5. Bracket, Bumper Front, RH
6. Bracket, Bumper Front, LH
7. Bracket, Bumper Lower Support, RH
8. Bracket, Bumper Lower Support, LH
9. Bolt, 5/8–11 x 2.0
10. Hardened Washer, 0.69 x 1.31 x 0.177

Fig. 4, Swept-Back 14-Inch Bumper Installation, 108SD Set-Back Axle with Front Frame Extension

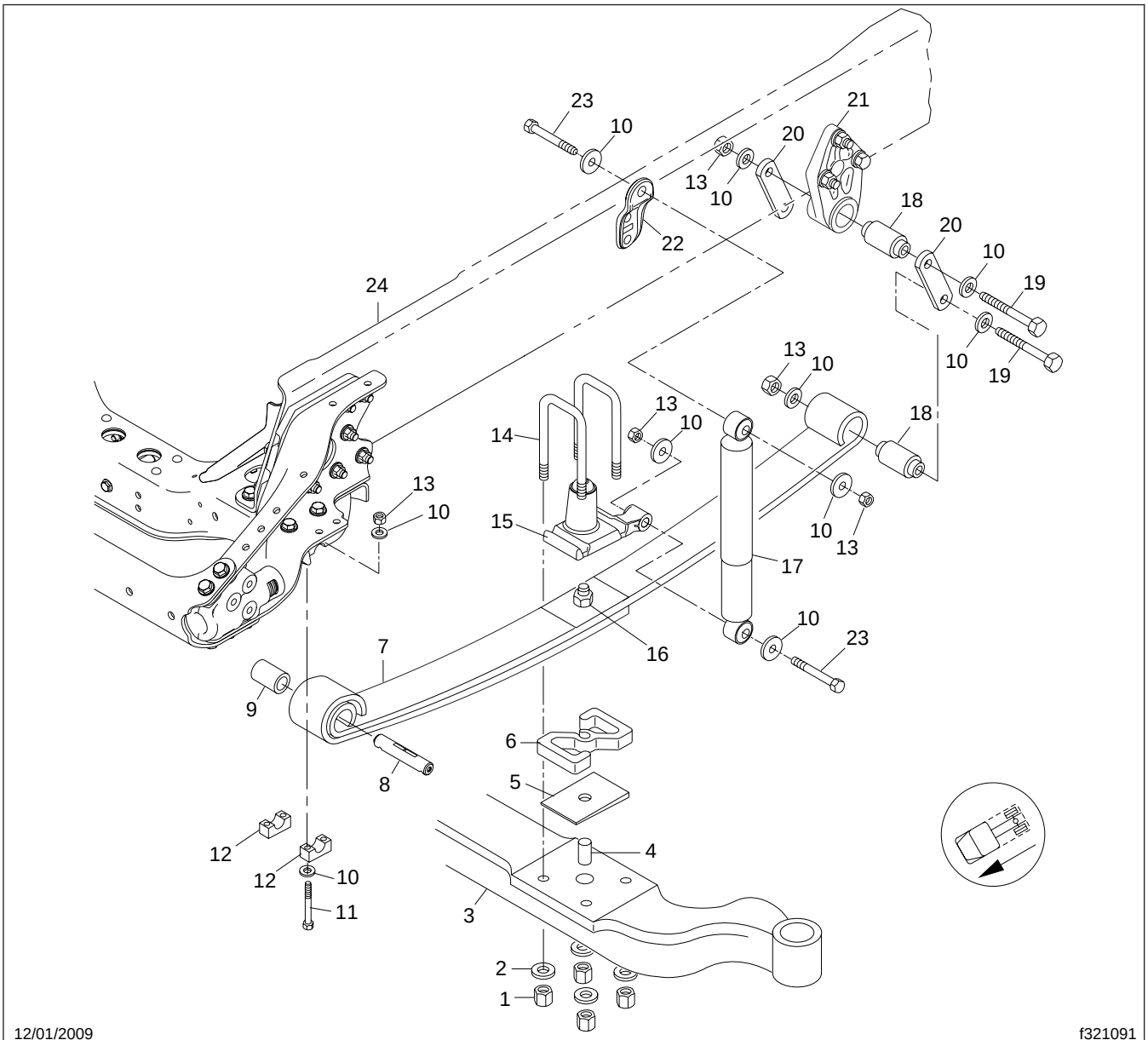
General Information

Standard Freightliner front suspensions are tapered-leaf spring assemblies with shock absorbers. The spring assemblies are attached to the axle with U-bolts, hardened washers, and high nuts. The forward end of each spring contains a bushing and spring pin that mounts to a stationary front suspension bracket. The rear of each spring mounts to a pair of spring shackles that are suspended from a frame-mounted bracket. The rear spring eye and shackle bracket each contain a bushing and use a spring-eye bolt or spring pin to allow the shackles to pivot. The spring shackles allow for variations in spring length during spring flexing, as the leaf spring assembly absorbs energy, then releases it.

The individual leaves are held together by a center bolt, with the center-bolt nut used as a locating dowel for the axle stop and shock-absorber lower bracket.

Steel spring pins with bronze bushings may be installed, and are graphite impregnated with a grease seal at each end. See **Fig. 1** for a front suspension assembly for axle-back installation. See **Fig. 2** for a front suspension assembly for axle-forward installation.

General Information



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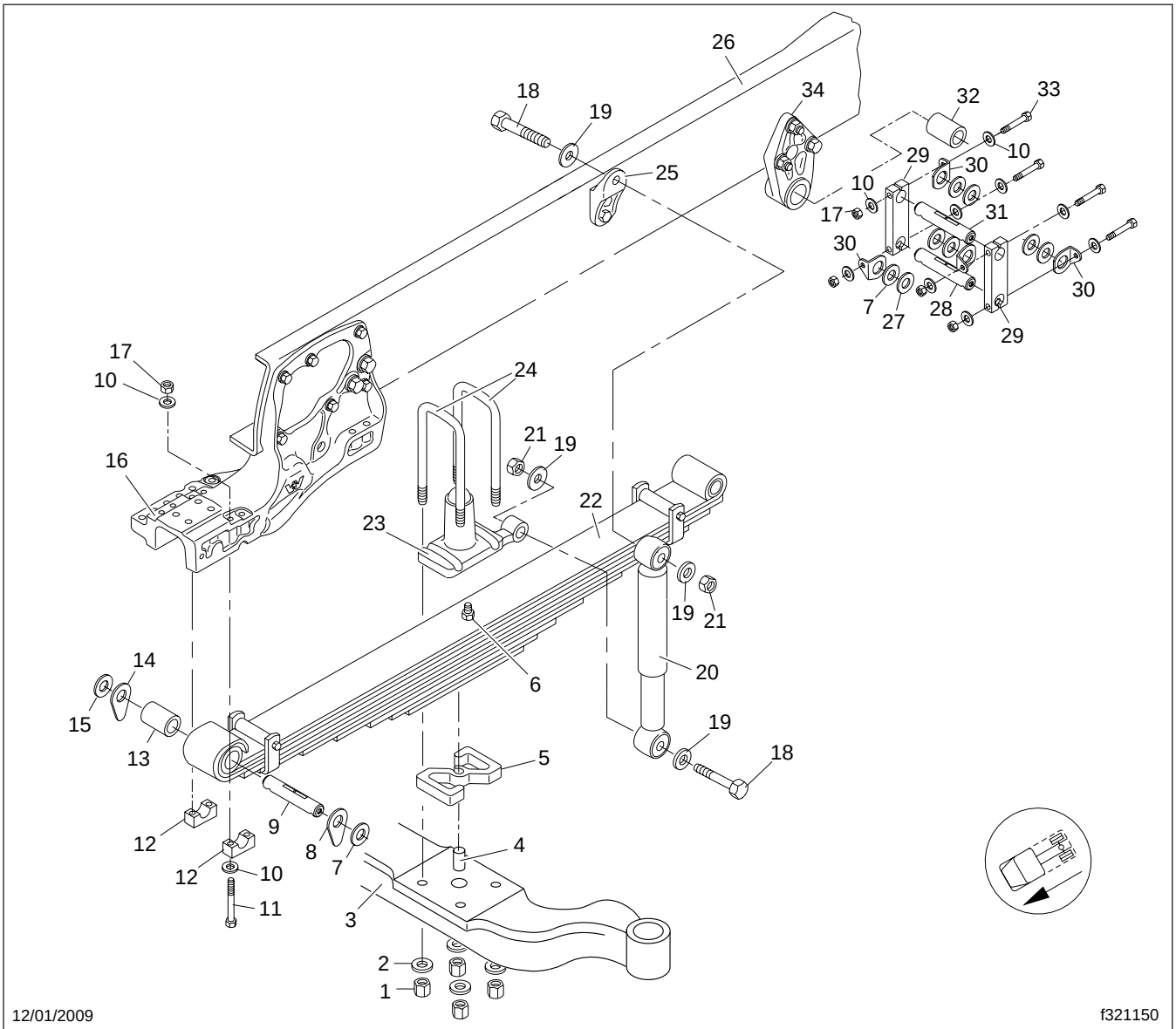
1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Caster Adjustment Shim
6. Spacer
7. Spring Assembly
8. Spring Pin, Forward Spring Eye
9. Spring-Eye Bushing
10. Hardened Washer
11. Hexbolt
12. Spring Pin Retainer
13. Hexnut
14. U-Bolt
15. Axle Stop and Shock-Absorber Lower Mounting Bracket
16. Spring Center-Bolt and Nut
17. Shock Absorber
18. Rubber Bushing Assembly
19. Shackle Bolt, 3/4–10
20. Spring Shackle
21. Shackle Bracket
22. Shock-Absorber Upper Mounting Bracket
23. Hexbolt, 3/4–10
24. Frame Rail

Fig. 1, Front Suspension Assembly, Axle-Back Installation



1. U-Bolt High Nut
2. Hardened Flatwasher
3. Axle
4. Dowel Pin
5. Spacer
6. Spring Center-Bolt and Nut
7. Outboard Spring Washer(s)
8. Outboard Spring Spacer
9. Spring Pin, Forward Spring Eye
10. Hardened Washer
11. Hexbolt
12. Spring Pin Retainer
13. Spring-Eye Bushing
14. Inboard Spring Spacer
15. Hardened Washer
16. Spring Drive Bracket
17. Hexnut
18. Hexbolt
19. Hardened Flatwasher
20. Shock Absorber
21. Hexnut
22. Spring
23. Axle Stop/Shock Absorber Mount
24. U-Bolt
25. Shock Absorber Mounting Bracket
26. Frame Rail
27. Hardened Washer
28. Spring Pin, Rear Spring Eye
29. Shackle
30. Wear Plate
31. Spring Pin, Shackle Bracket
32. Shackle Bracket Bushing
33. Pinch Bolt
34. Shackle Bracket

Fig. 2, Front Suspension Assembly, Axle-Forward Installation

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

Removal

See **Subject 050** for illustrations of front suspension assemblies.

1. Shut down the engine, apply the parking brakes, and chock the rear tires.
2. Disconnect both shock absorbers.

⚠ WARNING

Never work under a vehicle that is supported only by jacks. Jacks can slip, which can result in serious personal injury, death, or component damage. Always support the vehicle with safety stands capable of supporting the weight of the vehicle.

3. Raise the vehicle until both front tires are off the ground and the frame is supported with safety stands. The axle and leaf springs can now be manipulated with the floor jack.

IMPORTANT: Make sure the frame rails are level side-to-side and an equal distance off the ground.

NOTE: If necessary, remove the mud guards to access the shackles.

4. Using the floor jack, raise the axle just enough so the jack is supporting the weight of the axle, then support the axle with safety stands.
5. Remove the high nuts, U-bolts, axle-stop assembly, and spring liner (if equipped) from the spring.
6. Remove the locknuts from the shackle bolts that go through the rear spring shackle, then remove the bolts.

   If equipped with spring pins, remove the pinch bolts and nuts securing the shackle spring pin. Using a suitable drift, drive the pins outboard to remove them.

   Remove the spacing washers and keep them with the pin. Make note of their correct location for later installation.
7. Remove the pinch bolts and nuts from the forward frame bracket.

   Remove the four retainers at the front spring drive bracket. Using a suitable drift, drive the pin inboard to remove it.

   Remove the spacing washers (if equipped) and keep them with the pin. Make note of their correct location for later installation.
8. Remove the spring assembly by lifting it up off the axle and out the front of the truck. Note the taper direction of the caster shim so that it will not be reversed during installation

Cleaning and Inspection

1. Using a wire brush and solvent, or steam-cleaning equipment, wash all parts to remove dirt, grease, and scale.
2. Inspect the shackle bracket and the spring shackles for cracks, wear, or other damage. Replace any damaged parts.
3. Inspect the spring for cracks and corrosion. If any spring leaves are cracked or broken, replace the entire spring assembly.

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. On front spring assemblies, if cracks or breaks exist in the two top leaves, a loss of vehicle control could occur. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

4. If the protective coating is gone from some areas of the spring, paint the cleaned areas with a rust-inhibiting paint. If rusting or corrosion is severe, replace the leaf spring.
5. Check the spring-eye bolt and shackle bolts for wear. Replace any bolt that shows wear, cracking, pitting, or other damage.
6. Using a micrometer, check the spring pins and shackle pin for wear.

   On leaf spring assemblies, replace a pin if the diameter at any point on the pin is less than 1.242 inches (31.54 mm).
7. If spring pin bushings are not damaged, inspect them for wear. Using a micrometer, check the

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

inside diameter of each bushing. The inside diameter of any bushing should not exceed the diameter of its pin by more than 0.010 inch (0.25 mm). Replace any bushing that exceeds this limit.

Installation

⚠ WARNING

Failure to install identical spring assemblies could affect the balance of the front suspension and cause difficult handling of the vehicle, resulting in injury or property damage.

NOTE: Suspension bracket (frame) fasteners require periodic retorquing. Refer to **Group 31** in the *108SD and 114SD Maintenance Manual* for instructions.

1. Using multipurpose chassis grease, lubricate both spring pins, the shackle pin, and the inside surfaces of the bushings.
2. If the shackle was disconnected from the shackle bracket, attach it to the bracket.

   2.1 Apply Alumilastic® or similar compound to all areas of the shackle that contact metal. This includes all capscrews, washers, and locknuts that contact the aluminum shackle. Do not apply the compound to the inner (bearing) surface of the bushing or on fastener threads.

NOTICE

Failure to apply Alumilastic or similar compound will result in electrolytic corrosion of dissimilar metal components, and will damage the suspension system.

   2.2 Install the shackles.

   NOTE: When spring pins are used, make sure the correct spacing washers are inserted between bracket ends and shackles. Be sure the hardened wear washers are in direct contact with the spring eye.

   2.3 Insert the spring pin with its grease fitting end toward the outboard side. Install the split ring on the inboard end of the threaded pin. Align the grooves of the pin with the flanged pinch-bolt bores.

   2.4 Install the pinch bolts and nuts to hold the shackle pin and spacing washers in place. Torque the nuts 95 lbf·ft (130 N·m).

NOTICE

Do not overtighten the shackle pinch-bolt nuts. Overtightening these nuts could distort and weaken the aluminum shackles.

3. Place the caster shim on the front axle in the position referenced earlier.
4. Install the spring assembly on the caster shim; make sure the spring center-bolt head fits into the bore in the axle.
5. Place the axle-stop assembly and spring liner (if equipped) on top of the spring assembly.

IMPORTANT: Suspension U-bolts, washers, and high nuts cannot be reused; they must be replaced with new ones.

6. Place new U-bolts over the axle stop and spring assembly and through the holes in the axle. It may be necessary to slightly compress the sides of the U-bolts in order to get the U-bolt ends to align with the axle holes. A C-clamp attached above the U-bolt threads can be used for this purpose.
7. Install new hardened washers and high nuts on the U-bolts. Tighten the nuts just enough to hold the components in place.
8. Attach the spring assembly to the forward frame bracket.

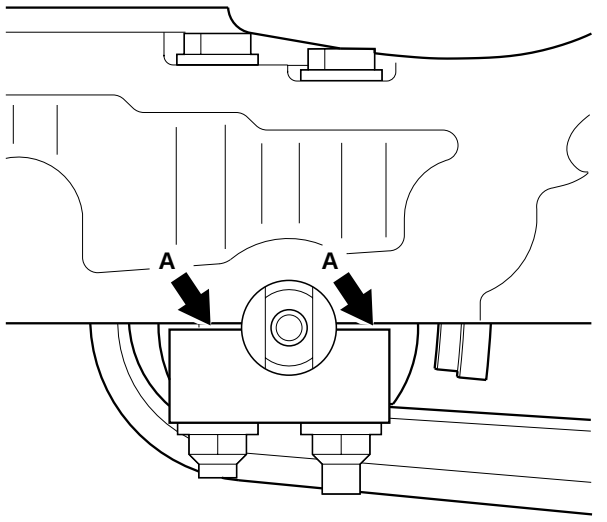
   8.1 If equipped with bronze bushings, hold the correct number of spacing washers, as referenced during removal, between the outboard end of the bracket and the spring; insert the grease fitting end of the pin far enough into the bushing to hold the spacers in place. Hold the remaining spacers in place and push the spring pin in until the grooves align with the frame bracket flanged pinch-bolt bores.

   Check for play between the spring and the bracket ends. If needed, install additional 1/32-inch spacing washers (1-1/8 inch i.d., 1-7/8 inch o.d.) so that there is less than

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

one washer thickness of end play. It is preferable to have an equal number of washers on each side of the spring. However, if the amount of play requires an uneven number of washers, the difference between the two sides should be no more than one spacing washer.

8.2 Install the retaining bolts up through the spring-drive bracket and attach the retainers. Tighten the nuts evenly to maintain equal clearance between the retainers and the spring-drive bracket. Do not fully tighten at this time. See **Fig. 1**.



A. Equal Distances

Fig. 1, Spring-Drive Bracket and Retainer Installation

9. Attach the spring assembly to the shackle bracket.

   9.1 Using the shackle bolt, washers, and the locknut, attach the leaf spring assembly to the shackle bracket. Face the bolt head outboard, then finger-tighten.

   9.2 If equipped with bronze bushings, hold the correct number of spacing washers, as referenced during removal, between the outboard shackle and the spring. With the grease fitting pointed to the outboard side, insert the spring pin far enough into the bushing to hold the spacers in place. Hold the remaining spacers in place and push the pin until the grooves align with the shackle pinch-bolt bores.

   Check for play between the spring and the shackle ends. If needed, install additional 1/32-inch spacing washers (1-1/8 inch i.d., 1-7/8 inch o.d.) so that there is less than one washer thickness of end play. It is preferable to have an equal number of washers on each side of the spring. However, if the amount of play requires an uneven number of washers, the difference between the two sides should be no more than one spacing washer.

10. If equipped with a steel shackle and shackle bolt, tighten the locknuts on the shackle bolt 240 lbf·ft (325 N·m). If equipped with an aluminum shackle and spring pins, tighten the locknut on the upper and lower shackle bolt 45 lbf·ft (61 N·m); if equipped with a steel shackle and spring pins, tighten the locknut on the upper and lower shackle bolt 68 lbf·ft (92 N·m).

11. Tighten the U-bolt high nuts. For tightening instructions and torque values, see the applicable table in **Specifications, 400**.

NOTICE

Failure to retorque the fasteners as instructed could result in spring breakage and abnormal tire wear.

12. Install both front shock absorbers and tighten the bolts 130 lbf·ft (176 N·m).

13. Wipe all dirt from the grease fittings on the spring pins and the shackle pin. Apply multipurpose chassis grease with a pressure gun until grease appears at the opposite end of the pin.

14. Raise the vehicle, remove the jack stands from the chassis, then lower the vehicle.

Shackle-Bracket Bushing Replacement

See **Subject 050** for illustrations of front suspension assemblies.

The shackle bracket comes with the bushing already installed. If the shackle-bracket bushing needs replacement, replace the entire shackle bracket and bushing as a unit.

1. Remove the shackle bracket from the frame rail.
2. Check the shackle bolt or shackle pin for ease of fit in the bushing. It should have an easy slip fit without wobble between it and the bushing.

NOTICE

Failure to apply Alumilastic or similar compound will result in electrolytic corrosion of dissimilar metal components, and will damage the suspension system.

3. Install the shackle bracket.

   Apply Alumilastic® or similar compound to all areas of the aluminum shackle bracket that contact the frame rail. This includes the fasteners that contact the shackle bracket. Do not apply the compound to the fastener threads.

Spring-Eye Bushing Replacement

1. Remove the leaf spring. See **Subject 100** for instructions.
2. Press out the worn or damaged bushing(s).

NOTICE

Do not press in the bushing by the center sleeve. To do so could damage the bushing.

3. *If installing rubber bushings,* apply a coating of Perma-Bond® HM–160 or Loctite® RC–609 adhesive to the inside of the spring eye, and to the outside of the bushing. Press the new bushing into the spring eye until the bushing is flush with the edges of the spring eye.

   If installing bronze bushings, press the new bushing into the spring eye until the bushing and the spring edges are flush. The split in the bushing must be within 3/16 inch (5 mm) of the top of the spring eye.
4. Install the leaf spring. See **Subject 100** for instructions.

Replacement

See **Subject 050** for illustrations of front suspension assemblies.

1. Remove the 3/4–10 hexbolt, hardened washers, and locknut from the shock absorber and the upper mounting bracket.
2. Swing the shock absorber down away from the upper mounting bracket.
3. Remove the 3/4–10 hexbolt, hardened washers, and locknut from the shock absorber and the lower mounting bracket.
4. Remove the shock absorber.
5. Align the upper eye of the shock absorber with the hole of the upper mounting bracket.
6. Install a hardened washer and the 3/4–10 hexbolt through the mounting hole and the eye of the shock absorber. Make sure the hexbolt head is facing inboard.
7. Install a washer and 3/4–10 locknut on the hexbolt. Tighten 130 lbf·ft (176 N·m).
8. Align the lower eye of the shock absorber with the holes in the lower mounting bracket.
9. Install a hardened washer and the 3/4–10 hexbolt through the the eye of the shock absorber and the holes of the lower mounting bracket. Make sure the hexbolt head is facing outboard.
10. Install a washer and 3/4–10 locknut on the hexbolt. Tighten 130 lbf·ft (176 N·m).

Vehicle Lean Inspection

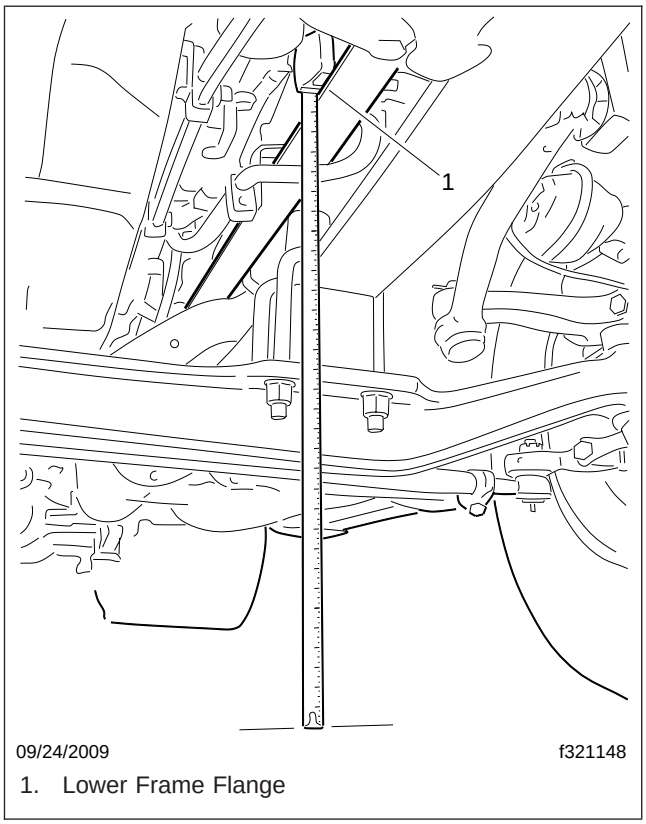
IMPORTANT: Chassis lean can be caused by several factors such as uneven vehicle weight distribution, mismatched springs, or improper spacer installation. The following instructions detail inspecting for and correcting chassis lean due to improper spring or spacer installation. Additional troubleshooting procedures may also be found at **www.hendrickson-intl.com**.

1. Park the vehicle on a level surface with the wheels pointing straight ahead. Set the parking brake, turn off the engine, and chock the tires. When exiting the vehicle, try not to rock the vehicle.

NOTE: The vehicle should be unloaded when performing the following inspection.

2. Check tire pressure and tire size. Pressures should be within 2 psi of each other. Tire size should be the same on each axle.
3. Check that the rear axle alignment and rear suspension ride height are within specification. Refer to **Group 32** and **Group 35** in this manual.
4. Check the springs, bushings and spring mounting hardware for damage. Replace damaged components before checking for chassis lean.
5. Measure the weight of the vehicle at each wheel position. Weight imbalance will cause the vehicle to lean. If the vehicle weight differs from side to side, check the cab alignment and the fuel tank levels, and correct if necessary.
6. Measure the distance from the bottom of the lower frame flange to the ground, forward of the front axle center line. This is frame height. See **Fig. 1**.
7. If the frame height differs from side to side by 3/8 inch (9.53 mm) or more, inspect the spring part numbers, and (if present) markings on the top side of the springs with a label marking plus (+) or minus (–). Verify that both spring labels match.

   If the labels or part numbers do not match, replace one or both springs so the vehicle has matching springs. See **Fig. 2**.
8. Measure the height difference at the end of the frame rails to ground. If this measurement is greater than 3/8 inch (9.53 mm), the front axle spacer adjustments will have minimal effect on lean and other actions are required. If the end of frame to ground measurements are less than 3/8



1. Lower Frame Flange

Fig. 1, Measuring Frame Height

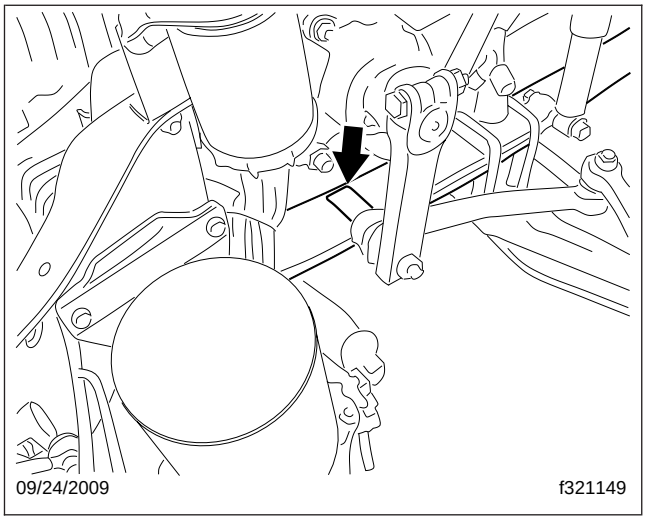


Fig. 2, Spring Label Location

inch (9.53 mm) difference, correct the lean by increasing the low side front axle spacer thickness by no more than 1/2 inch (13 mm). Use a 45, 55, or 65-mm spacer in place of the existing spacer.

See **Table 1** for parts information for ordering spacers.

Parts Information		
Part Description	**Part Number**	**Quantity**
Axle Spacer, 45 mm	16-15105-040	As Required
Axle Spacer, 55 mm	16-15105-055	As Required
Axle Spacer, 65 mm	16-15105-065	As Required

Table 1, Parts Information

9. Check the frame height again. If the difference between measurements is still equal to or greater than 3/8 inch (9.53 mm), swap springs from side to side and check the measurements again.

   If the chassis lean is still the same, the problem is with the vehicle. If the lean has changed sides, replace both springs.

   See **Fig. 3** for a checklist for weak or sagging springs.

Troubleshooting Tables

Problem—Vehicle Wanders

Problem—Vehicle Wanders	
Possible Cause	**Remedy**
One or more spring leaves are broken.	Replace the spring assembly.
The wheels are out of alignment.	Adjust the wheel alignment using the instructions in **Group 33** of this manual.
Caster is incorrect.	Install correct caster shims. Refer to **Group 33** of this manual for specifications.
Steering gear is not centered.	Adjust steering using the instructions in **Group 46** of this manual.
Drive axles are out of alignment.	Align the drive axles using the instructions in **Group 35** of this manual.

Problem—Vehicle Bottoms Out

Problem—Vehicle Bottoms Out	
Possible Cause	**Remedy**
Excessive weight on the vehicle is causing an overload.	Reduce the loaded vehicle weight to the maximum spring capacities.
One or more spring leaves are broken.	Replace the spring assembly.
The spring assembly is weak or fatigued.	Replace the spring assembly.

Problem—Frequent Spring Breakage

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
The vehicle is overloaded or operated under severe conditions.	Reduce the loaded vehicle weight to the maximum spring capacities. Caution the driver on improper vehicle handling.
There is insufficient torque on the U-bolt high nuts.	Torque the U-bolt high nuts to the value listed in the torque table in **Specifications, 400**.

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
A loose center bolt is allowing the spring leaves to slip.	Check the spring leaves for damage. If damaged, replace the spring assembly. If not, tighten the center-bolt nut to the value listed in torque table in **Specifications, 400**.
Worn or damaged spring pin bushings are allowing spring end-play.	Replace the spring pin and bushing.

Problem—Noisy Spring

Problem—Noisy Spring	
Possible Cause	**Remedy**
A loose U-bolt nut or center bolt is allowing spring leaf slippage.	Inspect the components for damage. Replace damaged components as necessary. Torque the fasteners to the values listed in the torque table in **Specifications, 400**.
A loose, bent, or broken spring shackle or front suspension bracket is impairing the spring flex.	Inspect the shackles and brackets for damage. Replace damaged components as necessary. Torque the fasteners to the values listed in the torque table in **Specifications, 400**.
Worn or damaged spring pins are allowing spring end-play.	Replace any worn or damaged spring pins.

Troubleshooting

The following is a checklist for weak or sagging springs. This information may be requested when filing for warranty.

Conditions

☐ Is the ground level?

(If ground is not level move the truck to a level location)

☐ Is the vehicle loaded?

(Vehicle should be measured unloaded)

☐ Are the spring part numbers the same?

(Part numbers should be the same)

☐ Is there any visible damage to the spring or bushings?

(Any damage to the springs, bushings, shocks, or suspension brackets should be repaired)

Tires

☐ Are the tire pressures and sizes the same?

(Tire pressure should be within 2 psi from side to side)

☐ Do the tires have the same amount of wear?

☐ Are the tires the same size?

Measurements

☐ Measure the distance from the floor to the bottom of the frame rail on each side of the truck as close to the front axle as possible.

Passenger Side _____

Driver Side _____

(Measurements should be within 3/8” from side to side)

Weight

☐ Measure the weight of the vehicle at each forward axle position.

Passenger Side _____

Driver Side _____

(Weight should be equal from side to side. If weight is more on one side, check that the cab is centered on the frame rails, and if equipped with dual tanks, that the fuel level is equal on both sides. Due to the many options available for mounting components, the vehicle may have a weight bias to one side. If the vehicle does have a weight bias to one side, the spring can be shimmed to level the vehicle.)

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Fig. 3, Checklist for Weak or Sagging Springs

Specifications

Front Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Shackle Bracket-to-Frame Locknut	5/8–11	136 (184)
Shackle Bolt (steel shackle)	3/4–10	240 (325)
Upper and Lower Shackle Bolt (steel shackle)	1/2–13	68 (92)
Upper and Lower Shackle Bolt (aluminum shackle)	1/2–13	45 (61)
Axle U-bolt High Nuts (Tighten in a diagonal pattern as shown in **Fig. 1**)	3/4–16	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 270–330 (367–449)
	7/8–14	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420–500 (571–680)
	1–14	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 520–600 (707–816)
Spring Assembly Center-Bolt Nut	1/2–20	65 (88)
Shock Absorber Upper and Lower Mounting Locknut	3/4–10	130 (176)

Table 1, Front Suspension Fastener Torque Values

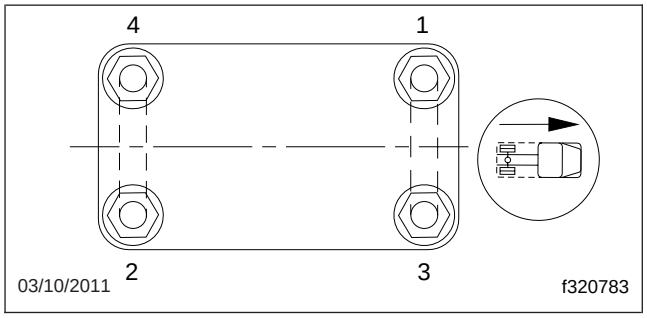


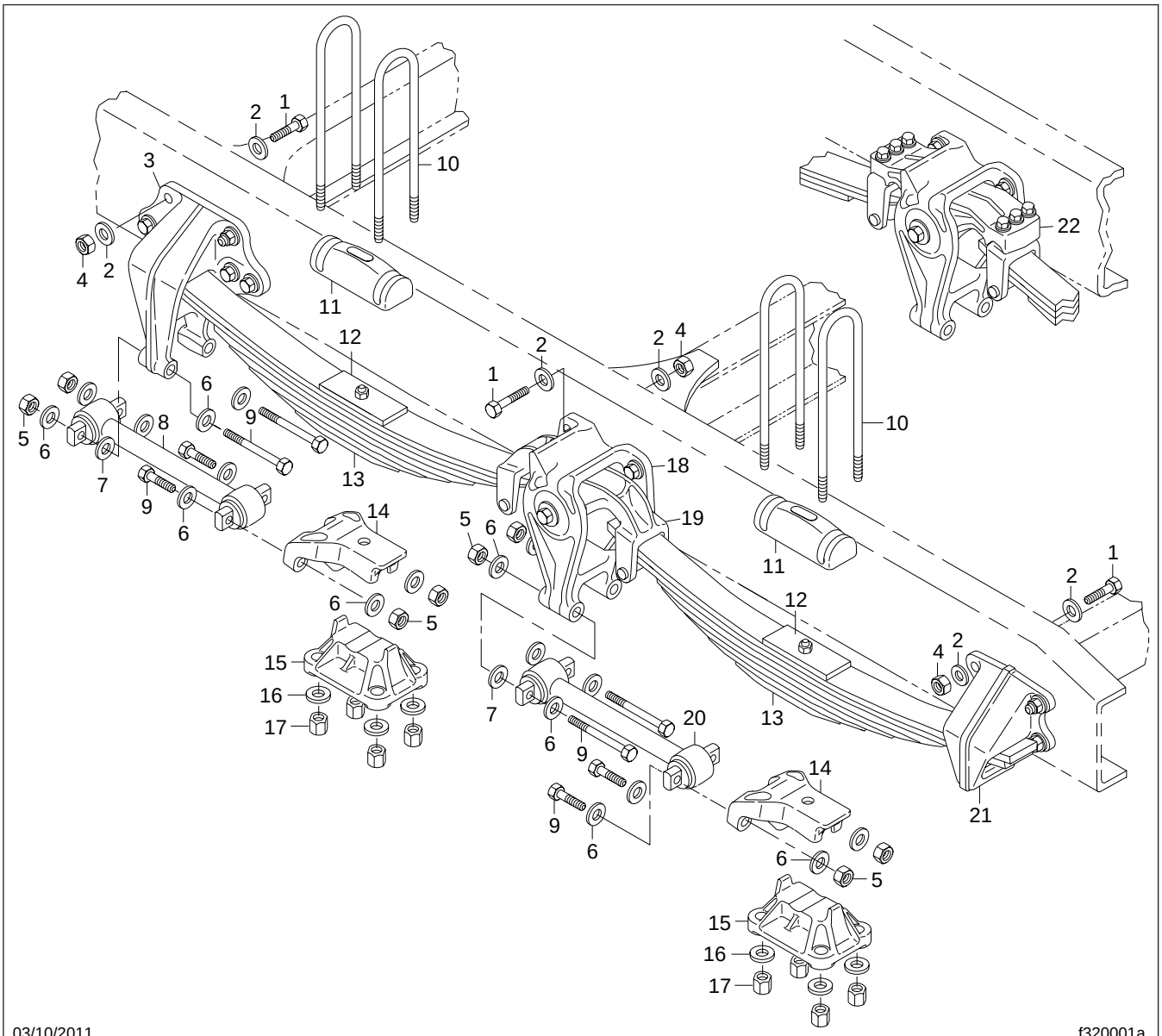
Fig. 1, Tightening Pattern for U-bolt High Nuts

General Description

The tandem-axle rear spring suspension uses a six-point equalizing leaf spring design, which compensates for axle articulation, from side to side, and front to rear. Four semi-elliptical spring assemblies are attached to the axles with U-bolts. On both sides of the vehicle, the forward end of the forward spring and the rear end of the rear spring ride in aluminum brackets that are mounted on the frame rails. Steel wear shoes are cast into each bracket. See **Fig. 1**.

At the center, between the forward and rear springs, the springs ride on an equalizer, which pivots on a sleeve in the equalizer bracket. Equalizer travel is stopped when the top of the equalizer and equalizer bracket make contact. Each axle is held in alignment by a pair of radius rods that extend forward from the axle seats to the forward spring brackets for the forward-rear axle, and to the equalizer brackets for the rearmost axle.

General Information



1. Huckbolt HP 8® Frame Fasteners
2. Hardened Washer
3. Forward Spring Bracket
4. Suspension Bracket Hex Locknut
5. Radius Rod Hex Locknut
6. Hardened Washer
7. Axle Alignment Washer
8. Forward Radius Rod
9. Radius Rod Hexbolt
10. U-Bolt
11. U-Bolt Pad
12. Spring Liner
13. Leaf Spring Assembly
14. Spring Seat
15. U-Bolt Retainer
16. Hardened Washer
17. U-Bolt High Nut
18. Equalizer Bracket
19. Equalizer, One-Piece (tandem drive axles)
20. Rear Radius Rod
21. Rear spring Bracket
22. Equalizer, Three-Piece (tag or pusher axle)

Fig. 1, Tandem-Axle Spring Suspension

Radius Rod Removal and Installation

Removal

1. Apply the parking brakes, and chock the tires.
2. Note the number of axle alignment washers (Item 4) at the forward end of each radius rod that is being removed. See **Fig. 1**.
3. Remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket, and to the axle seat.
4. Remove the radius rod and any axle alignment washers.

Installation

NOTICE

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

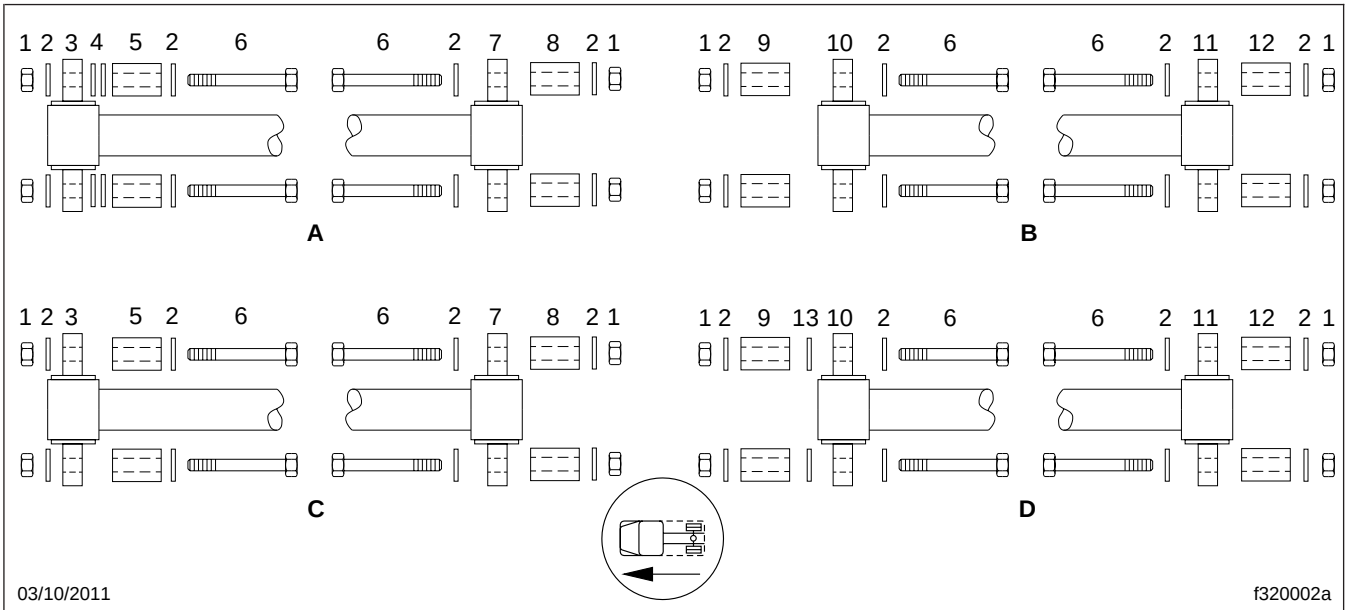
If installing forward and rear radius rods, install the forward radius rod first.

1. If installing a forward radius rod, place the radius-rod front pin on the front side of the forward-spring bracket, and place the radius-rod rear pin in front of the axle seat.

   If installing a rear-radius rod, place the radius-rod pins between the rear side of the equalizer bracket and the front side of the axle seat.
2. Install a hexhead bolt with a hardened washer through each end of the radius-rod rear pin and the axle seat ears. Install the hardened washers and locknuts.
3. If installing a forward radius rod, install any previously removed axle-alignment washers between the radius-rod front pin and the forward spring bracket. Install the hexhead bolts, hardened washers, and locknuts.

   If installing a rear radius rod, install any previously removed axle alignment washers between the radius rod front pin and the equalizer bracket. Install the hexhead bolts, hardened washers, and locknuts.
4. Tighten the radius-rod locknuts to the torque value in **Specifications, 400**.
5. After all of the radius rods are installed, check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the axle alignment, using the instructions in **Subject 140**.

Radius Rod Removal and Installation



A. Forward Right-Side Radius Rod
B. Rear Right-Side Radius Rod
C. Forward Left-Side Radius Rod
D. Rear Left-Side Radius Rod

1. Hex Locknut
2. Hardened Washer
3. Forward Radius-Rod Front Pin
4. Alignment Washers (Install only on one side of front axle; right-side installation shown.)
5. Forward Spring Bracket
6. Hexbolt
7. Forward Radius Rod Rear Pin
8. Forward Axle Seat
9. Equalizer Bracket
10. Rear Radius-Rod Front Pin
11. Rear Radius-Rod Rear Pin
12. Rear Axle Seat
13. Alignment Washers (Install only on one side of rear axle; left-side installation shown.)

Fig. 1, Radius Rod Attachment (top view)

Equalizer Removal, Inspection, and Installation

Removal

1. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs, then block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame. To allow access to the equalizer, remove the wheel assemblies on that side, using the instructions in **Group 40** in this manual.
3. If removing an equalizer from a vehicle with two drive axles, remove the cotter pin from the outboard end of each spring retainer pin, then remove the retainer pins. See **Fig. 1**.

   If removing an equalizer from a vehicle with a pusher or tag axle, remove the nuts from the flathead bolts in the wear-shoe side-restraints, on each end of the equalizer. Remove the flathead bolts and side-restraint sleeves. Remove the six capscrews and washers, and remove both wear-shoe side-restraints from the equalizer.
4. Remove the cap-and-tube assembly locknut, inboard-bearing washer, bolt, and outboard-bearing washer.
5. Insert a bar between the bottom of the equalizer and the equalizer bracket. Gently lever the weight of the equalizer off the cap-and-tube assembly. Insert a piece of barstock through the inboard cap-and-tube assembly bolt hole, and lightly tap the cap-and-tube assembly out of the equalizer.
6. Remove the equalizer from the equalizer bracket. Remove the wear washer(s) and equalizer bushings from the equalizer.

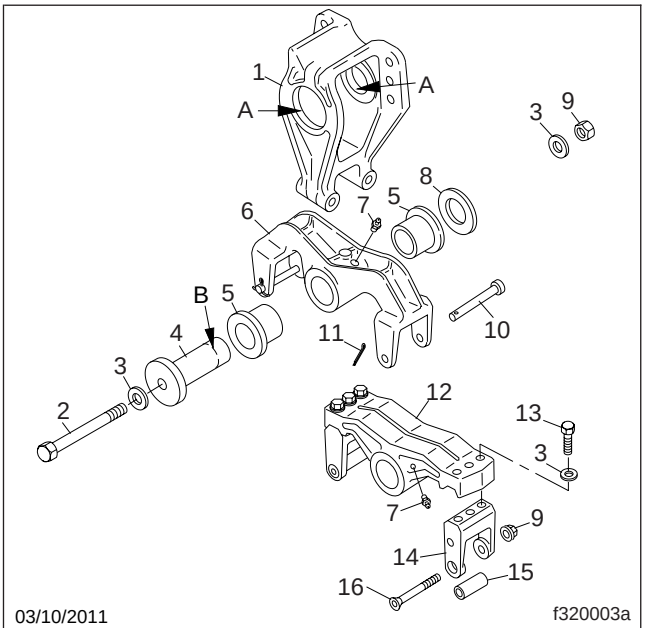
Inspection

1. Thoroughly clean the equalizer with steam or a hot soap solution. Inspect it for wear, cracks,or other damage. Replace the equalizer if any of these conditions are present.

⚠ CAUTION

Failure to replace the equalizer if it is cracked or otherwise damaged could result in progressive damage to, and eventual breakage of the equalizer. Breakage of the equalizer could cause a loss of vehicle control, resulting in personal injury or property damage.

2. Inspect the equalizer bushings, cap-and-tube assembly, and the equalizer bracket for wear, cracks, or other damage. If any of these conditions are present, replace the bushings or the cap-and-tube assembly.



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A. Apply Loctite here.
B. No grease.

1. Equalizer Bracket
2. Hexhead Bolt
3. Bearing Washer
4. Cap-and-Tube Assembly
5. Equalizer Assembly Bushing
6. Equalizer (used on vehicles with two drive axles)
7. Grease Fitting
8. Wear Washer(s)
9. Locknut
10. Spring Retainer Pin
11. Cotter Pin
12. Equalizer (used on vehicles with a tag or pusher axle)
13. Capscrew
14. Wear-Shoe Side-Restraint
15. Side-Restraint Sleeve
16. Flathead Bolt

Fig. 1, Equalizer Assembly

Equalizer Removal, Inspection, and Installation

Installation

1. Apply a thin film of multipurpose chassis grease to the outside of the equalizer bushings, then install the bushings in the equalizer. See **Fig. 1**.
2. Install the equalizer in the equalizer bracket.

NOTE: The next four steps must be completed before the Loctite begins to cure (approximately 5 to 10 minutes).

3. Apply Loctite 680 to both interior surfaces of the equalizer bracket, where the cap-and-tube assembly is inserted. Apply multipurpose chassis grease to the cap-and-tube assembly, except the last inch which connects to the equalizer bracket. Start the cap-and-tube assembly into the equalizer, through the equalizer bracket.
4. Push the cap-and-tube assembly part way through the equalizer, then place the wear washer(s) between the inboard equalizer bushing and the equalizer bracket. Push the cap-and-tube assembly the rest of the way into the equalizer bracket.
5. Place the inboard-bearing washer on the equalizer cap-and-tube assembly bolt, and install the bolt in the cap-and-tube assembly.
6. Install the inboard-bearing washer and locknut on the cap-and-tube assembly bolt. Tighten the locknut to the torque value in **Specifications, 400**.
7. Lubricate the equalizer assembly by applying multipurpose chassis grease at the grease fitting. Lubricate with a hand gun or pressure gun until grease is forced past the bushing seals, or if equipped with a pressure-relief grease fitting, until grease is forced out from the base of the pressure relief fitting.
8. If installing an equalizer on a vehicle with two drive axles, apply Alumilastic compound, or an equivalent, to the spring retainer pins, then install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

   If installing an equalizer on a vehicle with a pusher or tag axle, apply Alumilastic compound, or an equivalent, to the surfaces where the wear-shoe side-restraints contact the equalizer. Attach the side-restraints to the equalizer, offsetting them toward the inboard side of the equalizer. Tighten the equalizer wear-shoe capscrews to the torque value in **Specifications, 400**. Install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications, 400**.

NOTICE

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

9. Install the wheel assemblies. For instructions, see **Group 40** in this manual. Remove the safety stands from under the frame and axle, and lower the vehicle.
10. If the radius rods have been loosened, or the equalizer bracket has been removed, check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the axle alignment using the instructions in **Subject 140**.

Replacement

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Chock the front tires.
2. Raise the frame so that all weight is removed from the leaf springs; then block the frame with safety stands. Raise the rear axle until the spring no longer contacts the spring bracket wear shoes and the spring retainer pin (or side-restraint sleeve); then block the axle. Make sure the stands will securely support the weight of the axles and frame. To access the spring assembly, remove the wheel assembly. For instructions, see **Group 40** in this manual.
3. If equipped with two drive axles, remove the cotter pin from the spring retainer pin on the end of the equalizer where the spring is being replaced. Drive the spring retainer pin out of the equalizer. See **Subject 050** for an illustration of the tandem-axle spring suspension.

   If equipped with a pusher or tag axle, remove the nut from the flathead bolt on the end of the equalizer where the spring is being replaced. Remove the bolt and the side-restraint sleeve from the wear-shoe side-restraint.
4. Remove the U-bolt high nuts, hardened washers, U-bolt retainer, U-bolts, and upper U-bolt pad.
5. Remove the spring assembly by lifting it off the axle spring seat, then moving it toward the equalizer, out of the forward or rear spring bracket.
6. Using chassis grease, lubricate the new spring assembly where the ends will contact the stationary wear shoes in the spring bracket and equalizer.
7. Place the new spring assembly in the spring bracket and on the axle seat. Make sure the spring center-bolt head seats in the axle spring seat hole.
8. If the upper U-bolt pad is aluminum, apply Alumilastic compound, or an equivalent, to those areas of the pad that will come in contact with the U-bolts and with the upper spring leaf.

NOTICE

Failure to apply Alumilastic® compound, or an equivalent, to areas where aluminum and steel contact each other, could lead to corrosion of the metals, resulting in suspension damage.

IMPORTANT: Do not re-use high nuts.

9. Place the upper U-bolt pad on the spring assembly. Place the U-bolts over the upper U-bolt pad and the spring assembly.
10. Install the U-bolt retainer, hardened washers, and U-bolt high nuts. Tighten the high nuts until snug.
11. If installing a spring assembly on a vehicle with two drive axles, apply Alumilastic compound, or an equivalent, to the spring retainer pins, then install them from the inboard side. Be sure the hooked ends of the spring leaves are above the retainer pins. Install a cotter pin in the outboard end of each retainer pin, and lock it in place.

    If installing a spring assembly on a vehicle with a pusher or tag axle, install the side-restraint sleeves and flathead bolts in the wear-shoe side-restraints. Be sure the hooked ends of the spring leaves are above the side-restraint sleeves. Install the nuts, and tighten them to the applicable torque value in **Specifications, 400**.
12. Tighten and torque the U-bolts as shown in **Specifications, 400**.

NOTICE

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking inter-

Spring Assembly Replacement

vals and instructions, see **Group 32** of the *108SD and 114SD Maintenance Manual*.

13. Install the wheel assembly, using the instructions in **Group 40** in this manual. Remove the safety stands from under the frame and axle, and lower the vehicle.
14. Check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the axle alignment using the instructions in **Subject 140**.

Spring Bracket and Equalizer Bracket Replacement

Replacement

WARNING

Replace worn, cracked, or damaged spring brackets or equalizer brackets. Failure to do so could result in breakage of the bracket, possibly leading to loss of vehicle control and resulting in personal injury or property damage.

NOTICE

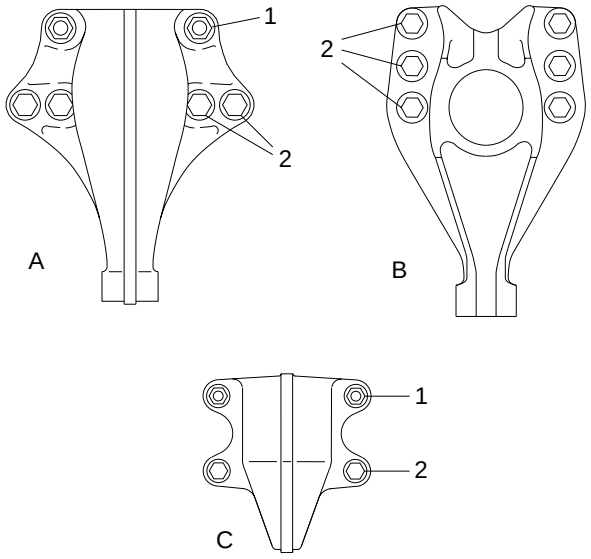
Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the suspension.

1. Chock the front tires.
2. Raise the rear of the vehicle, and block the axles with safety stands. Raise the vehicle frame so that all weight is removed from the leaf springs, then block the frame with safety stands. Make sure the stands will securely support the weight of the axles and frame.
3. If removing the forward spring bracket or the equalizer bracket, note the number of any axle alignment washers, then remove the fasteners that attach the radius rod to the forward spring bracket or equalizer bracket. Remove any axle alignment washers. See **Subject 050** for an illustration of a tandem-axle spring suspension.
4. If removing an equalizer bracket, remove the equalizer. For instructions, see **Subject 110**.

IMPORTANT: See **Section 31.00** of this manual for correct removal and installation of Huckbolt HP 8® Frame Fasteners.

5. Remove the fasteners that attach the forward or rear spring bracket, or equalizer bracket, to the frame rail. Remove the bracket.
6. Place the new spring bracket or equalizer bracket on the frame rail. Align the mounting holes, and install the bracket bolts, hardened washers, and locknuts. See **Fig. 1**.

NOTE: If installing the forward spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom four bolts on the inboard side of the frame rail.



NOTE: All bolts are Huck bolts except those represented by callout "2" in Item C, which are standard bolts.

A. Forward Spring Bracket
B. Equalizer Bracket
C. Rear Spring Bracket

1. Nut (outboard)
2. Bolt Head(s) (outboard)

Fig. 1, Frame Brackets

If installing the equalizer bracket, for clearance, install all of the nuts on the inboard side of the frame rail.

If installing the rear spring bracket, install the nuts for the top two bolts on the outboard side of the frame rail, and install the nuts for the bottom two bolts on the inboard side of the frame rail. See .

7. Tighten the bracket mounting locknuts to the applicable torque value in **Specifications, 400**.

NOTICE

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All suspension fasteners require periodic torquing. For suspension component

Spring Bracket and Equalizer Bracket Replacement

inspecting and fastener torque checking intervals and instructions, see **Group 32**in the *108SD and 114SD Maintenance Manual*.

8. When replacing the forward spring bracket or equalizer bracket, install any previously removed axle alignment washers between the forward radius rod front pin and the forward spring bracket, or between the rear radius rod front pin and the equalizer bracket, as applicable. See **Subject 100** for an illustration of a radius rod attachment.

   Install bolts with hardened washers in the radius rod front pin, and the forward spring bracket or equalizer bracket. Install the hardened washers and locknuts, and tighten the locknuts to the torque value in **Specifications, 400**.

9. If replacing an equalizer bracket, install the equalizer. For instructions, see **Subject 110**.

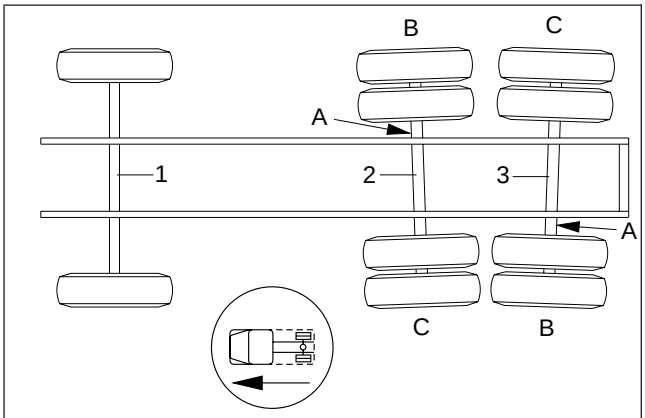
10. Remove the safety stands from under the frame and axle, and lower the vehicle.

11. Check the rear axle alignment. For instructions, see **Group 35** in this manual. If necessary, adjust the axle alignment using the instructions in **Subject 140**.

Adjustment

1. Using a straightedge and a tape measure, determine the amount of adjustment needed to align the forward-rear axle at a right angle to the frame. For instructions, see **Group 35** in this manual. The difference in measurements between the sides of the vehicle is the approximate amount that the trailing end of the forward-rear axle will have to be brought forward, or the leading end will have to be moved back to align it at a right angle to the frame. See **Fig. 1**.

   If the forward-rear axle alignment is within specifications, go to the step that begins "Using a center-point bar, determine...".



A. Adjust here.
B. Leading End
C. Trailing End
1. Front Axle
2. Forward Rear Axle
3. Rearmost Axle

Fig. 1, Tandem Axle (shown out of alignment)

2. Chock the front tires. On both sides of the forward-rear axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
3. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the forward radius rod to the forward spring bracket. Remove any axle alignment washers.

NOTE: To adjust the forward-rear axle alignment, add alignment washers between the radius rod and the forward spring bracket on the leading end, to adjust the leading end backward. Or, remove alignment washers from the trailing end, to bring the trailing end forward. When possible, alignment washers should be removed instead of added.

4. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
5. Move the loosened end of the axle forward or backward as needed, by rolling the wheels.
6. Between one end of the radius rod front pin and the forward spring bracket, insert the correct thickness of axle alignment washers needed to bring the forward-rear axle into alignment. Install the hexhead bolt, hardened washers, and locknut in the radius rod pin and forward spring bracket.
7. Place an equal thickness of washers on the other end of the radius rod pin, and install the fasteners.
8. Tighten the radius rod locknuts to the torque value in **Specifications, 400**.
9. Remove the safety stands, and lower the vehicle.
10. Check the forward-rear axle alignment with the straightedge and the tape measure. If alignment is within specifications, center the spring in the forward spring bracket, if needed, then tighten the axle U-bolt nuts to the torque value in **Specifications, 400**.

    If not in alignment, repeat all of the steps above.

NOTICE

Failure to periodically torque the suspension fasteners can result in abnormal tire wear, and damage to the springs, spring brackets, and frame rail.

IMPORTANT: All standard suspension fasteners require periodic torquing. For suspension component inspecting and fastener torque checking intervals and instructions, see **Group 31** in the *108SD and 114SD Maintenance Manual*.

11. Using a center-point bar, determine the difference between the forward-rear and the rearmost axles' center-to-center measurements on each side of the vehicle. For instructions, see **Group 35** in this manual. This difference is the approximate distance that the leading end of the

Rear Axle Alignment Adjustment

rearmost axle will have to be adjusted rearward, or that the trailing end will have to be adjusted forward, to align it at a right angle to the frame, and to align it parallel to the forward-rear axle. See **Fig. 1.**

12. On both sides of the rearmost axle, loosen the axle U-bolts enough to allow the springs to shift on the axle seats.
13. On the side of the vehicle that is to be adjusted, remove the fasteners that attach the rear radius rod to the equalizer bracket. Remove any axle alignment washers.
14. Raise the frame just enough to relieve the weight from the springs. Place safety stands under the frame. Make sure the stands will securely support the weight of the frame.
15. Move the loosened end of the axle forward or backward, by rolling the wheels. Move the axle just enough to provide space to allow installation of alignment washers between the equalizer bracket and the radius rod pin.
16. Between one end of the radius rod pin and the equalizer bracket, insert the additional thickness of alignment washers needed to make up for the difference in center-point bar measurements.

    For example, if one end of the axle was equipped with a 3/16-inch (4.5-mm) thickness of washers, and the difference in the center-point bar measurements is 1/4 inch (6 mm) less on that side, add an additional 1/4 inch (6 mm) of washers (for a total of 7/16 inch [10.5 mm]) to correct the alignment.

    Or, if one end of the axle was equipped with a 1/4-inch thickness of washers, and the difference in center-point bar measurements is 3/16 inch (4.5 mm) more on that side, install a 1/16-inch (1.6-mm) thickness of washers in place of the 1/4-inch (6-mm) thickness.
17. Install the bolt, hardened washers, and locknut in the equalizer bracket and the radius rod pin. Place an equal thickness of alignment washers on the other end of the radius rod pin, and install the fasteners at that end.
18. Tighten the radius rod locknuts to the torque value in **Specifications, 400**.
19. Remove the safety stands, and lower the vehicle. Remove the chocks from the front tires.
20. Using the center-point bar, check the rearmost axle alignment. If alignment is within specifications, center the spring in the rear spring bracket, if needed, then tighten the axle U-bolt nuts to the applicable torque value in **Specifications, 400**.

    If not in alignment, repeat the applicable steps above.

Specifications

Torque Values			
Description	**Size**	**IFI Grade**	**Torque lbf·ft (N·m)**
Equalizer Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Forward Spring Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Rear Spring Bracket-to-Frame Rail Locknut *	5/8–11	C	135 (184)
Axle U-bolt High Nuts Tighten in a diagonal pattern as shown in **Fig. 1**.	7/8–14	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420–500 (571–680)
	1–14	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 520–600 (707–816)
Radius Rod Locknut *	5/8–18	C	135 (184)
Equalizer Cap and Tube Assembly Locknut *	3/4–16	C	270 (365)
Equalizer Wear Shoe Capscrew	5/8–11	8	135 (184)
Side-Restraint Sleeve Locknut	1/2–13	C	68 (93)

* Cadmium-plated, wax-coated nuts, and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.

Table 1, Torque Values

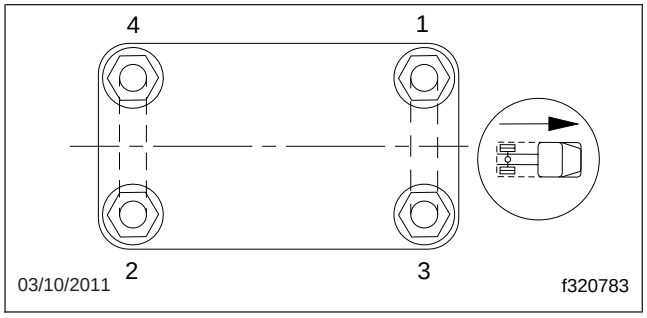


Fig. 1, Tightening Pattern for U-bolt High Nuts

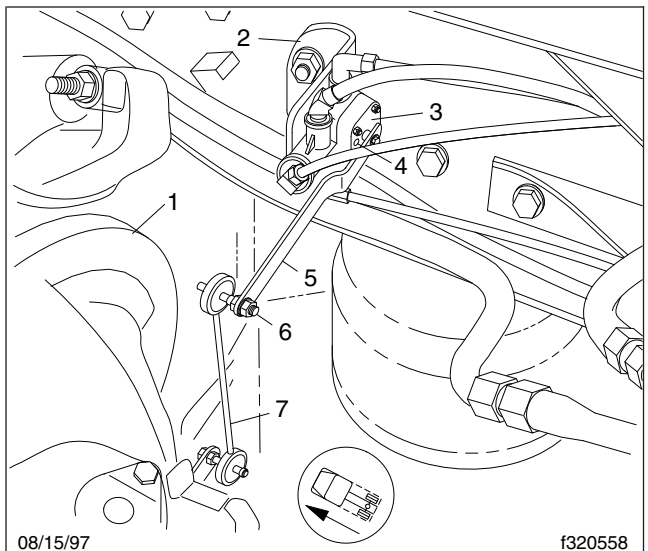
General Information

The Freightliner AirLiner Suspension is a single axle or tandem axle suspension that uses a combination of air and leaf springs. The suspension is manufactured at numerous weight ratings up to 46,000 pounds (20 865 kg). The top of the air spring is bolted to a bracket on the frame rail or through the bottom flange of the frame rail; the bottom is bolted to the rear end of the tapered leaf spring assembly or, for the 23,000-pound (10 433 kg) and 46,000-pound suspensions, to a cross bar. The axle housing is fastened to the leaf spring assembly by U-bolts. A control rod, mounted between the axle housing and the frame rail, can be used to help locate the assembly laterally.

The air springs compensate for changes in road conditions and vehicle load, maintaining vehicle height. The air springs also absorb road shock.

A height-control valve regulates the air flow into or out of all the air springs. As the air spring compresses or expands, changes in the clearance between the vehicle frame and the differential housing activate the height-control valve. See **Fig. 1**.

The pressure-holding valve, located in the air line to the height-control valve, is preset to maintain a minimum pressure of 65 psi (448 kPa) in the vehicle secondary air system if a leak should occur in the air suspension system.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Pilot Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Barksdale Height-Control Valve Assembly

Ride Height Adjustment

IMPORTANT: Before checking the suspension height, make sure there is no load on the chassis. For tractors, unhitch the trailer. Trucks must be empty.

Vehicles with dual ride height control valves follow the same procedure as single valves, but with two height gauge blocks, and both height control valves adjusted simultaneously. Both linkages should be disconnected when adjusting, and both valves should be repositioned once the correct ride height has been reached on both sides.

1. Park the vehicle on a level surface, using a light application of the brakes. Set the parking brake and chock the tires. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.
2. Space the tire chocks 2 inches (5 cm) ahead and behind the tire so the vehicle can roll 2 inches in either direction.
3. Release the parking brake and verify by hand that the vehicle can roll forward and aft. This should remove any load from the suspension.
4. Determine the correct ride height for the suspension:
    - Some common suspensions and ride height dimensions are shown in **Table 1**, **Table 2**, **Table 3**, **Table 4**, and **Table 5**.
    - In PartsPro, enter the VIN and Module "622" (Rear Suspension), and retrieve the Parts List. The installation drawing will be listed as a part with a D16 prefix. Use the EZ Wiring icon to view this drawing, which will specify where to measure the ride height and the target ride height distance for that suspension. This dimension is usually labeled the "E" dimension; the target ride height should be in a table on the same page of the drawing.
5. Measure the distance between either forward-most axle stop and the suspension using the dimension indicated in the drawing or figure for the suspension.
6. If the distance is within the acceptable range, no adjustment is needed. Apply the parking brakes. If the measurement is not within the acceptable range, go to the next step.
7. Disconnect the height-control valve linkage at the lever stud. (For dual valves, disconnect both.)
8. If there is not enough room for the block between the axle stop and the top pad, lift the valve lever to inflate the airbags enough to fit the block. (For dual valves, lift both levers.) Do not install the block yet.
9. Pin the lever in neutral position with a 5/32-inch drill bit or nylon rod to lock the lever in neutral position. See **Figure 1**.

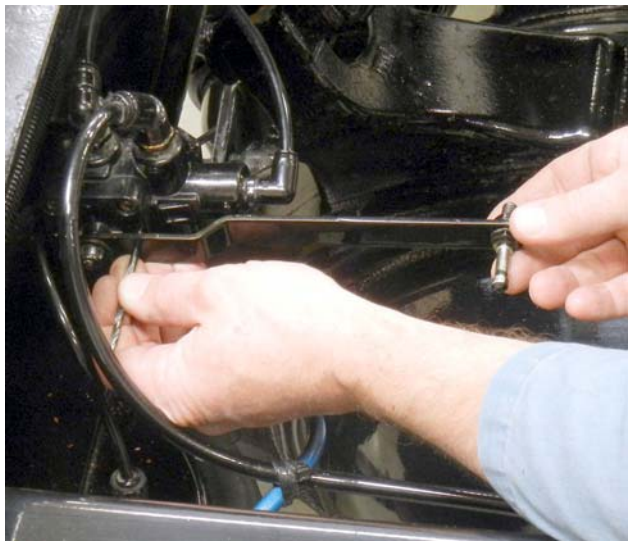

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Fig. 1, Inserting a 5/32-inch drill bit or nylon rod to lock the lever in neutral position.

10. Install the height gauge block. (For dual valves, install a block on both sides.)
11. Unpin the valve lever and use it to lower the suspension until the axle stop rests on the block. (For dual valves, unpin and lower with both valves.)
12. Move the lever to neutral and pin. (For dual valves, pin both.) The vehicle should now be at the target ride height.

Ride Height Adjustment

NOTICE

When loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

13. While holding the height-control valve mounting studs in place with an Allen wrench, loosen the nuts that attach the valve to the mounting bracket. See **Figure 2**.

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Fig. 2, Holding the height control valve mounting stud in place with an Allen wrench when loosening the nut.

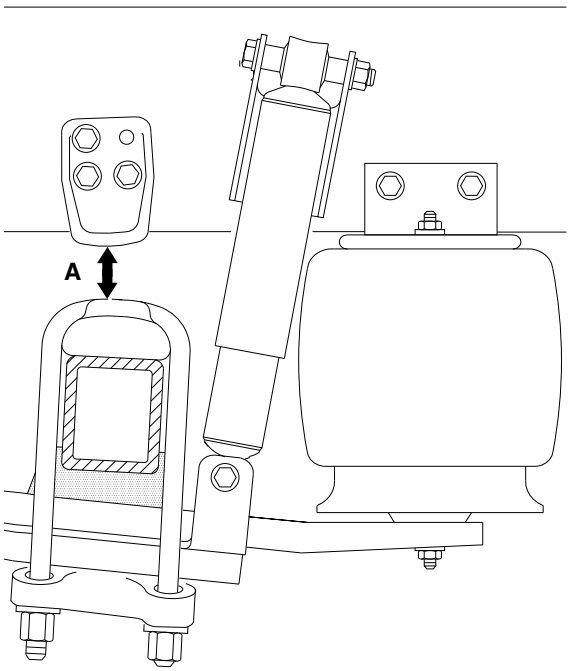
14. Adjust the position of the valve body until the lever—still pinned in neutral position—can connect to the linkage. Attach the linkage. The linkage rod should be vertical, and the valve body should now be in the correct position for the vehicle's ride height. (For dual valves, adjust and connect both.)

    If the linkage cannot reach the stud, check the surrounding components for bent or damaged parts and remedy as needed.

15. While holding the height-control valve mounting studs in place with an Allen wrench, tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten, as that could damage the valve. (For dual valves, tighten both.)
16. Disconnect the linkage from the valve lever stud. (For dual valves, disconnect both.)
17. Raise the valve lever to raise the suspension enough to remove the block, then pin the valve lever in neutral position. (For dual valves, raise and pin both valves.)
18. Remove the block. (For dual valves, remove both blocks.)
19. Remove the pin or drill bit holding the height-control lever in neutral position, then connect the valve lever to the linkage. (For dual valve, unpin and connect both valve levers.)
20. Drive the vehicle unloaded for about 1/4 mile (1/2 km), then park the vehicle on a level surface using a light brake application. Chock the tires on one axle only, and put the transmission in neutral. Do not apply the parking brakes.
21. Check the ride height of the vehicle again, measuring where indicated in the drawing or figure for the suspension.

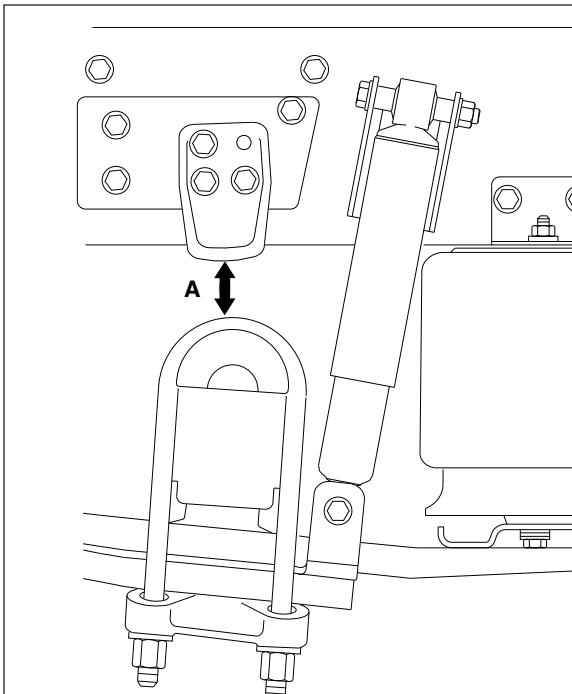
    If the distance is within the acceptable range, the ride height is correctly set. Apply the parking brakes.

    If the distance is not within the acceptable range, repeat the adjustment procedure.



Measure Point	Height Measurement (A) Inches (mm)		
	Min.	Target	Max.
A = Measure Here	2-3/8 (60)	2-5/8 (67)	2-7/8 (73)

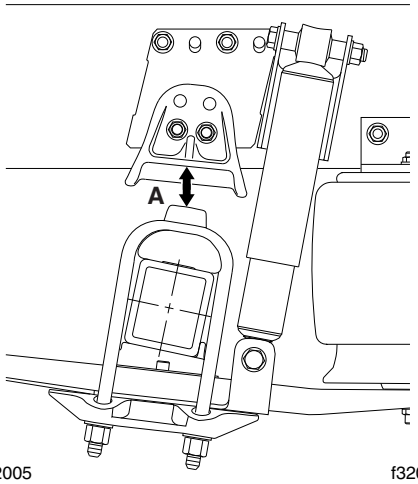
Table 1, Suspension Ride-Height Measurement, Dual-Leaf Spring, 20k/21k/22k/40k High-Ride



Measure Point	Height Measurement (A) Inches (mm)		
	Min.	Target	Max
A = Measure Here	2-3/4 (70)	3 (76)	3-1/4 (83)

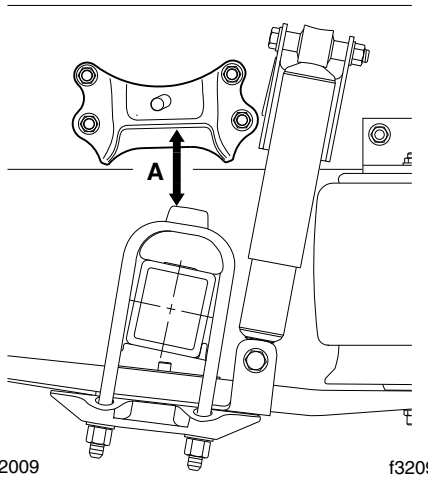
Table 2, Suspension Ride-Height Measurement, Dual-Leaf Spring, 23k/46k/69k High-Ride

Ride Height Adjustment



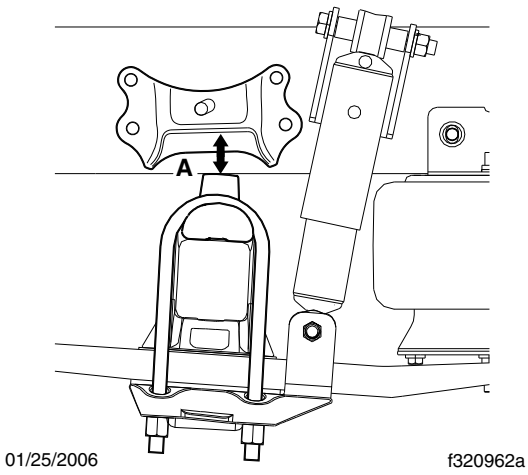
Measure Point	Height Measurement (A) Inches (mm)		
	Min.	Target	Max.
A = Measure Here	2-3/8 (60)	2-5/8 (67)	2-7/8 (73)

Table 3, Suspension Ride-Height Measurement, Single-Leaf Spring, 20k/40k, High-Ride Height



Measure Point	Height Measurement (A) Inches (mm)		
	Min.	Target	Max.
A = Measure Here	2-3/8 (60)	2-1/2 (64)	2-7/8 (73)

Table 4, Suspension Ride-Height Measurement, Single-Leaf Spring, 10k/12k/15k/18k Mid-Ride Height and 40k Low- and Mid-Ride Height



Measure Point	Height Measurement (A) Inches (mm)		
	Min.	Target	Max.
A = Measure Here	2-1/8 (54)	2-9/32 (58)	2-5/8 (67)

Table 5, Suspension Ride-Height Measurement, Single-Leaf Spring, 10k/12k/15k Low or Extra-Low Ride-Height

Height-Control Valve Checking

It is normal to hear air escaping from the height-control valve for as much as 10 minutes after getting out of the vehicle when it is in an unladen condition. This air "leaking" is just the height-control valve exhausting air from the suspension air springs in order to return to the neutral mode.

A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Overtightening the four bolts in the valve housing may crack the valve housing. These bolts should not be loose, and should not normally require tightening. There are no serviceable parts in the valve.

IMPORTANT:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

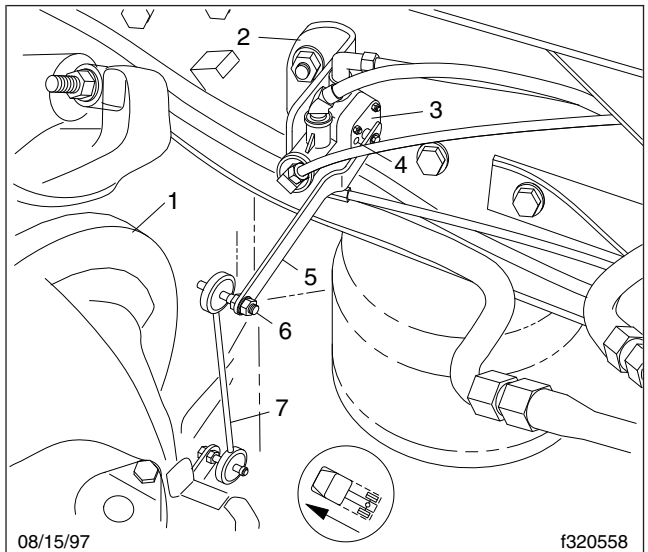
When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Checking the Height-Control Valve Without Using a Test Kit

1. Apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Disconnect the vertical linkage from the control lever; see **Fig. 1**.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Pilot Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Linkage Rod

Fig. 1, Height-Control Valve Assembly

5. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is working.
6. Return the control lever to the neutral position. Air should stop flowing. If so, that section of the valve is working.

Height-Control Valve Checking

7. Push the control lever down about 45 degrees for 6 to 8 seconds. If air exhausts from the valve, that section of the valve is working.
8. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
9. If the valve works as stated in all of the above steps, then no further checking is necessary. Connect the vertical linkage to the control lever, then tighten the linkage nut.

   If needed, adjust the ride height or replace the height-control valve. For adjustment of the ride height, see **Subject 110**. For replacement of the height-control valve, see **Subject 130**.

NOTE: If a leak is detected on a Barksdale height-control valve, go to "Checking a Barksdale Height-Control Valve Using a Test Kit". Barksdale valves have an acceptable leak rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

Checking the Height-Control Valve Using a Test Kit

IMPORTANT: The procedure described below is for use on Barksdale height-control valves only.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle. Refer to **Specifications 400** for information on ordering the Barksdale height-control valve test kit KD2264.

1. If not already done, park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. For valves without an integral dump port, go to the next step.

   For valves with an integral dump port, check the rubber exhaust flapper at the back of the valve housing for leaks; see **Fig. 2**. Use a soapy solution.

   If a leak is found, there may be contaminants blocking the piston. Cycle the height-control valve switch inside the cab for two-second bursts, four or five times, to clear away any contaminants.

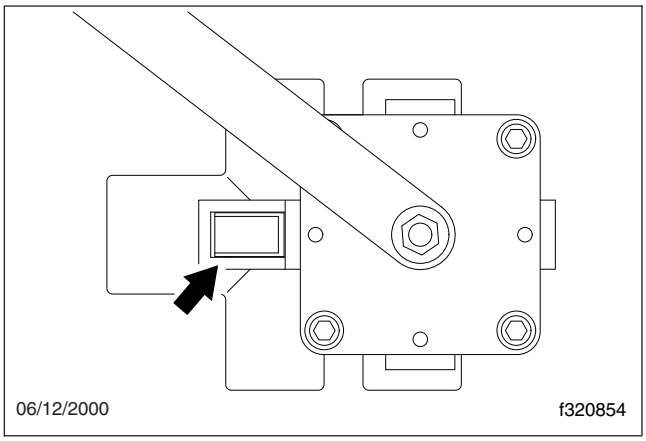
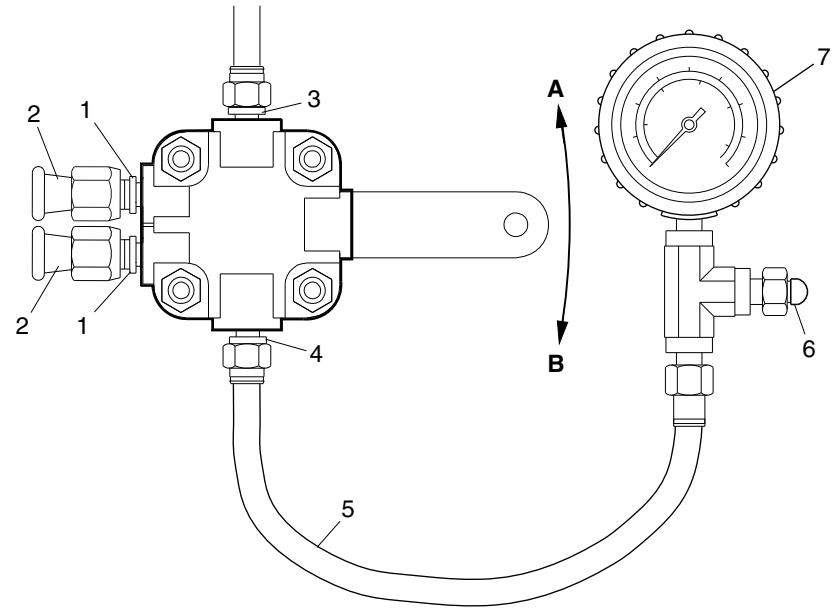


Fig. 2, Exhaust Flap Location (height-control valve with integral dump port)

5. Disconnect the vertical linkage from the horizontal control lever.
6. Rotate and hold the horizontal control lever down at about 45 degrees to exhaust air from the air springs.
7. *If equipped with an integral dump port,* turn on the quick dump switch on the dash. Leave the switch on until testing is complete.

   If not equipped with an integral dump port, disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 3**.
8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.
9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the



A. Fill
B. Exhaust

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting
5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 3, Test Connections

slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 3**.

NOTE: It may be necessary to cut the tie straps that hold the chassis wiring running below the height-control valve, in order to access the exhaust port.

10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.
11. Check the height-control valve in the fill mode, as follows.
    - 11.1 Rotate the valve control lever up 45 degrees from the horizontal to the fill position.
    - 11.2 Press the reset button on the test gauge.
    - 11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable exhaust pressure change versus inlet pressure.

      The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

      If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

12. Check the height-control valve in the exhaust mode, as follows.
    - 12.1 Rotate the valve control lever down 45 degrees from the horizontal to the exhaust position.
    - 12.2 Press the reset button on the test gauge.
    - 12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 4** for the maximum allowable exhaust pressure change versus inlet pressure.

Height-Control Valve Checking

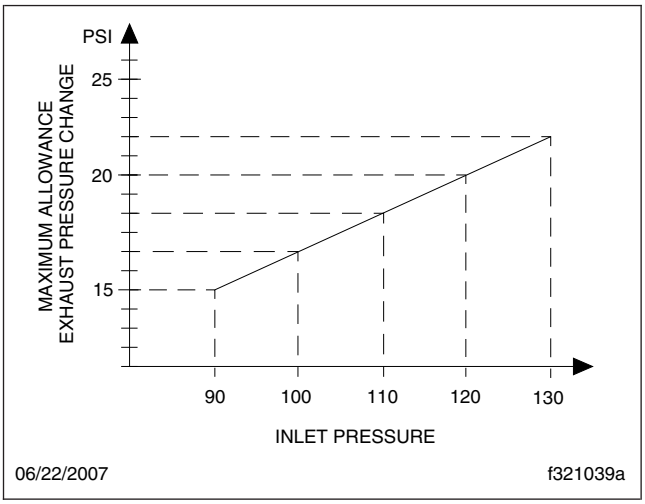


Fig. 4, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 130**.
15. Install the flapper on the exhaust port by pressing it into place.
16. *For height-control valves with an integral dump port,* connect the vertical linkage to the height-control valve control lever. Turn off the quick dump switch on the dash. The ride height will automatically return to the correct position.

    For height-control valves without an integral dump port, remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.

Replacement

1. Apply the parking brakes and chock the tires.

⚠ WARNING

Keep your hands and all objects away from the area under and around the slack adjusters and suspension components when removing the pressure from the air system. These parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

2. Drain all air from the air tanks.

⚠ WARNING

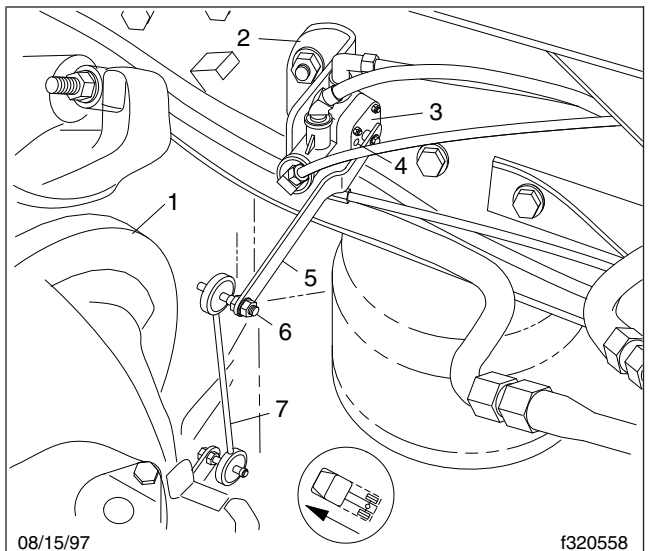
Air lines under pressure can whip dangerously if disconnected. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

3. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
4. Rotate and hold the horizontal control lever down until all air is exhausted from the air springs.
5. Disconnect the air lines at the height-control valve, and mark the lines for later reference. Using tape, cover the open ends of the air lines and fittings to prevent dirt or foreign material from entering.

IMPORTANT: For quick-connect tube fittings, do not remove the tube by cutting it close to the fitting. If the remaining part of the tube cannot be pulled from the fitting, the fitting will not be reusable and the warranty on that unit will be void.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.



1. Forward Drive Axle
2. Valve Mounting Bracket
3. Height-Control Valve
4. Pilot Hole
5. Horizontal Control Lever
6. Stud Bolt
7. Vertical Linkage

Fig. 1, Height-Control Valve Installation

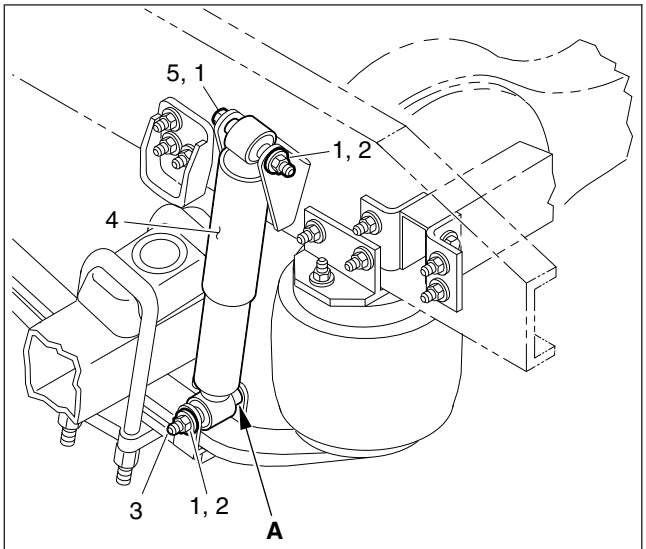
6. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
7. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and tighten the nuts 95 lbf·in (1100 N·cm). Do not overtighten.
8. Remove the tape from the air lines and fittings, and connect the air lines to the height-control valve as marked earlier. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance, then tighten one-sixth turn more.

Height-Control Valve Replacement

9. Connect the vertical linkage to the horizontal control lever.
10. Close the drain cocks on all reservoirs.
11. Build up normal operating pressure in the air system. Check all air lines and connections for leaks. Eliminate all leaks.
12. Adjust the height-control valve; see **Subject 110**.

Replacement

1. Chock the tires.
2. Remove the hexnut, hexbolt, and hardened washers from the shock-absorber lower mounting bracket. See **Fig. 1**.



A. Longer Section of Sleeve Facing Inboard

1. Hardened Washer
2. Hexnut, 3/4–10
3. Hexbolt, 3/4–10 x 5
4. Shock Absorber
5. Hexbolt, 3/4–10 x 6

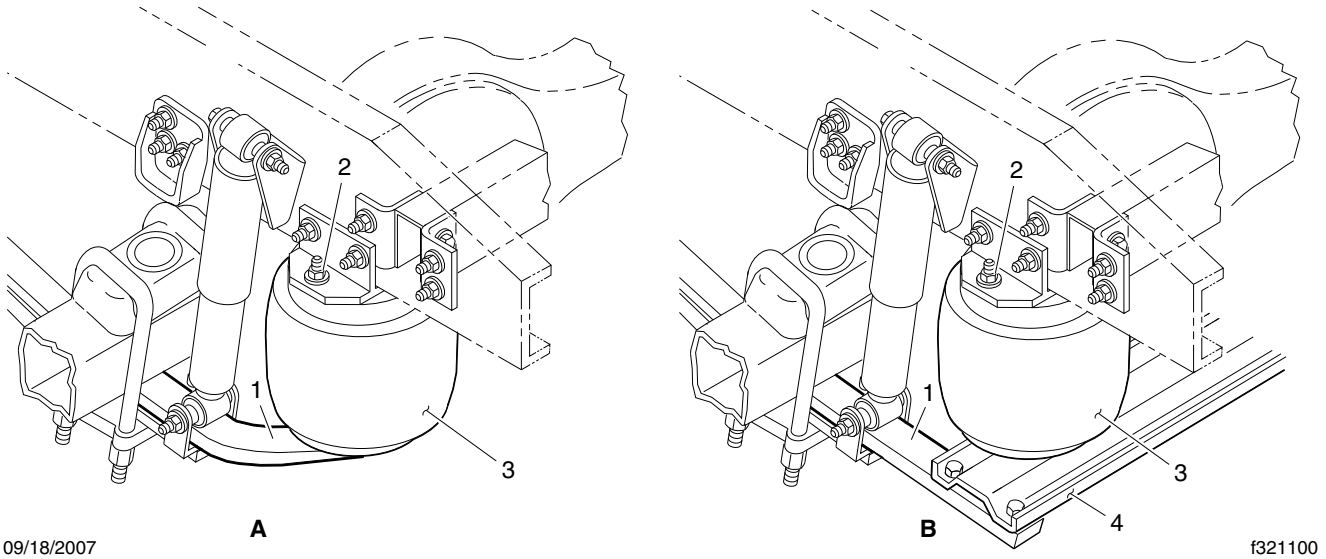
Fig. 1, Shock Absorber Installation

3. Remove the nut, upper retainer, and upper bushing from the top of the shock absorber, then pull the shock absorber out of the upper mounting bracket,
4. Install the replacement shock absorber. At the lower mounting, make sure the longer section of the sleeve is facing inboard. See **Fig. 1**.
5. Tighten the shock-absorber mounting hexnuts 165 lbf·ft (220 N·m).

Replacement

1. Apply the parking brakes and chock the tires.
2. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs. The height-control valve automatically releases air from the air springs when all weight is removed from the suspension.
3. Disconnect the air supply line, including the brass tee, from the air spring. Using tape, cover the ends of the air supply line and the fitting to prevent dirt or foreign material from entering.
4. Remove the locknut and washer that hold the top of the air spring to the mounting bracket on the frame rail; see **Fig. 1**.
5. Remove the locknut and lockwasher that connect the air spring to the rear of the leaf spring, or the crossbar, as applicable; see **Fig. 1**. Remove the air spring.
6. Place the new air spring on the rear of the leaf spring (or the crossbar on the 23,000- and 46,000-pound suspensions), and install the washers and locknut that hold the air spring (and crossbar) in place. Tighten the locknut 55 lbf·ft (75 N·m).
7. Using a 1/2–13 locknut and washer, attach the top of the air spring to the mounting bracket on the frame; see **Fig. 1**. Tighten it 23 lbf·ft (31 N·m).
8. Remove the tape from the ends of the air supply line, the fitting, and the brass tee. Connect the air supply line to the air spring. Tighten nylon tube air fittings until only two threads show on the fitting. On wire-braid hose fittings, tighten the nut with a wrench until there is firm resistance, then tighten one-sixth turn more.
9. Raise the vehicle, remove the safety stands, then lower the vehicle.

Air Spring Replacement



A. 21,000- and 40,000-lb Suspensions
1. Leaf Spring
2. Air Bag Upper Mounting Hexnut, 1/2–13

B. 23,000- and 46,000-lb Suspensions
3. Air Spring
4. Crossbar

Fig. 1, Leaf Spring and Air Spring Assembly

Leaf Spring Replacement

WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs, then securely support the frame with safety stands. Remove the wheel and tire assembly to easily access the suspension. See **Group 40** in this manual for instructions.
3. Remove the nut, bolt, and washers from the shock-absorber lower mounting bracket.
4. Note and record the direction of the arrow on the bottom of the axle clamp. Remove the high nuts and flatwashers from each U-bolt, then the axle clamp. Support the leaf spring assembly with a jack. See **Fig. 1**.
5. If the air spring mounts to the leaf spring, disconnect the bottom of the air spring from the leaf spring.

   If the air spring mounts to a crossbar, disconnect the crossbar from the leaf spring by removing the capscrews, nuts, and washers. See **Fig. 2**.
6. Note the number and position of the alignment shims on the spring mounting bolt. See **Fig. 1**.
7. Remove the hexnut, washers, alignment shim(s), spring mounting bolt, and wear-shoe clip from the spring hanger. See **Fig. 1**.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

8. Remove and discard the leaf spring assembly.
9. While supporting a new leaf spring assembly with a jack, position the assembly on the spring hanger. Install the bolts, wear-shoe clips, washers, alignment shims, and hexnuts. Tighten the bolts just enough to hold the leaf spring assembly in place.
10. If the air spring mounts to the leaf spring, attach the air spring to the leaf spring assembly. Install the washer and locknut. Tighten the locknut 55 lbf·ft (75 N·m).

    If the air spring mounts to a crossbar, attach the crossbar to the leaf spring assembly. The longer capscrews attach in the forwardmost holes; the shorter capscrews attach in the aft holes.
11. Making sure that the U-bolt pads are in place on the top of the axle, fasten the leaf spring assembly to the axle using the U-bolts, axle clamp, washers, and high nuts making sure the U-bolt pads and axle clamps are positioned correctly. Install the axle clamps with the arrows pointing in the same direction as previously recorded.

NOTE: On single drive axles angled 5 degrees, the arrow on the U-bolt pads must point to the front of the axle housing. See **Fig. 3**. On single drive axles angled 3 degrees, make sure that the axle bump-stop on the U-bolt pad is positioned toward the vehicle centerline. See **Fig. 4**.

On tandem axle suspensions, refer to **Table 1** for U-bolt pad orientation.

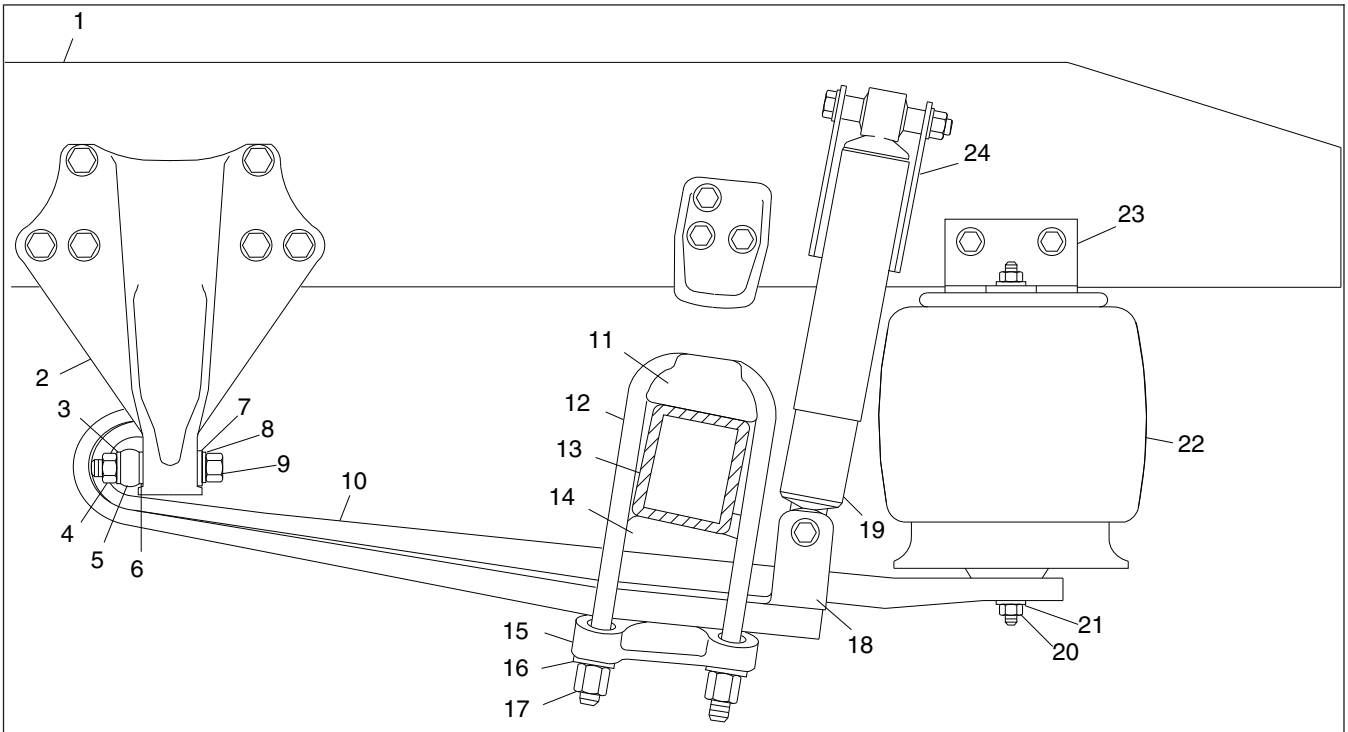
12. Hand-tighten the high nuts. In a diagonal pattern, tighten the axle U-bolt high nuts 60 lbf·ft (81 N·m). Then, in the same pattern, tighten them 200 lbf·ft (271 N·m); then, tighten to a final torque value of 400 to 460 lbf·ft (542 to 624 N·m).

    For the 23,000-pound and 46,000-pound suspensions, tighten the high nuts in a diagonal pattern to a final torque value of 520 to 600 lbf·ft (705 to 813 N·m).
13. Using the bolt, washers, and hexnut, attach the shock absorber to its lower mounting bracket. Tighten the hexnut 165 lbf·ft (220 N·m).
14. Tighten the locknut on the bottom of the air spring 55 lbf·ft (75 N·m).

    On 23,000-pound and 46,000-pound suspensions, tighten the locknuts on the bottom of the crossbar 241 lbf·ft (327 N·m).
15. Tighten the hexnuts at the front of the leaf spring 170 lbf·ft (230 N·m).

Leaf Spring Replacement

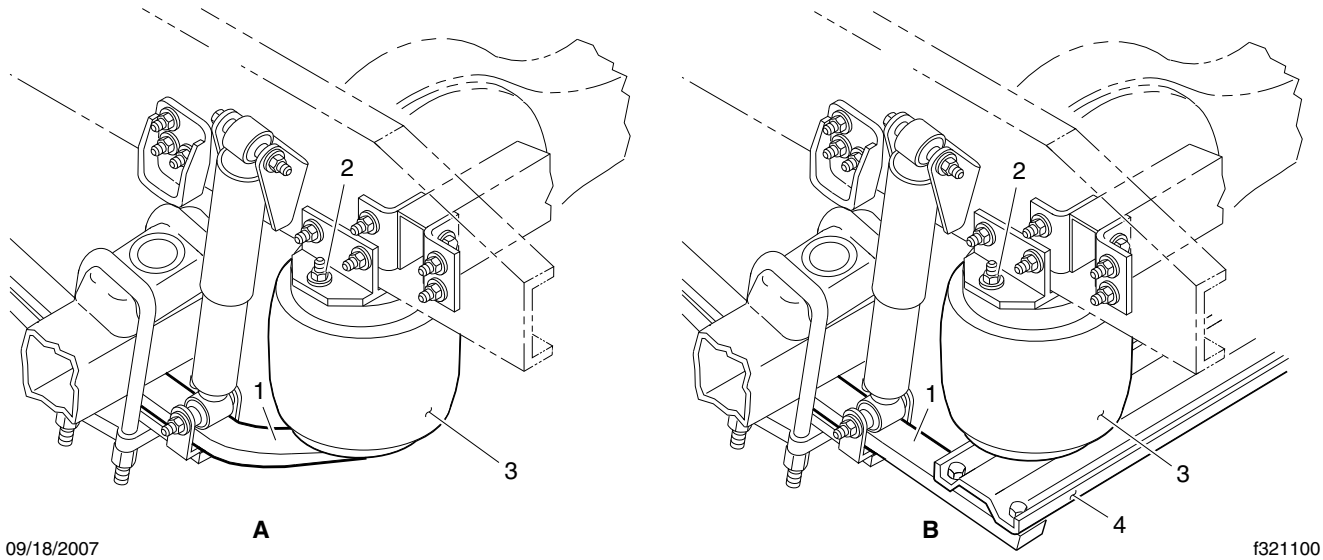
16. Install the wheel and tire assembly. For instructions, refer to **Group 40**.
17. Raise the vehicle, remove the safety stands, then lower the vehicle.
18. Check the rear axle alignment. For instructions, refer to **Group 33**. If necessary, adjust the rear axle alignment using the instructions in **Subject 170**.



04/27/2011 f320462

1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring-Eye Mounting Pin
6. Alignment Shim
7. Wear-Shoe Clip
8. Washer
9. Spring Mounting Bolt
10. Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock-Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring
23. Air-Spring Mounting Bracket
24. Shock-Absorber Upper Mounting Bracket

Fig. 1, AirLiner Leaf Spring Assembly



A. 21,000- and 40,000-lb Suspensions

1. Leaf Spring
2. Air Bag Upper Mounting Hexnut

B. 23,000- and 46,000-lb Suspensions

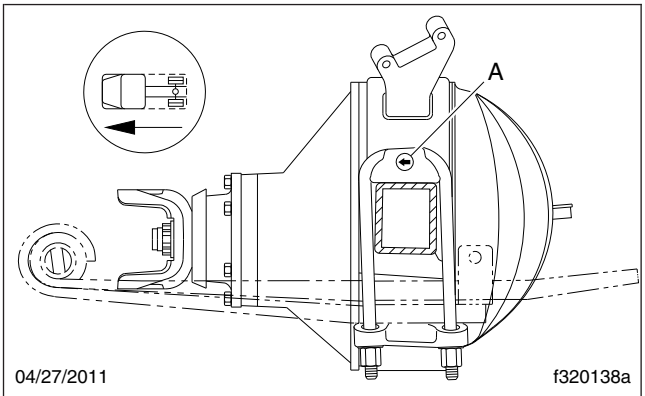
3. Air Spring
4. Crossbar

Fig. 2, Leaf Spring and Air Spring Assembly

U-Bolt Pad Orientation for Axles		
Axle Designation		**U-Bolt Pad Orientation**
Meritor SQ 100, SSHD	Forward Rear Axle	No arrow; axle bump-stop toward vehicle centerline.
	Rearmost Axle	No arrow; axle bump-stop toward vehicle centerline.
Meritor RT40-145, RT44-145, RT46-160	Forward Rear Axle	No arrow; axle bump-stop toward vehicle centerline.
	Rearmost Axle	Arrow toward front of vehicle.

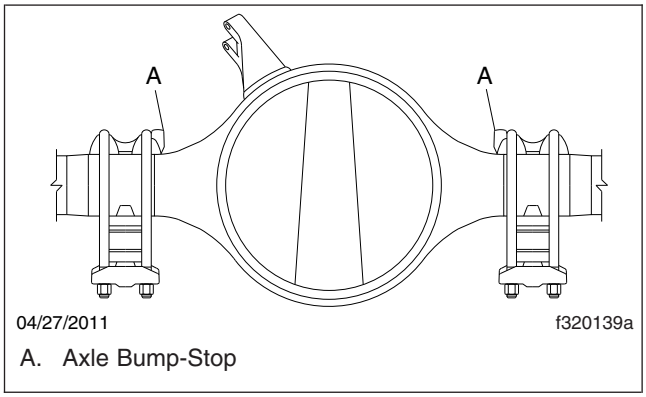
Table 1, U-Bolt Pad Orientation for Axles

Leaf Spring Replacement



A. Arrow on U-Bolt Pad

Fig. 3, U-bolt Pad Arrow Positioning



A. Axle Bump-Stop

Fig. 4, Axle Bump-Stop Positioning

Rear-Axle Alignment Adjusting

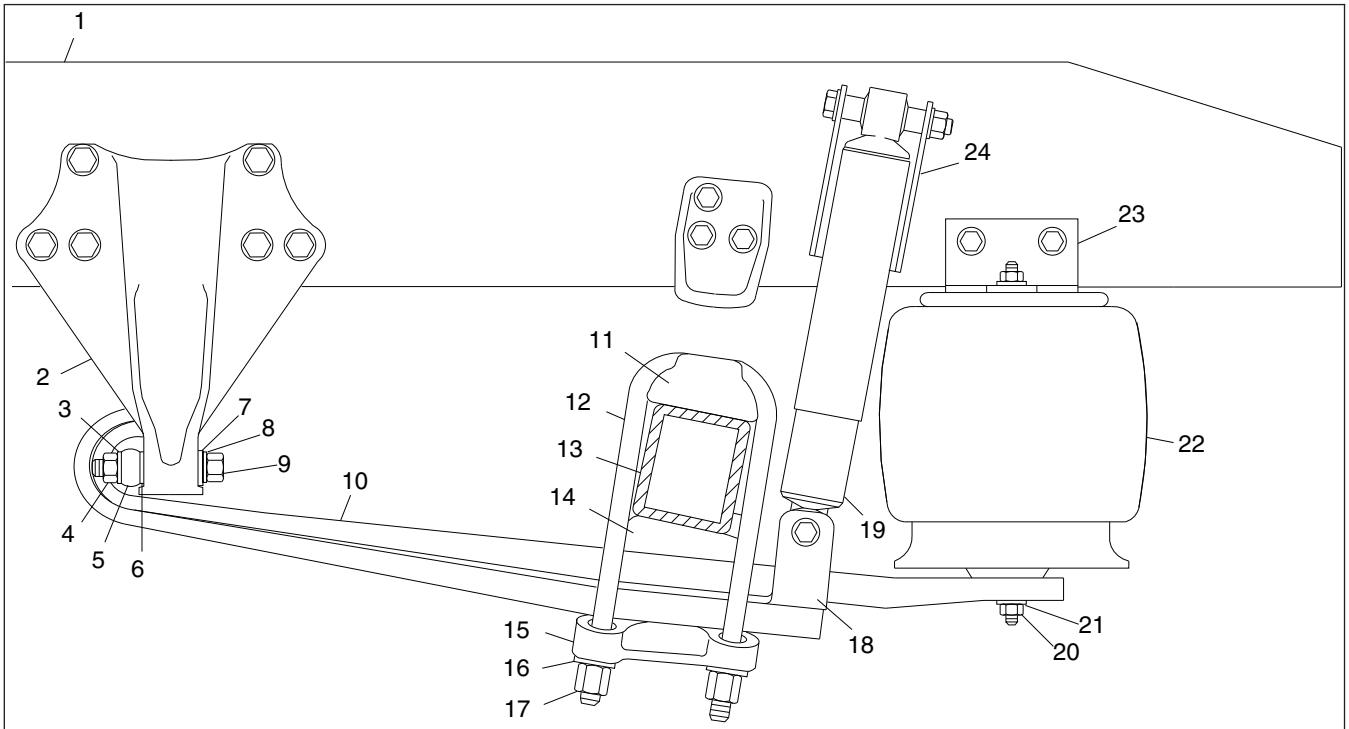
NOTE: See **Fig. 1** for this procedure.

Follow the instructions in the rear axle section in this manual to see if rear axle alignment adjustment is needed. If adjustment is needed, proceed as follows:

1. Loosen the spring pinch-bolts so that the forward end of the leaf spring can slide fore and aft in the spring hanger.
2. Move the axle forward or backward until it is aligned within the tolerances in **Group 35**.
3. When the axle is in alignment, install alignment shim(s) to take up the slack between the spring hanger and the spring pin.

IMPORTANT: Make sure the same number of shims is installed on each pinch bolt. The pinch bolts must be shimmed equally.

4. Tighten the spring pinch-bolts 170 lbf·ft (230 N·m).
5. Check the axle alignment again. If necessary, repeat the above procedure until the alignment is within tolerances.



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1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Pin
6. Alignment Shim
7. Wear-Shoe Clip
8. Washer
9. Spring Pinch-Bolt
10. Leaf Spring Assembly
11. U-Bolt Pad
12. U-Bolt
13. Axle
14. Axle Seat
15. Axle Clamp
16. Flatwasher
17. High Nut
18. Shock-Absorber Lower Mounting Bracket
19. Shock Absorber
20. Nylon Locknut
21. Washer
22. Air Spring
23. Air-Spring Mounting Bracket
24. Shock-Absorber Upper Mounting Bracket

Fig. 1, Rear Axle Suspension

Rear-Axle Tracking Adjustment

Single Axle

1. At the forward edge of the right rear tire, measure the distance from the inner side of the tire to the outer side of the right frame rail. See **Fig. 2**.

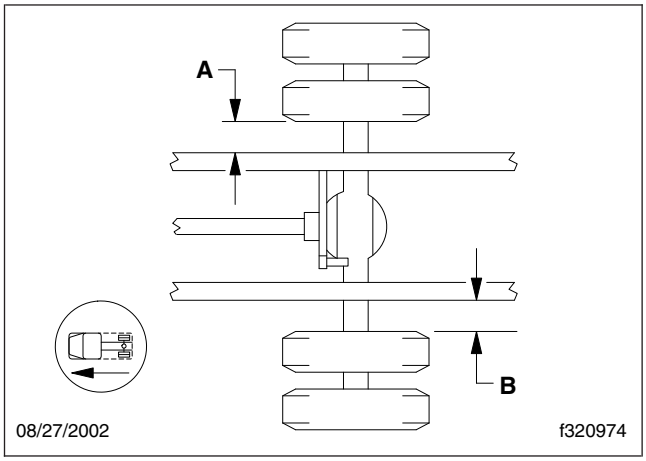


Fig. 2, Rear-Axle Tracking Measurements (single axle)

2. At the rear edge of the left rear tire, measure the distance from the inner side of the tire to the outer side of the left frame rail. See **Fig. 2**.

   Measurement "A" should not vary by more than 1/4-inch (6 mm) from measurement "B."

3. If measurements "A" and "B" vary by more than 1/4-inch (6 mm), loosen the fasteners that hold the lateral torque rod to the frame rail. Add or remove torque-rod shims as needed.
4. Tighten the torque rod fasteners 136 lbf·ft (184 N·m).

Tandem Axles

1. Check the tracking of the forward-rear axle. For instructions, see "Single Axle" in this subject. Adjust the tracking if needed.
2. At the forward-rear drive axle, measure the distance from the inner side of the right rear tire to the outer side of the right frame rail. Measure at the forward edge of the tire. See **Fig. 3**.
3. At both sides of the rear-rear drive axle, measure the distance from the inner side of the rear tires

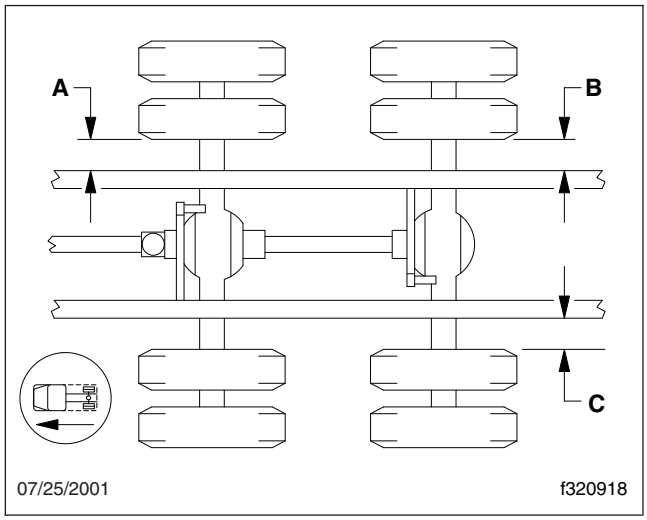


Fig. 3, Rear-Axle Tracking Measurements (tandem axles)

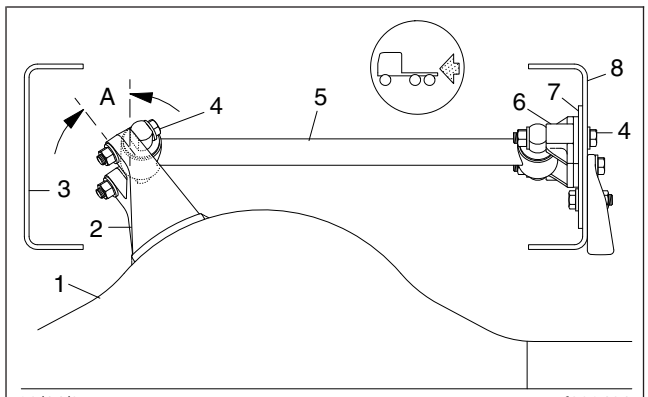
   to the outer side of each frame rail. Measure at the rear edge of each tire. See **Fig. 3**.

IMPORTANT: Measurements "B" and "C" should not vary by more than 1/4-inch (6 mm) from measurement "A."

4. If measurements "B" and "C" vary by more than 1/4-inch (6 mm) from measurement "A," loosen the fasteners that hold the axle lateral torque rod at the rear-rear drive axle to the frame rail. Add or remove torque-rod shims as needed.
5. Tighten the torque rod fasteners 136 lbf·ft (184 N·m).

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Raise the vehicle. Support the frame rails with jack stands.
3. Remove the fasteners that hold the control rod to the frame rail bracket. Remove the shims, and set the shims aside.
4. Remove the control rod.
5. Position the new control rod so that the end with the fasteners angled up at 35 degrees is installed in the axle housing bracket. See **Fig. 1**.
6. Install the fasteners with the bolt heads facing up. Tighten the fasteners enough to hold the control rod in place.
7. Install the shims that were previously removed.
8. Install the other end of the control rod in the frame rail bracket; then, install the fasteners. Tighten the fasteners enough to hold the control rod in place.
9. Tighten all the fasteners 136 lbf·ft (184 N·m).
10. Raise the vehicle, remove the jack stands, then lower the vehicle.
11. Remove the chocks.



A. Angle: 35 degrees

1. Axle Housing
2. Control-Rod Axle Bracket
3. Left Frame Rail
4. Bolt
5. Control Rod
6. Control-Rod Frame Bracket
7. Shim
8. Right Frame Rail

Fig. 1, AirLiner Control Rod Installation

Replacement

⚠ WARNING

Do not replace individual leaves of a damaged leaf spring assembly; replace the complete spring assembly. Visible damage (cracks or breaks) to one leaf causes hidden damage to other leaves. Replacement of only the visibly damaged part(s) is no assurance that the spring is safe. Failure to replace a damaged spring assembly could cause an accident resulting in serious personal injury or property damage.

1. Shut down the engine, set the parking brakes, and chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle(s) with safety stands. Raise the vehicle so that all weight is removed from the leaf springs, then securely support the frame with safety stands.
3. Remove the wheel and tire assembly to easily access the suspension. For instructions, see the information in **Group 40**.
4. Remove the leaf spring assembly. See removal information in **Subject 160**.

⚠ WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

5. Remove the bushing from the spring eye as follows:

⚠ WARNING

Do not use a cutting torch to remove the outer metal of the bushing from the spring eye. Welding, torching, or cutting the leaf spring assembly can damage the leaf spring material, which may result in the failure of the components and cause serious personal injury, death, or property damage.

   5.1 Using a shop press with a capacity of at least 10 tons (9 072 kg), place the spring assembly in the shop press with the spring assembly squarely supported on the press bed for safety and to avoid bending the spring assembly.

   5.2 Center the bushing tool on the outer metal of the bushing and push the bushing from the spring eye.

   5.3 Remove any burrs or material left behind by the old bushing.

6. Install the new bushing in the spring eye.

   6.1 Position the bushing on the shop press.

   6.2 Apply a bonding agent, either Perma-bond HM–160 or Loctite RC–609 or 680, liberally around the outside surface of the bushing.

   6.3 Press the bushing into place.

   6.4 Allow the bonding agent to cure for 24 hours.

   NOTE: After the curing time, the bushing must resist a minimum 7700 lb (3490 kg) pushout force.

7. Install the leaf spring assembly. See the information in **Subject 160**.
8. Install the wheel and tire assembly. For instructions, see **Group 40**. Raise the vehicle, remove the safety stands, then lower the vehicle.
9. Check the rear axle alignment. For instructions, see **Group 35**. If necessary, adjust the rear axle alignment using the instructions in **Subject 170**.
10. Remove the chocks.

Torque Specifications

For fastener torque values, see **Table 1**.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Special Tools

Use the kit shown in **Fig. 2** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in Paragon.

Torque Values for AirLiner Suspension

Description	Size	Torque	
		lbf·ft (N·m)	lbf·in (N·cm)
Height-Control Valve Housing Bolts	1/4–20	—	45 (500)
Shock-Absorber Mounting Locknuts	3/4–10	165 (220)	—
Air-Spring Upper Mounting Locknuts	3/4–16	45 (61)	—
	1/2–13	23 (31)	—
Air-Spring Lower Mounting Locknuts	1/2–13	55 (75)	—
Leaf-Spring Mounting-Eye Bolt Locknuts	3/4–10	241 (327)	—
Control-Rod Mounting-Bolt Locknuts	5/8–11	136 (184)	—

Specifications

Torque Values for AirLiner Suspension			
Description	**Size**	**Torque**	
		lbf·ft (N·m)	**lbf·in (N·cm)**
Axle U-Bolt High Nuts Tighten in a diagonal pattern as shown in Fig. 1.	5/8–18	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 180 to 230 (245 to 313)	—
	3/4–16	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 270 to 330 (367 to 449)	—
	7/8–14	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (571 to 680)	—
	1–14	Stage 1: Hand-tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 520 to 600 (707 to 816)	—
Air-Spring Upper Mounting Bracket	5/8–11	136 (184)	—
Spring-Hanger Mounting Locknuts	3/4–10	240 (325)	—

Table 1, Torque Values for AirLiner Suspension

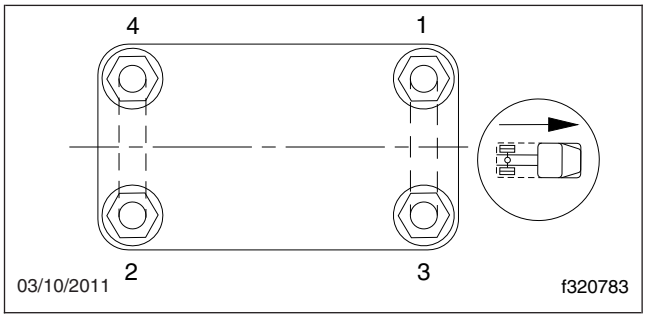
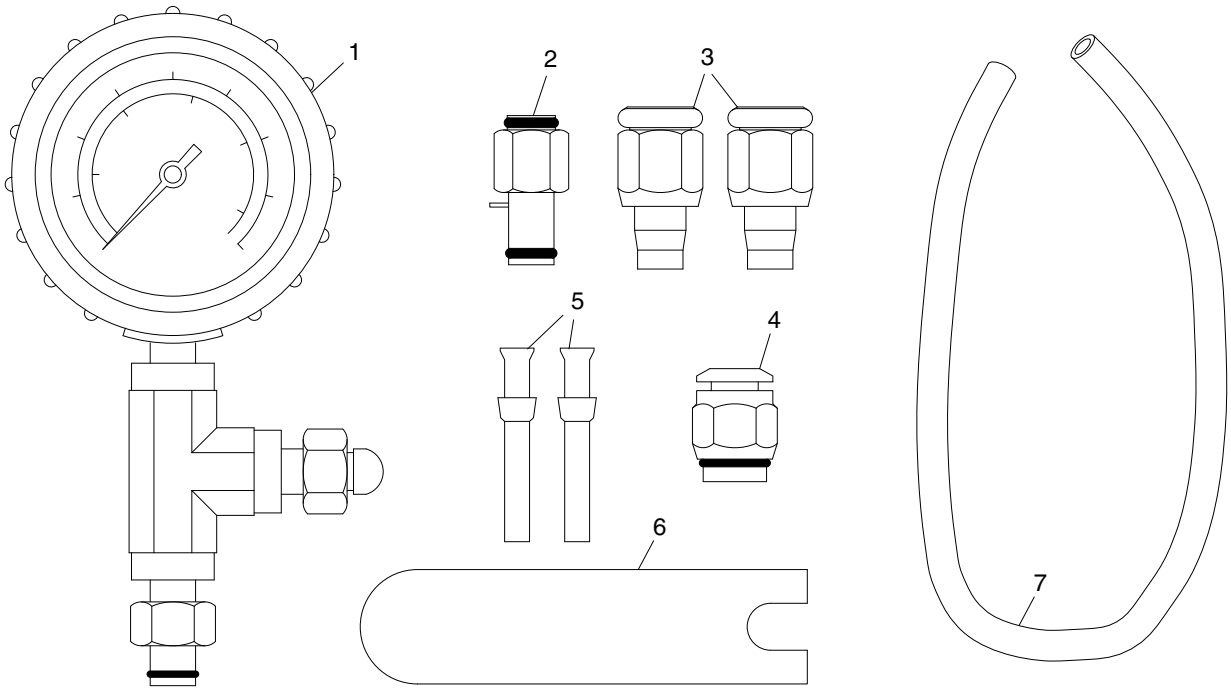


Fig. 1, Tightening Pattern for U-Bolt High Nuts



NOTE: Parts for cab suspension valve testing included.

1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve (used for cab suspension valve testing)
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve (used for cab suspension valve testing)
6. Special Tool for Disconnecting Air Line
7. Air Line

Fig. 2, Barksdale Height-Control Valve Test Kit BKS KD2264

The front axle requires periodic servicing to maintain accurate wheel alignment. Correct front axle wheel alignment is needed to ensure long tire life, ease of handling, and steering stability.

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**.

Three factors are involved in wheel alignment: camber angle, caster angle, and wheel toe-in.

Camber Angle

Camber angle (**Fig. 1**) is the vertical tilt of the wheel as viewed from the front of the vehicle. Camber angle is measured in degrees, and is not adjustable. Positive camber is the outward tilt of the wheel at the top. Excessive positive camber in one wheel causes the vehicle to pull in the opposite direction, rapidly wearing the outboard side of the tire tread. Negative camber is the inward tilt of the wheel at the top. Excessive negative camber in one wheel causes the vehicle to pull in the same direction that the negative-camber wheel is on, wearing the inboard side of the tire tread. If camber angles are not correct, the tires will wear smooth around the edge on one side. See **Fig. 2**. If the front axle is damaged enough to affect the camber angle it must be replaced.

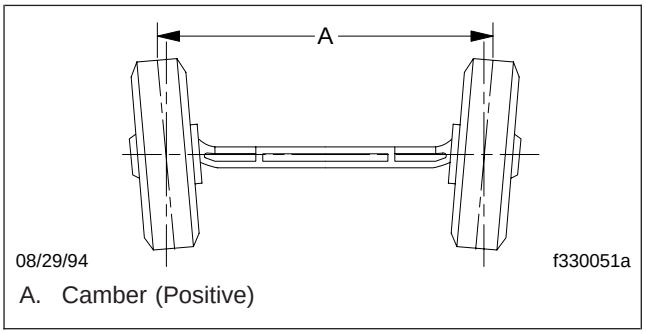


Fig. 1, Camber Angle (front view)

Caster Angle

Caster angle (**Fig. 3**) is the tilt of the knuckle pin (or kingpin) as viewed from the side. Caster angle is measured in degrees and is adjustable. A positive caster angle is the tilt of the top of the knuckle pin toward the rear of the vehicle. A negative caster angle is the tilt of the top of the knuckle pin toward the front of the vehicle. Caster angles are based on the design load of the vehicle. An incorrect caster angle does not cause tire wear. However, a positive caster angle that exceeds specifications could cause vehicle shimmy, road shock, and an increased steering effort. A negative caster angle that does not meet specifications could cause unstable steering. The vehicle may wander and weave, and extra steering effort may be necessary. After leaving a turn, the tendency to return to and maintain a straight-ahead position is reduced. Too much or too little caster in one wheel can cause erratic steering when the service brakes are applied to stop the vehicle.

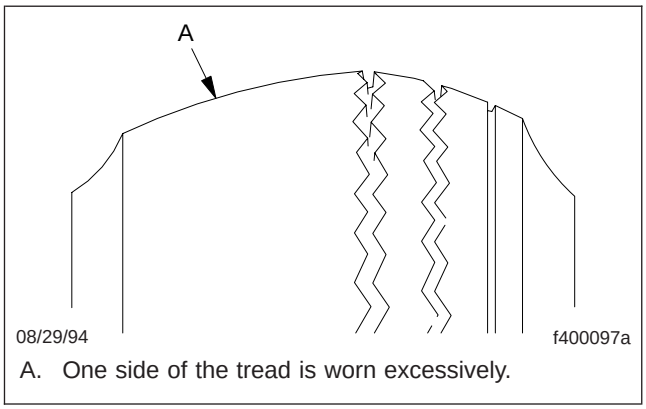


Fig. 2, Tire Damage Due to Excessive Camber

Wheel Toe-In

Wheel toe-in (**Fig. 4**) is the distance in inches that the front of the wheels are closer together than the rear of the wheels, as viewed from the top. Wheel toe-in is adjustable. If it is not adjusted correctly, the vehicle could pull to one side while driving. Wheel shimmy and cupped tire treads (indentations on the road contact surface of the treads) could occur. Also, rapid or severe tire wear on the steering axle could occur, usually in a feather-edged pattern. See **Fig. 5**.

Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

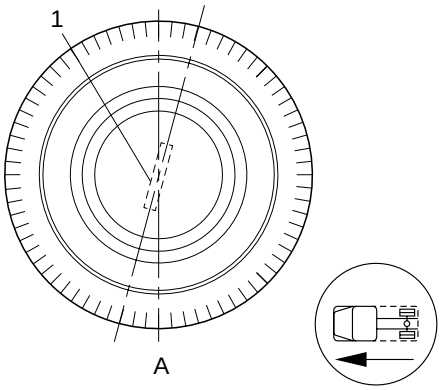
Feather-edging more often affects the front tire on the passenger's side of the vehicle, and is usually more apparent on the outside grooves of the tire.

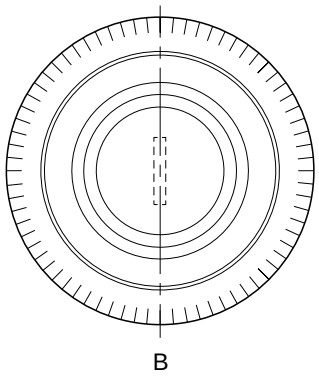
General Information

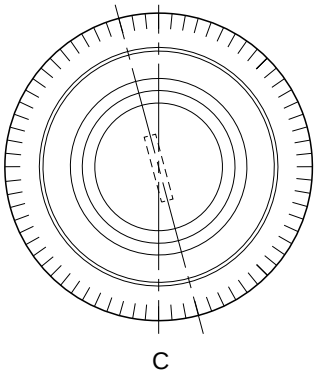
Diagnosis

If any of the conditions listed above occur, the vehicle could need a front end wheel alignment, and possibly, drive axle alignment. However, in some cases these conditions are not wheel alignment related.

If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires.







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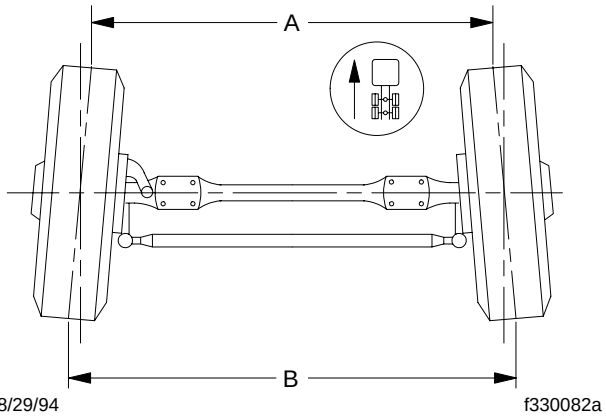
1. Knuckle Pin (King Pin)

A. Positive Caster B. Zero Caster C. Negative Caster

Fig. 3, Caster Angle



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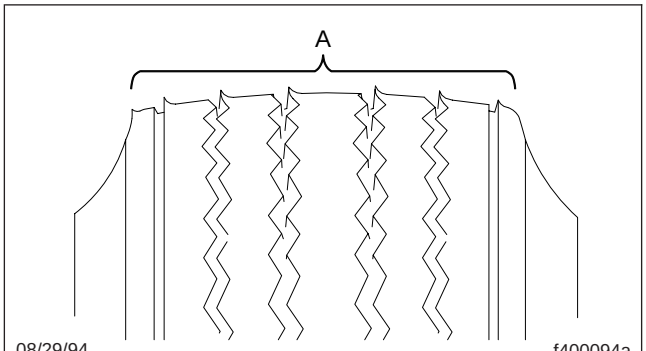
NOTE: B minus A equals toe-in.

Fig. 4, Wheel Toe-In (overhead view)



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A. Feathered Edges

Fig. 5, Tire Damage Due to Excessive Toe-In or Incorrect Drive Axle Alignment

The following preliminary checks should be completed before checking the camber or caster angles.

Preliminary Checks

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**.

1. Steering axle wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires, and steering suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. Refer to **Group 40** in this manual for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to **Group 40** in this manual for recommended pressures. An underinflated tire causes tread wear completely around both tire shoulders. An overinflated tire causes tread wear in the center of the tire. See **Fig. 1.**

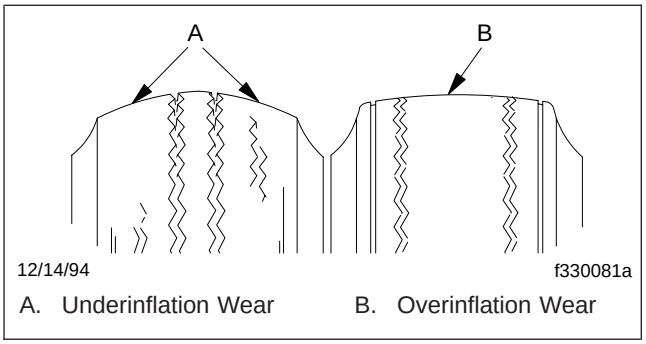
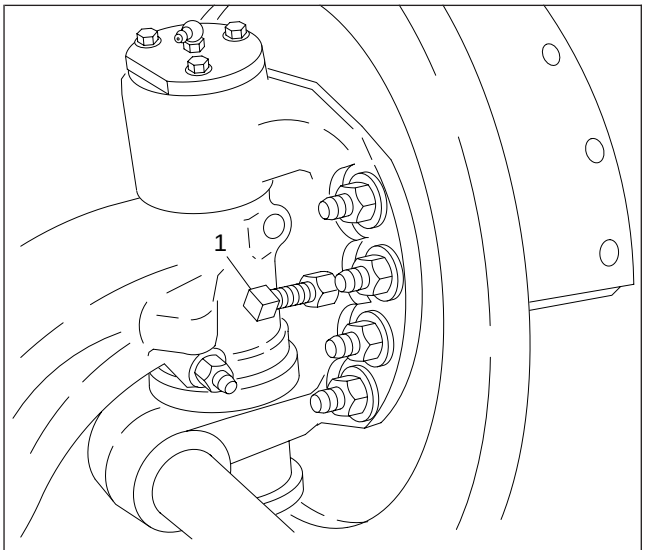


Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels and wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground. Sagging, fatigued, or broken suspension springs create a lopsided vehicle appearance. This causes an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in the applicable suspension section.
6. Inspect the front axle beam (also called the axle center) for bends or twists. If the axle beam is bent or twisted over 1/2 degree, replace it before aligning the front axle wheels.
7. Check for damaged, worn, or bent steering gear or linkage parts. Make sure the steering gear is centered. Replace damaged components, and adjust the steering gear. See **Group 46** in this manual for more information.
8. Check the steering angle, and adjust the axle steering stops as needed. Refer to **Subject 110**.
9. Check the tie-rod ends for correct adjustment, tightness, and damage. Refer to **Group 33** of the *108SD and 114SD Maintenance Manual* for instructions.
10. Inspect the wheel ends for loose or damaged components; oil leakage; contaminated lubricant; and correct wheel bearing end-play. Refer to **Group 33** of the *108SD and 114SD Maintenance Manual* for instructions.
11. Check the front wheel bearings for wear and incorrect adjustment. Refer to **Section 33.01** for instructions.

Checking and Adjusting

Steering (or turning) angle is the degree of front wheel movement from a straight-ahead position to either an extreme right or left position. Although front wheel movement can be limited by the amount of internal travel in the steering gear, it generally depends on how much clearance there is between chassis components and the tire and wheel assemblies. All axles have adjustable stopscrew- and locknut-type axle stops (**Fig. 1**), which are located on the rear side of each front axle spindle.



1. Stopscrew and Locknut

Fig. 1, Axle Stop

1. Make sure the steering gear is in the center of travel when the wheels are in a straight-ahead position. Center the gear, using the instructions in the applicable steering section in this manual. Bottoming of the steering gear must not occur when making an extreme right or left turn.
2. If using stationary turn-plates or turntables (**Fig. 2**), drive the vehicle on the plates; the tires must be exactly straight ahead. Apply the parking brakes.

   If using portable gauges, apply the parking brakes, chock the rear tires, and raise the front of the vehicle. Place a turn-plate or turntable under each tire. With the tires exactly straight ahead, lower the vehicle so that the tires rest on the center of the gauges.

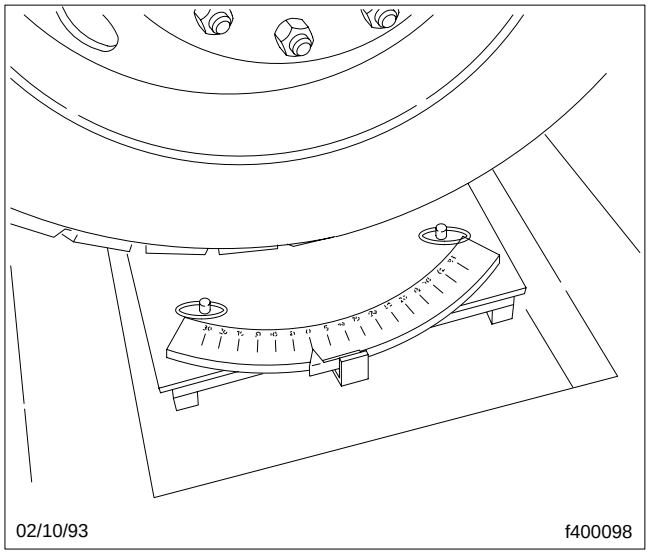


Fig. 2, Turn-Plate (Turntable), Stationary Type

3. Remove the lockpins from the gauges, and adjust the dials so that the pointers on both gauges read zero.
4. With the brakes fully applied, turn the steering wheel clockwise to the end of travel. Have someone check both sides of the vehicle for interference at the tires and wheels. There must be at least 0.50 inch (13 mm) clearance from any fixed object, and 0.75 inch (19 mm) from any moving object.

   If necessary, loosen the stopscrew locknut; adjust the stopscrew to contact the axle when the maximum turning angle of the wheels is determined.

   Tighten the locknut to the value in the torque table in **Specifications 400**.
5. Repeat the step above with the steering wheel turned counterclockwise. Adjust the axle stop, as needed.

Steering Angle Checking and Adjusting

6. Adjust the steering gear so that pressure is released ahead of the axle stop. This will prevent possible damage to the steering or axle components. For poppet valve adjustment instructions, refer to **Group 46**.
7. Drive the vehicle off the turn-plates or turntables, or remove them from under the tires and lower the vehicle.

Measuring

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Precision instruments and equipment are needed for accurately measuring and adjusting wheel alignment. Refer to the operating instructions provided by the wheel alignment equipment manufacturer.

Before checking or correcting wheel alignment, make sure the vehicle is at curb weight. Curb weight is the weight of the unloaded vehicle complete with accessories and full fuel tanks.

If a road test is necessary, the route should be one that allows full left and right turns and full stops. It should also include a length of straight, level road to check the steering wheel position during straight-ahead driving.

During the road test, note any steering effort and possible roughness. Check for looseness, too much wheel play, any tendency for the vehicle to lead in one direction, and for pull during stopping.

Note the position of the steering wheel while driving on a straight, level road. When the wheels are centered and the vehicle is traveling straight, the upper steering wheel spokes should be at the 9 and 3 o'clock positions, or within 10 degrees of that position. See **Fig. 1.**

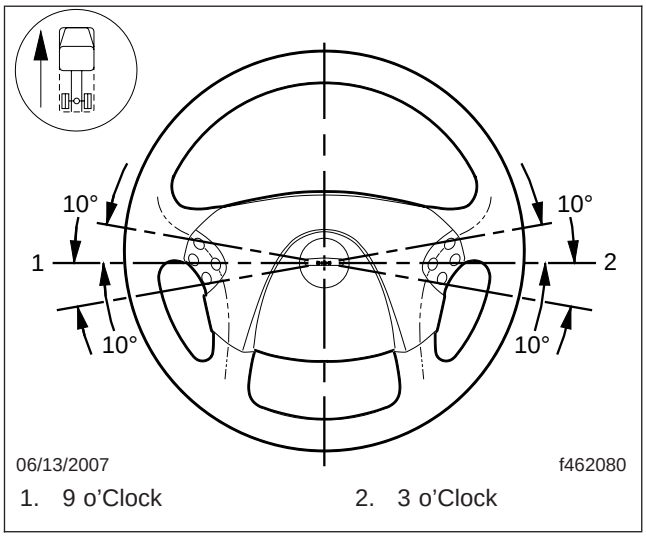
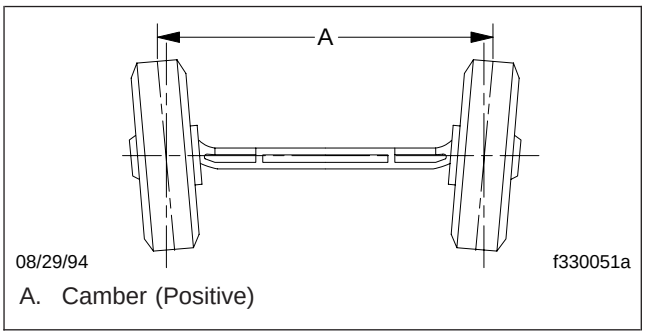


Fig. 1, Steering Wheel Position

Camber angle is the vertical tilt of the wheel as viewed from the front of the vehicle. See **Fig. 1**.

IMPORTANT: Do all the preliminary checks in **Subject 100** before checking the camber angle.



A. Camber (Positive)

Fig. 1, Camber Angle

Checking

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

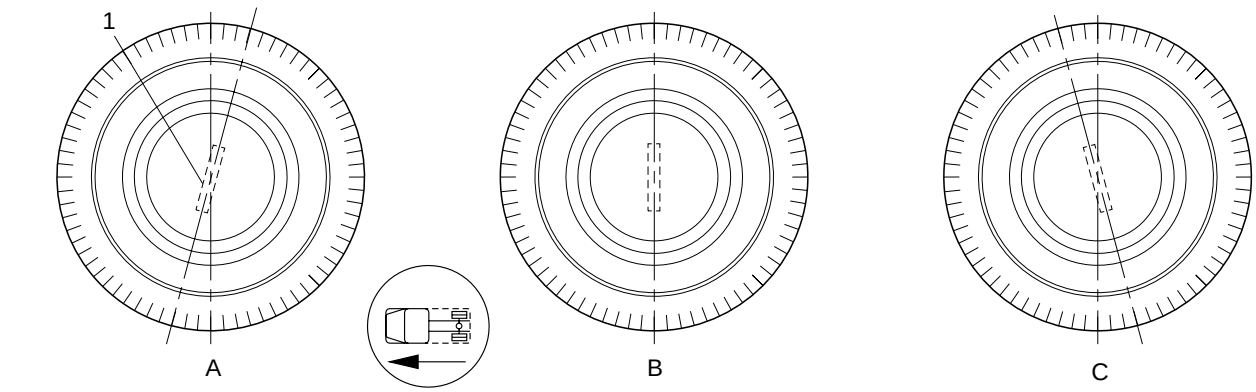
1. Apply the parking brakes, and chock the rear tires.
2. Using the alignment equipment manufacturer's instructions, measure the front wheel camber.
3. Compare the camber angles with those shown in the appropriate table in **Specifications, 400**. Differences between the measurements taken in the step above and the angles in the table are caused by damaged (bent) axle components.

   Incorrect camber angles could be caused by damage in one or more of the following front axle components: the knuckle pin, the knuckle pin bushings, the axle spindle, or the axle beam. Replace twisted or otherwise damaged components. Don't try to straighten twisted or bent components; replace them with new components. If a bent or twisted front axle knuckle pin, axle spindle, or axle beam has been straightened, the axle warranty will be voided.

Caster Angle Checking and Adjusting

Caster angle is the tilt of the knuckle pin (or kingpin) as viewed from the side of the vehicle. See **Fig. 1**.

IMPORTANT: Do all the preliminary checks in **Subject 100** before checking the caster angle.



1. Knuckle Pin (Kingpin)

A. Positive Caster B. Zero Caster C. Negative Caster

Fig. 1, Caster Angle

Checking and Adjusting

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Using the alignment equipment manufacturer's operating instructions, measure the front wheel caster.

Compare the caster angles with those shown in the appropriate table in **Specifications 400**. If needed, adjust the caster angle by placing wedge-shaped shims between the axle spacer and the axle beam, as follows (see **Fig. 2**):

IMPORTANT: Extreme angle shims cannot be used to correct caster angles that vary by more than 2 degrees from the values in the table. Weak or broken leaf springs, or worn shackle bushings, can cause extreme deviations to caster angles. Replace damaged parts before doing caster adjustments.

1. Apply the parking brakes, and chock the front and rear tires.
2. Back off the U-bolt nuts from the U-bolts on one side of the front axle. See **Fig. 2**.
3. Raise the spring away from the axle enough to allow removal of the front caster shim.
4. Remove the shim, and install one that will provide the correct caster angle, as specified in the table in **Specifications 400**. Install the dowel pin and check penetration.

IMPORTANT: Place front caster shims between the axle beam and the axle spacer, or between the axle beam and the shock absorber bracket. See **Fig. 2.**

5. Lower the vehicle onto the axle.
6. Coat the threaded ends of the U-bolts with chassis lube or an antiseize compound, such as Loctite® 242. Tighten the U-bolt nuts to the value in the appropriate table in **Specifications 400**.

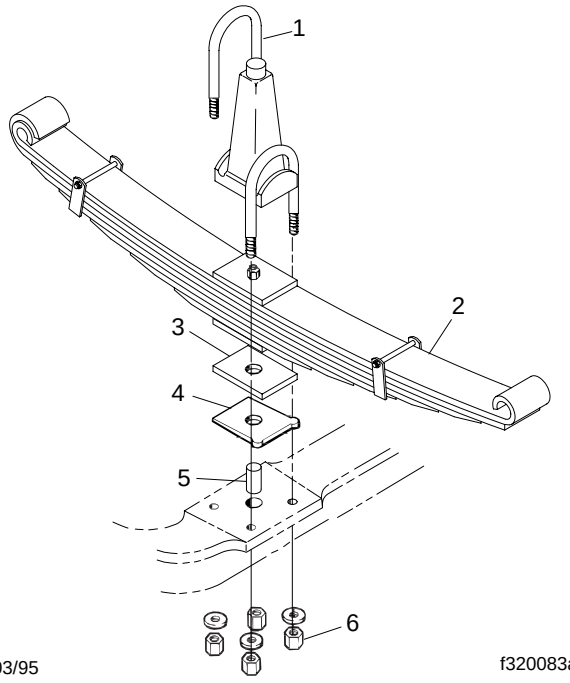
   U-bolt nuts need periodic retightening. Refer to **Group 00** of the *108SD and 114SD Maintenance Manual* for recommended intervals.

Caster Angle Checking and Adjusting

NOTICE

Failure to periodically retighten the U-bolt nuts could result in spring breakage and abnormal tire wear.

7. Using the steps above, replace the shim on the other side of the axle.
8. Do a final caster angle check.

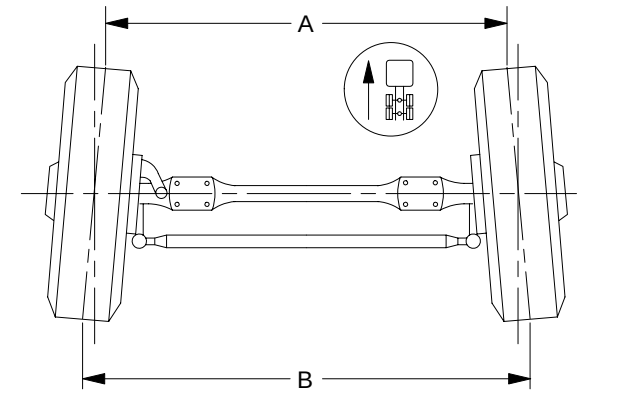


1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 2, Axle Spring Installation

Wheel Toe-In Checking and Adjusting

Wheel toe-in is the distance that the front of the wheels are closer together than the rear of the wheels, as viewed from the top. See **Fig. 1**.



NOTE: B minus A equals toe-in.

Fig. 1, Wheel Toe-In (Overhead View)

Checking Toe-In Using Alignment Equipment

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Using the alignment equipment manufacturer's operating instructions, measure the wheel toe-in. Compare the measurement with that shown in the appropriate table in **Specifications 400**. If corrections are needed, go to "Adjusting Toe-In".

Checking Toe-In Using a Manual Method

1. Apply the parking brakes, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle. Make sure the stands will support the weight of the cab, axle, and frame.
3. Using spray paint or a piece of chalk, mark the entire center rib of each front tire.
4. Place a scribe or pointed instrument against the marked center rib of each tire, and turn the tires. The scribes must be held firmly in place so that a single straight line is scribed all the way around each tire.
5. Place a turn-plate or turntable under each tire. Remove the safety stands from under the axle, then lower the vehicle. Remove the lockpins from the gauges; make sure the tires are exactly straight ahead.

NOTE: If turn-plates or turntables are not available, lower the vehicle. Remove the chocks from the rear tires and release the parking brakes. Move the vehicle backward and then forward about six feet (2 meters). Apply the parking brakes and chock the rear tires.

6. Place the trammel bar at the rear of the front tires; locate the trammel pointers at spindle height, and adjust the pointers to line up with the scribe lines. Lock in place. Make sure that the scale is set on zero.
7. Place the trammel bar at the front of the tires as shown in **Fig. 2**. Adjust the scale end so that the pointers line up with the scribe lines. See **Fig. 3.**

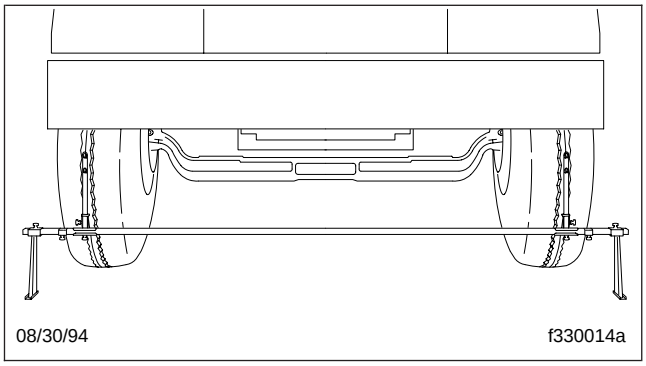


Fig. 2, Trammel Bar Positioning

8. Read the toe-in from the scale. Compare the toe-in with the value in the appropriate table in **Specifications 400**. If corrections are needed, go to the next heading.

Wheel Toe-In Checking and Adjusting

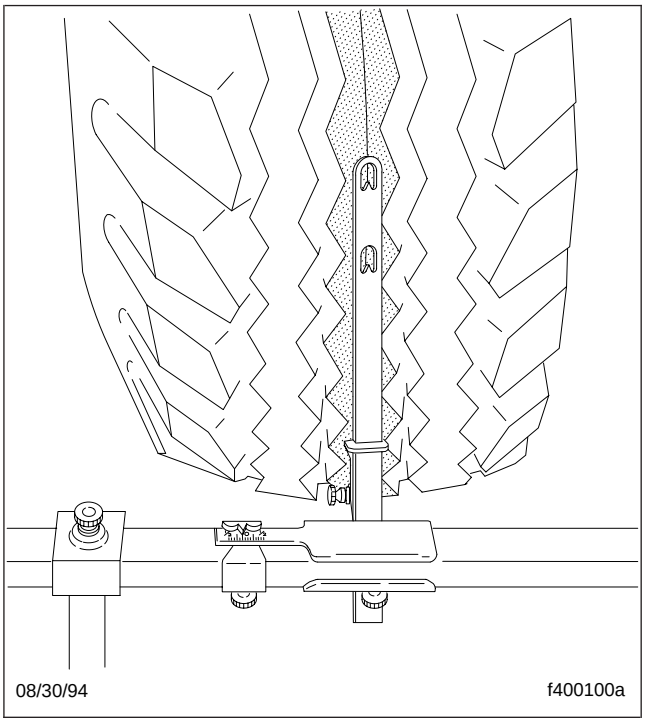


Fig. 3, Calculating Wheel Toe-In

Adjusting Toe-In

1. Loosen the tie rod (cross tube) clamp nuts, and turn the tie rod as needed.

   If the vehicle is not on turn-plates or turntables, move the vehicle backward and then forward about six feet (two meters) — this is important when setting the toe-in on vehicles equipped with radial tires. Apply the parking brakes and chock the rear tires.

   Do a final wheel toe-in check to make sure that it is correct.

   Tighten the clamp nuts to the values in the appropriate table in **Specifications 400**.

2. Road test the vehicle.

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. Refer to **Section 35.00**.

NOTE: The alignment specifications below are for unloaded vehicles. These specifications will vary as weight is added to the vehicle and transferred to the front axle.

Alignment Specifications

Caster

IMPORTANT: Caster settings for the left and right sides *must* be within ½ degree of each other. It is necessary for only one side to be within the specifications given in **Table 1**, **Table 2**, **Table 3**, and **Table 4**.

Caster Target and Limits, Hunter Equipment	
Target: degrees	**Limits: degrees**
+3-1/2	+2 to +5

Table 1, Caster Target and Limits, Hunter Equipment

Caster Target and Limits, Bee Line Equipment (except LC4000)	
Target: degrees	**Limits: degrees**
+3-1/2	+3 to +6-1/2

Table 2, Caster Target and Limits, Bee Line Equipment (except LC4000)

Caster Target and Limits, Bee Line LC4000	
Target: degrees	**Limits: degrees**
+3-1/2	+2-1/4 to +4-3/4

Table 3, Caster Target and Limits, Bee Line LC4000

Caster Target and Limits, Beissbarth	
Target: degrees	**Limits: degrees**
+3-1/2	+3 to +6-1/2

Table 4, Caster Target and Limits, Beissbarth

Toe-In

Toe-In Target and Limits, Hunter Equipment	
Target: degrees	**Limits: degrees**
+0.09	0.00 to +0.18

Table 5, Toe-In Target and Limits, Hunter Equipment

Toe-In Target and Limits, Bee Line Equipment	
Target: in (mm)	**Limits: in (mm)**
+1/16 (+1.6)	0 to +1/8* (0 to +3.2)

* If adjustment is required, set the toe-in as close as possible to +1/16 inch (+1.6 mm).

Table 6, Toe-In Target and Limits, Bee Line Equipment

Camber

Camber, Detroit and Meritor Axles		
Axle Model	**Left Camber: degrees**	**Right Camber: degrees**
All	–1/4 ± 7/16	–1/4 ± 7/16

Table 7, Camber, Detroit and Meritor Axles

Camber, Dana/Eaton Axles		
Axle Model	**Left Camber: degrees**	**Right Camber: degrees**
All E Series	+1/4 ± 7/16	0 ± 7/16

Table 8, Camber, Dana/Eaton Axles

Camber, Hendrickson Axles		
Axle Model	**Left Camber: degrees**	**Right Camber: degrees**
STEERTEK	0 ± 1	0 ± 1

Table 9, Camber, Hendrickson Axles

Specifications

Torque Values

Tie Rod Clamp Nut Torque Values				
Axle Manufacturer	**Axle Model**	**Tie Rod Clamp Nut Size**	**Plain Nut Torque: lbf·ft (N·m)***	**Locknut Torque: lbf·ft (N·m)***
Meritor	All	5/8–11	50–60 (68–81)	50–60 (68–81)
Detroit	All	5/8–11	60–80 (81–108)	60–80 (81–108)

* All torque values in this table apply to parts lightly coated with rust-preventive type oil.

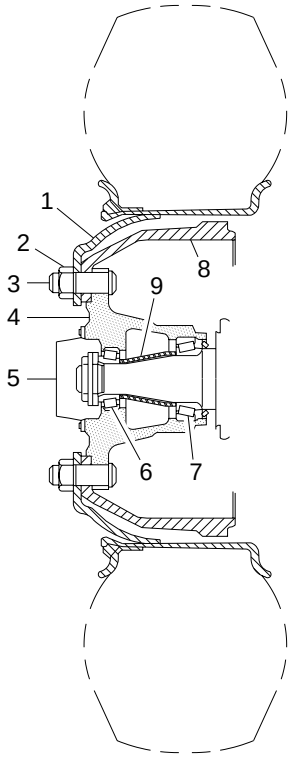
Table 10, Tie Rod Clamp Nut Torque Values

Miscellaneous Torque Values	
Description	**Torque: lbf·ft (N·m)**
U-Bolt Nuts 7/8–14	400 (542)
U-Bolt Nuts 7/8–16	460 (624)
U-Bolt Nuts 3/4–16	300 (406)
U-Bolt Nuts 5/8–18	200 (271)
Meritor Stopscrew Locknut	50–65 (68–88)
Dana/Eaton Stopscrew Locknut	90–120 (122–163)
Detroit Stop Bolt Jam Nut	80–120 (109–163)

Table 11, Miscellaneous Torque Values

General Information

Wheel end assemblies include the wheel hub, wheel bearings, brake drum (or rotor), wheel studs, and spindle nut. See **Fig. 1**.



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1. Disc Wheel
2. Wheel Nut
3. Wheel Stud
4. Hub
5. Hub Cap
6. Outer Wheel Bearing
7. Inner Wheel Bearing
8. Brake Drum
9. Bearing Spacer

Fig. 1, Wheel End Assembly with Drum Brakes

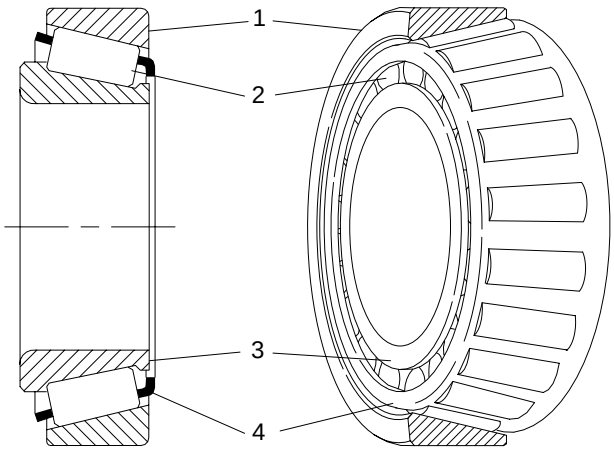
Wheel Hubs

ConMet PreSet® hubs have a spacer between the inner and outer bearings that adjusts the bearings to the correct end-play and preload when the retaining nut is tightened.

For more information about PreSet hubs, and removal and installation procedures, see **Subject 100**.

Tapered Wheel Bearings

Each hub has a set of inner and outer tapered wheel bearing assemblies. A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.



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1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly

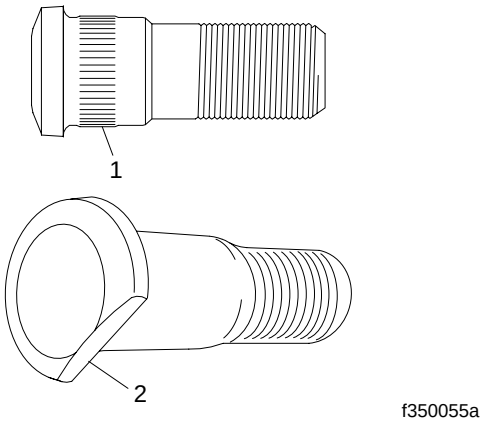
Brake Drum

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.

Wheel Studs

A headed wheel stud is used on disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 3**. Wheel studs are press-fit in the hub. For replacement procedures, see **Subject 180**.

General Information



1. Serrations
2. Clipped Head

Fig. 3, Typical Wheel Studs

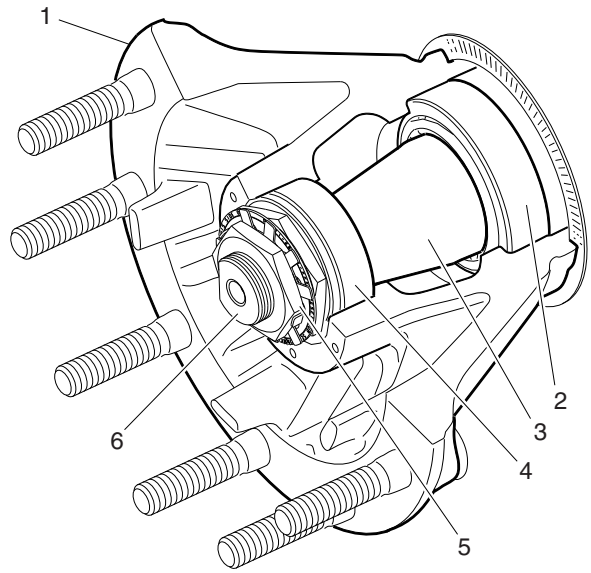
General Information

ConMet PreSet® and PreSet Plus™ steer axle hubs are equipped with a special tubular spacer inside the hub, between the inner and outer bearings. See **Fig. 1**.

When installing a PreSet or PreSet Plus hub with the spacer and special PreSet bearings, the correct end play is set automatically and wheel bearing adjustment is unnecessary.

For vehicles equipped with ConMet PreSet hubs, it is highly recommended to **stay with the PreSet system** to optimize bearing and seal life. However, if you are replacing the bearings for a PreSet hub, and the special PreSet bearings are not available, standard wheel bearings can be used. In this case, the bearing spacer must be removed and the bearings adjusted manually. See the installation instructions for more information.

Wheel ends equipped with ConMet PreSet Plus hubs must use PreSet Plus components. Do not substitute non-PreSet-Plus components on these installations.



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NOTE: PreSet Plus hubs use a special spindle nut system.

1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Retaining Nut (double spindle nut system)
6. Axle Spindle

Fig. 1, ConMet PreSet Hub, Cut-Away View

Removal

For typical wheel end and axle assemblies, see **Fig. 2** and **Fig. 3**.

1. Chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. For drum brakes, back off the slack adjuster to release the front axle brake shoes. See **Group 42** for instructions.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

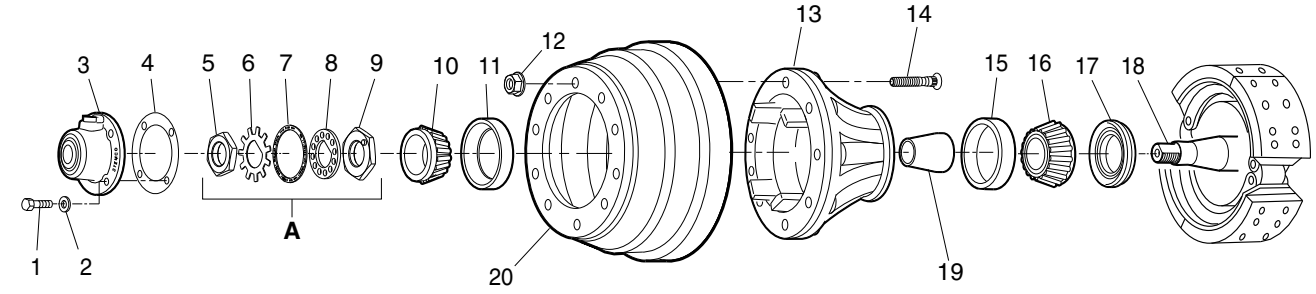
4. Remove the wheel and tire assembly. See **Group 40** for instructions.
5. For drum brakes, remove the brake drum. See **Subject 140** for instructions.

   For disc brakes, remove the brake caliper. See **Section 42.18** for instructions.

NOTE: Oil will spill as the hub cap and wheel hub are removed. Place a suitable container under the axle spindle to catch any spilled oil, and avoid contaminating the brake shoes with oil. Dispose of the oil properly.

6. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket.
7. Remove the wheel bearing locking device:
   - For an Axilok spindle nut, see **Subject 110**; then go to the next step.
   - For a Pro-Torq spindle nut, see **Subject 120**; then go to the next step.

Hub Assembly Removal and Installation

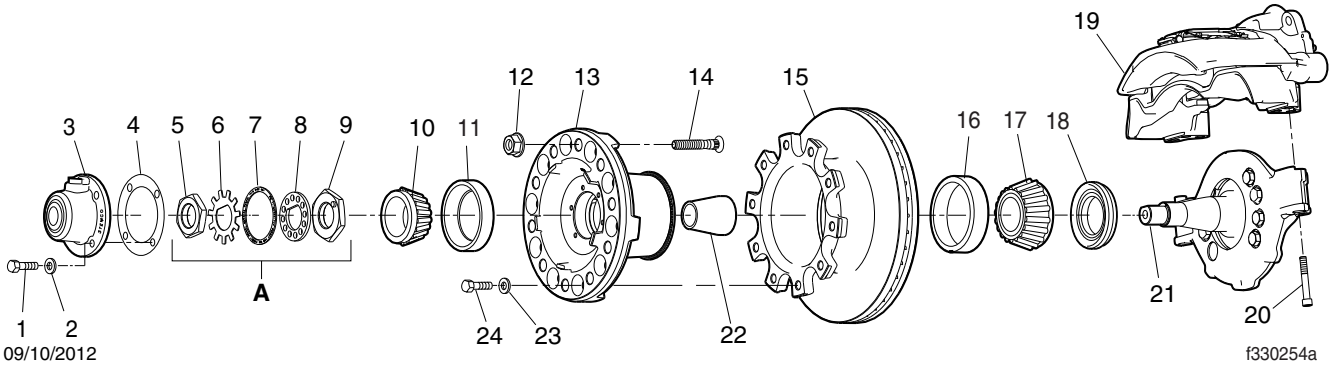


NOTE: An ID ring and bearing spacer are used with ConMet PreSet hubs only.

A. Double spindle nut set shown. Axilok or Pro-Torq spindle nuts could be used on some installations. ConMet PreSet Plus hubs use a special spindle nut system.

1. Hub Cap Capscrew
2. Washer
3. Hub Cap
4. Gasket
5. Jam Nut
6. Bend-Type Locking Washer
7. ID Ring
8. Lockring
9. Adjusting Nut
10. Outer Wheel Bearing
11. Outer Wheel Bearing Cup
12. Wheel Nut
13. Hub
14. Wheel Stud
15. Inner Wheel Bearing Cup
16. Inner Wheel Bearing
17. Oil Seal
18. Axle Spindle
19. Bearing Spacer
20. Brake Drum

Fig. 2, Typical Wheel End Assembly, Front Axle with Drum Brakes



NOTE: An ID ring and bearing spacer are used with ConMet PreSet hubs only.

A. Double spindle nut set shown. Axilok or Pro-Torq spindle nuts could be used on some installations. ConMet PreSet Plus hubs use a special spindle nut system.

1. Hub Cap Capscrew
2. Washer
3. Hub Cap
4. Gasket
5. Jam Nut
6. Bend-Type Locking Washer
7. ID Ring
8. Lockring
9. Adjusting Nut
10. Outer Wheel Bearing
11. Outer Wheel Bearing Cup
12. Wheel Nut
13. ConMet PreSet Hub
14. Wheel Stud
15. Brake Rotor
16. Inner Wheel Bearing Cup
17. Inner Wheel Bearing
18. Oil Seal
19. Brake Caliper
20. Caliper Mounting Capscrew
21. Axle Spindle
22. Bearing Spacer
23. Washer
24. Capscrew

Fig. 3, Typical Wheel End Assembly, Front Axle with Disc Brakes

- For a double spindle nut system, see **Subject 130**; then go to the next step.
- For ConMet PreSet Plus hubs, see **Subject 210**; then go to the next applicable step.

NOTICE

Be careful not to let the outer wheel bearing drop from the axle spindle. Dropping the bearing can warp the cage or damage the rollers, ruining the bearing. On vehicles equipped with WABCO ABS, use care when working with the hubs. To prevent damage to the tone wheel, do not drop the hub, or lay it down in a way that would damage the tone wheel.

8. Move the hub about 1/2 inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only assembly to rest on the axle spindle; be careful not to damage the axle spindle threads). Then, carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in either clean oil-proof paper or lint-free rags.

NOTICE

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

9. Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.
10. Remove the inner wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in clean, oil-proof paper or lint-free rags. If the inner wheel bearing remains in the hub after the hub is removed, place a protective cushion where it will catch the bearings, and use a hardwood drift and a light hammer to gently tap the bearing (and seal, if necessary) out of the cup.
11. Remove the oil seal from the axle spindle, if not already removed. See **Section 33.02** for additional information.

NOTE: For vehicles equipped with disc brakes, instructions for removing the brake rotor are given in **Section 42.18**.

Installation

For typical wheel end and axle assemblies, see **Fig. 2** and **Fig. 3**.

NOTE: For vehicles equipped with disc brakes, instructions for installing the brake rotor are given in **Section 42.18**.

1. Using cleaning solvent, remove the old oil from the axle spindle (steering knuckle) and the disassembled parts. Allow the parts to dry, or dry them with clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.

   For PreSet hubs that are being reused, the bearing spacer must be replaced. For PreSet Plus hubs, the bearing spacer must be cleaned and inspected before being reused; see **Subject 150**. If the bearing spacer is worn or damaged, replace it with a new one.

NOTICE

Ensure that both bearing assemblies are coated with fresh oil. Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.

2. Coat both bearing assemblies with fresh oil. Install the inner wheel bearings and oil seal. Handle the bearings with clean, dry hands. See **Section 33.02** for oil seal installation instructions.
3. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
4. If present, remove the temporary plastic bearing cover from the front of the hub.

NOTICE

- **When installing a ConMet PreSet hub, always use a new bearing spacer. Reinstalling a used bearing spacer could preload the wheel bearings and reduce the life of the wheel end.**

Hub Assembly Removal and Installation

- **Do not use the bearing spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.**

5. If using PreSet bearings, ensure the tubular spacer is in the PreSet hub.

   If replacing PreSet bearings with non-PreSet bearings, remove the tubular spacer from inside the hub.

NOTICE

- **On vehicles equipped with WABCO ABS, use care when installing the hubs. To prevent damage to the tone wheel, do not drop the hub or lay it down in a way that would damage the tone wheel.**
- **Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.**

6. Mount the hub assembly on the axle spindle.
7. Remove the friction tape, then adjust (if needed) and secure the bearings:
   - For an Axilok spindle nut, see **Subject 110**; then go to the next step.
   - For a Pro-Torq spindle nut, see **Subject 120**; then go to the next step.
   - For a double spindle nut system, see **Subject 130**; then go to the next step.
   - For ConMet PreSet Plus hubs, see **Subject 210**; then go to the next applicable step.
8. Place the hub cap and a new gasket in position, then install the washers and capscrews. In a star pattern, tighten the capscrews 15 lbf·ft (20 N·m).
9. If applicable, add fresh oil to the wheel hub to the level indicated on the hub cap.

WARNING

Failure to add oil to the wheel hub after the hub has been serviced will cause the wheel bearings to overheat and seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury and property damage.

10. Rotate the hub to distribute the oil, then check the level at the hub cap. Add lubricant as needed.
11. For drum brakes, install the brake drum on the wheel hub. See **Subject 140** for instructions.

    For disc brakes, install the the brake caliper. See **Section 42.18** for instructions.
12. Install the wheel and tire assembly. See **Group 40** for instructions.

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the wheel hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

13. Adjust the front axle brakes. For instructions, see **Group 42**.
14. Remove the safety stands from under the axle and lower the vehicle.

Axilok Spindle Nut Removal, Installation, and Adjustment

Service Guidelines

Axilok® spindle nuts may be used on ConMet PreSet hubs. See **Fig. 1** and **Fig. 2**. These nuts can be damaged if they are not removed or installed correctly. Use the following guidelines when removing and installing Axilok retaining nuts.

- Use only the correct size, *six-point* socket to remove or install Axilok spindle nuts. Do not use a worn or loose-fitting socket. **Do not use a 12-point socket.**
- Do not use hammers, chisels, pliers, wrenches, or power tools to remove or install Axilok nuts.
- Do not use an Axilok nut if the locking clips are damaged or missing, or if the retainer cage tab or D-flat is damaged or missing.
- Never try to repair a damaged Axilok nut; always replace it with a new one.
- Always start an Axilok installation by hand. A good-fitting six-point socket will completely disengage the nut's locking clips, allowing it to spin freely by hand. See **Fig. 3**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

Installation

Instructions for installing an Axilok nut for both PreSet and non-PreSet type bearings are provided in this subject. See the pertinent instructions for the type you are installing.

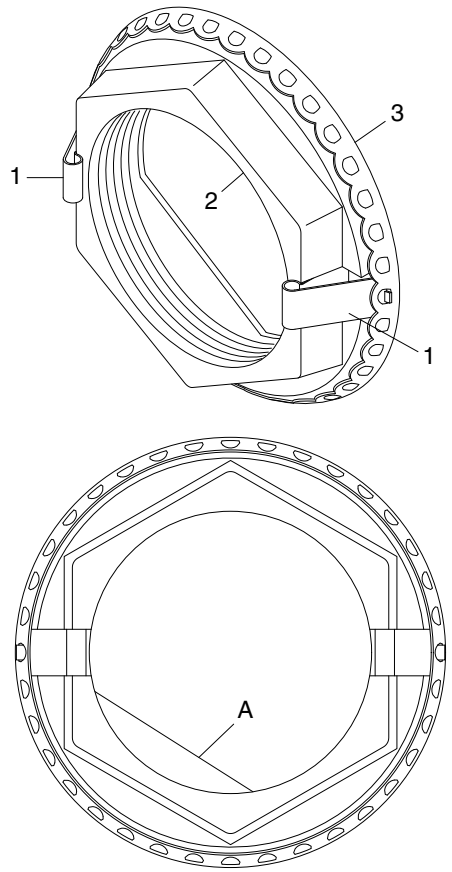
NOTICE

Always use a new spindle nut when installing the hub. A used spindle nut may have wear, causing uneven contact with the wheel bearing and reducing the life of the wheel end.

Using PreSet Bearings

⚠ WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.



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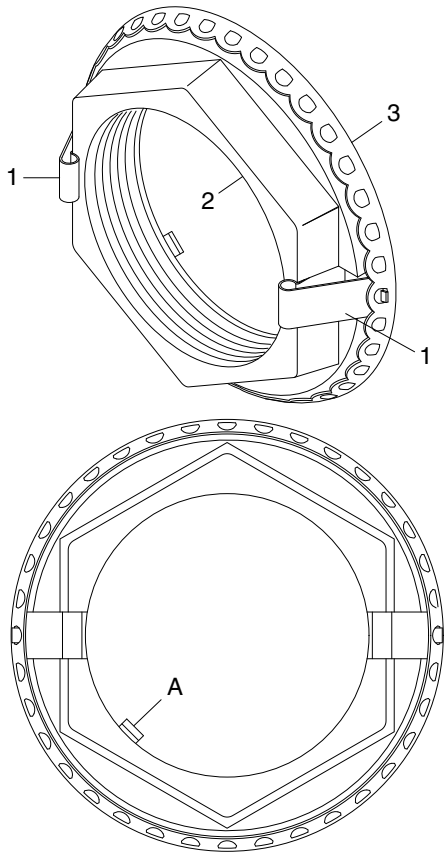
A. The flat side of the retainer must engage the flat side of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer Cage

Fig. 1, Axilok Retaining Nut, Meritor Front Axle

1. Apply a few drops of oil through one of the holes in the Axilok retainer cage to reduce friction between the retainer cage and nut.
2. By hand, install the Axilok nut onto the axle spindle. See **Fig. 1** and **Fig. 2**.
3. Tighten the retaining nut 250 lbf·ft (339 N·m). The nut should lock in place when you remove the wrench. If it does not, advance the nut until it does. **Do not back it off**.
4. Ensure that both locking clips are present and engaged in the retainer cage. See **Fig. 3**. If the

Axilok Spindle Nut Removal, Installation, and Adjustment



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A. This retainer tab must engage the keyway of the axle spindle.

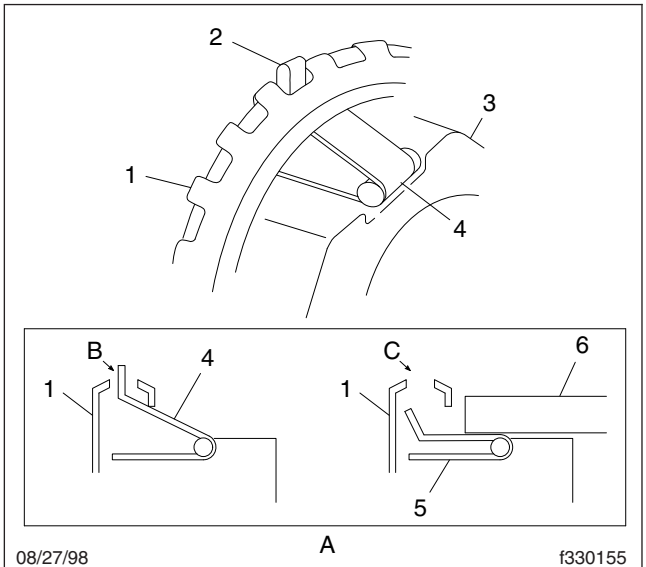
1. Locking Clip
2. Nut
3. Retainer Cage

Fig. 2, Axilok Retaining Nut, Eaton Front Axle

locking clips are not engaged, the nut is not locked in position and can rotate freely.

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.



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A. Cross-Section View
B. The tab is engaged.
C. The tab is disengaged.

1. Retainer Cage
2. Locking Clip Tab
3. Nut
4. Locking Clip
5. Locking Clip (compressed)
6. Six-Point Socket

Fig. 3, Axilok Nut, Checking the Position of the Locking Clip

⚠ WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

1. Apply a few drops of oil through one of the holes in the Axilok retainer cage to reduce friction between the retainer cage and nut. See **Fig. 1** and **Fig. 2**.
2. Install the Axilok nut and adjust the wheel bearings, as follows.
   - 2.1 By hand, install the Axilok nut onto the axle spindle and turn it against the bearing while spinning the hub.
   - 2.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the hub in both directions.

2.3 Loosen the nut to zero torque, and spin the hub a few turns.

2.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the hub in both directions. Back off the nut one-eighth to one-sixth turn.

2.5 Remove the wrench from the nut, and verify whether both locking clips are present and engaged in the retainer cage. See **Fig. 3**. If the locking clips are not engaged, advance the Axilok until they are.

3. Measure the end play; see **Subject 200** for instructions.

⚠ WARNING

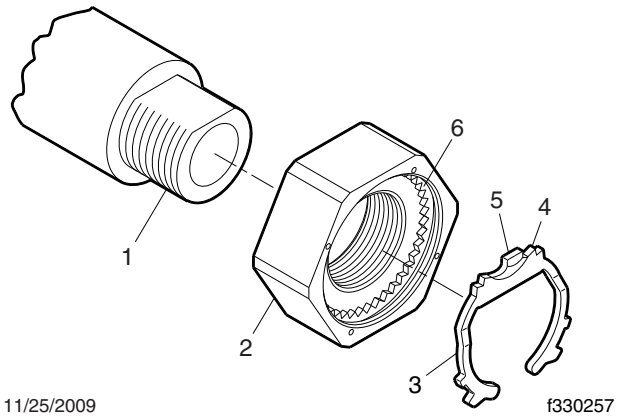
Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

4. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Axilok nut, and repeat the tightening sequence as described earlier in this procedure. Once the end play is correct, continue with your service procedure.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

General Information

Pro-Torq® spindle nuts may be used on ConMet Pre-Set hubs. See **Fig. 1** and **Fig. 2**.



1. Axle Spindle
2. Pro-Torq Nut
3. Keeper Arm
4. Mating Teeth, Keeper
5. Keeper Tab
6. Mating Teeth, Nut

Fig. 1, Pro-Torq Spindle Nut and Keeper

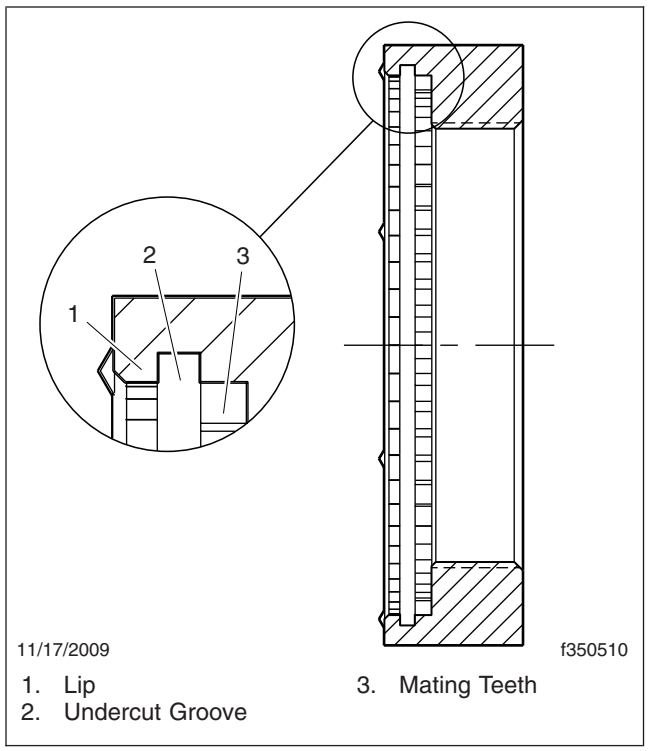
Each time the Pro-Torq nut assembly is removed for maintenance purposes, replacing the "keeper" is recommended.

Removal

⚠ WARNING

Do not place the nut on the spindle or tighten or loosen the nut on the spindle while the keeper is locked inside the nut. Doing so may damage the spindle threads and deform the keeper, and allow the nut to unthread during operation. Failure to follow this instruction could cause the hub to separate from the axle, resulting in severe personal injury or death.

1. Insert the blade of a flathead screwdriver (or similar tool) in the slot of one of the keeper arms; see **Fig. 3**. Ensuring that the tool contacts the keeper and not the teeth of the nut, turn the tool slightly and carefully pry the arm from the undercut groove of the nut.



1. Lip
2. Undercut Groove
3. Mating Teeth

Fig. 2, Pro-Torq Spindle Nut, Cross Section

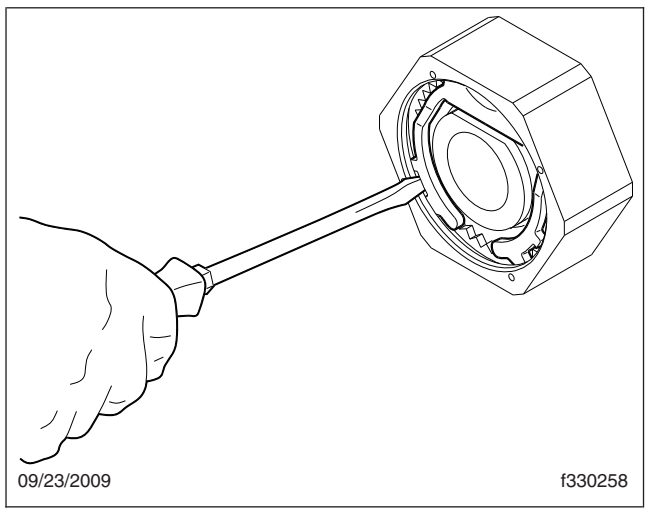


Fig. 3, Removing the Keeper

2. Repeat at the other arm, and remove the keeper from the nut.
3. Remove the Pro-Torq nut.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

Installation

The following procedure applies to Pro-Torq steer axle nut 448-4836. The part number is stamped on the nut.

⚠ WARNING

Do not place the nut on the spindle or tighten or loosen the nut on the spindle while the keeper is locked inside the nut. Doing so may damage the spindle threads and deform the keeper, and allow the nut to unthread during operation. Failure to follow this instruction could cause the hub to separate from the axle, resulting in severe personal injury or death.

Instructions for installing a Pro-Torq spindle nut for both PreSet and non-PreSet type bearings are provided in this subject. See the instructions pertaining to the bearing type used with the hub you are securing.

NOTICE

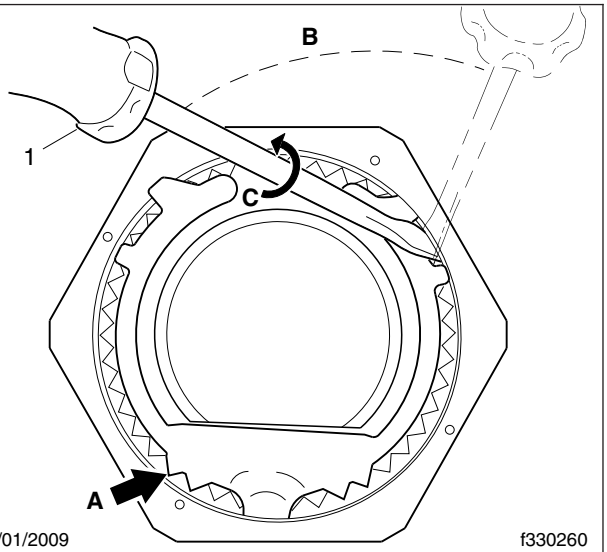
Always use a new spindle nut when installing the hub. A used spindle nut may have wear, causing uneven contact with the wheel bearing and reducing the life of the wheel end.

Using PreSet Bearings

1. Ensure the keeper is removed from the nut.
2. Install the Pro-Torq spindle nut, and tighten it 250 lbf·ft (339 N·m). **Do not back it off**.
3. Install the keeper.
   - 3.1 With the correct side of the keeper facing out, insert the keeper tab in the undercut groove of the Pro-Torq nut, and engage the mating teeth.

   IMPORTANT: If the keeper cannot be engaged, advance the nut until it can be. Do not back off the nut.

   - 3.2 Use a flathead screwdriver to carefully compress and guide each arm past the lip and into the undercut groove of the nut as shown in **Fig. 4**. To secure the keeper it may be necessary to nudge the arms into the groove.



A. Engage the mating teeth.
B. Compress the arm.
C. Turn the screwdriver to seat the keeper in the groove.

1. Flathead Screwdriver

Fig. 4, Installing the Keeper

⚠ WARNING

Failure to secure the keeper and lock the Pro-Torq nut could cause the wheel assembly to come off the vehicle, resulting in severe personal injury or death.

4. Inspect the installation; ensure the keeper is locked in the undercut groove of the nut.

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.

1. Ensure the keeper is removed from the nut.
2. Seat the bearings.
   - 2.1 Using a torque wrench, tighten the nut 200 lbf·ft (270 N·m). Spin the hub at least one full rotation.

   NOTE: Torque is lost when the hub is spun.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

2.2 Tighten the nut 200 lbf·ft (270 N·m). Spin the hub at least one full rotation.

2.3 Tighten the nut 200 lbf·ft (270 N·m), but *do not spin the hub*.

3. Loosen the nut to zero torque. *Do not spin the hub*.
4. Adjust the bearing.

4.1 Using a torque wrench, tighten the nut 100 lbf·ft (136 N·m). Spin the hub at least one full rotation.

NOTE: Torque is lost when the hub is spun.

4.2 Tighten the nut 100 lbf·ft (136 N·m). Spin the hub at least one full rotation.

4.3 Tighten the nut 100 lbf·ft (136 N·m).

4.4 Back off the nut one-quarter turn.

IMPORTANT: If the keeper cannot be engaged, advance the nut until it can be. Do not back off the nut.

5. Install the keeper.

5.1 With the correct side of the keeper facing out, insert the keeper tab in the undercut groove of the Pro-Torq nut, and engage the mating teeth.

5.2 Use a flathead screwdriver to carefully compress and guide each arm past the lip and into the undercut groove of the nut as shown in **Fig. 4**. To secure the keeper it may be necessary to nudge the arms into the groove.

⚠ WARNING

Failure to secure the keeper and lock the Pro-Torq nut could cause the wheel assembly to come off the vehicle, resulting in severe personal injury or death.

6. Inspect the installation; ensure the keeper is locked in the undercut groove of the nut.
7. Measure the end play; see **Subject 200** for instructions.

⚠ WARNING

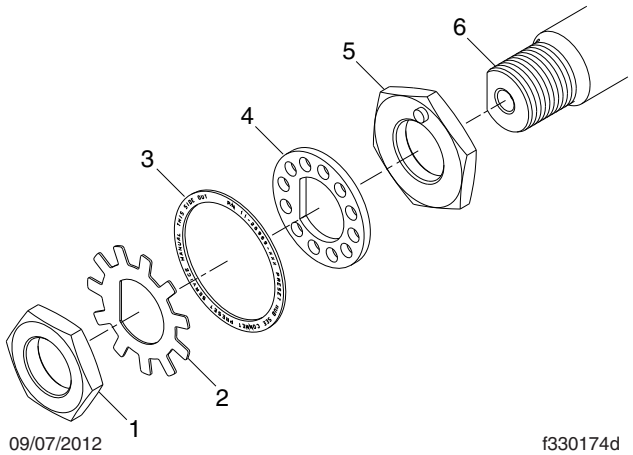
Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

8. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Pro-Torq nut, and repeat the tightening sequence as described in previous steps. Once the end play is correct, continue your service procedure.

Double Spindle Nut Removal, Installation, and Adjustment

General Information

ConMet PreSet hubs may use a double spindle nut system. See **Fig. 1**. A plastic ID ring between the adjusting nut and locking washer indicates that a ConMet Preset hub has been installed.



NOTE: ID ring used with ConMet PreSet hubs only.

1. Jam Nut
2. Bend-Type Locking Washer
3. ID Ring
4. Lockring
5. Adjusting Nut
6. Axle Spindle

Fig. 1, Double Spindle Nut Set

Removal

Once a double spindle nut set is removed, discard the bend-type locking washer. Inspect the adjusting nut, lockring, and jam nut for visible damage prior to reuse.

Installation

Instructions for installing a double spindle nut set for both PreSet and non-PreSet type bearings are provided in this subject. See the pertinent instructions for the type you are installing.

Using PreSet Bearings

1. Install the adjusting nut onto the axle spindle, and tighten it 300 lbf·ft (407 N·m). See **Fig. 1**.

NOTE: The gaps between holes in the lockring are spaced unevenly, so to fit the tab on the adjusting nut into one of the holes with minimal turning of the adjusting nut, gauge the distance on one side of the lockring, then the other, and choose the side that requires the adjusting nut to be advanced the least. Do not back off the nut.

2. Install the lockring (as described in the note above), ID ring (for ConMet PreSet hubs only), and bend-type locking washer.
3. Install the jam nut, and tighten it 200 lbf·ft (271 N·m).
4. Bend the tabs on the locking washer at 6 o'clock and 12 o'clock to lock the jam nut in place. See **Fig. 2**.

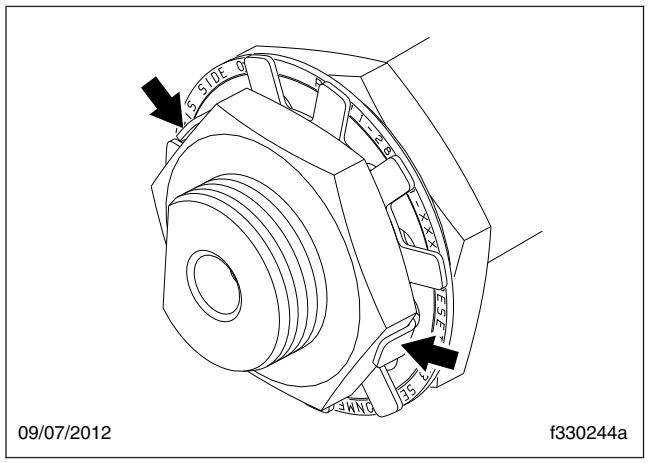


Fig. 2, Tabs Bent to Lock the Jam Nut

5. Rotate the hub in both directions. It should turn freely with no dragging or binding.

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.

1. Install the adjusting nut, as follows. See **Fig. 1**.
   - 1.1 Install the adjusting nut on the spindle, and tighten it finger-tight.
   - 1.2 While rotating the wheel hub assembly, tighten the adjusting nut 200 lbf·ft (271 N·m).

Double Spindle Nut Removal, Installation, and Adjustment

1.3 Back off the adjusting nut one full turn.

1.4 Tighten the adjusting nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.

1.5 Back off the adjusting nut one-quarter turn.

NOTE: The gaps between holes in the lockring are spaced unevenly, so to fit the tab on the adjusting nut into one of the holes with minimal turning of the adjusting nut, gauge the distance on one side of the lockring, then the other, and choose the side that requires the adjusting nut to be advanced the least. Do not back off the nut.

2. Install the lockring (as described in the note above) and bend-type locking washer.
3. Install the jam nut, and tighten it 200 to 300 lbf·ft (270 to 405 N·m).
4. Measure the end play; see **Subject 200** for instructions.

⚠ WARNING

Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

5. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm).** If the end play is not within this range, adjust the end play as follows.

   5.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

   5.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the adjusting nut again.

   5.3 Measure the end play.

   If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), repeat the adjustment procedure until the correct end play is achieved.

   IMPORTANT: The correct end play **must** be achieved before completing the hub assembly installation procedure.

6. Once the end play is between 0.001 and 0.005 inch (0.03 and 0.13 mm), bend two tabs on the locking washer at 6 o'clock and 12 o'clock to lock the jam nut in place. See **Fig. 2**.
7. Rotate the hub in both directions. It should turn freely with no dragging or binding.

Brake Drum Removal and Installation

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- **Always reline both sets of brakes on an axle at the same time.**
- **Always replace both rotors/drums on an axle at the same time.**
- **Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.**

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

Removal

1. Chock the rear tires and apply the parking brakes.
2. Raise the front of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. Back off the slack adjuster to release the front axle brake shoes. See **Group 42** for instructions.

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. Remove the wheel and tire assembly. See **Group 40** for instructions.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust.

   Don't use compressed air or dry brushing to clean the brake assembly.
5. Remove the brake drum.
6. Inspect the drum. See **Subject 150** for instructions.

Installation

1. Install the brake drum on the wheel hub.

   1.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub's pilot pads should be at the twelve o'clock (top center) position. See **Fig. 1**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are tightened.

   1.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

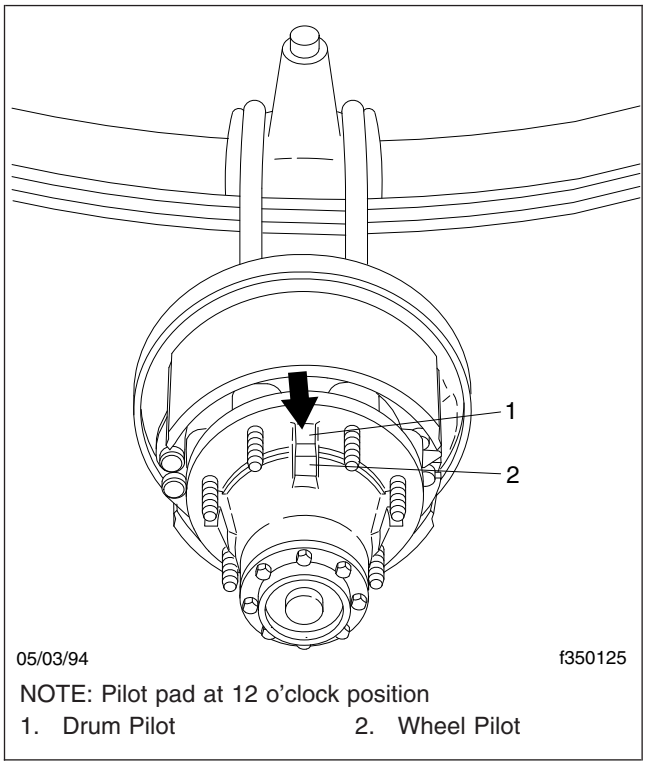
   IMPORTANT: If damage to the pads prevents the drum from centering, replace the hub. If necessary to hold the drum in position, adjust the brakes before installing the wheels.
2. Install the wheel and tire assembly. To ensure that the drum does not slip off the pilot pad, follow the proper nut tightening sequence. For instructions, see **Group 40** in this manual.

WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury and property damage.

3. Adjust the front axle brakes.
4. Remove the safety stands from under the axle; lower the vehicle.
5. Remove the chocks from the rear tires.

Brake Drum Removal and Installation



NOTE: Pilot pad at 12 o'clock position

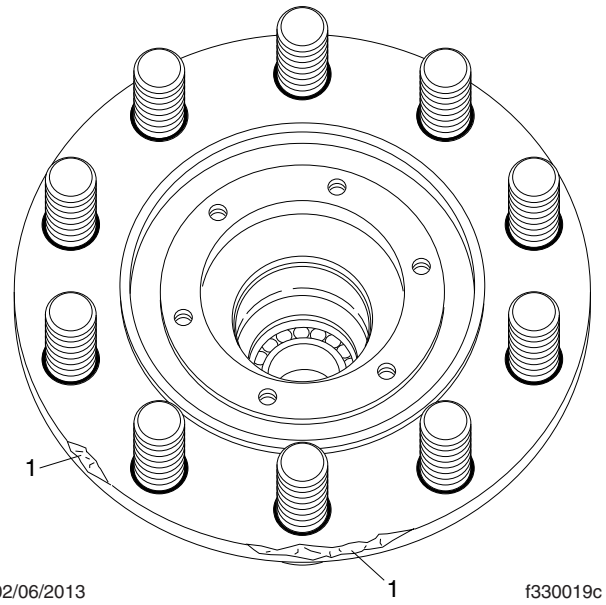
1. Drum Pilot
2. Wheel Pilot

Fig. 1, Hub Pilot Pads

Wheel Hub Assembly Inspection

1. Inspect the wheel hub mounting flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

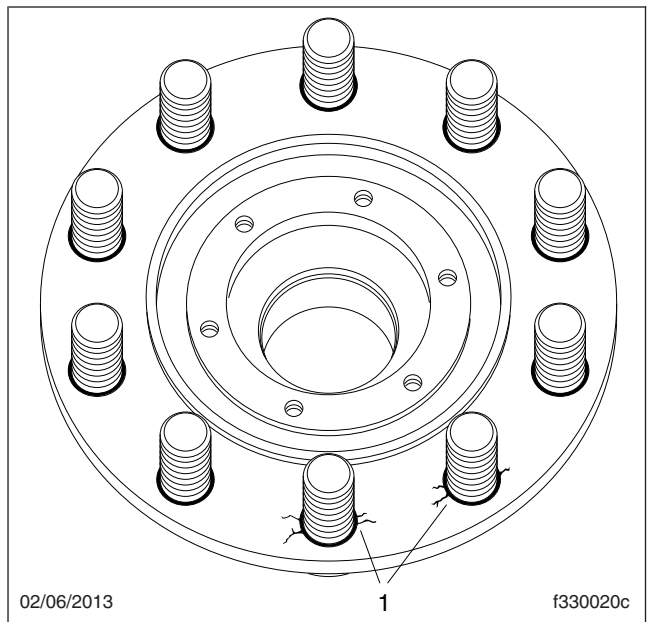
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

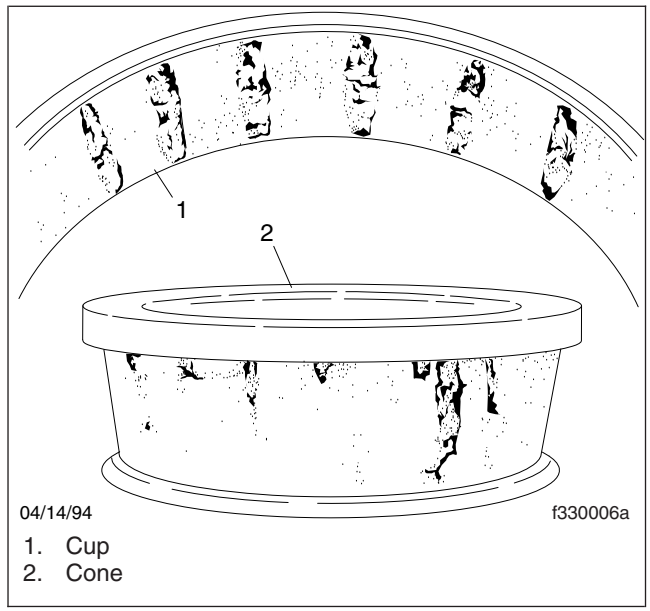
Fig. 1, Damaged Front Axle Wheel Hub

2. Remove all the oil from the wheel hub cavity. Inspect the inner surface of the hub for cracks, dents, wear, or other damage. Replace the wheel hub if damage exists.
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the wheel bearing cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. For aluminum hubs, see **Subject 160**; for ferrous hubs, see **Subject 170**.



1. Cracked Stud Grooves

Fig. 2, Damaged Front Axle Wheel Hub



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

4. Inspect the wheel studs. Replace studs that are stripped, broken, bent, or otherwise damaged. For instructions, see **Subject 180**.

Axle Components Cleaning and Inspection

Wheel Bearing Inspection

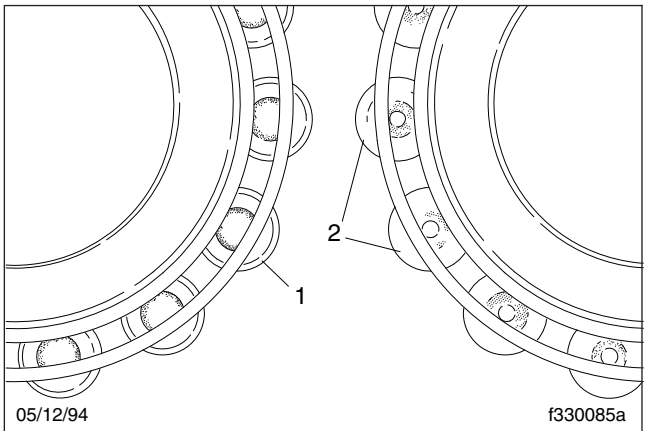
Wheel bearings should be very closely inspected at the time of disassembly. Optimal inspection conditions are possible only after the bearings have been thoroughly cleaned using nonflammable solvent and a stiff brush. Before inspecting, clean the bearings.

1. Remove the wheel hub and bearing cones. For instructions, see **Subject 100**.
2. Using nonflammable solvent and a stiff brush, clean all the oil from the bearings and hub cavity. Do not use gasoline or heated solvent.
3. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper. Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface that is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

NOTICE

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

4. After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies:
    - Large ends of rollers worn flush to the recess, or radii at the large ends of the rollers worn sharp. These are indications of advanced wear. See **Fig. 4**.
    - Visible step wear, particularly at the small end of the roller track. Deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 5**.
    - Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 6**.
    - Water etch on any bearing surface. Water etch appears as gray or black stains on the steel surface, and it greatly weakens the affected area. If water etch is present, replace the bearing seals.
    - Etching or pitting on functioning surfaces. See **Fig. 7**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 4, Wheel Bearing Roller Wear

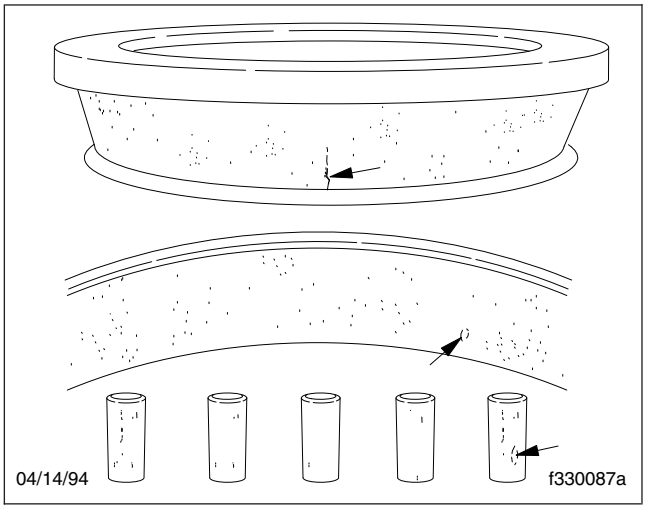


Fig. 5, Indentations, Cracks, or Breaks in Bearing Surfaces

- Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, coat the bearings with fresh axle lubricant.

Brake Drum Inspection

New brake drums are purposely undersized to allow for turning (remachining), since in mounting drums on the hub, there can be some eccentricity. If a new drum is installed, the protective coating on the inner friction surface must be removed with a solvent, prior

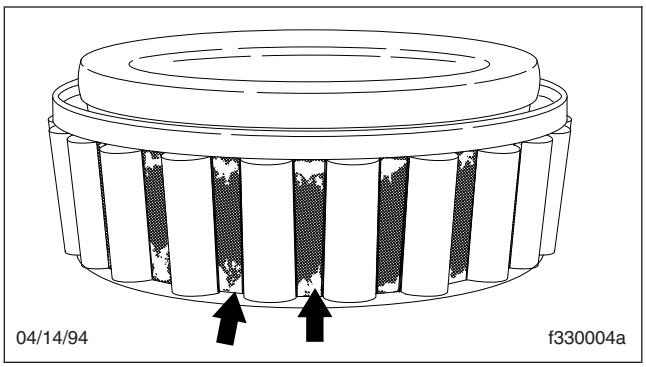


Fig. 6, Rubbing Marks on Bearing Cage

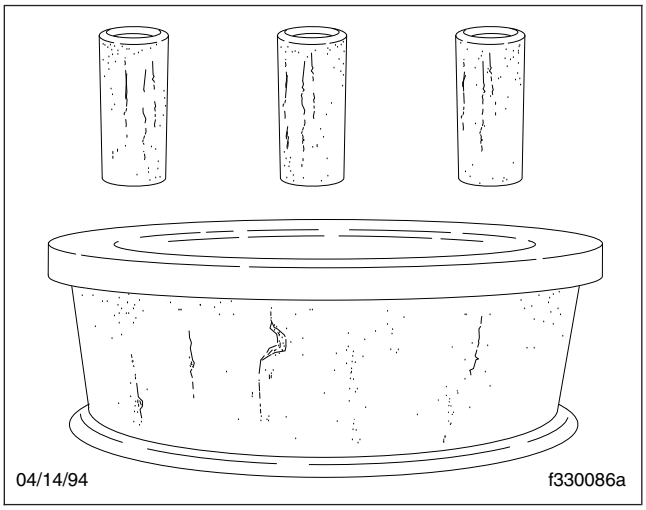
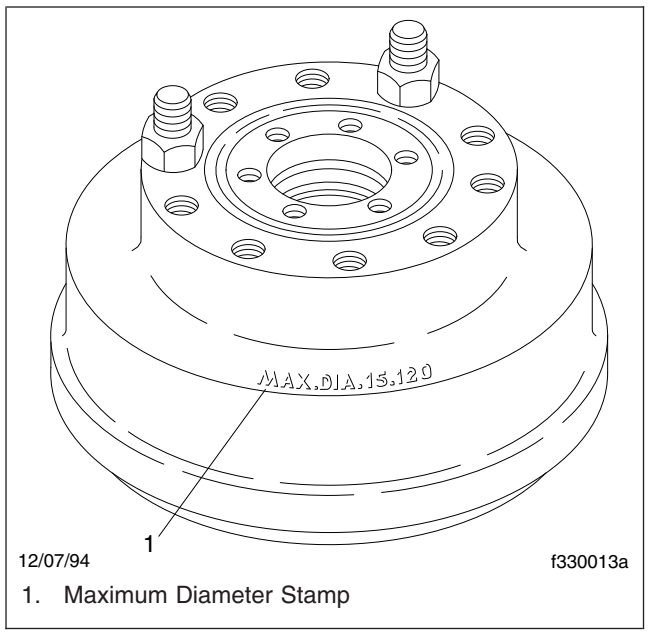


Fig. 7, Etching (Pitting) on Bearing Surfaces

to drum installation, then rinsed with hot water. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See **Fig. 8** for a typical location of this stamp.

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be followed with a hot water wash.



1. Maximum Diameter Stamp

Fig. 8, Outboard Mounted Hub and Drum Assembly

NOTICE

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will result in drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimately, drum breakage.

If the drums are turned or replaced, replace the brake linings. See **Group 42** in this manual for instructions.

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums.
2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not impair performance and lining life if the network of fine hairline cracks remains small. Examine heat checks of drums frequently to be certain the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). Replace the same-axle drums

Axle Components Cleaning and Inspection

if substantial cracks are present, or if widening of the fine hairline cracks occurs.

NOTE: If normal heat checking as described above is present, inspect the drums at least every 12,000 miles (19 300 km) thereafter. Inspect the drums (using a flashlight from the inboard side of the wheels) every 6000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove the contaminants. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil or grease saturated linings cannot be salvaged, they must be replaced. For brake lining replacement procedures, see **Group 42** in this manual.

⚠ WARNING

If the brake drums are contaminated with fluids, replace the brake linings. Failure to replace fluid contaminated brake linings could result in a partial loss of braking capacity, which could lead to personal injury or property damage.

4. Measure the inside diameter of the drum. If the measured diameter is greater than the maximum allowable diameter, replace the same-axle drums and linings.

NOTE: It may be necessary to remove the brake dust shield to measure the roundness of the drum.

5. Ensure the roundness of the drum is within acceptable limits, as follows. Set the measuring tip of a dial indicator against the working surface of the drum between the brake shoes as far outboard as possible. Zero the gauge, then turn the drum one revolution and note the highest and lowest measurements.

   If the difference is 0.010 inch (0.25 mm) or less, proceed to the next step. If the difference is more than 0.010 inch (0.25 mm), mark the drum and hub to record their relative positions, and remove the drum. Clean the mating surfaces of the hub and drum, and re-install the drum rotated 90 degrees from its earlier position. Tighten four wheel nuts 50 lbf·ft (68 N·m), and repeat the measurement. If the difference is more than 0.010 inch (0.25 mm), the drum is out of round beyond acceptable limits and all drums on the axle must be re-machined or replaced.

6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.

7. Check for hard, slightly raised dark-colored spots on the inner friction surface or for a bluish cast on the brake parts, both of which are caused by high temperatures. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If the spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs.

Bearing Spacer Cleaning and Inspection, PreSet Plus™ Hubs

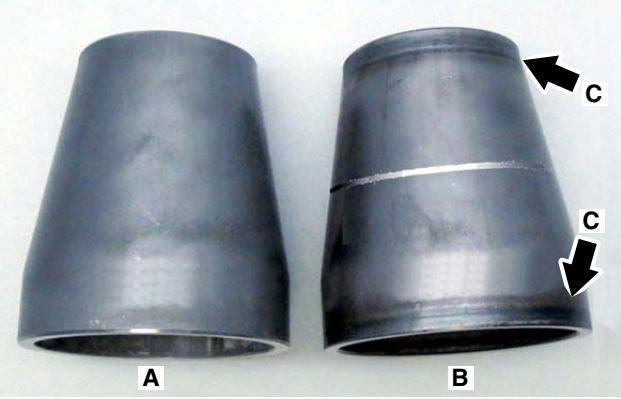
⚠ WARNING

Do not repair or recondition a damaged or worn bearing spacer; replace it. Using repaired, reconditioned, damaged, or worn components can cause wheel end failure, which can result in serious injury and property damage.

1. Use a cleaning solvent to clean the bearing spacer; do not use gasoline. Remove the solvent completely with clean, absorbent cloth or paper.

NOTE: PreSet Plus bearing spacers have undergone a heat-treating process that discolors the ends; see **Fig. 9**. This type of discoloration is normal for heat-treated spacers.

2. Inspect the bearing spacer for signs of wear or damage. Look for a sharp ring of standing metal that has been worn into the spacer at either end; see **Fig. 10**. If the spacer is worn or damaged, replace it.



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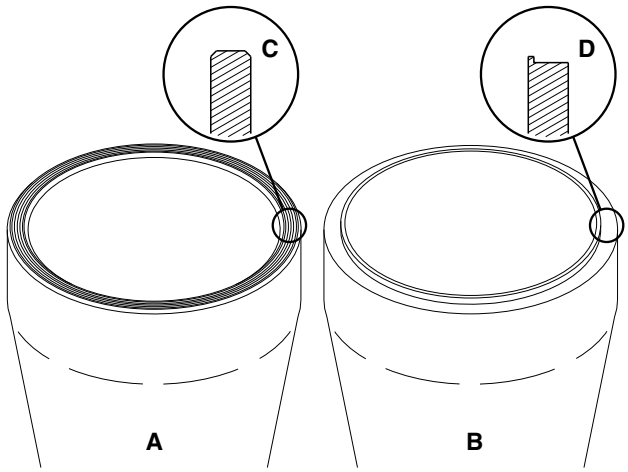
A. PreSet Spacer (Not Heat-Treated)
B. PreSet Plus Spacer (Heat-Treated)
C. Discoloration from Heat Treating Process

Fig. 9, PreSet and PreSet Plus Bearing Spacers



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A. New Spacer
B. Worn Spacer
C. Machined Surfaces with Chamfers and Grooves
D. Sharp Edge Worn into Machined End

Fig. 10, Comparison of New and Worn Bearing Spacers

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

Removal

To ensure a tight fit, wheel bearing cups (**Fig. 1**) are purposely larger than the wheel hub bores they occupy. To remove the bearing cups, aluminum hub bores must be temporarily expanded using the heat of an oven or boiling water (the bearing cups will also expand, but to a considerably lesser extent). If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

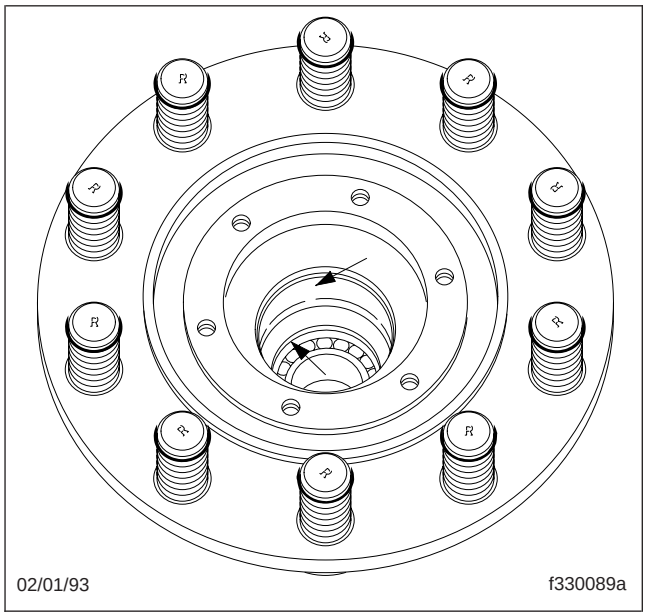


Fig. 1, Wheel Bearing Cup Locations

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Heat the hub to a temperature range of 175 to 215°F (79 to 102°C). If using an oven, make sure the thermostat is accurate; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

   If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

⚠ WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

3. Wearing heavy protective gloves, remove the hub from the oven or water. Place the hub on a suitable press so that the base is fully supported. Quickly press out the bearing cups.

   If the cup is loose, allow a few minutes for the temperatures of the components to equalize before moving the hub.

IMPORTANT: Inspect the bearing cup bore for evidence of cup rotation (spun cups). If found, replace the hub.

Installation

To install the bearing cups, aluminum hubs must be temporarily expanded using the heat of an oven or boiling water. When the hub is properly heated throughout, the bearing cup and hub can be press-fit together, using a suitable press. Cooling the cups in a freezer can further ease the installation.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Heat the hub to a temperature range of 175 to 215°F (79 to 102°C). If using an oven, verify that the oven thermostat is accurate; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

⚠ WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

4. Wearing heavy protective gloves, remove the hub from the oven or water.
5. Coat the replacement bearing cup hub contact surface with a film of grease.

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

6. Place the hub on a suitable press so that the base is fully supported. Quickly press-fit the bearing cup into the wheel hub until it is completely and evenly seated. Be careful not to shave the sides of the bearing cup bore as the bearing cup is seated. The accumulation of debris will prevent the cup from being seated and will also cause permanent damage to the wheel hub. If the sides of the bearing cup bore are damaged during installation, replace the wheel hub assembly.
7. Allow the wheel hub to cool before handling. Then, using a 0.0015-inch feeler gauge, check at several places for the seating of the bearing cup in the bearing cup bore. The gauge should not enter beneath the cup. If it does, there is probably dirt or debris preventing the cup from seating. Using the instructions above, remove the cup, then remove the foreign matter. Reinstall the cup.
8. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean, lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups on ferrous hubs are removed and installed by driving them out and pressing them in without heating the hub.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild-steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

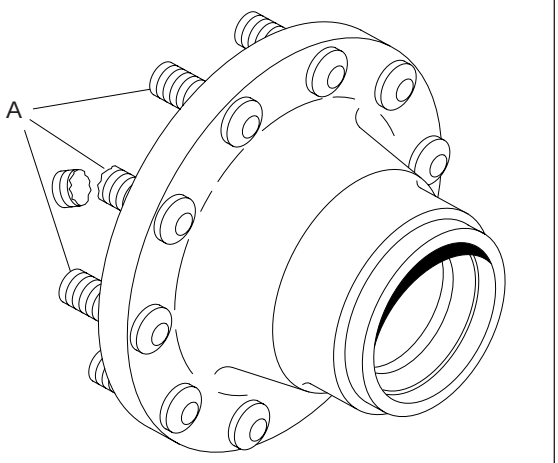
Installation

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it. See Fig. 1. If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury.



A. Replace the damaged stud and both adjacent studs.

Fig. 1, Wheel Stud Replacement

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.

NOTICE

Do not use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is necessary to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

3. Place the wheel hub on a suitable press; make sure the hub flange is supported evenly around and next to the stud being removed. With steady movement, press the stud out of the hub.
4. Apply a coating of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is supported evenly around and next to the stud being installed.

NOTICE

If headed studs with serrations are being installed, position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques during wheel installation cannot be achieved, replace the wheel hub assembly.

6. Position the stud in its hole. *Be sure the flat edge of the head flange on clipped studs is in line with the shoulder on the hub.*
7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded into the hub. If the head of the stud is embedded into the hub, replace the hub.

WARNING

Do not embed the wheel stud heads in the wheel hub. Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange. Weakness in the wheel hub can result in the loss of a wheel or loss of steering control, possibly resulting in personal injury and property damage.

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

If either the lateral or radial runout of the hub is beyond acceptable limits, replace the hub. For instructions, see **Subject 100** in this section.

Measurements

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

2. Remove the wheel and tire assembly. See **Group 40** for instructions.
3. For drum brakes, remove the brake drum. See **Subject 140** for instructions.
4. Clean the hub surfaces where the measurements will be taken—see **Fig. 1** and **Fig. 2**.
5. To measure lateral runout, set up a dial indicator as shown in **Fig. 1**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable lateral runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable lateral runout specification.
6. To measure radial runout, set up a dial indicator as shown in **Fig. 2**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable radial runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable radial runout specification.

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1. Hub
2. Dial Indicator (with roller point)

Fig. 1, Setup to Measure Lateral Runout

Hub Runout Measurements

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1. Hub
2. Dial Indicator (with roller point)

Fig. 2, Setup to Measure Radial Runout

Wheel Bearing End Play Measurement

⚠ WARNING

Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

IMPORTANT: Do not measure the wheel bearing end play with the wheel mounted on the hub; you cannot accurately measure or adjust bearing end play with the wheel mounted on the hub. Also, ensure that the brakes are not applied so that that drum and hub can move freely.

Measurement

Using a dial indicator, measure the end play as follows.

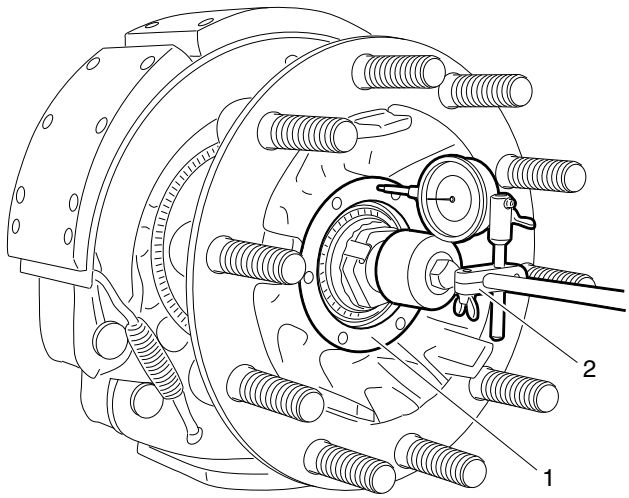
1. Attach the magnetic base of a dial indicator to the end of the spindle, and place the measuring end of the indicator against the hub cap mounting flange. See **Fig. 1**.

IMPORTANT: Maintain continual pressure on the hub until you have taken both the inboard and outboard measurements. If you release the hub, an accurate measurement is not possible.

2. To seat the bearings, grip the hub at the three o'clock and nine o'clock positions, and push inward while oscillating it approximately 45 degrees. Maintain pressure on the hub, note the inboard measurement, and then pull the hub outward while oscillating it as before. Maintain pressure on the hub, and note the outboard measurement. See **Fig. 2**.

   The end play is the difference between the two measurements.

NOTE: If the end play exceeds the limit, the hub may need to be serviced. See **Subject 150** and manufacturer literature for procedures.



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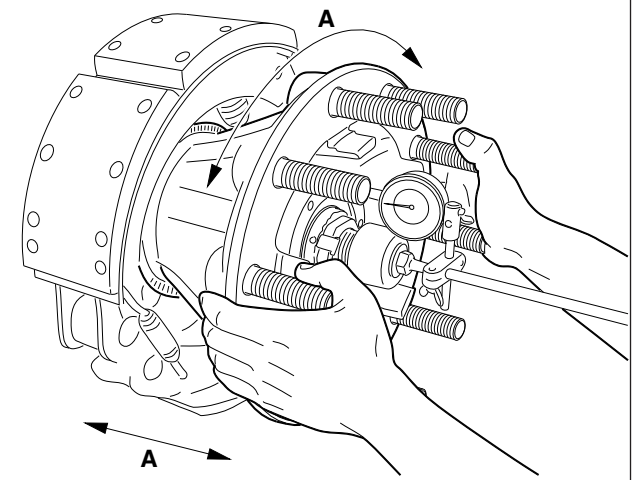
1. Hub Cap Mounting Flange
2. Dial Indicator (with magnetic base)

Fig. 1, Dial Indicator Setup



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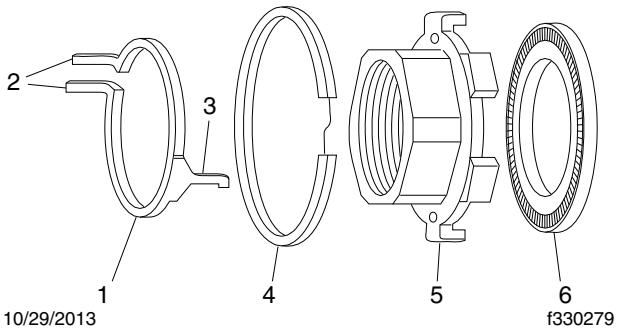
A. Pull and push the hub while oscillating it.

Fig. 2, Measuring End Play

ConMet PreSet Plus Spindle Nut Removal and Installation

General Information

ConMet PreSet Plus hubs use a special integrated spindle nut designed specifically for PreSet Plus hubs. See **Fig. 1**.



1. Locking Ring
2. Tabs
3. Lock Tab
4. Spiral Snap Ring
5. Spindle Nut
6. Locking Washer

Fig. 1, PreSet Plus Spindle Nut System

Removal

1. To remove the red locking ring from the spindle nut assembly, compress the tabs and pivot the ring to unlock it from the nut.

IMPORTANT: Do not exceed 50 lbf·ft (68 N·m) of torque when removing a PreSet Plus hub using the spindle-nut system as a hub puller.

2. Loosen the spindle nut. As the spindle nut is loosened, it can act as a hub puller. However, if the hub will not come off of the spindle without exceeding 50 lbf·ft (68 N·m) of torque, remove the spiral snap ring (see **Fig. 2**) and then the spindle nut assembly.

Installation

⚠ WARNING

Each PreSet Plus hub assembly requires special bearings, a PreSet Plus bearing spacer, and the unique PreSet Plus spindle nut system. Wheel ends equipped with the PreSet Plus hub assembly must use these special components; do not use non-PreSet-Plus components with a PreSet Plus hub.

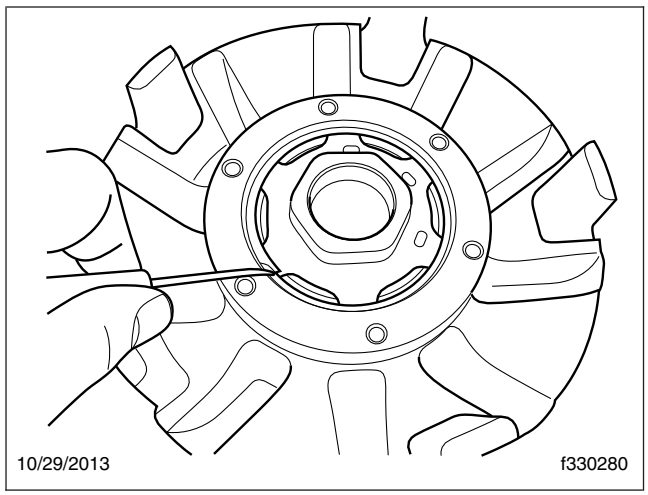


Fig. 2, Removing a Spiral Snap Ring

If a PreSet Plus hub is not correctly installed with the required components, the hub could separate from the axle, resulting in property damage, severe personal injury, or death.

The following instructions are for installing a PreSet Plus spindle nut. In some cases, the spindle nut components will have been removed along with the hub; in other cases, they will have been already installed in the hub. Use the pertinent instructions for your installation.

1. If the red locking snap ring is locked into the spindle nut, compress the tabs and pivot the ring to remove it from the nut. See **Fig. 1**.
2. If needed, begin installing the PreSet Plus spindle nut components, as follows.
   - 2.1 Seat the flat washer into the back of the spindle nut.
   - 2.2 Position the spindle nut and washer against the outer bearing.
   - 2.3 Install the spiral snap ring into the snap ring groove in the hub. Ensure that it fully seats into the groove in the hub. See **Fig. 3** and **Fig. 4**.
3. Tighten the spindle nut 300 lbf·ft (407 N·m) while rotating the hub. Do not back off the spindle nut.

ConMet PreSet Plus Spindle Nut Removal and Installation

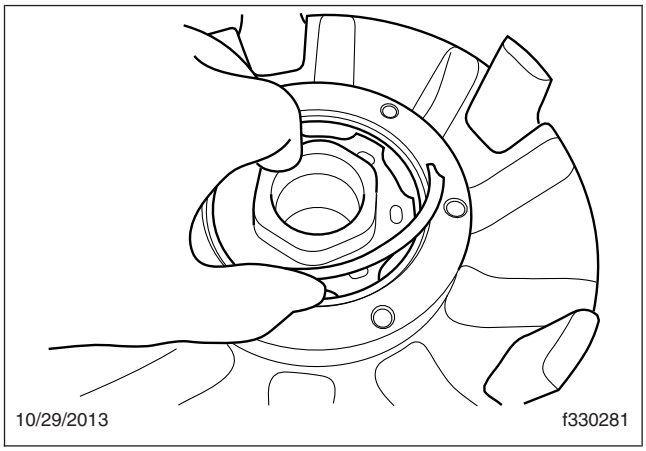


Fig. 3, Installing a Spiral Snap Ring

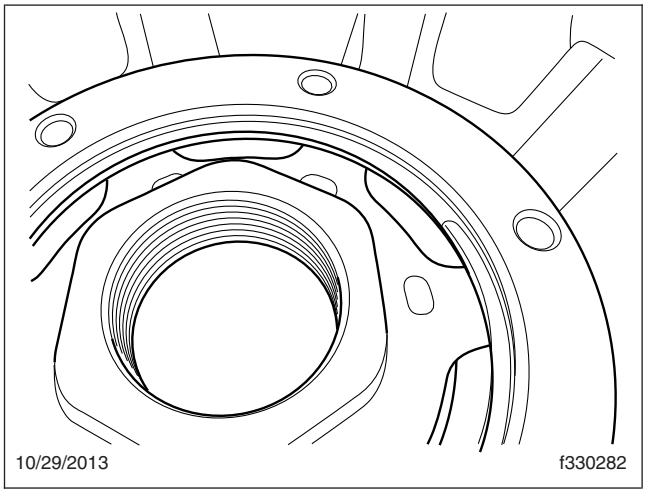


Fig. 4, Fully Seated Spiral Snap Ring

NOTICE

When bending the locking ring, be careful not to deform it permanently. If the locking ring is damaged or bent, replace it with a new one.

4. Install the locking ring, as follows.
   - 4.1 One of the holes in the face of the spindle nut will line up with a hole in the washer. Insert the lock tab of the locking ring through aligned holes.
   - 4.2 Using the handle tabs, seat the locking ring in the machined grooves of the spindle nut.

General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. Seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub.

The oil seal fits between the hub bore and the axle spindle. See **Fig. 1**.

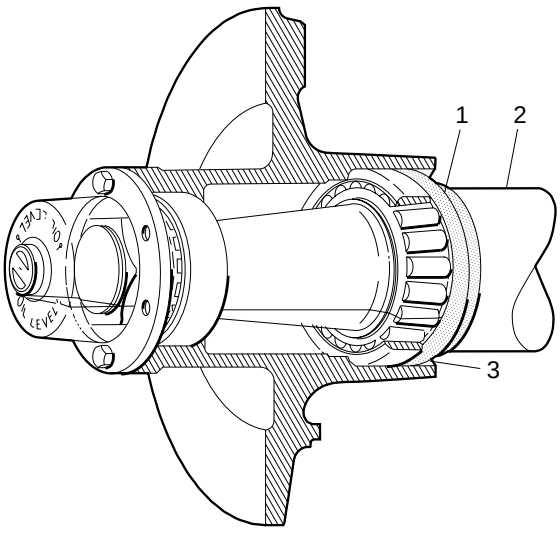


Fig. 1, Wheel Oil Seal

Most wheel oil seals consist of four basic parts (**Fig. 2**):

- the outside edge (also called the outer "cup" or "case")
- the inside edge (also called the inner "cup" or "case")
- the sealing element
- the garter spring

The outside edge is usually metal coated with rubber or another sealing agent so that it grips the hub bore tightly enough to prevent oil escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

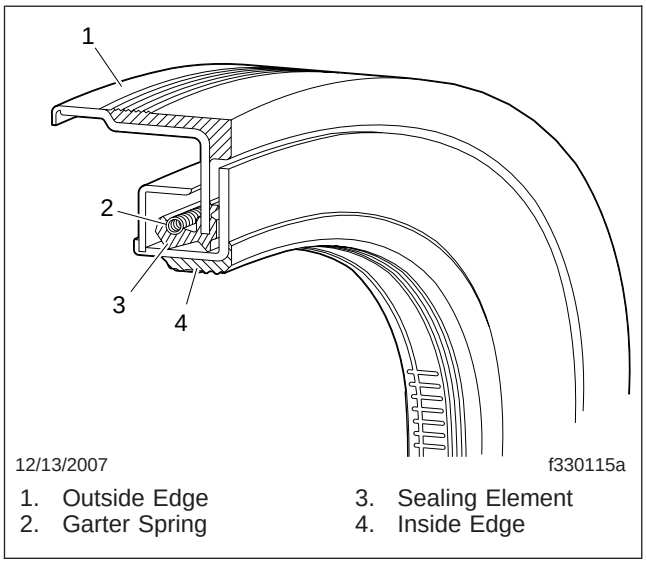


Fig. 2, Wheel Oil Seal Parts

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips that will seal against the axle spindle or against the outside or inside edge described above.

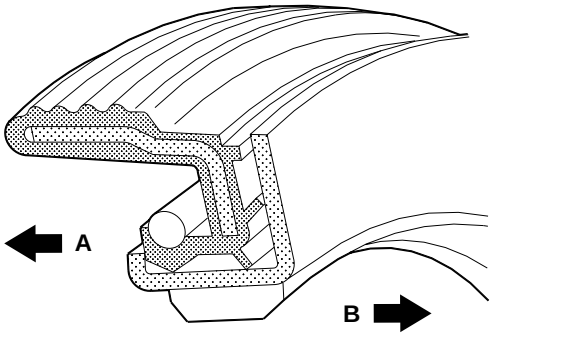
The garter spring is a loop of coiled wire spring that presses the sealing element against the sealing surface.

Chicago Rawhide Scotseal Plus XL

The Chicago Rawhide Scotseal Plus XL is a unitized, one-piece seal with one primary spring-loaded sealing lip and three secondary contacting sealing lips, which rotate with the housing. See **Fig. 3**. The outer diameter of the metallic case and the bore diameter of the seal counter face are coated with rubber. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal Plus XL directly onto the axle spindle.*

Although you install the Scotseal Plus XL into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle and seals against the outer cup, which turns with the hub.

General Information



A. Oil and Bearing Side B. Air Side

Fig. 3, Scotseal Plus XL Oil Seal

Seal Replacement, Chicago Rawhide Scotseal Plus XL

IMPORTANT: Make sure the required tools are available before beginning the service procedures described here. See **Fig. 1** for a diagram of the installation tool. See **Specifications, 400** for tool and seal numbers.

Replacement

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01**.
2. Remove the inner wheel bearing assembly from the axle. Handling the bearings with clean dry hands, wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the hub is removed from the axle. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing and seal out of the inner wheel bearing cup. Discard the seal.
3. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 2** and **Fig. 3**.
4. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.

NOTICE

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

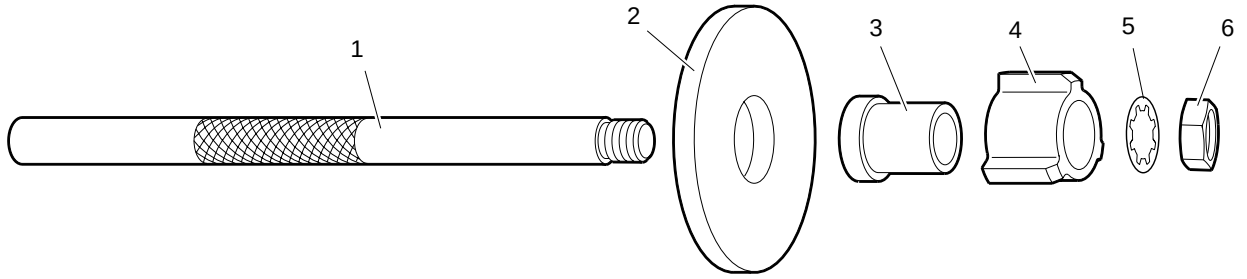
IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

5. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
6. Coat the wheel bearing cones with oil.
7. Install the inner wheel bearing cone in the inner wheel bearing cup.
8. Inspect a new seal for damage (such as cuts or being out of round) and contamination. If damage is evident, discard it and use a suitable seal.
9. Apply a thin layer of lubricant to the inside and outside diameters of the seal using the same lube used in the hub.
10. Seat the seal in the seal bore with the "air side" facing outward ("air side" is stamped on the sleeve flange of the seal), then press it down firmly with the flat side of the driver plate.
11. Insert the centering tool into the bore of the inner bearing cone. The plug prevents cocking of the seal in the bore.
12. Hold the tool handle firmly, and strike it until the seal bottoms out. See **Fig. 4**. Hold the tool firmly to avoid bounce or unseating of the seal from the adapter.
13. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation. If any damage is visible, remove the seal and install a new one.
14. Install the wheel, drum, and hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

15. Adjust the brake shoe-to-drum clearance. For instructions, see **Group 42**.

Seal Replacement, Chicago Rawhide Scotseal Plus XL



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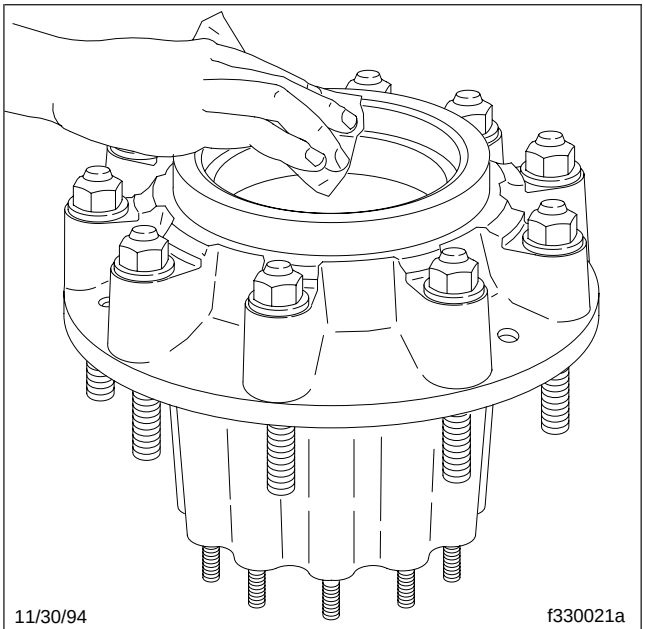
1. Handle
2. Driver Plate
3. Plug Bushing
4. Centering Tool
5. Washer
6. Nut

Fig. 1, Installation Tool



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NOTE: Rear hub shown.

Fig. 2, Cleaning the Hub

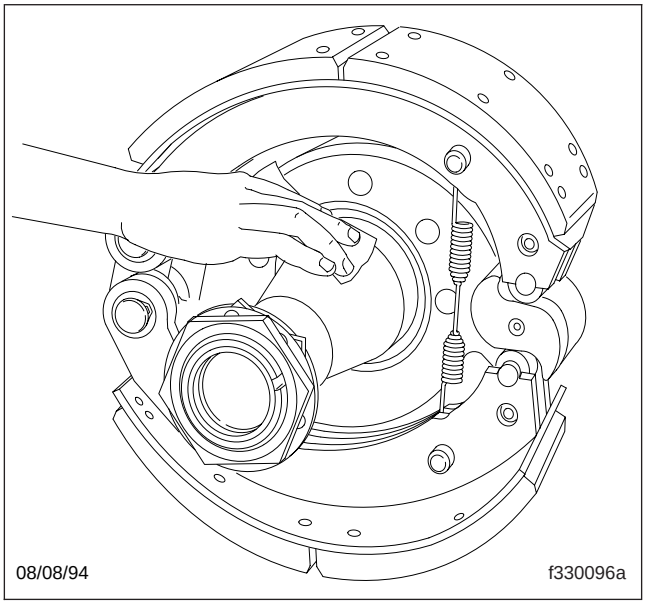

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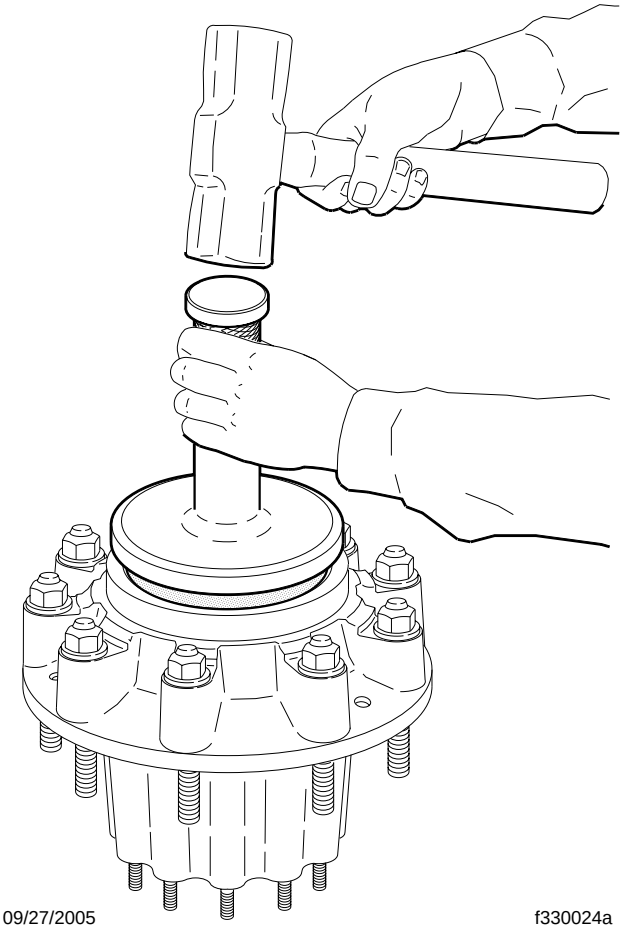
Fig. 3, Cleaning the Spindle

Seal Replacement, Chicago Rawhide Scotseal Plus XL



NOTE: Rear hub shown.

Fig. 4, Striking the Tool

Specifications

Scotseal Plus XL Tool and Seal Numbers			
Cone, Inner Bearing	**Seal Stock Number**	**Centering Tool**	**Driver Plate**
HM212049	35058*	706	436

* The seal stock number is listed on the air-side flange of the seal.

Table 1, Scotseal Plus XL Tool and Seal Numbers

General Information

Detroit front axles have a unique steering knuckle design that reduces vibration and wear. Low-friction, high-strength needle bearings roll on a large-diameter kingpin, replacing the conventional bushings. They are compatible with industry-standard brakes, hubs, and wheel bearings.

The following explains a typical model code found on a Detroit front axle identification tag. See **Fig. 1**.

Typical Model Code: AF-12-3.

- *AF* = front axle
- *12* = Weight Rating (times 1000 lb)
- *3* = Model Number

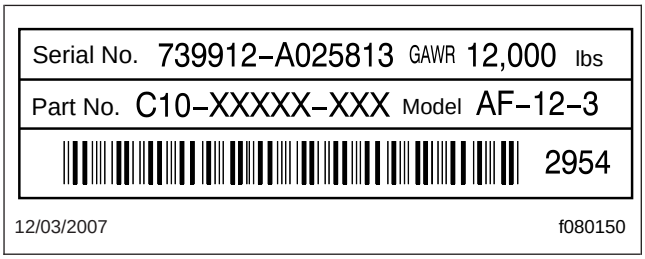


Fig. 1, Front Axle ID Tag

NOTE: Detroit axles are a proprietary product, though in some applications they may be referred to as "Freightliner" or "Axle Alliance" axles or "MB components."

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Put the transmission in neutral.
2. At both ends of the front axle, loosen all the wheel nuts.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, causing the vehicle to fall, which could result in serious injury or death.

3. Raise the front of the vehicle and support it with safety stands.
4. Drain the air system.
5. Remove the front wheel and tire assemblies. For instructions, see **Group 40**.
6. Remove the front hubs from the axle. See **Section 33.01, Subject 100** for instructions.
7. For drum brakes, remove the brake shoes; see the applicable service brake section in **Group 42** for instructions.
8. Remove the ABS sensors and wiring from the brake spiders (anchor plates) and secure them and their wiring out of the way.
9. Remove the brake air chambers and the slack adjusters. For instructions, see the applicable sections in **Group 42**.
10. Remove the brake spiders from the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
11. Disconnect the drag link from the axle steering arm.
12. If so equipped, disconnect the sway bar from the axle brackets.
13. Using a suitable jack, support the front axle.
14. Remove the U-bolt nuts or remove the nuts holding the axle beam to the leaf springs and the air bag brackets, as applicable.
15. Remove the U-bolts, if applicable.
16. Remove the axle from the vehicle.
17. If you are replacing the steering knuckles, put the axle on a suitable stand and secure it to prevent it from moving.

Installation

1. With the axle on a suitable jack, position it under the vehicle.
2. For vehicles with front air suspension, raise the axle so that the holes in the axle beam line up with the bolts holding the air bags to the leaf springs. Install the nuts and washers and tighten the nuts 220 lbf·ft (298 N·m).

   For vehicles with a leaf-spring front suspension, install the U-bolts and nuts. For instructions on tightening U-bolt nuts, see the applicable section in **Group 32**.
3. If so equipped, connect the sway bar to the axle brackets. Tighten the sway bar fasteners 100 lbf·ft (136 N·m).
4. Connect the drag link to the steering arm. For instructions, see the applicable section in **Group 46**.
5. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
6. Install the brake air chambers and slack adjusters onto the axle. For instructions, see the applicable sections in **Group 42**.
7. Install the ABS sensors.
8. For drum brakes, install the brake shoes; see the applicable service brake section in **Group 42** for instructions.
9. Install the hubs. For instructions, see **Section 33.01, Subject 100**.
10. Install the brake drums.
11. Adjust the slack adjusters. For instructions, see the applicable section in **Group 42**.
12. Install the tire and wheel assemblies. For instructions, see **Group 40**.
13. Raise the vehicle, remove the safety stands, and lower the vehicle.
14. Start the engine and build the air pressure.
15. If equipped with a front air suspension, ensure that the suspension air bags inflate correctly.

Disassembly

NOTE: The following procedures can be done with the axle installed on the vehicle or with the axle removed from the vehicle.

1. If the axle has been removed, make sure it is securely mounted on a suitable stand. Go to the step for removing the tie rod from the tie-rod arm.

   If the axle is on the vehicle, park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the rear tires. Drain the air system.

2. If the axle is on the vehicle, do the following substeps to gain access to the steering knuckle.

   2.1 Remove the wheel and tire assembly from the applicable side of the vehicle.

   2.2 Remove the hub. For instructions, see **Section 33.01, Subject 100**.

   2.3 Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.

   2.4 Remove the ABS sensor and wiring from the brake spider (anchor plate), and secure the sensor and the wiring out of the way.

   2.5 Disconnect the air line from the brake air chamber, then remove the air chamber and the slack adjusters. For instructions, see the applicable sections in **Group 42**.

   2.6 Remove the brake spider from the axle flange. For instructions, see the applicable service brake section in **Group 42**.

   2.7 Disconnect the drag link from the steering arm, if present.

   NOTE: On the driver side of the vehicle, the steering arm connects to the steering knuckle; on the passenger side, no steering arm is present.

3. If not already done, disconnect the tie rod from the tie-rod arm.

4. Remove the tie-rod arm from the steering knuckle. See **Fig. 1**.

5. Remove the steering arm. See **Fig. 1**.

6. Remove the steering knuckle and spindle assembly from the axle beam. See **Fig. 1**.

   6.1 Remove the upper and lower snap rings that hold the cover plates in place.

   6.2 Remove the upper and lower cover plates from the steering knuckle.

   6.3 Remove and discard the O-ring from the edges of each cover plate.

   6.4 Note the orientation of the draw keys and the kingpin, then remove the draw keys and nuts that hold the kingpin in place.

   6.5 Using a brass drift, remove the kingpin by driving it downward. Note where the needle bearings were installed.

   6.6 Remove the spacer(s) and shim(s) from the upper surface of the axle beam bore.

   6.7 Push down on the steering knuckle and spindle assembly to clear the lip on the thrust friction bearing and remove the assembly from the axle beam bore.

NOTE: The steering knuckle on the passenger side (side without a steering arm) has a thrust roller bearing instead of a thrust friction bearing. Unlike the thrust friction bearing, the thrust roller bearing has no protruding lip at the top. When removing the thrust roller bearing from the axle beam bore, it is not necessary to push down on the steering knuckle.

7. Remove the grease seal from the upper steering-knuckle bore.

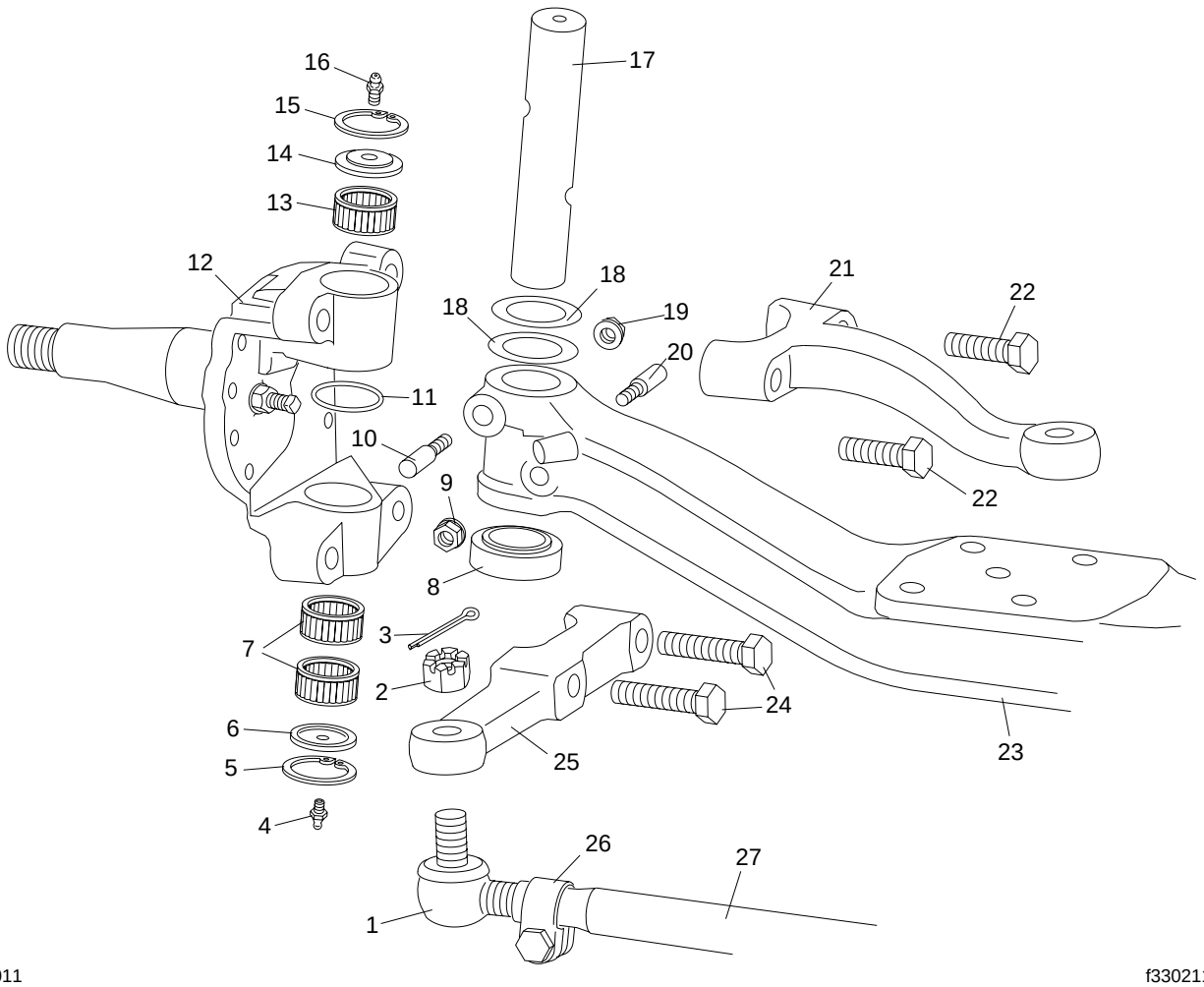
8. Remove the thrust friction bearing (driver side) or the thrust roller bearing (passenger side) from the top of the lower steering knuckle bore.

NOTE: If removing the thrust friction bearing (driver side), note the orientation of the bearing for future reference.

9. Using a suitable bushing driver, drive out the needle bearings from the steering knuckle bores.

10. If needed, repeat the entire procedure for the other side of the axle assembly.

Steering Knuckle Disassembly and Assembly



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NOTE: The number of upper and lower needle bearing sets may vary, depending on the axle model.

1. Tie-Rod Ball Joint
2. Castle Nut
3. Cotter Pin
4. Lower Grease Fitting
5. Lower Snap Ring
6. Lower Cover Plate
7. Lower Needle Bearings (may be one or two sets)
8. Thrust Friction Bearing (thrust roller bearing on the passenger side)
9. Lower Draw Key Nut
10. Upper Draw Key
11. Grease Seal
12. Steering Knuckle
13. Upper Needle Bearing (may be one or two sets)
14. Upper Cover Plate
15. Upper Snap Ring
16. Upper Grease Fitting
17. Kingpin
18. Shim
19. Upper Draw Key Nut
20. Lower Draw Key
21. Steering Arm
22. Steering Arm Capscrew
23. Axle Beam
24. Tie-Rod Arm Capscrews
25. Tie-Rod Arm
26. Tie-Rod Clamp
27. Tie-Rod Tube

Fig. 1, Front Axle Components (driver side shown)

Assembly

IMPORTANT: If replacing the kingpin, use a complete rebuild kit with all new components.

1. Clean the steering knuckle bores and the axle beam bores. Check for damage such as grooves, scratches, and pitting.

   If any bores show significant damage, replace the component.

2. Install the grease seal — with the grooved side down (toward the road) — into the top of the upper steering knuckle bore. Carefully drive the seal down into the bore until the outer edge of the seal is flush with the bottom edge of the bore. Make sure the seal is not cocked.

3. Install new needle bearings into the bores of one of the steering knuckles. Install the same number of bearings as was removed.

NOTE: Install the needle bearings just far enough into the bores so that the cover plates can be installed.

4. Install a new thrust friction bearing (driver side) or thrust roller bearing (passenger side) into the top of the lower steering knuckle bore. Install the thrust friction bearing (or thrust roller bearing) with the sealed side up.

NOTE: The thrust friction bearing has a protruding lip at the top; the thrust roller bearing has no such protruding lip.

5. Partially install the steering knuckle onto the axle beam.

   5.1 Making sure the flats on the kingpin are aligned with the draw-key holes in the axle beam, put the new kingpin into the top bore of the steering knuckle. Note that the top of the new kingpin is clearly marked. Push the kingpin through the axle beam bore until the upper end of the kingpin is flush with the upper surface of the axle beam bore.

   IMPORTANT: To correctly check the clearance, the thrust friction or thrust roller bearing must be installed correctly, and upward pressure must be applied to the steering knuckle.

   5.2 Align the steering knuckle with the axle beam, then check the clearance between the axle beam bore and the upper steering knuckle bore. Clearance is to be a maximum of 0.007 inch (0.18 mm).

   5.3 If needed, install sufficient spacers to reduce the clearance to a maximum of 0.007 inch (0.18 mm).

6. Install the kingpin fully into the steering knuckle bores, ensuring that the flats on the kingpin are still aligned with the draw-key holes in the axle beam, and that the top of the kingpin (marked "Top") is properly positioned.

IMPORTANT: Make sure the new draw keys are the same length as those removed. On some axle models the lower draw key is longer than the upper one.

7. Install new upper and lower draw keys and nuts. See **Fig. 1**.

   IMPORTANT: Incorrect installation of the draw keys could cause interference with the steering stop bolt.

   7.1 Install the upper draw key from the back of the axle, and the lower one from the front of the axle.

   7.2 Tighten the draw-key nuts 30 to 55 lbf·ft (40 to 75 N·m).

8. Install new grease fittings and cover plates.

   8.1 Install the new upper cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

   8.2 Install the new lower cover plate (with a new O-ring) and the snap ring. Install the new grease fitting into the cover plate.

9. Install the steering arm. Apply Loctite® 277 to the threads and tighten the steering arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).

10. Attach the tie-rod arm to the steering knuckle. Apply Loctite® 277 to the threads and tighten the tie-rod arm capscrews: if M20 capscrews are used, tighten them 425 lbf·ft (575 N·m); if M24 capscrews are used, tighten them 664 lbf·ft (900 N·m).

Steering Knuckle Disassembly and Assembly

11. Attach the tie-rod arm to the tie rod. Tighten the castle nut 120 to 170 lbf·ft (163 to 230 N·m) plus a maximum of one-sixth of a turn to align a slot in the castle nut with the cotter pin hole in the tie rod stud. Insert the cotter pin and bend the tangs to secure it.
12. If removed, install the axle.
13. If removed, connect the drag link to the steering arm.
14. Install the brake spider on the axle flange. For instructions, see the applicable service brake section in **Group 42**.
15. Install the brake air chambers and slack adjusters on the axle. For instructions, see the applicable sections in **Group 42**.
16. Install the ABS sensor.
17. Install the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. Install the hub. For instructions, see **Section 33.01**.
19. If so equipped, install the brake drum.
20. Install the tire and wheel assembly. For instructions, see **Group 40**.
21. If necessary, repeat the entire procedure for the other side of the vehicle.
22. Raise the vehicle, remove the safety stands, then lower the vehicle.

Specifications

Torque Values			
Application	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Draw-Key Nuts	—	—	30–55 (40–75)
Steering Arm Capscrews	M20 x 1.5	10.9	425 (575)*
	M24 x 1.5	10.9	664 (900)*
Sway Bar Fasteners	—	—	100 (136)
Tie-Rod Arm Capscrews	M20 x 1.5	10.9	425 (575)*
	M24 x 1.5	10.9	664 (900)*

* Apply Loctite® 277.

Table 1, Torque Values

General Information

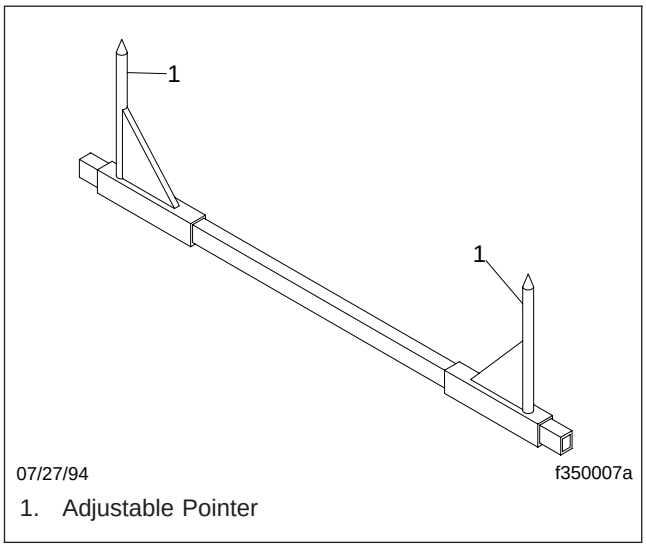
Rear axle alignment should be checked whenever rear axle or suspension components are replaced. It should also be checked when there is excessive front and rear tire wear, or hard or erratic steering.

Manufacturers of axle alignment equipment offer a variety of systems to precisely measure and correct rear axle alignment. If this type of equipment is not available, the basic tools needed for checking rear axle alignment on tandem or single axles are a straightedge (that is nonflexible and at least as long as the axle), steel tape rule, and trammel bar or center point bar.

The straightedge is used to see if a single axle, or a forward-rear axle of a tandem axle installation, is in alignment with the frame. The distance from the straightedge to the center of the wheel hub is measured on each side of the vehicle; any difference in the measurements means that the axle is out of alignment.

A center point bar (**Fig. 1**) is used to see if the forward-rear axle and rearmost axle of a tandem installation are aligned with each other (parallel). It has adjustable pointers at each end, which are inserted into the axle cap holes of each axle. By comparing the distance between the two axles on one side to the distance on the other side, it can be determined if the axles are parallel.

Instructions and a list of materials for making a center point bar are in **Subject 130**.



1. Adjustable Pointer

Fig. 1, Center Point Bar

The following preliminary checks should be completed before checking any alignment measurements.

Preliminary Checks

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line.

1. Wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires and suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. Refer to **Group 40** in this manual and **Group 40** in the *108SD and 114SD Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to **Group 40** in this manual for recommended pressures. An underinflated tire causes tread wear completely around both tire shoulders. An overinflated tire causes tread wear in the center of the tire. See **Fig. 1.**

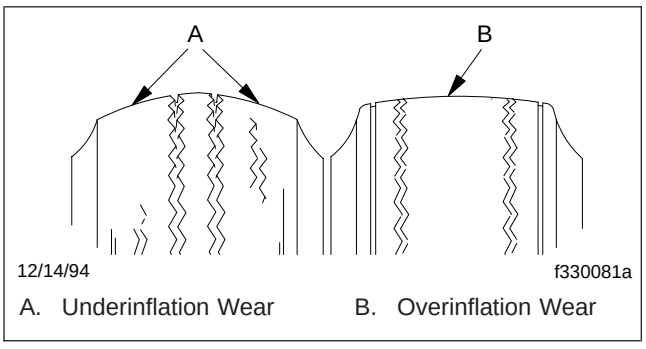


Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels and wheel stud holes. Replace the wheel if any of these conditions exist.
5. On each side of the vehicle, check the height of the chassis above the ground; for instructions, see **Group 32** in this manual or the suspension manufacturer's service literature. Sagging, fatigued, or broken suspension springs create a lopsided vehicle appearance and an unbalanced weight distribution. Anything that changes the ratio of weight on the springs affects the alignment angles and also the tire tread contact area. Replace damaged springs as instructed in the applicable suspension section.
6. Check and, if necessary, correct frame rail alignment as instructed in **Group 31** in this manual.
7. Check and, if necessary, adjust rear axle tracking. For instructions, see **Group 32** in this manual or the suspension manufacturer's service literature.
8. Check the rear axle wheel bearings for wear and incorrect adjustment. Refer to **Section 35.01** for instructions.

Checking Using Computerized Alignment Systems

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

Follow the manufacturer's instructions for use of the alignment equipment, and use the alignment measurements given in **Fig. 1** and the applicable tables in **Specifications 400**.

Checking Using the Manual Method

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction.

1. Park the vehicle on a level surface. Relieve internal stresses in the suspension by driving the vehicle back and forth in a straight line, or by jacking the axle up and letting it down.
2. Chock the front tires and place the transmission in neutral. Release the parking brakes.

NOTICE

Do not use scribe lines for marking on frame rails. Scribe lines, which cut or scratch the metal, can develop into starting points for structural damage to the frame.

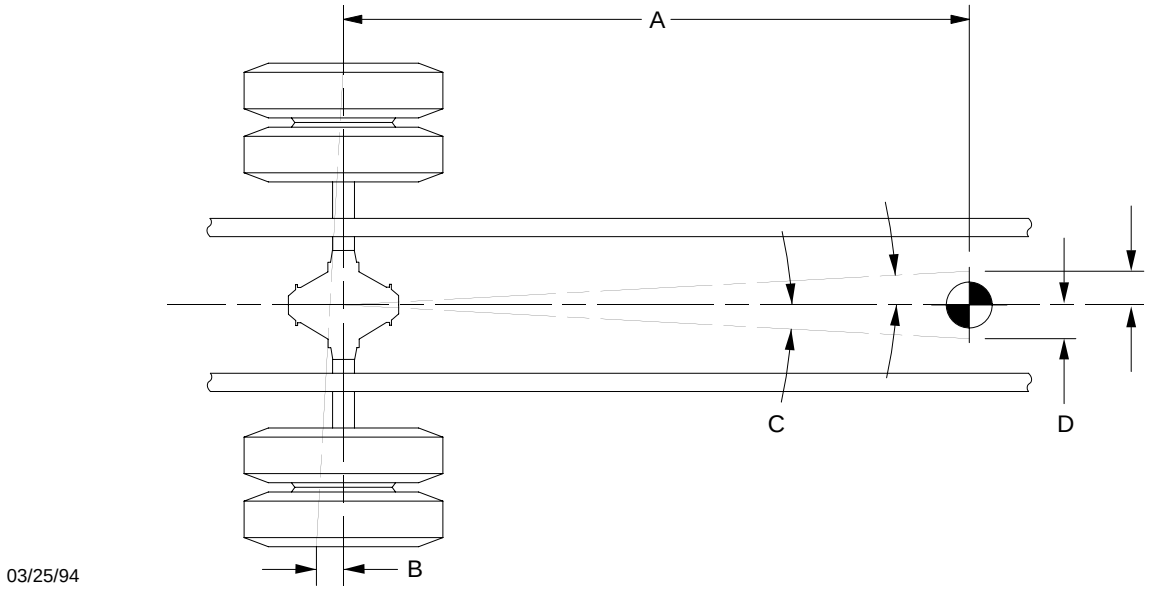
3. Select a point on the frame rail forward of the rear axle, and mark it using a pencil or soapstone. Then mark two other points, exactly 4 inches (102 mm) forward and to the rear of the original point. Make sure that all three marks are aligned and of equal distance from the outside edge of the frame rail. Using a center point or trammel bar, place one pointer on the forwardmost point, and make an arc with a pencil or soapstone on the opposite frame rail. Then place the pointer on the rearmost point and make an arc on the opposite frame rail intersecting the first arc. See **Fig. 2**. The point where the two arcs intersect and the original (or middle) point on the opposite frame rail have matching locations.
4. Line up the straightedge with the two matching points. Check that the straightedge extends out about the same distance on each side of the frame rail. Using C-clamps, clamp the straightedge to the frame; see **Fig. 3**. The straightedge must line up exactly with the points.
5. Measuring from the outside edge of each frame rail, mark the straightedge on both sides of the frame. The marks (**Fig. 3**, Ref. A) must be of equal distance from the frame and as far from the frame rail as the tires are at their farthest point from the frame.

IMPORTANT: The distance between the mark on the straightedge and the frame rail must be equal on both sides of the vehicle.

6. On each side of the vehicle, measure the distance from the mark on the straightedge to the center of the wheel hub. See **Fig. 3**.

   The difference between these measurements should be 1/4 inch (6 mm) or less. See **Fig. 1**. If the difference is more than 1/4 inch (6 mm), adjust the axle alignment. For instructions, see **Group 32** in this manual, or the suspension manufacturer's service literature.

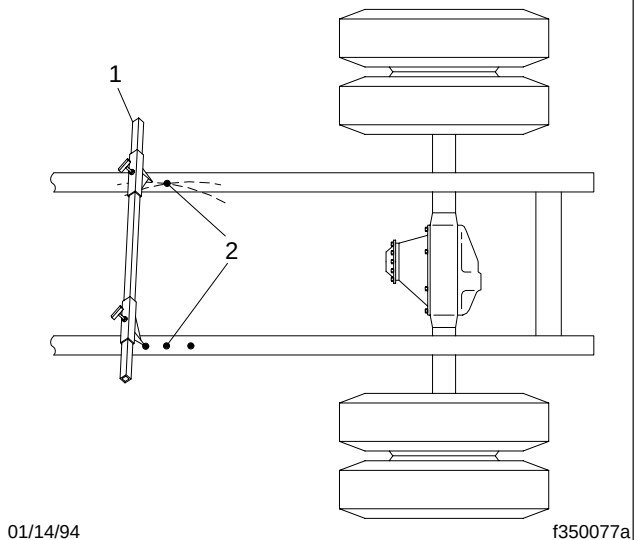
Alignment Checking, Single Axle



For items A and D, see **Specifications 400**.

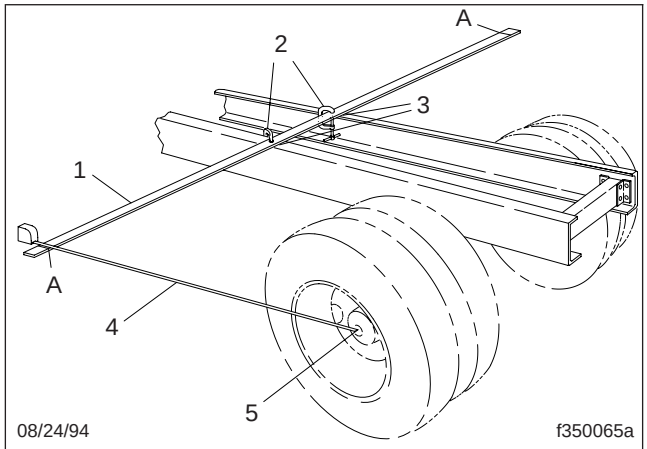
A. Distance from Rear Axle to Target (using Bee Line Alignment Tools)
B. Maximum Allowable Difference if Aligned Manually = ±1/4 inch (6 mm)
C. Maximum Allowable Tolerance if Aligned with Hunter Tools = ±0.18 degree
D. Maximum Allowable Tolerance if Aligned with Bee Line Tools

Fig. 1, Alignment Measurements



1. Center Point/Trammel Bar
2. Matching Points

Fig. 2, Marking an Arc



A. Marks

1. Straightedge
2. C-Clamps
3. Matching Points
4. Tape Measure
5. Wheel Hub

Fig. 3, Straightedge to Wheel Hub Measurement

Alignment Checking, Tandem Axle

To align a tandem axle, first, check and (if needed) align the rearmost axle; then, check and (if needed) align the forward-rear axle.

Checking Using Computerized Alignment Systems

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

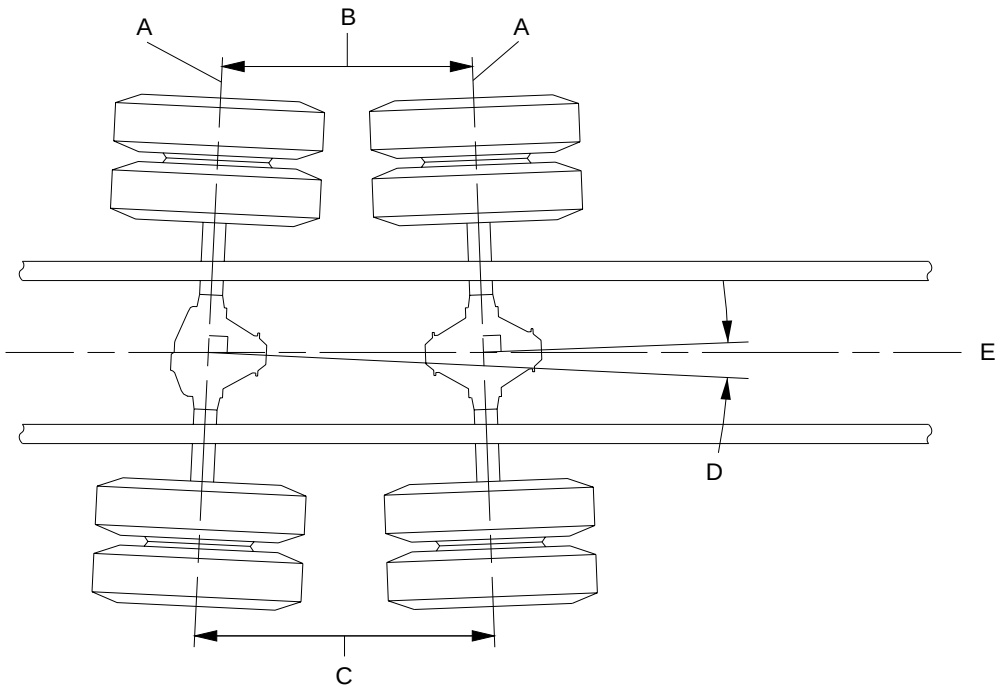
Follow the manufacturer's instructions for use of the alignment equipment, and use the alignment measurements given in **Fig. 1** and the applicable tables in **Specifications 400**.

Checking Using the Manual Method

A straightedge and a center point bar are needed to manually align a tandem axle. For instructions for making a center point bar, see **Subject 130**.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction.

1. Using the instructions in **Subject 110**, check and align the rearmost axle.
2. Using a center point bar, set the two points into the axle cap holes as shown in **Fig. 2**. Lock them in place by tightening the setscrews.
3. With the points still locked in place, move the center point bar to the other side of the vehicle, set the two points into the axle cap holes, and compare the axle spacing. If there is a difference



A. Axle Centerline
B. Left-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
C. Right-Hand Axle End Spacing, Measured Manually or with Bee Line Alignment Tools
D. Maximum Tolerance as Measured with Hunter Alignment Tools = ±0.08 degree
E. Vehicle Centerline

Fig. 1, Tandem Axle Measurements

Alignment Checking, Tandem Axle

of 1/8 inch (3 mm) or less between the spacing on one side of the vehicle compared to the other, no further action is necessary. If the difference is more than 1/8 inch (3 mm), adjust the forward-rear axle alignment. See **Fig. 1**. For instructions, see **Group 32** in this manual, or the suspension manufacturer's service literature.

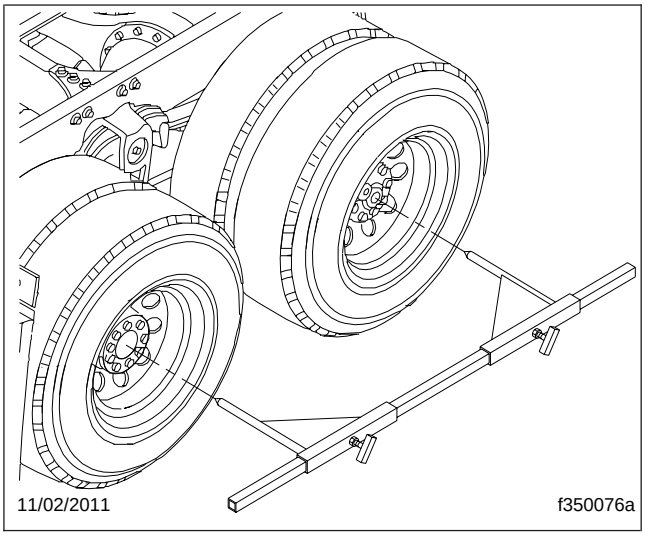


Fig. 2, Center Point Bar Placement

Center Point Bar Construction

Materials Required

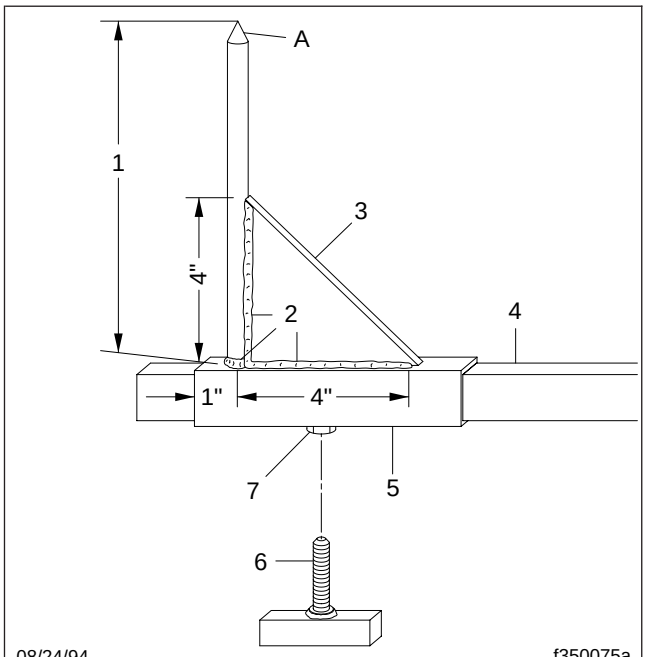
NOTE: To obtain metric conversions (millimeters), multiply the number of inches by 25.4.

The following materials are required:

- 62" of square steel tube (1" x 1", measured outside)
- 12" of square steel tube (1-1/8" x 1-1/8", measured inside)
- 20" of 3/8" steel rod
- two 1/2" x 3" pieces of steel square-bar stock
- one 4" x 4" steel plate, 1/8" thick
- two 3/8–16 capscrews (grade 5), 2" long
- two 3/8–16 hexnuts (equivalent to grade 5)

Construction

1. Cut the 1-1/8 x 1-1/8 inch (inside measurement) square steel tube in half to obtain two pieces 6 inches long. These will be the sliding members (slides) of the center point bar.
2. Cut the 4-inch by 4-inch steel plate diagonally into two pieces (gussets). Weld one gusset to each slide, as shown in **Fig. 1**.
3. Cut the steel rod in half to obtain two 10-inch rods. Grind one end of each to form a point.
4. Weld the pointed steel rods to the slides and gussets, as shown in **Fig. 1**.
5. Drill a 1/2-inch hole in the center of each slide, on the side opposite where the pointer was welded. Drill through only one side of the tube.
6. Directly over each hole drilled in the step above, weld a 3/8–16 nut (equivalent to grade 5).
7. Weld a piece of steel stock, about 1/2-inch wide by 3-inches long, over the head of each of two 3/8–16 by 2-inch long capscrews.
8. Place a slide over each end of the 60-inch piece of steel tube, with the pointed rods to the outside. Screw the handscrews (made in the step above) into the slides until they are clamped tightly to the cross tube.



A. Grind to a point.

1. 3/8-Inch Diameter Rod
2. Weld
3. Gusset
4. 1-Inch Square Steel Tube
5. 1–1/8 Inch Square Steel Tube
6. 3/8–16 Bolt
7. 3/8–16 Nut

Fig. 1, Center Point Bar Construction

Specifications

Maximum Tolerance from Perpendicular, Manual Method	
Method	**Maximum Tolerance ± from Perpendicular**
Manual	1/4 inch (6 mm)

Table 1, Maximum Tolerance from Perpendicular, Manual Method

Maximum Tolerance from Perpendicular, Hunter Equipment	
Method	**Maximum Tolerance ± from Perpendicular**
Hunter*	±0.18 degree

* To use Hunter alignment equipment, refer to the applicable Hunter service literature.

Table 2, Maximum Tolerance from Perpendicular, Hunter Equipment

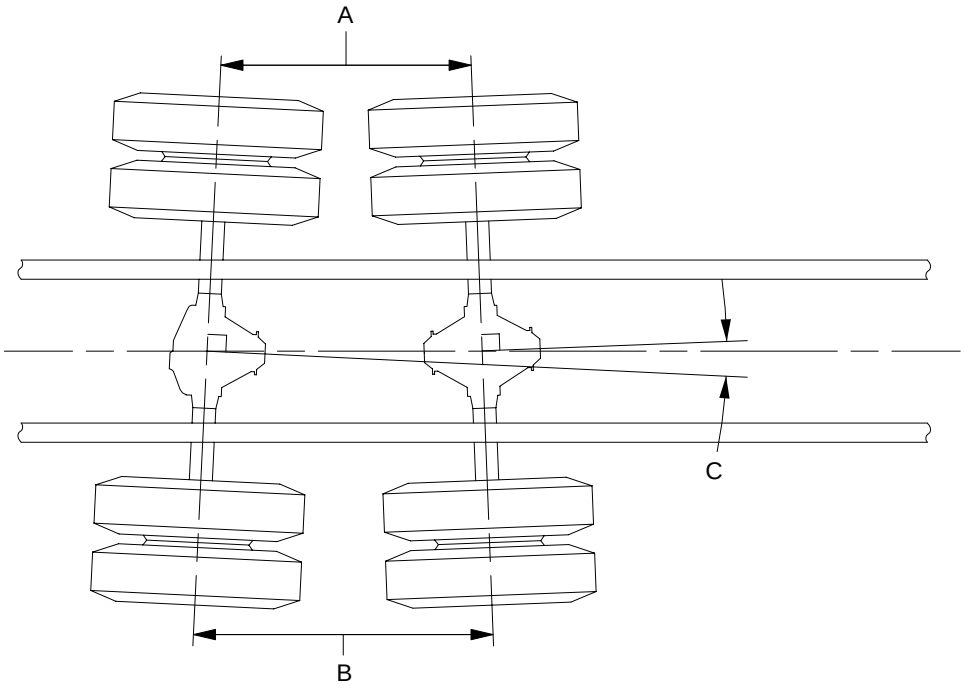
Maximum Tolerance from Perpendicular at Target, Bee Line Equipment	
Distance from the Forward or Rear Drive Axle to Target: inches (mm)	**Maximum Tolerance ± from Perpendicular: inches (mm)**
100 (2540)	5/16 (8)
120 (3048)	3/8 (10)
140 (3556)	7/16 (11)
160 (4064)	1/2 (13)
180 (4572)	9/16 (14)
200 (5080)	5/8 (16)
220 (5588)	11/16 (17)
240 (6096)	3/4 (19)
260 (6604)	13/16 (21)

Table 3, Maximum Tolerance from Perpendicular at Target, Bee Line Equipment

Rear Axle Parallelism Specifications	
Method	**Maximum Tolerance**
Hunter	±0.08 degree maximum axle-to-axle difference; reference "C" in **Fig. 1**.
Bee Line or Manual	±1/8 inch max. difference in axle end-spacing; reference "B" minus "A" in **Fig. 1**.

Table 4, Rear Axle Parallelism Specifications

Specifications



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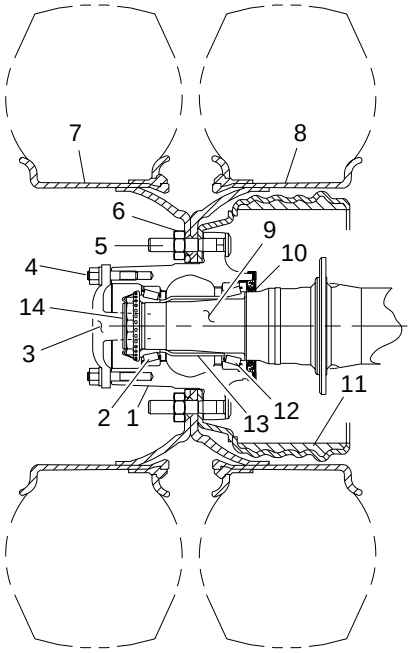
NOTE: See **Table 4** for values corresponding to callouts A, B, and C.

Fig. 1, Tandem Axle Measurements

General Information

Wheel end assemblies include the wheel hub, wheel bearings, axle spindle, brake drum (or rotor), wheel studs, and spindle nut. See **Fig. 1**.



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1. Hub
2. Outer Wheel Bearing
3. Drive Axle Shaft
4. Drive Axle Stud
5. Wheel Stud
6. Wheel Nut
7. Outer Wheel
8. Inner Wheel
9. Spindle
10. Oil Seal
11. Brake Drum
12. Inner Wheel Bearing
13. Bearing Spacer
14. Spindle Nut

Fig. 1, Wheel End Assembly with Drum Brakes

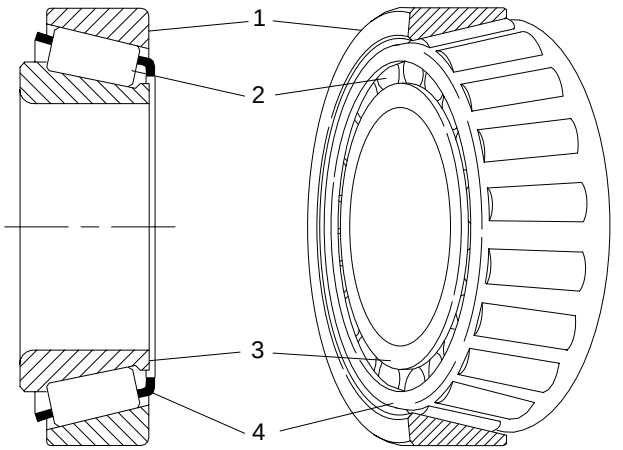
Wheel Hub

ConMet PreSet® hubs have a spacer between the inner and outer bearings that adjusts the bearings to the correct end-play when the retaining nut is tightened.

For more information about PreSet hubs, and removal and installation procedures, see **Subject 100**.

Tapered Wheel Bearings

Each hub has a set of inner and outer tapered wheel bearing assemblies. A typical tapered wheel bearing assembly consists of a cone, tapered rollers, a roller cage, and a separate cup that is press-fit in the hub. See **Fig. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.



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1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly

Drive Axle Spindle Assembly

The drive axle spindle assembly is made up of a drive axle flange and shaft, drive axle studs and stud nuts, a flange gasket, an axle spindle, an oil seal, and the locking assembly described above.

The surfaces of the spindle and the nut threads are machined. When these surfaces become damaged, repairs are necessary. There are standard methods for performing those repairs that preserve the proper alignment of the axle spindle assembly. Refer to the axle manufacturer for instructions.

NOTICE

The National Highway Traffic Safety Administration (NHTSA) has warned against repairs that involve cutting off a portion of a damaged spindle and welding on a replacement part. The heat of

welding can reduce the strength of spindles made with heat-treated materials and lead to spindle failure. After the cutting and welding operations, the replacement part may not be correctly aligned on the spindle. This can cause damage to the spindle nut.

Brake Drum

The brake drum and lining work together as a mated friction pair, with the drum responsible for both heat absorption and dissipation. Lining performance and life largely depend on the condition of the drum and whether it can adequately absorb and dissipate heat generated by braking action.

Wheel Studs

A headed wheel stud is used on rear axle disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 3**. Wheel studs are press-fit in the hub. For replacement procedures, see **Subject 180**.

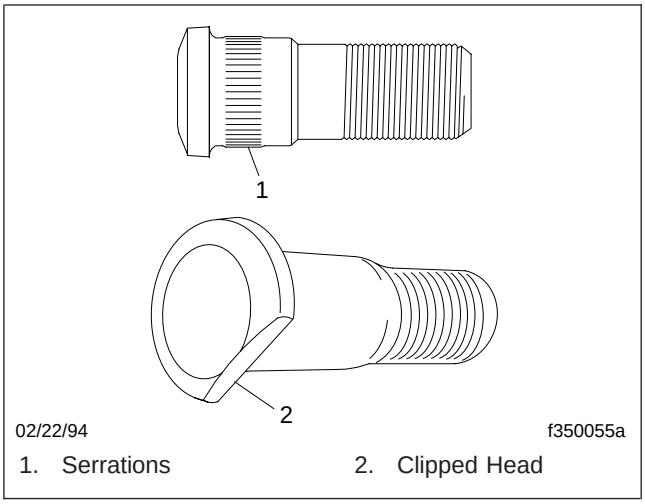
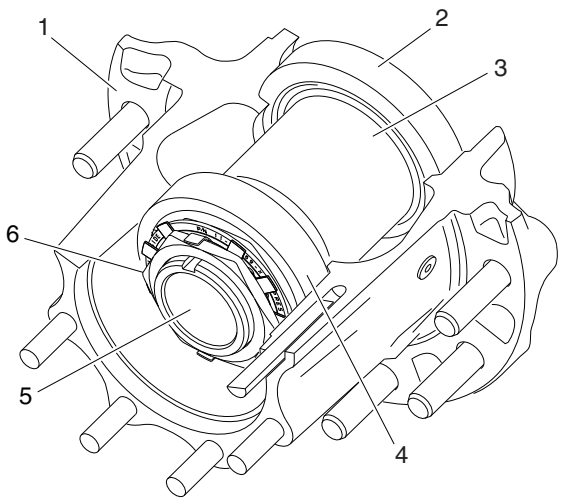


Fig. 3, Typical Wheel Studs

General Information

ConMet PreSet® and PreSet Plus™ hubs are equipped with a unique bearing spacer between special inner and outer bearings. See **Fig. 1.**



NOTE: PreSet Plus hubs use a special spindle nut system.

1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Axle Spindle
6. Retaining Nut (double spindle nut system)

Fig. 1, ConMet PreSet Hub, Cut-Away View

When installing a PreSet or PreSet Plus hub with the spacer and special PreSet bearings, the correct end play is set automatically and wheel bearing adjustment is unnecessary.

For vehicles equipped with ConMet PreSet hubs, it is highly recommended to **stay with the PreSet system** to optimize bearing and seal life. However, if you are replacing the bearings for a PreSet hub, and the special PreSet bearings are not available, standard wheel bearings can be used. In this case, the bearing spacer must be removed and the bearings adjusted manually. See the installation instructions for more information.

Wheel ends equipped with ConMet PreSet Plus hubs must use PreSet Plus components. Do not substitute non-PreSet-Plus components on these installations.

Removal

For typical wheel end and axle assemblies, see **Fig. 2** and **Fig. 3**.

1. Shut down the engine and chock the front tires. Release the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. For drum brakes, back off the slack adjuster to release the rear axle brake shoes.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. Remove both wheel and tire assemblies. For instructions, see **Group 40**.
5. For drum brakes, remove the brake drum. See **Subject 140** for instructions.

   For disc brakes, remove the brake caliper. See **Section 42.18** for instructions.

NOTE: Oil will spill as the drive axle shaft (or hub cap) and the wheel hub are removed. Place a suitable container under the drive axle flange or hub cap to catch any spilled oil. Dispose of the oil properly.

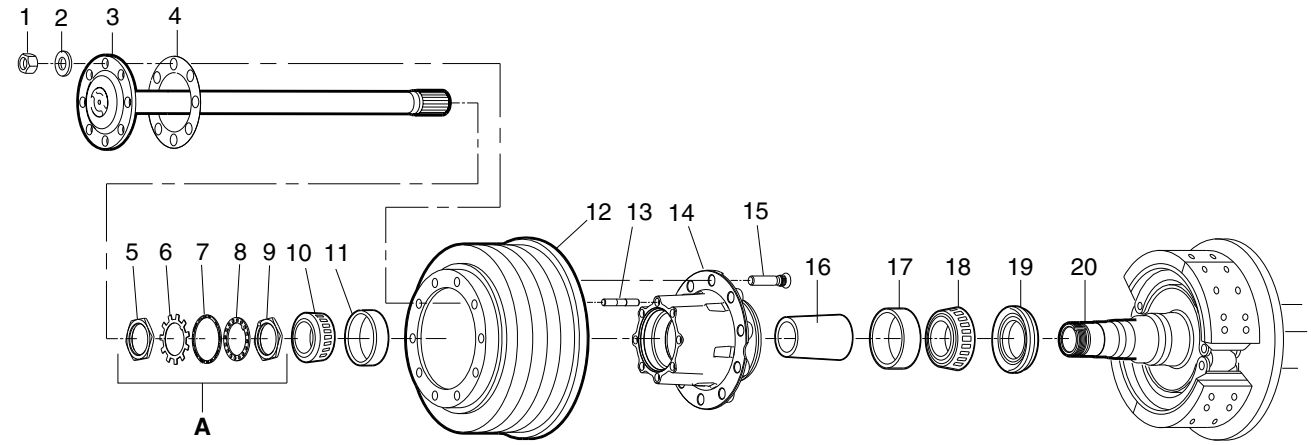
6. Remove the drive axle stud nuts and washers. See **Fig. 4**.

NOTICE

When tapping the drive axle flange, avoid striking the drive axle studs. If struck, the studs may bend or break, or the stud threads can be damaged. Replace damaged studs.

7. Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. The shaft will usually spring slightly outward after the seal has broken.

Hub Assembly Removal and Installation



NOTE: An ID ring and bearing spacer are used with ConMet PreSet hubs only.

A. Double spindle nut set shown. Axilok or Pro-Torq spindle nuts could be used on some installations. ConMet PreSet Plus hubs use a special spindle nut system.

1. Drive Axle Stud Nut
2. Washer
3. Drive Axle Shaft
4. Gasket
5. Jam Nut
6. Bend-Type Locking Washer
7. ID Ring
8. Lockring
9. Adjusting Nut
10. Outer Wheel Bearing
11. Outer Wheel Bearing Cup
12. Brake Drum
13. Drive Axle Stud
14. ConMet PreSet Hub
15. Wheel Stud
16. Bearing Spacer
17. Inner Wheel Bearing Cup
18. Inner Wheel Bearing
19. Oil Seal
20. Axle Spindle

Fig. 2, Typical Wheel End Assembly, Drive Axle with Drum Brakes

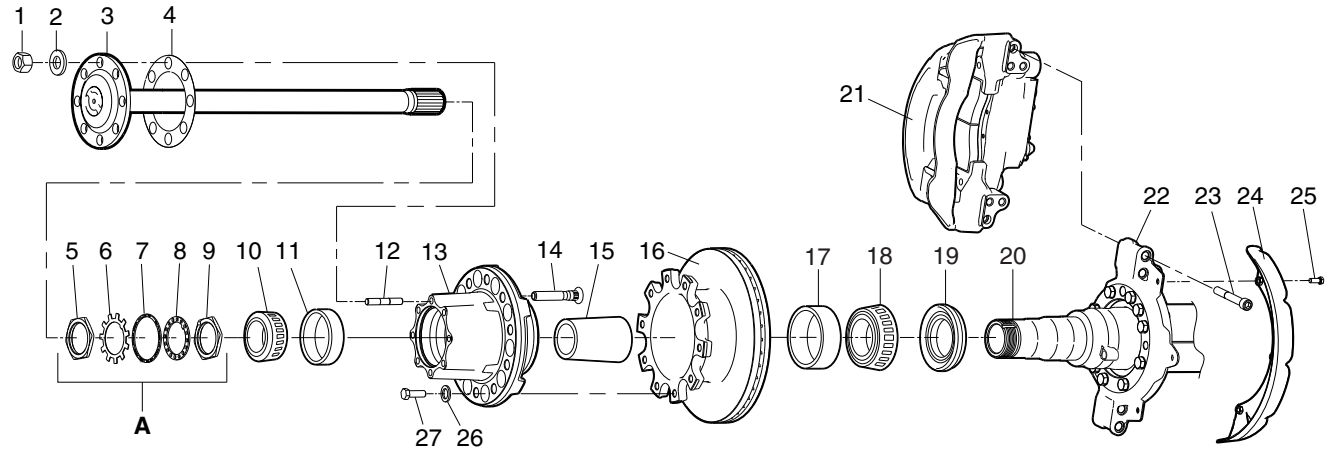
NOTE: Even if the drive axle shaft doesn't spring outward, the seal may have loosened enough to allow the shaft to be pulled from the axle housing. If the seal has not broken, repeat the step above.

8. If so equipped, remove the tapered dowels and washers from the drive axle flange.
9. Remove the drive axle shaft.
10. Remove and discard the gasket.
11. Remove the wheel bearing locking device:
    - For an Axilok spindle nut, see **Subject 110**; then go to the next step.
    - For a Pro-Torq spindle nut, see **Subject 120**; then go to the next step.
    - If the axle is equipped with a double spindle nut system, see **Subject 130**; then go to the next step.
    - For ConMet PreSet Plus hubs, see **Subject 230**; then go to the next applicable step.

NOTICE

Be careful not to let the outer wheel bearing drop from the axle spindle. Dropping the bearing can warp the cage or damage the rollers, ruining the bearing. On vehicles equipped with WABCO ABS, use care when working with the hubs. To prevent damage to the tone wheel, do not drop the hub, or lay it down in a way that would damage the tone wheel.

12. Move the hub about ½ inch (13 mm) to jar loose the outer wheel bearing (allow the hub-only assembly to rest on the axle spindle; be careful not to damage the axle spindle threads).
13. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in either clean oil-proof paper or lint-free rags.



NOTE: An ID ring and bearing spacer are used with ConMet PreSet hubs only.

A. Double spindle nut set shown. Axilok or Pro-Torq spindle nuts could be used on some installations. ConMet PreSet Plus hubs use a special spindle nut system.

1. Drive Axle Stud Nut
2. Washer
3. Drive Axle Shaft
4. Gasket
5. Jam Nut
6. Bend-Type Locking Washer
7. ID Ring
8. Lockring
9. Adjusting Nut
10. Outer Wheel Bearing
11. Outer Wheel Bearing Cup
12. Drive Axle Stud
13. ConMet PreSet Hub
14. Wheel Stud
15. Bearing Spacer
16. Brake Rotor
17. Inner Wheel Bearing Cup
18. Inner Wheel Bearing
19. Oil Seal
20. Axle Spindle
21. Brake Caliper
22. Anchor Plate
23. Caliper Mounting Capscrew
24. Rotor Shield
25. Rotor Shield Capscrew
26. Washer
27. Capscrew

Fig. 3, Typical Wheel End Assembly, Drive Axle with Disc Brakes

NOTICE

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

14. Remove the hub. Be careful not to damage the axle spindle threads as the assembly is removed.
15. Remove the inner wheel bearing. Handle the bearings with clean, dry hands, then wrap the bearings in either clean oil-proof paper or lint-free rags. If the inner wheel bearing remains in the hub after the hub is removed from the axle, place a protective cushion where it will catch the bearings, then use a hardwood drift and a light hammer to gently tap the bearing (and seal, if necessary) out of the cup.
16. Remove the oil seal from the axle spindle, if not already removed. See **Section 35.02** for oil seal removal instructions.

NOTE: For vehicles equipped with disc brakes, instructions for removing the rotor from the hub are given in **Section 42.18**.

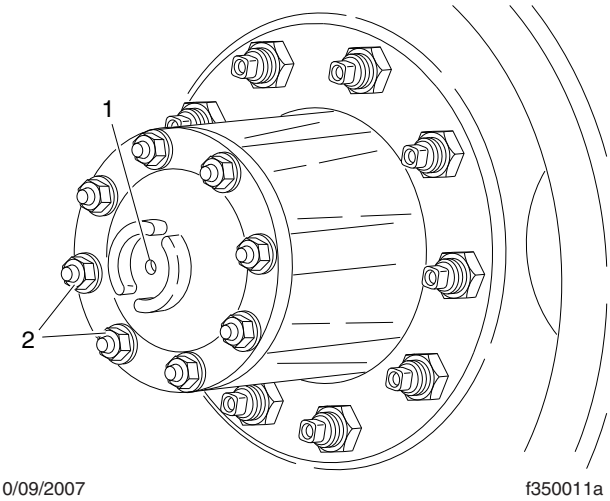
Installation

For typical wheel end and axle assemblies, see **Fig. 2** and **Fig. 3**.

NOTE: For vehicles equipped with disc brakes, instructions for installing the rotor to the hub are given in **Section 42.18**.

1. Using cleaning solvent, remove the old oil from the axle spindle and the disassembled parts. Allow the parts to dry, or dry them with clean, absorbent, and lint-free cloth or paper. Wrap a

Hub Assembly Removal and Installation



1. Center Portion of Drive Axle Flange
2. Drive Axle Studs and Nuts

Fig. 4, Wheel Assembly and Hub

protective layer of friction tape on the axle spindle threads.

For PreSet hubs that are being reused, the bearing spacer must be replaced. For PreSet Plus hubs, the bearing spacer must be cleaned and inspected before being reused; see **Subject 150**. If the bearing spacer is worn or damaged, replace it with a new one.

2. Coat both bearing assemblies with fresh oil. Then install the inner wheel bearing and oil seal. Handle the bearings with clean, dry hands. See **Section 35.02** for oil seal installation instructions.

NOTICE

Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.

3. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.

NOTICE

- **When installing a ConMet PreSet hub, always use a new bearing spacer. Reinstalling a used bearing spacer could preload the wheel bearings and reduce the life of the wheel end.**
- **Do not use the bearing spacer with standard wheel bearings. To do so may result in too much bearing end-play, which could damage the wheel bearings, oil seals, the axle spindle, and the hub.**

4. If using PreSet bearings, ensure the tubular spacer is in the PreSet hub.

   If replacing PreSet bearings with non-PreSet bearings, remove the tubular spacer from inside the hub.

NOTICE

- **On vehicles equipped with WABCO ABS, use care when installing the hubs. To prevent damage to the tone wheel, do not drop the hub or lay it down in a way that would damage the tone wheel.**
- **Do not remove the outer wheel bearing once the hub is installed on the axle. Removing the outer bearing could cause the oil seal to become misaligned, which could cause damage to the wheel bearings, the hub, and the axle spindle.**

NOTE: A temporary plastic alignment sleeve may be installed in the center of a new hub. It will be pushed out when the hub is installed on the axle spindle. If it is present, remove and discard this sleeve.

5. Mount the bearings and hub on the spindle.
6. Remove the friction tape, then adjust and secure the bearings:
   - For an Axilok spindle nut, see **Subject 110**; then go to the next step.
   - For a Pro-Torq spindle nut, see **Subject 120**; then go to the next step.
   - If the axle is equipped with a double spindle nut system, see **Subject 130**; then go to the next step.
   - For ConMet PreSet Plus hubs, see **Subject 230**; then go to the next applicable step.

7. Install a new gasket, and the drive axle shaft or, on non-drive axles, the hub cap. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.
8. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle stud nuts. Using the sequence shown in **Fig. 5**, tighten the nuts to the torque values given in the table in **Specifications, 400**.

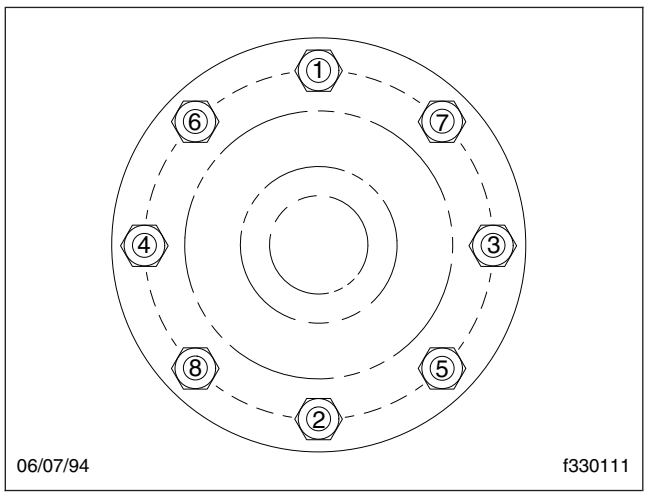


Fig. 5, Tightening Sequence, Drive Axle Stud Nuts

9. For drum brakes, install the brake drum on the wheel hub. See **Subject 140** for instructions.

   For disc brakes, install the brake caliper. See **Section 42.18** for instructions.

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the wheel hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

10. Install the inner and outer wheel and tire assemblies. For instructions, see **Group 40**.

⚠ WARNING

Add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced. Failure to add oil will damage the wheel bearings and cause them to seize during vehicle operation. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

11. Lubricate the wheel bearings, as follows.
    - For drive axles, see **Subject 220**.
    - For non-drive axles, add about 1 to 1-1/2 pints (0.5 to 0.7 liter) of oil to the level shown on the hub cap. Do not overfill. Install the vent plug or threaded filler plug.
12. Adjust the rear axle brakes. For instructions, see **Group 42**.
13. Remove the safety stands from under the axle, then lower the vehicle.

Axilok Spindle Nut Removal, Installation, and Adjustment

Service Guidelines

Axilok® spindle nuts may be used on ConMet PreSet hubs. See **Fig. 1**. These nuts can be damaged if they are not removed or installed correctly. Use the following guidelines when removing and installing Axilok retaining nuts.

- Use only the correct size, *six-point* socket to remove or install Axilok spindle nuts. Do not use a worn or loose-fitting socket. **Do not use a 12-point socket.**
- Do not use hammers, chisels, pliers, wrenches, or power tools to remove or install Axilok nuts.
- Do not use an Axilok nut if the locking clips are damaged or missing, or if the retainer cage tab or D-flat is damaged or missing.
- Never try to repair a damaged Axilok nut; always replace it with a new one.
- Always start an Axilok installation by hand. A good-fitting six-point socket will completely disengage the nut's locking clips, allowing it to spin freely by hand. See **Fig. 2**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

Installation

Instructions for installing an Axilok nut for both PreSet and non-PreSet type bearings are provided in this subject. See the pertinent instructions for the type you are installing.

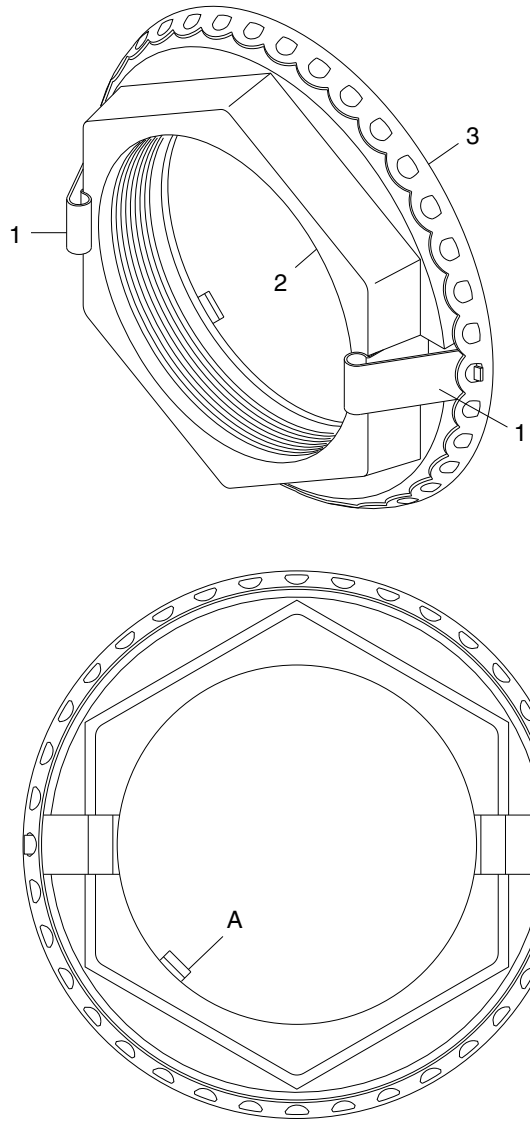
NOTICE

Always use a new spindle nut when installing the hub. A used spindle nut may have wear, causing uneven contact with the wheel bearing and reducing the life of the wheel end.

Using PreSet Bearings

⚠ WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.



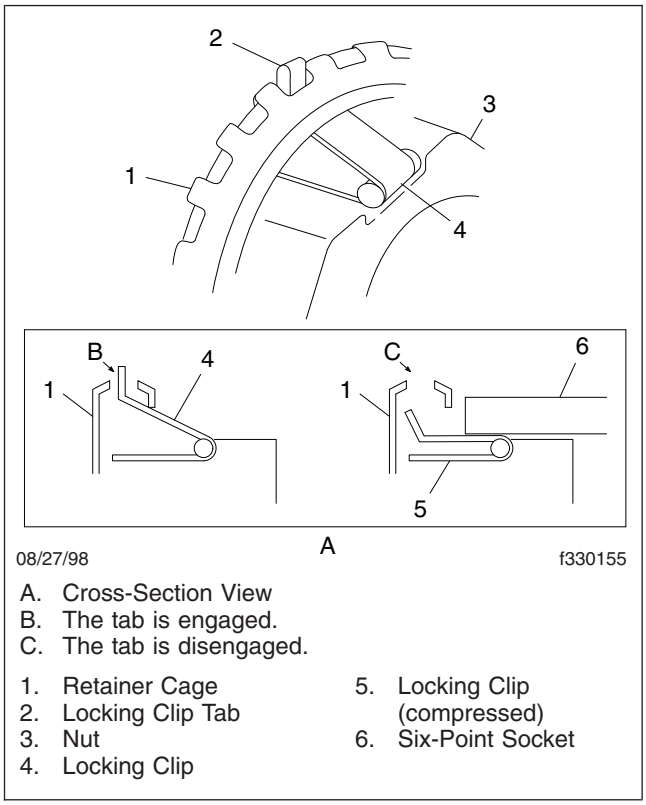
A. The retainer tab must engage the keyway of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer Cage

Fig. 1, Rear Axle Axilok Nut

1. Apply a few drops of oil through one of the holes in the Axilok retainer cage to reduce friction between the retainer cage and nut.

Axilok Spindle Nut Removal, Installation, and Adjustment



A. Cross-Section View
B. The tab is engaged.
C. The tab is disengaged.

1. Retainer Cage
2. Locking Clip Tab
3. Nut
4. Locking Clip
5. Locking Clip (compressed)
6. Six-Point Socket

Fig. 2, Axilok Nut, Checking the Position of the Locking Clip

2. By hand, install the Axilok nut onto the axle spindle. See **Fig. 1**.
3. Tighten the retaining nut 250 lbf·ft (339 N·m). The nut should lock in place when you remove the wrench. If it does not, advance the nut until it does. **Do not back it off**.
4. Ensure that both locking clips are present and engaged in the retainer cage. See **Fig. 2**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.

WARNING

Follow the guidelines at the beginning of this subject when installing an Axilok nut. Axilok retaining nuts secure the hub assemblies on the axle. If the Axilok nut is not correctly installed, the hub could separate from the axle, resulting in severe personal injury or death.

1. Apply a few drops of oil through one of the holes in the Axilok retainer cage to reduce friction between the retainer cage and nut.
2. Install the Axilok nut and adjust the wheel bearings, as follows.
   - 2.1 By hand, install the Axilok nut onto the axle spindle. Then turn it against the bearing while spinning the hub. See **Fig. 1**.
   - 2.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the hub in both directions.
   - 2.3 Loosen the nut to zero torque, and spin the hub a few turns.
   - 2.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the hub in both directions. Back off the nut one-eighth to one-sixth turn.
   - 2.5 Remove the wrench from the nut, and verify whether both locking clips are present and engaged in the retainer cage. See **Fig. 2**. If the locking clips are not engaged, advance the Axilok until they are.
3. Measure the end play; see **Subject 210** for instructions.

WARNING

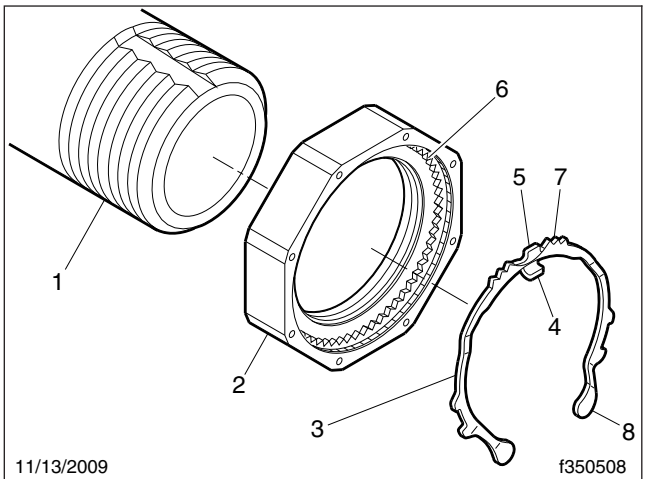
Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

4. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Axilok nut, and repeat the tightening sequence as described earlier in this procedure. Once the end play is correct, continue with your service procedure.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

General Information

Pro-Torq® spindle nuts may be used on ConMet Pre-Set hubs. See **Fig. 1** and **Fig. 2**.



1. Axle Spindle
2. Pro-Torq Nut
3. Keeper Arm
4. Keyway Tab
5. Keeper Tab
6. Mating Teeth, Nut
7. Mating Teeth, Keeper
8. Keeper Protrusion

Fig. 1, Pro-Torq Spindle Nut and Keeper

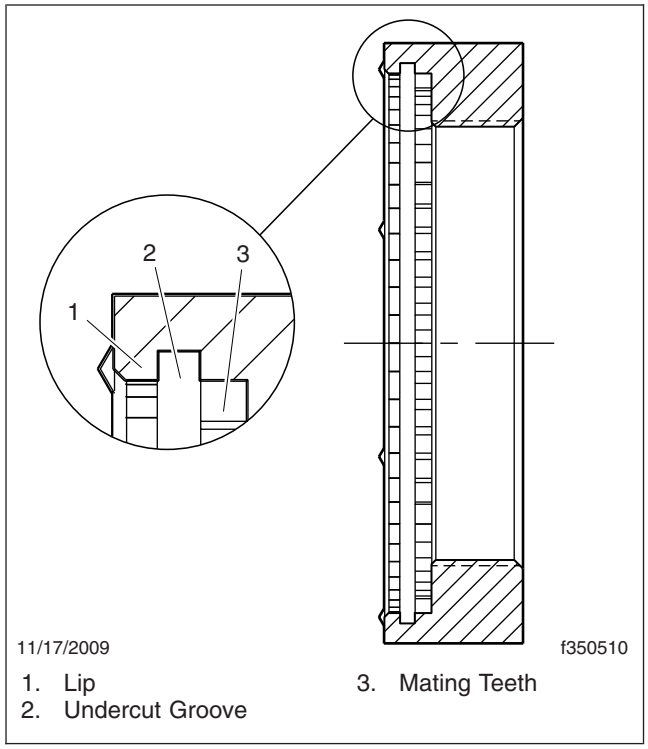
Each time the Pro-Torq nut assembly is removed for maintenance purposes, replacing the "keeper" is recommended.

Removal

⚠ WARNING

Do not place the nut on the spindle or tighten or loosen the nut on the spindle while the keeper is locked inside the nut. Doing so may damage the spindle threads and deform the keeper, and allow the nut to unthread during operation. Failure to follow this instruction could cause the hub to separate from the axle, resulting in severe personal injury or death.

1. Insert the blade of a flathead screwdriver (or similar tool) in the slot of one of the keeper arms; see **Fig. 3**. Ensuring that the tool contacts the keeper and not the teeth of the nut, turn the tool slightly and carefully pry the arm from the undercut groove of the nut.



1. Lip
2. Undercut Groove
3. Mating Teeth

Fig. 2, Pro-Torq Spindle Nut, Cross Section

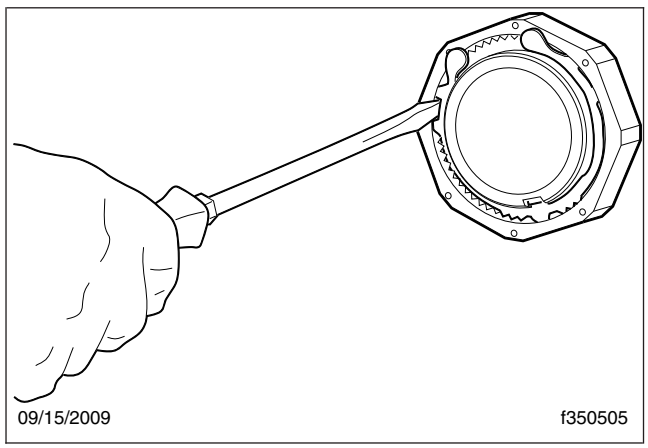


Fig. 3, Removing the Keeper

2. Repeat at the other arm, and remove the keeper from the nut.
3. Remove the Pro-Torq nut.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

Installation

The following procedure applies to Pro-Torq drive axle nut 449-4973. The part number is stamped on the nut.

⚠ WARNING

Do not place the nut on the spindle or tighten or loosen the nut on the spindle while the keeper is locked inside the nut. Doing so may damage the spindle threads and deform the keeper, and allow the nut to unthread during operation. Failure to follow this instruction could cause the hub to separate from the axle, resulting in severe personal injury or death.

Instructions for installing a Pro-Torq spindle nut for both PreSet and non-PreSet type bearings are provided in this subject. See the instructions pertaining to the bearing type used with the hub you are securing.

NOTICE

Always use a new spindle nut when installing the hub. A used spindle nut may have wear, causing uneven contact with the wheel bearing and reducing the life of the wheel end.

Using PreSet Bearings

1. Ensure the keeper is removed from the nut.
2. Install the Pro-Torq spindle nut, and tighten it 250 lbf·ft (339 N·m). **Do not back it off**.

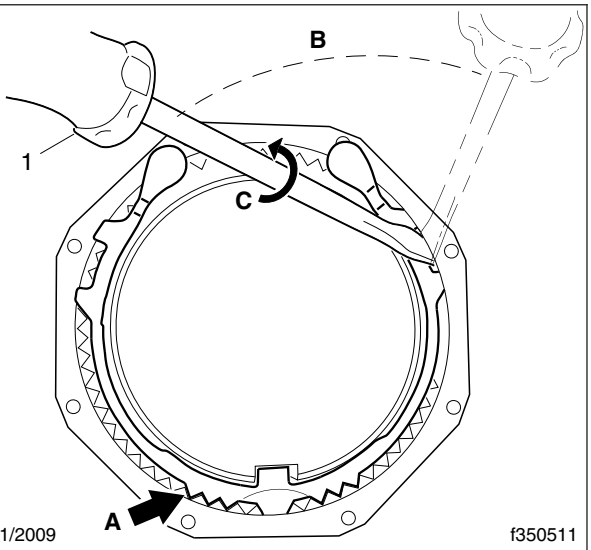
⚠ WARNING

Do not bend or manipulate the keyway tab in any way. Doing so may cause it to break off in service, which could lead to the hub separating from the axle and result in severe personal injury or death.

3. Install the keeper.
   - 3.1 With the protrusions facing outboard, insert the keeper tab in the undercut groove of the Pro-Torq nut and the keyway tab in the spindle keyway.

   IMPORTANT: If the keeper cannot be engaged, advance the nut until it can be. Do not back off the nut.

   - 3.2 Engage the mating teeth.
   - 3.3 Use a flathead screwdriver to carefully compress and guide each arm past the lip and into the undercut groove of the nut as shown in **Fig. 4**. To secure the keeper it may be necessary to nudge the arms into the groove.



A. Engage the mating teeth.
B. Compress the arm.
C. Turn the screwdriver to seat the keeper in the groove.

1. Flathead Screwdriver

Fig. 4, Installing the Keeper

⚠ WARNING

Failure to secure the keeper and lock the Pro-Torq nut could cause the wheel assembly to come off the vehicle, resulting in severe personal injury or death.

4. Inspect the installation; ensure the keeper is locked in the undercut groove and that the keyway tab does not contact the bottom of the keyway.

Pro-Torq Spindle Nut Removal, Installation, and Adjustment

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.

1. Ensure the keeper is removed from the nut.
2. Seat the bearings.
   - 2.1 Using a torque wrench, tighten the nut 200 lbf·ft (270 N·m). Spin the hub at least one full rotation.

   NOTE: Torque is lost when the hub is spun.

   - 2.2 Tighten the nut 200 lbf·ft (270 N·m). Spin the hub at least one full rotation.
   - 2.3 Tighten the nut 200 lbf·ft (270 N·m), but *do not spin the hub*.
3. Loosen the nut to zero torque. *Do not spin the hub*.
4. Adjust the bearing.
   - 4.1 Using a torque wrench, tighten the nut 100 lbf·ft (136 N·m). Spin the hub at least one full rotation.

   NOTE: Torque is lost when the hub is spun.

   - 4.2 Tighten the nut 100 lbf·ft (136 N·m). Spin the hub at least one full rotation.
   - 4.3 Tighten the nut 100 lbf·ft (136 N·m).
   - 4.4 Back off the nut one-eighth turn.

⚠ WARNING

Do not bend or manipulate the keyway tab in any way. Doing so may cause it to break off in service, which could lead to the hub separating from the axle and result in severe personal injury or death.

IMPORTANT: If the keeper cannot be engaged, advance the nut until it can be. Do not back off the nut.

5. Install the keeper.
   - 5.1 With the protrusions facing outboard, insert the keeper tab in the undercut groove of the Pro-Torq nut and the keyway tab in the spindle keyway.
   - 5.2 Engage the mating teeth.
   - 5.3 Use a flathead screwdriver to carefully compress and guide each arm past the lip and into the undercut groove of the nut as shown in **Fig. 4**. To secure the keeper it may be necessary to nudge the arms into the groove.

⚠ WARNING

Failure to secure the keeper and lock the Pro-Torq nut could cause the wheel assembly to come off the vehicle, resulting in severe personal injury or death.

6. Inspect the installation; ensure the keeper is locked in the undercut groove and that the keyway tab does not contact the bottom of the keyway.
7. Measure the end play; see **Subject 210** for instructions.

⚠ WARNING

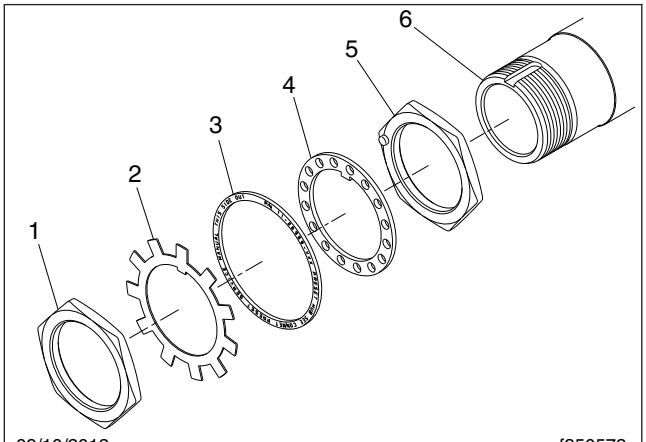
Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

8. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm)**. If it is not within this range, remove the Pro-Torq nut, and repeat the tightening sequence as described in previous steps. Once the end play is correct, continue your service procedure.

Double Spindle Nut Removal, Installation, and Adjustment

General Information

ConMet PreSet hubs may use a double spindle nut system. See **Fig. 1**. A plastic ID ring between the adjusting nut and locking washer indicates that a ConMet Preset hub has been installed.



NOTE: ID ring used with ConMet PreSet hubs only.

1. Jam Nut
2. Bend-Type Locking Washer
3. ID Ring
4. Lockring
5. Adjusting Nut
6. Axle Spindle

Fig. 1, Double Spindle Nut Set

Removal

Once a four-piece wheel bearing lock set is removed, discard the bend-type locking washer. Inspect the adjusting nut, lockring, and jam nut for visible damage prior to reuse.

Installation

Instructions for installing a four-piece wheel bearing lock set for both PreSet and non-PreSet type bearings are provided in this subject. See the pertinent instructions for the type you are installing.

NOTICE

Always use a new spindle nut when installing the hub. A used spindle nut may have wear, causing uneven contact with the wheel bearing and reducing the life of the wheel end.

Using PreSet Bearings

1. Install the adjusting nut onto the axle spindle, and tighten it 300 lbf·ft (407 N·m). See **Fig. 1**.

NOTE: The gaps between holes in the lockring are spaced unevenly, so to fit the tab on the adjusting nut into one of the holes with minimal turning of the adjusting nut, gauge the distance on one side of the lockring, then the other, and choose the side that requires the adjusting nut to be advanced the least. **Do not back off the nut**.

2. Install the lockring (as described in the note above) and bend-type locking washer.
3. Install the jam nut, and tighten it 200 lbf·ft (271 N·m).
4. Bend the tabs on the locking washer at 6 o'clock and 12 o'clock to lock the jam nut in place. See **Fig. 2**.

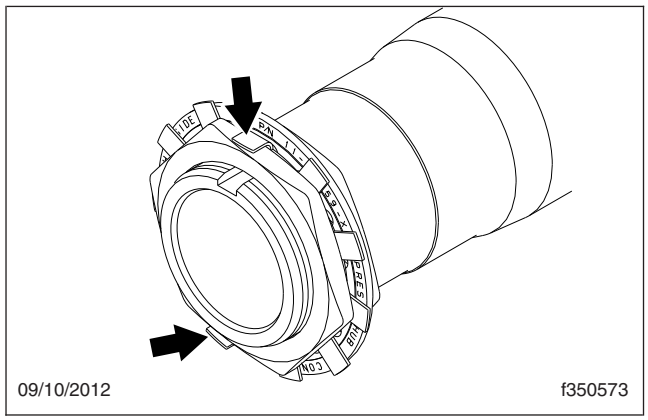


Fig. 2, Tabs Bent to Lock the Jam Nut

5. Rotate the hub in both directions. It should turn freely with no dragging or binding.

Using Non-PreSet Bearings

For ConMet PreSet hubs, when there is no bearing spacer installed and non-PreSet type bearings are being used, proper wheel bearing adjustment is critical to the performance of the bearings, wheel seals, and other related wheel end components.

1. Install the adjusting nut, as follows. See **Fig. 1**.
   - 1.1 Install the adjusting nut on the spindle, and tighten it finger-tight.

Double Spindle Nut Removal, Installation, and Adjustment

1.2 While rotating the wheel hub assembly, tighten the adjusting nut 200 lbf·ft (271 N·m).

1.3 Back off the adjusting nut one full turn.

1.4 Tighten the adjusting nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.

1.5 Back off the adjusting nut one-quarter turn.

NOTE: The gaps between holes in the lockring are spaced unevenly, so to fit the tab on the adjusting nut into one of the holes with minimal turning of the adjusting nut, gauge the distance on one side of the lockring, then the other, and choose the side that requires the adjusting nut to be turned the least.

2. Install the lockring (as described in the note above) and bend-type locking washer.
3. Install the jam nut, and tighten it 300 to 400 lbf·ft (410 to 540 N·m).
4. Measure the end play; see **Subject 210** for instructions.

⚠ WARNING

Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

5. **The end play must be between 0.001 and 0.005 inch (0.03 and 0.13 mm).** If the end play is not within this range, adjust the end play as follows.

5.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

5.2 Install the locking device and jam nut as described earlier, and measure the end play. If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), turn the adjusting nut again.

5.3 Measure the end play.

If the end play is not between 0.001 and 0.005 inch (0.03 and 0.13 mm), repeat the adjustment procedure until the correct end play is achieved.

IMPORTANT: The correct end play **must** be achieved before completing the hub assembly installation procedure.

6. Once the end play is between 0.001 and 0.005 inch (0.03 and 0.13 mm), bend two tabs on the locking washer at 6 o'clock and 12 o'clock to lock the jam nut in place. See **Fig. 2**.
7. Rotate the hub in both directions. It should turn freely with no dragging or binding.

Brake Drum Removal and Installation

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- **Always reline both sets of brakes on an axle at the same time.**
- **Always replace both rotors/drums on an axle at the same time.**
- **Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.**

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

Removal

1. Shut down the engine, release the parking brakes, and chock the front tires.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes. See **Group 42** for instructions.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

4. Remove the wheel and tire assembly. See **Group 40** for instructions.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust.

   Don't use compressed air or dry brushing to clean the brake assembly.
5. Remove the brake drum.

Installation

1. Install the brake drum on the wheel hub, as follows.

   1.1 On hub-piloted drums, position the brake drum on the top step of the pilot pad. One of the hub's pilot pads should be at the twelve o'clock (top center) position. See **Fig. 1**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are tightened.

   1.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

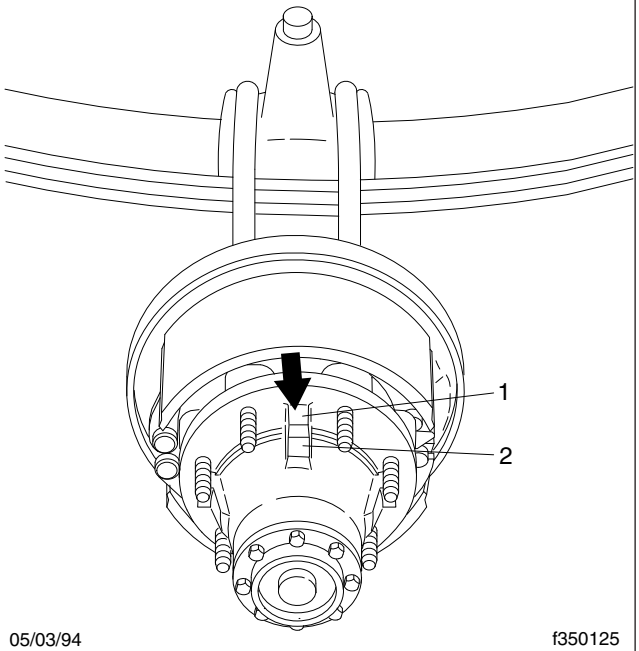
   IMPORTANT: If damage to the pads prevents the drum from centering, replace the hub. If necessary to hold the drum in position, adjust the brakes before installing the wheels.
2. Install the wheel and tire assembly. To ensure that the drum does not slip off the pilot pad, follow the correct nut tightening sequence. For instructions, see **Group 40**.

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when the conditions described above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury and property damage.

3. Adjust the rear axle brakes.
4. Remove the safety stands from under the axle; lower the vehicle.

Brake Drum Removal and Installation



NOTE: Pilot pad at 12 o'clock position

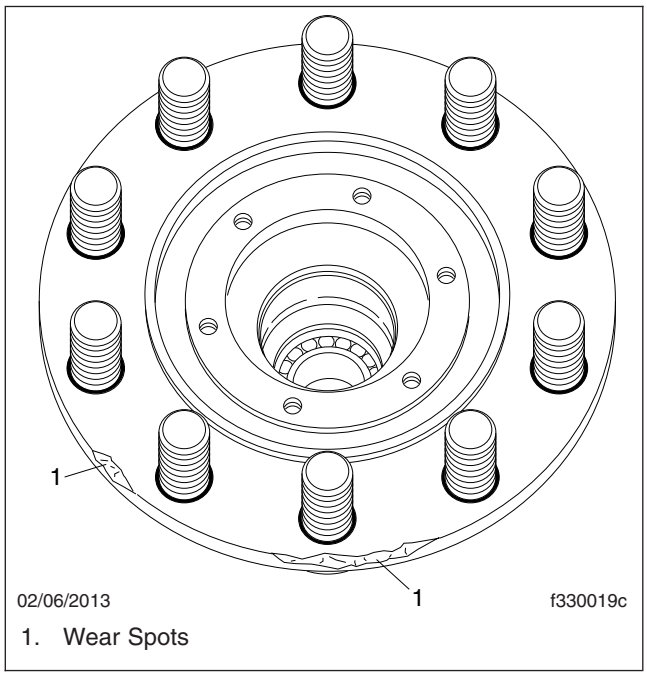
1. Drum Pilot
2. Wheel Pilot

Fig. 1, Hub Pilot Pads

Wheel Hub Assembly Inspection

1. Inspect the wheel hub mounting flange. A loose wheel assembly will cause the flange to be worn, jagged, or warped. See **Fig. 1**. Replace the wheel hub if any of these conditions exist.

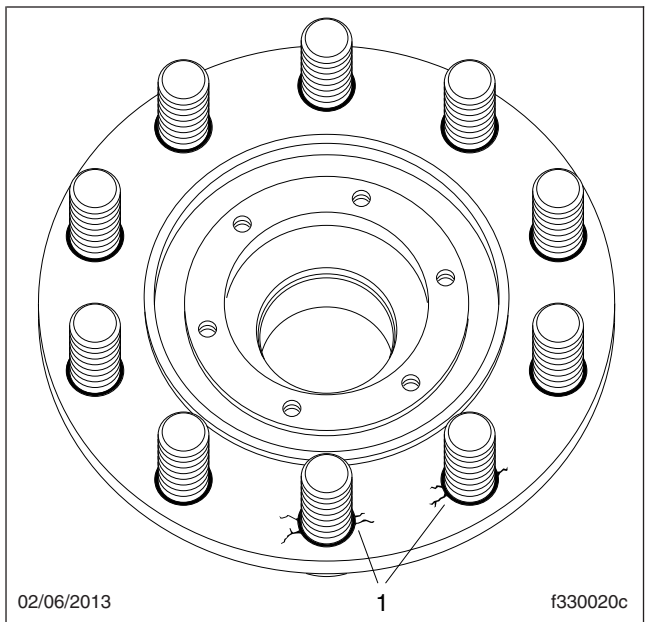
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

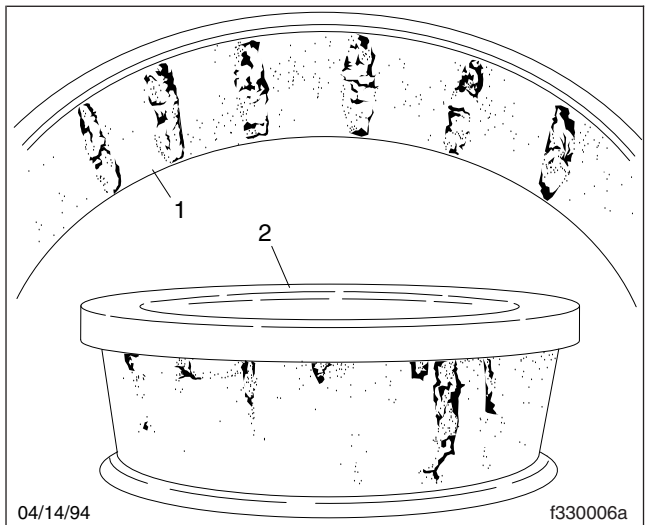
Fig. 1, Damaged Front Axle Wheel Hub

2. Remove all the old oil from the wheel hub cavity. Inspect the inner surface of the hub for cracks, dents, wear, or other damage. Replace the wheel hub if damage exists.
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the wheel bearing cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. See **Subject 160** or **Subject 170**.



1. Cracked Stud Grooves

Fig. 2, Damaged Front Axle Wheel Hub



1. Cup 2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

4. Inspect the wheel studs. Replace studs that are stripped, broken, bent, or otherwise damaged. See **Subject 180**.

Axle Components Cleaning and Inspection

Wheel Bearing Inspection

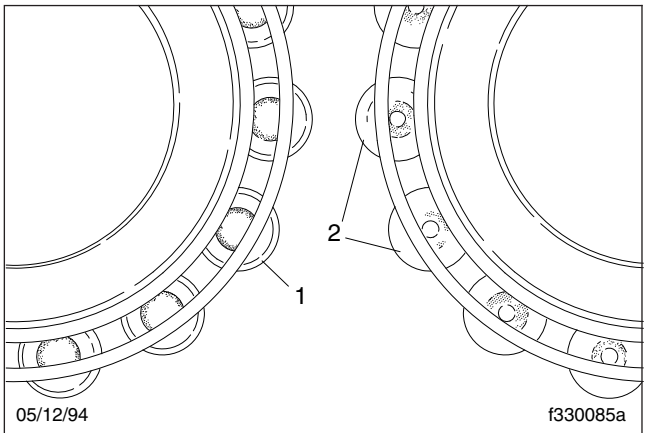
Wheel bearings should be very closely inspected at the time of disassembly. Optimal inspection conditions are possible only after the bearings have been thoroughly cleaned using nonflammable solvent and a stiff brush. Before inspecting, clean the bearings.

1. Remove the wheel hub and bearing cones. See **Subject 100**.
2. Using nonflammable solvent and a stiff brush, clean all the oil from the bearings and hub cavity. Do not use gasoline or heated solvent.
3. Allow the cleaned parts to dry, or dry them with a clean absorbent cloth or paper. Clean and dry your hands and all tools used in the maintenance operation. Oil will not stick to a surface that is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

NOTICE

Do not spin the bearing rollers at any time. Dirt or grit can scratch the roller surface and cause premature wear of the bearing assembly. Treat a used bearing as carefully as a new one.

4. After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies:
    - Large ends of rollers worn flush to the recess, or radii at the large ends of the rollers worn sharp. These are indications of advanced wear. See **Fig. 4**.
    - Visible step wear, particularly at the small end of the roller track. Deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 5**.
    - Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 6**.
    - Water etch on any bearing surface. Water etch appears as gray or black stains on the steel surface, and it greatly weakens the affected area. If water etch is present, replace the bearing seals.
    - Etching or pitting on functioning surfaces. See **Fig. 7**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 4, Wheel Bearing Roller Wear

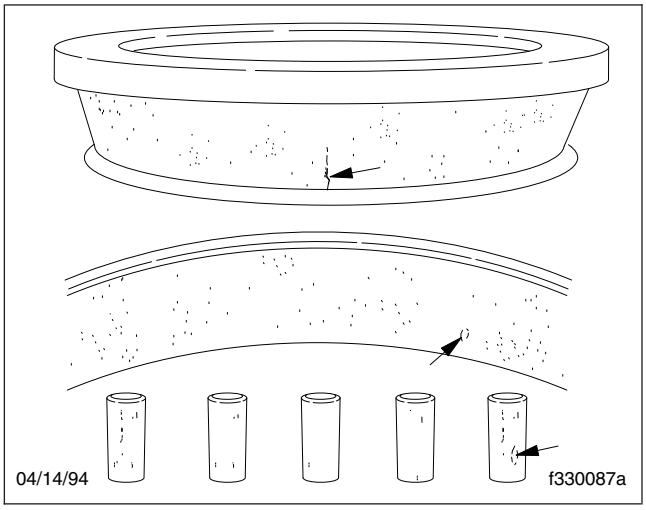


Fig. 5, Indentations, Cracks, or Breaks in Bearing Surfaces

- Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, coat the bearings with fresh axle lubricant.

Brake Drum Inspection

New brake drums are purposely undersized to allow for turning (remachining), since in mounting drums on the hub, there can be some eccentricity. If a new drum is installed, the protective coating on the inner friction surface must be removed with a solvent, prior

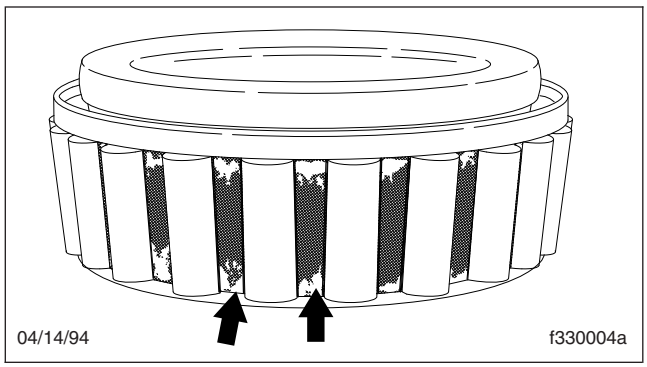


Fig. 6, Rubbing Marks on Bearing Cage

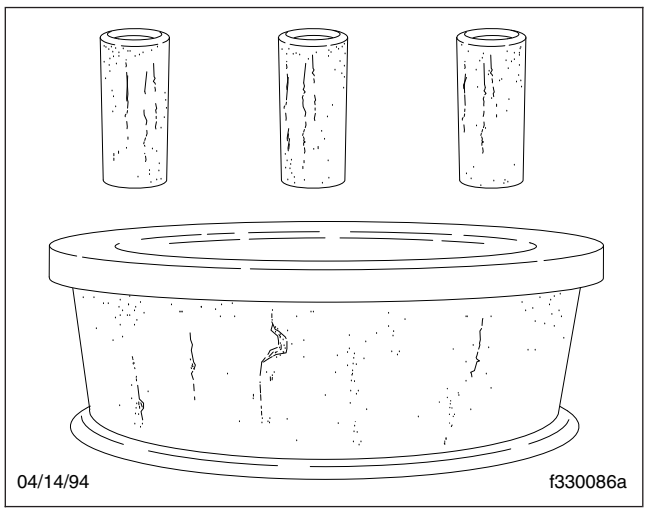
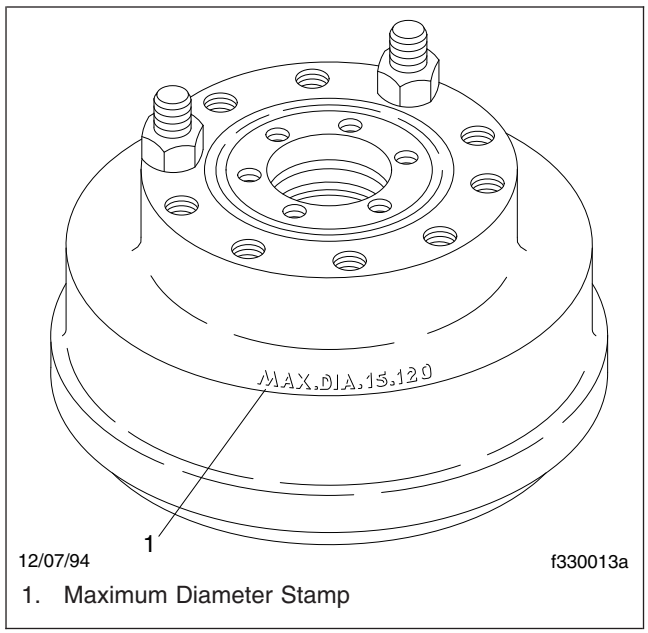


Fig. 7, Etching (Pitting) on Bearing Surfaces

to drum installation, then rinsed with a hot water wash. Use a clean rag to remove any oily residue or metal chips from the friction surface.

If a drum must be turned or replaced, the other same-axle drum must be similarly turned or replaced to provide the same braking power on both wheels. Turned drums should not exceed the maximum allowable diameter, which is stamped on the outside surface of the drum. See **Fig. 8** for a typical location of this stamp.

NOTE: Drums that have been turned should then be cleaned, using fine emery cloth followed with a hot water wash. Drums that have been renewed using emery cloth should also be washed with hot water.



1. Maximum Diameter Stamp

Fig. 8, Outboard Mounted Hub and Drum Assembly

NOTICE

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will result in drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimately, drum breakage.

If the drums are turned or replaced, replace the brake linings. See **Group 42** for instructions.

1. Inspect the inner friction surface. If a veneered (highly glossed) or glazed surface exists, renew the drum by using 80-grit emery cloth or by turning the drums.
2. Inspect for heat checking, which is a form of buckling (cracking) resulting from a temperature differential in the drum wall between a relatively cool exterior and a hot friction surface. Heat checking is normal on all drums and may not impair performance and lining life if the network of fine hairline cracks remains small. Examine heat checks of drums frequently to be certain the checks have not widened into drum weakening cracks (substantial cracks extending to the open edge of the drum). Replace the same-axle drums if substantial cracks are present, or if widening of the fine hairline cracks occurs.

Axle Components Cleaning and Inspection

NOTE: If normal heat checking as described above is present, inspect the drums at least every 12,000 miles (19 300 km) thereafter. Inspect the drums (using a flashlight from the inboard side of the wheels) every 6000 miles (9700 km). Inspect more often under adverse operating conditions.

3. Check for a contaminated inner friction surface. If fluids are present, such as oil or grease, remove the contaminants. Locate and correct the source of the contamination. If the brake drums are contaminated with fluids, the brake linings will also be affected. Since oil- or grease-saturated linings cannot be salvaged, they must be replaced. For brake lining replacement procedures, see **Group 42**.

⚠ WARNING

If the brake drums are contaminated with fluids, replace the brake linings. Failure to replace fluid contaminated brake linings could result in a partial loss of braking capacity, which could lead to personal injury or property damage.

4. Measure the inside diameter of the drum. If the measured diameter is greater than the maximum allowable diameter, replace the same-axle drums and linings.

NOTE: It may be necessary to remove the brake dust shield to measure the roundness of the drum.

5. Ensure the roundness of the drum is within acceptable limits, as follows. Set the measuring tip of a dial indicator against the working surface of the drum between the brake shoes as far outboard as possible. Zero the gauge, then turn the drum one revolution and note the highest and lowest measurements.

   If the difference is 0.010 inch (0.25 mm) or less, proceed to the next step. If the difference is more than 0.010 inch (0.25 mm), mark the drum and hub to record their relative positions, and remove the drum. Clean the mating surfaces of the hub and drum, and re-install the drum rotated 90 degrees from its earlier position. Tighten four wheel nuts 50 lbf·ft (68 N·m), and repeat the measurement. If the difference is more than 0.010 inch (0.25 mm), the drum is out of round beyond acceptable limits and all drums on the axle must be re-machined or replaced.

6. Inspect the outside surface of the drum. Remove any accumulation of mud, dirt, or rust; foreign matter acts as an insulator, trapping heat within the drum.

7. Check for hard, slightly raised dark-colored spots on the inner friction surface or for a bluish cast on the brake parts, both of which are caused by high temperatures. If the drums' maximum allowable diameters have not been exceeded, remachine both same-axle drums. If the spots or discoloration cannot be removed, or if remachining is not possible, replace the drums. Also replace the brake shoe return springs.

Bearing Spacer Cleaning and Inspection, PreSet Plus™ Hubs

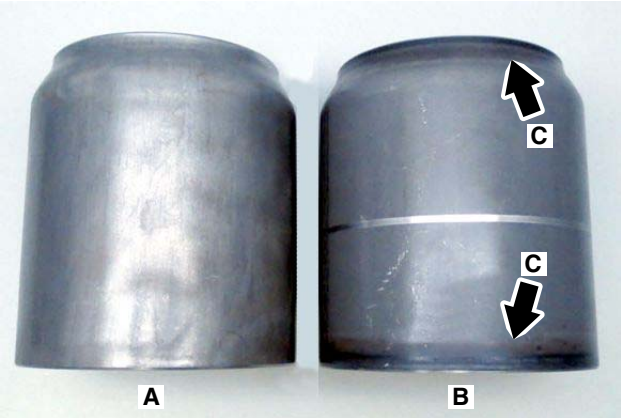
⚠ WARNING

Do not repair or recondition a damaged or worn bearing spacer; replace it. Using repaired, reconditioned, damaged, or worn components can cause wheel end failure, which can result in serious injury and property damage.

1. Use a cleaning solvent to clean the bearing spacer; do not use gasoline. Remove the solvent completely with clean, absorbent cloth or paper.

NOTE: PreSet Plus bearing spacers have undergone a heat-treating process that discolors the ends; see **Fig. 9**. This type of discoloration is normal for heat-treated spacers.

2. Inspect the bearing spacer for signs of wear or damage. Look for a sharp ring of standing metal that has been worn into the spacer at either end; see **Fig. 10**. If the spacer is worn or damaged, replace it.



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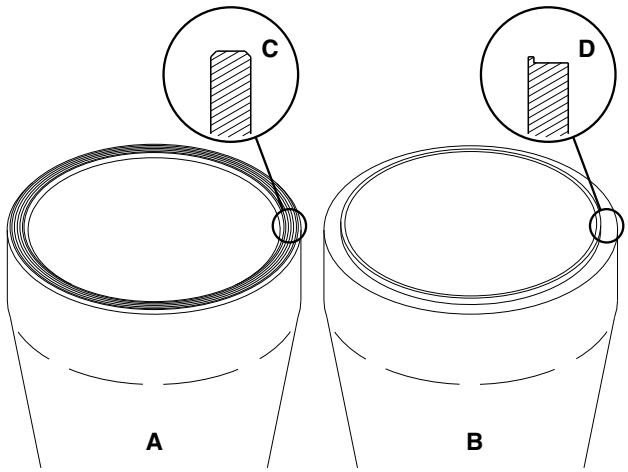
A. PreSet Spacer (Not Heat-Treated)
B. PreSet Plus Spacer (Heat-Treated)
C. Discoloration from Heat Treating Process

Fig. 9, PreSet and PreSet Plus Bearing Spacers



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A. New Spacer
B. Worn Spacer
C. Machined Surfaces with Chamfers and Grooves
D. Sharp Edge Worn into Machined End

Fig. 10, Comparison of New and Worn Bearing Spacers

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

Removal

To ensure a tight fit, wheel bearing cups are purposely larger than the wheel hub bores they occupy. To remove the bearing cups, aluminum hub bores must be temporarily expanded using the heat of an oven or boiling water (the bearing cups will also expand, but to a considerably lesser extent). If adequate heating facilities are not available, replace the hub, wheel stud, and bearing cup assembly.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Heat the hub to a temperature range of 175° to 215°F (79° to 102°C). If using an oven, make sure the thermostat is accurate; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

⚠ WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

IMPORTANT: If a bearing cup or cone shows signs of deterioration, replace the suspect part along with the mating component. Use the appropriate replacement parts to help ensure proper bearing adjustment.

3. Wearing heavy protective gloves, remove the hub from the oven or water. Place the hub on a suitable press so that the base is fully supported. Quickly press out the bearing cups.

   If the cup is loose, allow a few minutes for the temperatures of the components to equalize before moving the hub.

IMPORTANT: Inspect the bearing cup bore for evidence of cup rotation (spun cups). If found, replace the hub.

Installation

To install the bearing cups, aluminum hubs must be temporarily expanded using the heat of an oven or boiling water. When the hub is properly heated throughout, the bearing cup and hub can be press-fit together, using a suitable press. Cooling the cups in a freezer can further ease the installation.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Heat the hub to a temperature range of 175° to 215°F (79° to 102°C). If using an oven, verify that the oven thermostat is accurate; if unsure, use an oven thermometer to check the temperature of the oven before placing the hub inside.

⚠ WARNING

Do not use oxyacetylene equipment or similar equipment to heat the hub. Oxyacetylene equipment or similar equipment will cause cracks in the hub which could cause loss of a wheel and loss of vehicle control, leading to personal injury or property damage.

4. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
5. Wearing heavy protective gloves, remove the hub from the oven or water.
6. Place the hub on a suitable press so that the base is fully supported. Quickly press-fit the bearing cup into the wheel hub until it is completely and evenly seated. Be careful not to shave the sides of the bearing cup bore as the bearing cup is seated. The accumulation of debris will prevent the cup from being seated and will also cause permanent damage to the wheel hub. If the sides of the bearing cup bore are damaged during installation, replace the wheel hub assembly.
7. Allow the wheel hub to cool before handling. Then, using a 0.0015-inch feeler gauge, check at several places for the seating of the bearing cup in the bearing cup bore. The gauge should not enter beneath the cup. If it does, there is probably dirt or debris preventing the cup from seating. Using the instructions above, remove the cup, then remove the foreign matter. Install the cup.

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

8. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean, lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups on ferrous hubs are removed and installed by driving them out and pressing them in without heating the hub.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly.
2. Using a mild-steel rod through the opposite end of the hub, drive against the inner edge of the bearing cup. Alternately drive on opposite sides of the cup to avoid cocking the cup and damaging the inside of the hub.

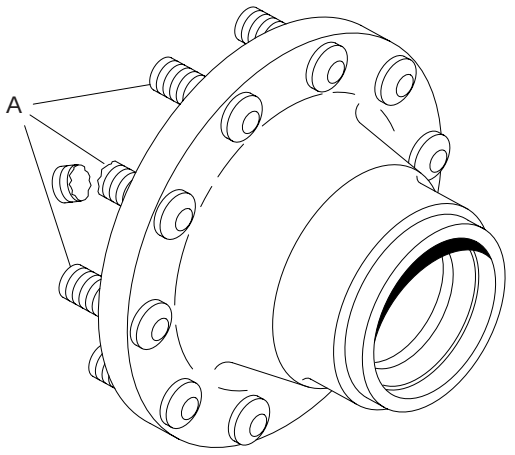
Installation

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

If a wheel stud breaks, the remaining studs are subjected to undue strain and could fail due to fatigue. When a broken stud is replaced, replace the stud on each side of it. See Fig. 1. If more than one stud is broken, replace all of the studs. Failure to replace the studs could result in the loss of a wheel or loss of vehicle control, possibly resulting in personal injury and property damage.



NOTE: Front hub shown.
A. Replace

Fig. 1, Wheel Stud Replacement

1. Remove the wheel hub from the axle. For instructions, see **Subject 100**.
2. If a bent portion of a wheel stud will have to pass through the wheel stud bore, cut off the bent portion before removing the wheel stud.
3. Place the wheel hub on a suitable press; make sure the hub flange is supported evenly around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.

NOTICE

Do not use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is necessary to ensure the least amount of metal removal from the wheel stud bore. Concentrated heat will damage the hub. If the hub is damaged during wheel stud removal or installation, replace it.

4. Apply a coating of clean axle grease to the entire shaft on headed studs.
5. With the hub on a suitable press, make sure the hub flange is supported evenly around and next to the stud being installed.
6. Position the stud in its hole. *Be sure the flat edge of the head flange on clipped studs is in line with the shoulder on the hub.*

NOTICE

If headed studs with serrations are being installed, position the teeth of the serrated portion in the notches carved by the original wheel studs during factory installation. If additional metal is scraped from the wheel stud bores, the locking action provided by the serrations will be greatly weakened. Loss of locking action will prevent achieving final torque of the wheel nuts during wheel installation. If final wheel nut torques during wheel installation cannot be achieved, replace the wheel hub assembly.

7. With steady movement, press the new stud all the way into the hub.
8. Make sure the stud is fully seated and that its head (flange) is not embedded into the hub. If the head of the stud is embedded into the hub, replace the hub.

WARNING

Do not embed the wheel stud heads in the wheel hub. Wheel studs with heads embedded in the wheel hub will weaken the wheel hub flange. Weakness in the wheel hub can result in the loss of a wheel or loss of steering control, possibly resulting in personal injury and property damage.

Wheel Stud Replacement

9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Replacement

1. Remove the wheel hub from the axle. For instructions, refer to **Subject 100**.
2. If enough threads remain on the damaged stud, remove it by double-nutting the stud. Turn the inner nut with a wrench in order to remove the stud. Then, proceed to the next step.

   If the drive axle stud is broken near the surface of the hub, the stud should be center-drilled using a high-speed drill, and then removed with an easy-out tool. If needed, grind off a flat surface on the damaged stud, then center-punch the surface as a starting point for drilling. Follow these recommendations:

   2.1 Determine the correct drill diameter by referring to the easy-out tool manufacturer's guidelines. At no time should it be large enough to penetrate the threads of the stud; if the stud threads in the wheel hub are damaged, replace the hub.

   2.2 Do not drill more than 1.25 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel hub. Drilling through the bottom of the drive axle stud could damage the hub. If the wheel hub is drilled into, replace it.

   2.3 While drilling, keep the cutting surfaces of the drill well lubricated with oil, which acts as a coolant. Allow the drill and drill bit to cool frequently.
3. After the damaged stud is removed, tap out the drive axle stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate sized tap, depending on the original drive axle stud installation size.
4. Be sure the threads of the new stud are clean and dry. Then, coat the insertion end of the drive axle stud (the coarse threads) with an anaerobic thread-lock compound.
5. Using double nuts on the fine-thread portion of the stud, install the new stud. Seat the drive axle stud using the torque values in the torque table in **Specifications, 400**.
6. Allow sufficient time for the thread-lock compound to set, as suggested by the manufacturer.
7. If the hub was removed from the axle, refer to **Subject 100** for installation instructions.

If either the lateral or radial runout of the hub is beyond acceptable limits, replace the hub. For instructions, see **Subject 100** in this section.

Measurements

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.

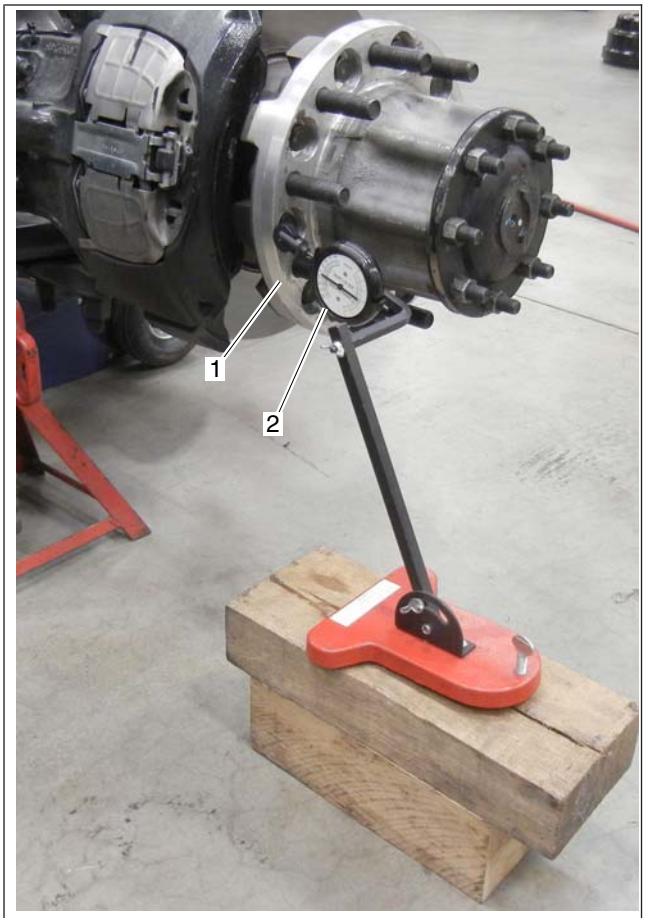
⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

2. Remove the wheel and tire assembly. See **Group 40** for instructions.
3. For drum brakes, remove the brake drum. See **Subject 140** for instructions.
4. Clean the hub surfaces where the measurements will be taken—see **Fig. 1** and **Fig. 2**.
5. To measure lateral runout, set up a dial indicator as shown in **Fig. 1**, then turn the hub one revolution and note the highest and lowest measurements.

   For ConMet hubs, the acceptable lateral runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable lateral runout specification.
6. To measure radial runout, set up a dial indicator as shown in **Fig. 2**, then turn the hub one revolution and note the highest and lowest

   For ConMet hubs, the acceptable radial runout is 0.008 inch (0.2 mm); for other hubs, see the hub OEM for the acceptable radial runout specification.



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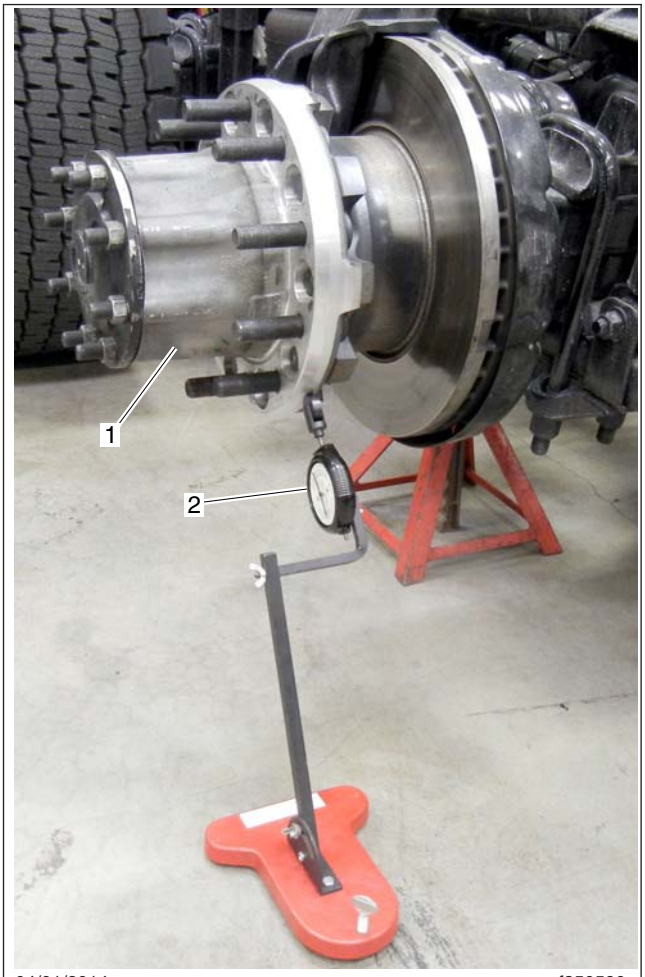
1. Hub
2. Dial Indicator (with roller point)

Fig. 1, Setup to Measure Lateral Runout

Hub Runout Measurements



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1. Hub
2. Dial Indicator (with roller point)

Fig. 2, Setup to Measure Radial Runout

Wheel Bearing End Play Measurement

⚠ WARNING

Correct wheel-bearing end play is crucial to the safe and sound operation of the vehicle. If the end play is not correct, the wheel bearings could fail and cause the loss of the wheel and hub assembly and result in an accident causing property damage, serious injury, or death. Use a dial indicator to measure the end play.

IMPORTANT: Do not measure the wheel bearing end play with the wheel mounted on the hub; you cannot accurately measure or adjust bearing end play with the wheel mounted on the hub. Also, ensure that the brakes are not applied so that that drum and hub can move freely.

Measurement

Using a dial indicator, measure the end play as follows.

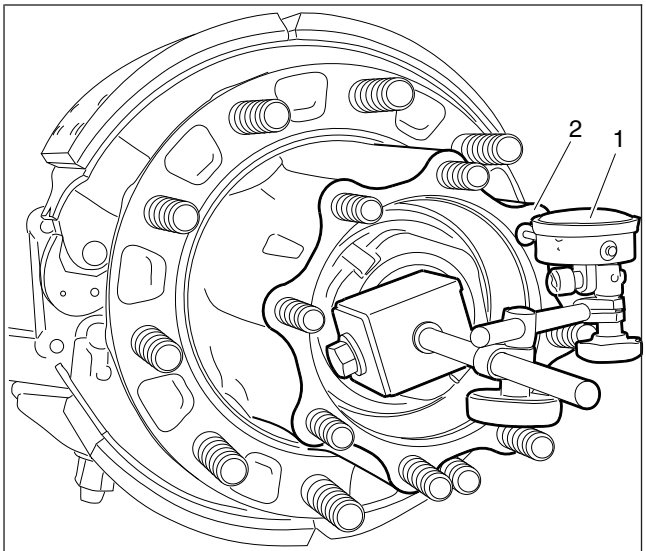
1. Attach the magnetic base of a dial indicator to the spindle, and place the measuring end of the indicator squarely against the flange as shown in **Fig. 1**.

IMPORTANT: Maintain continual pressure on the hub until you have taken both the inboard and outboard measurements. If you release the hub, an accurate measurement is not possible.

2. To seat the bearings, grip the hub at the three o'clock and nine o'clock positions, and push inward while oscillating it approximately 45 degrees. Maintain pressure on the hub, note the inboard measurement, and then pull the hub outward while oscillating it as before. Maintain pressure on the hub, and note the outboard measurement.

   The end play is the difference between the two measurements.

NOTE: If the end play exceeds the limit, the hub may need to be serviced. See **Subject 150** and manufacturer literature for procedures.



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1. Dial Indicator (with magnetic base)
2. Axle Shaft Mounting Flange

Fig. 1, Dial Indicator Setup

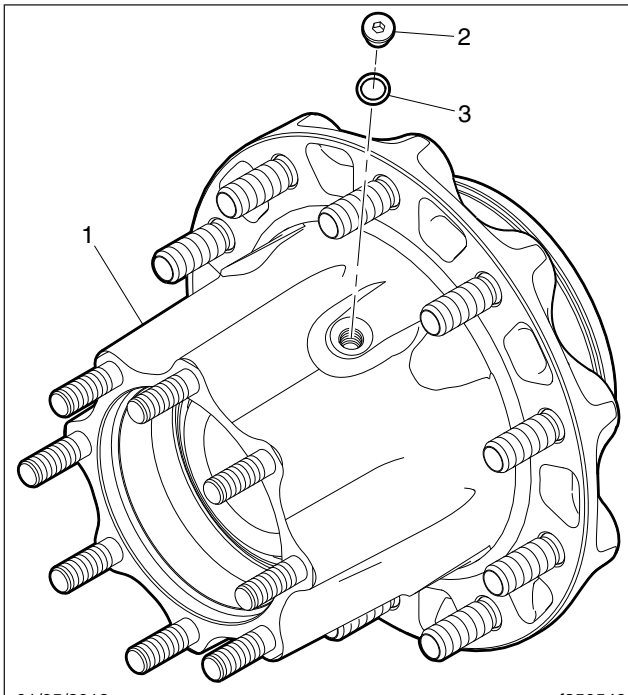
General Information

Proper wheel bearing lubrication is critical to sound wheel end health and safe vehicle operation. Insufficient lubrication can lead to catastrophic consequences that can be avoided.

The procedure for lubricating wheel bearings depends on whether or not the hub has an oil fill port. This subject provides instructions for ConMet hubs with and without a fill port.

ConMet Hub with an Oil Fill Port

For ConMet hubs with an oil fill port, lubricant is added through the fill port; see **Fig. 1** and use the following instructions.



1. Hub
2. Fill Port Plug
3. O-Ring

Fig. 1, ConMet Hub with Oil Fill Port

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.

IMPORTANT: When removing the fill port plug, make sure the rubber O-ring is attached to it and not stuck inside the fill port.

2. Clean the area surrounding the oil fill port plug, then remove the plug and O-ring.

NOTE: The fill port plug is magnetic. On drive axles, it is normal to find a small amount of very fine metallic particles from the carrier housing on the magnetic fill plug. These particles should be removed from the magnet anytime the plug is removed for inspection.

3. Inspect the plug for metallic particles picked up by the magnet. If very fine metallic particles are found, remove them from the magnet. If larger particles or chunks of metal are found, remove the hub from the spindle and inspect the bearings and other wheel end and axle components for signs of damage or excessive wear, and make the necessary repairs.

⚠ WARNING

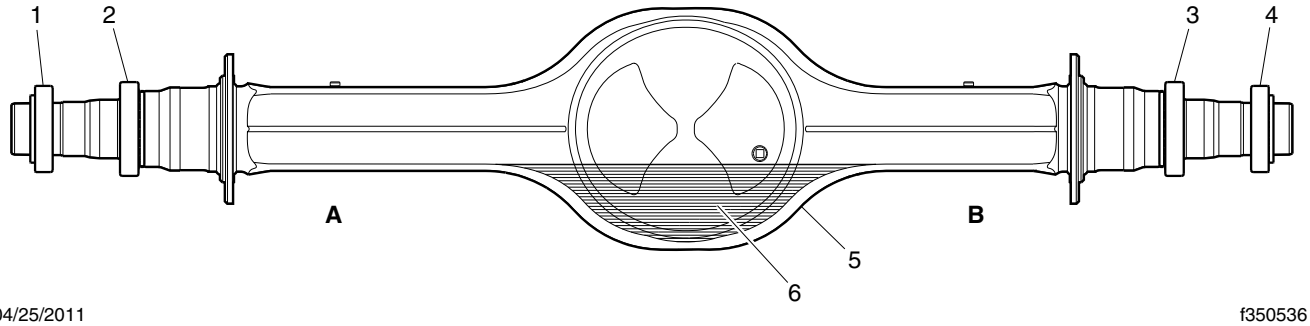
Failure to adequately lubricate wheel bearings can cause them to seize during vehicle operation. Seized wheel bearings can cause sudden, catastrophic damage to the wheel end and axle, possibly resulting in severe personal injury or death.

4. Using a clean funnel, add 1.0 quart (0.95 liter) of the recommended drive axle lubricant through the oil fill port. For recommended lubricants, see the vehicle maintenance manual.
5. Install the fill port plug, and tighten it 20 to 25 lbf·ft (27 to 34 N·m).

ConMet Hub without an Oil Fill Port

For ConMet hubs without an oil fill port, lubricant must be transferred from the axle carrier housing to the hubs. To ensure each bearing is adequately lubricated, the axle must be filled with lubricant and tilted *three* times. See **Fig. 2** and use the following instructions to lubricate the wheel bearings on a rear drive axle.

Wheel Bearing Lubrication



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For an axle equipped with hubs without fill ports, when side A is raised first, bearing 4 is lubricated. Side B is raised next to lubricate bearings 3 and 1. Side A is raised again to lubricate bearing 2. The carrier housing must be refilled before and after each time the axle is lifted to ensure there is enough lubricant to reach the bearings.

A. Driver Side
B. Passenger Side

1. Outer Wheel Bearing, Driver Side
2. Inner Wheel Bearing, Driver Side
3. Inner Wheel Bearing, Passenger Side
4. Outer Wheel Bearing, Passenger Side
5. Carrier Housing
6. Lubricant (full)

Fig. 2, Rear Drive Axle and Wheel Bearings

1. Park the vehicle on level ground, apply the parking brakes, and chock the front wheels.

NOTE: Some Detroit and Meritor axles have a small tapped and plugged hole located below the housing oil fill hole. This smaller hole is for a lubricant temperature sensor only and must not be used as a fill hole.

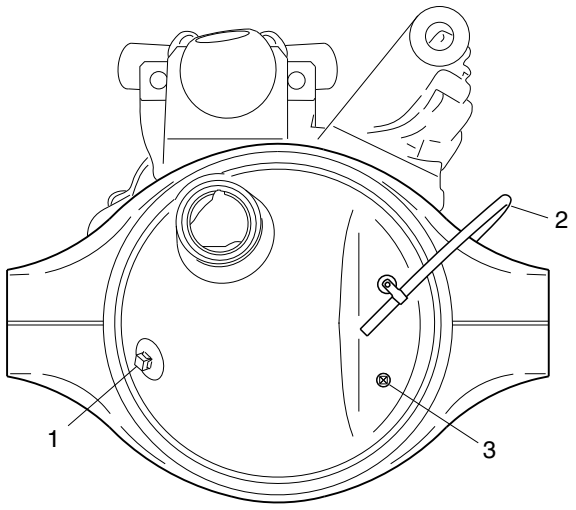
2. With the axle level and all wheels on the ground, clean the oil fill hole plug and the area surrounding it, then remove the fill plug. For Detroit axles, see **Fig. 3**; for Meritor axles, see **Fig. 4**; for Dana Spicer axles, see **Fig. 5**.

⚠ WARNING

Failure to adequately lubricate wheel bearings can cause them to seize during vehicle operation. Seized wheel bearings can cause sudden, catastrophic damage to the wheel end and axle, possibly resulting in severe personal injury or death.

IMPORTANT: A lubricant level close enough to be seen or touched is not sufficient; it must be level with the bottom of the fill hole. See **Fig. 6**.

3. Use a clean funnel to add lubricant until it reaches the fill hole, then install the fill plug. For recommended lubricants, see the vehicle maintenance manual. For fill plug torque values, see **Table 1**.



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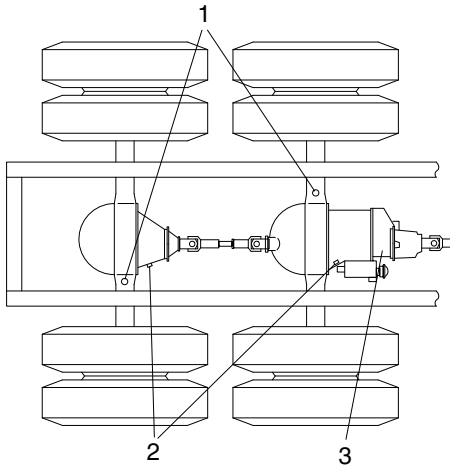
NOTE: Rear view of forward-rear axle shown.

1. Oil Fill Plug
2. Breather Hose
3. Temperature Sensor Port Plug

Fig. 3, Fill Hole Plug Location, Detroit Tandem Axle



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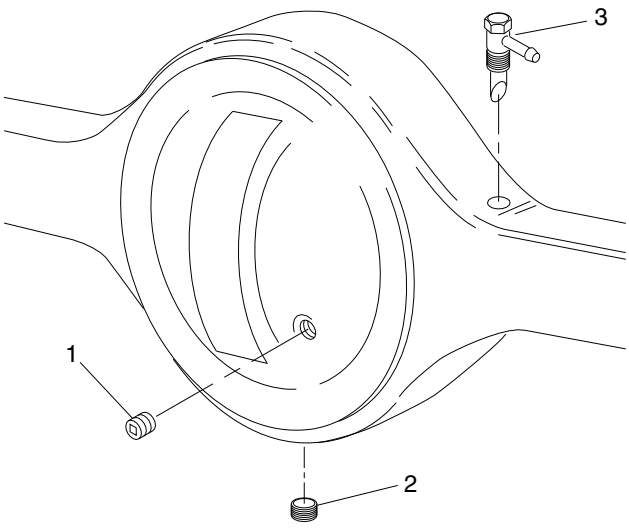
1. Axle Housing Breathers
2. Carrier Oil Fill Plugs
3. Interaxle Differential

Fig. 4, Fill Hole Plug Locations, Meritor Axles



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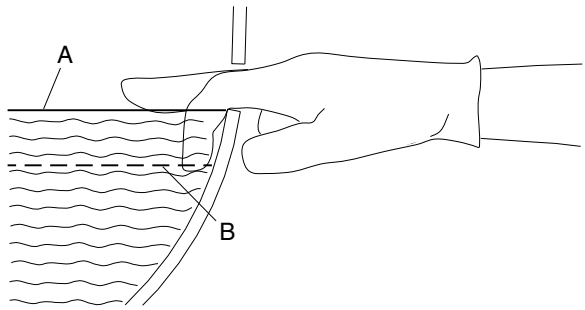
1. Oil Fill Plug
2. Oil Drain Plug
3. Axle Breather

Fig. 5, Fill Hole Plug Location, Dana Spicer Axles



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A. Correct (lube level at bottom of fill hole)
B. Incorrect (lube level below fill hole)

Fig. 6, Axle Lubricant Level Check

Oil Fill Plug Torque Values	
Brand	**Torque: lbf·ft (N·m)**
Detroit	30 (41)
Meritor	35 (47)
Dana Spicer	40 to 60 (54 to 81)

Table 1, Oil Fill Plug Torque Values

IMPORTANT: The axle must be tilted three times and the tilted position must be held for two minutes each time to allow enough lubricant to reach the hub and wheel bearings.

4. To tilt the axle, position a suitable jack at a leaf spring U-bolt, and raise it until the bottom of the outside part of the outside tire is 8 inches (20 cm) above the ground. See **Fig. 7** and **Fig. 8**.

   After two minutes, lower the axle, and add lubricant as described earlier in this procedure.

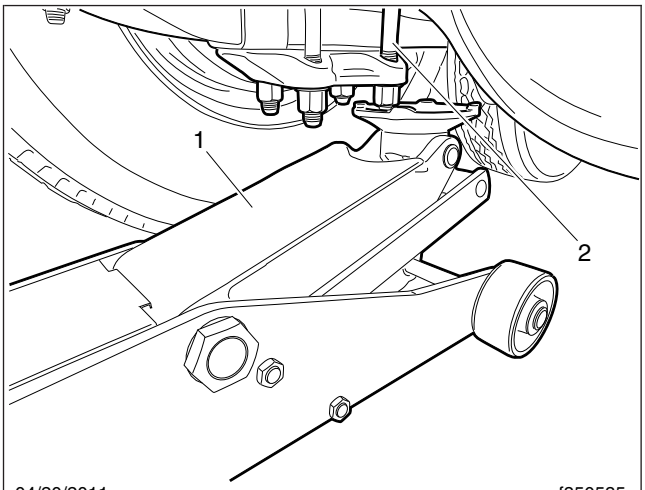
5. At a leaf spring U-bolt on the other end of the axle, tilt the axle as described earlier in this procedure.

   After two minutes, lower the axle, and add lubricant as described earlier in this procedure.

6. At the U-bolt where the axle was first lifted, tilt the axle as described earlier in this procedure.

   After two minutes, lower the axle, and add lubricant as described earlier in this procedure.

Wheel Bearing Lubrication



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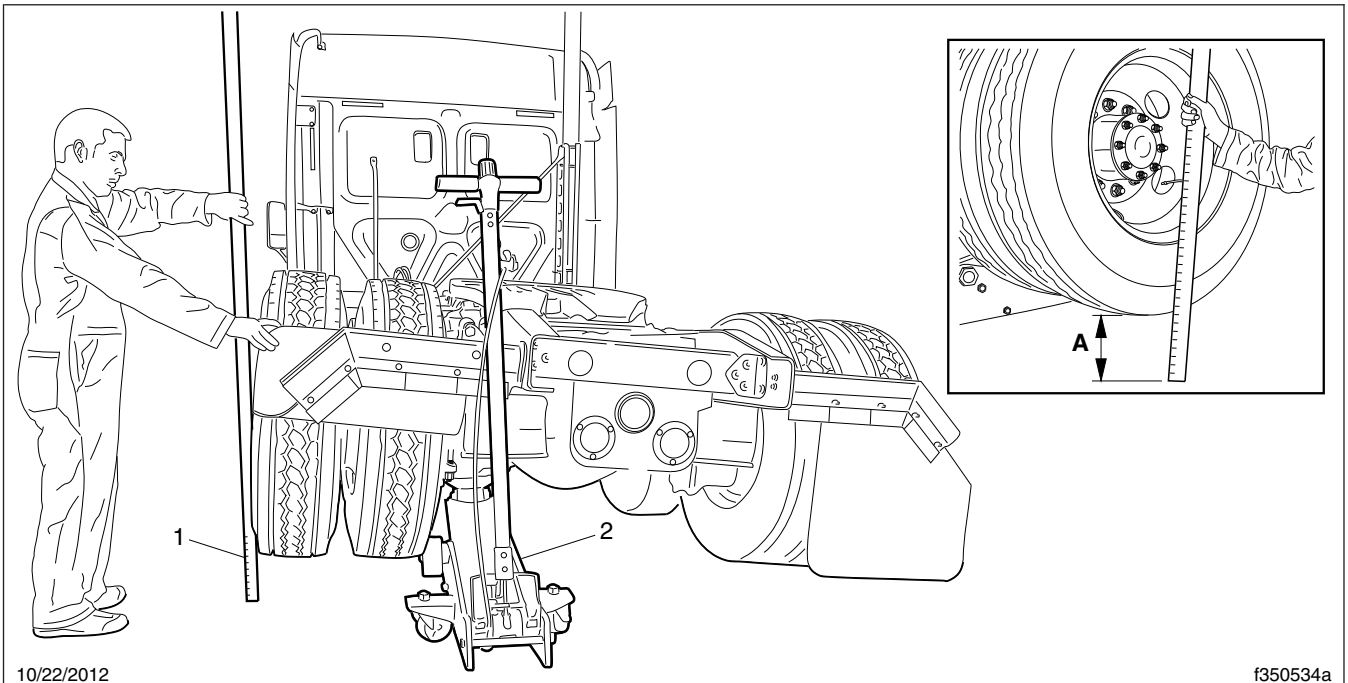
1. Jack
2. U-bolt

Fig. 7, Axle Lifted at Leaf Spring U-bolt



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Each time you lift a side of the axle to distribute lubricant, raise it until the bottom of the outside part of the outside tire is 8 inches (20 cm) above the ground.

A. 8 inches (20 cm)

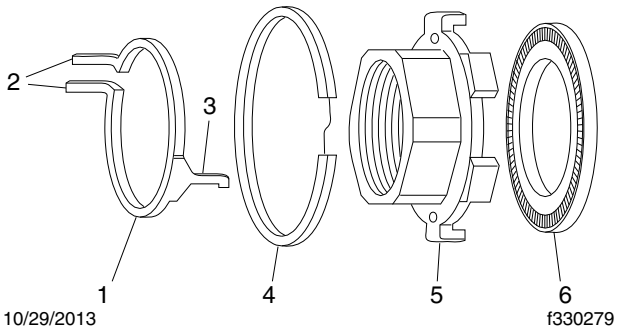
1. Ruler
2. Jack

Fig. 8, Distributing Lubricant from Carrier Housing to Wheel Bearings for ConMet Hubs without Oil Fill Ports

ConMet PreSet Plus Spindle Nut Removal and Installation

General Information

ConMet PreSet Plus hubs use a special integrated spindle nut designed specifically for PreSet Plus hubs. See **Fig. 1**.



1. Locking Ring
2. Tabs
3. Lock Tab
4. Spiral Snap Ring
5. Spindle Nut
6. Locking Washer

Fig. 1, PreSet Plus Spindle Nut System

Removal

1. To remove the red locking ring from the spindle nut assembly, compress the tabs and pivot the ring to unlock it from the nut.

IMPORTANT: Do not exceed 50 lbf·ft (68 N·m) of torque when removing a PreSet Plus hub using the spindle-nut system as a hub puller.

2. Loosen the spindle nut. As the spindle nut is loosened, it can act as a hub puller. However, if the hub will not come off of the spindle without exceeding 50 lbf·ft (68 N·m) of torque, remove the spiral snap ring (see **Fig. 2**) and then the spindle nut assembly.

Installation

⚠ WARNING

Each PreSet Plus hub assembly requires special bearings, a PreSet Plus bearing spacer, and the unique PreSet Plus spindle nut system. Wheel ends equipped with the PreSet Plus hub assembly must use these special components; do not use non-PreSet-Plus components with a PreSet Plus hub.

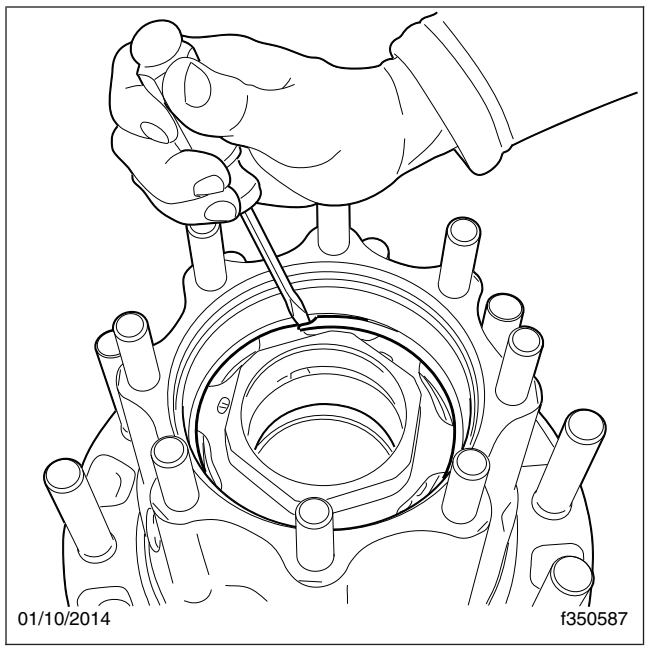


Fig. 2, Removing a Spiral Snap Ring

If a PreSet Plus hub is not correctly installed with the required components, the hub could separate from the axle, resulting in property damage, severe personal injury, or death.

The following instructions are for installing a PreSet Plus spindle nut. In some cases, the spindle nut components will have been removed along with the hub; in other cases, they will have been already installed in the hub. Use the pertinent instructions for your installation.

1. If the red locking snap ring is locked into the spindle nut, compress the tabs and pivot the ring to remove it from the nut. See **Fig. 1**.
2. If needed, begin installing the PreSet Plus spindle nut components, as follows.
   - 2.1 Seat the flat washer into the back of the spindle nut.
   - 2.2 Position the spindle nut and washer against the outer bearing.
   - 2.3 Install the spiral snap ring into the snap ring groove in the hub. Ensure that it fully seats into the groove in the hub. See **Fig. 3** and **Fig. 4**.
3. Tighten the spindle nut 500 lbf·ft (678 N·m) while rotating the hub. Do not back off the spindle nut.

ConMet PreSet Plus Spindle Nut Removal and Installation

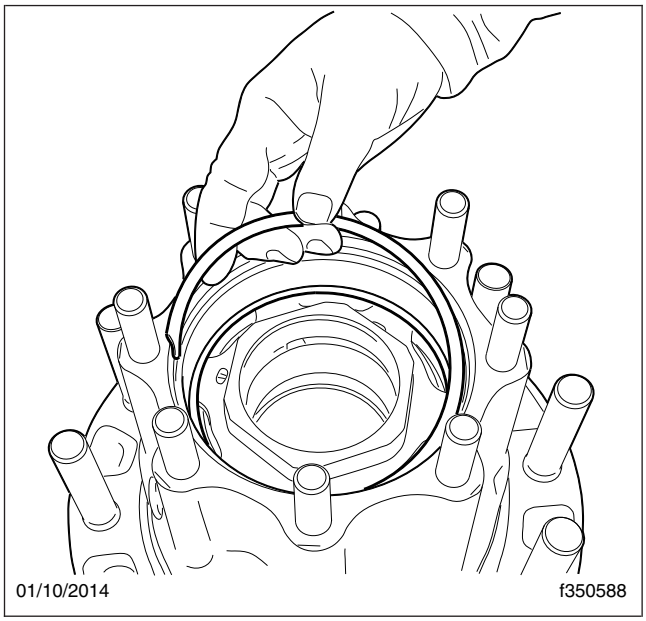


Fig. 3, Installing a Spiral Snap Ring

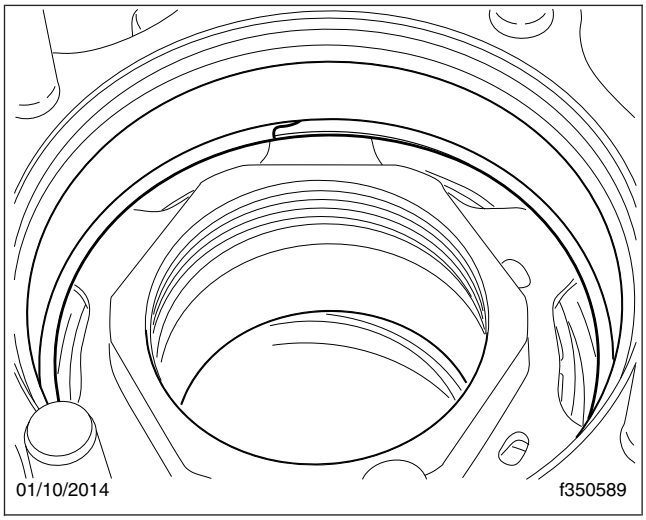


Fig. 4, Fully Seated Spiral Snap Ring

NOTICE

When bending the locking ring, be careful not to deform it permanently. If the locking ring is damaged or bent, replace it with a new one.

4. Install the locking ring, as follows.
   - 4.1 One of the holes in the face of the spindle nut will line up with a hole in the washer. Insert the lock tab of the locking ring through aligned holes.
   - 4.2 Using the handle tabs, seat the locking ring in the machined grooves of the spindle nut.

Specifications

Torque Values			
Description		**Size (grade 8)**	**Torque: lbf·ft (N·m)**
Drive Axle Studs (to Hub)		1/2–13	70 (95)
		5/8–11	135 (185)
Drive Axle Stud Nuts	With Dowels	5/8–18	130 to 140 (175 to 190)
	Without Dowels	5/8–18	150 to 170 (203 to 230)
Hub Cap Capscrews		5/16–18	15 (20)
Oil Filler Plug, Detroit axles		—	30 (41)
Oil Filler Plug, Meritor axles		—	35 (47)
Fill Port Plug, ConMet hubs		—	20 to 25 (27 to 34)

Table 1, Torque Values

General Information

Wheel oil seals (also called "oil bath seals" or "hub seals") work as a dam to keep oil in the hub cavity so that it constantly "bathes" the wheel bearings. The seals also protect the wheel bearings by keeping dirt, dust, and water out of the hub. The oil seal is installed between the hub bore, which rotates, and the non-rotating axle spindle.

Most wheel oil seals consist of four basic parts (**Fig. 1**):

- outside edge (also called outer "cup" or "case")
- inside edge (also called inner "cup" or "case")
- sealing element
- garter spring

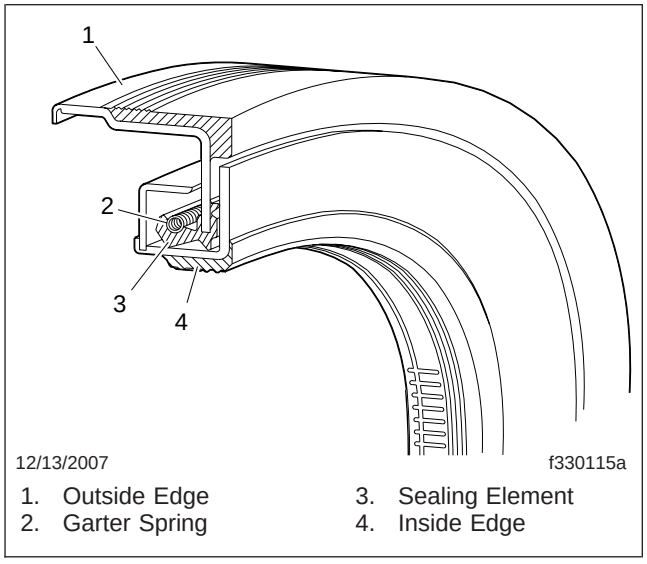


Fig. 1, Wheel Oil Seal Parts

The outside edge is usually metal that's coated with rubber or another sealing agent so that it grips the hub bore tightly enough to prevent oil from escaping between the outer edge of the seal and the hub bore.

The inside edge is usually metal or rubber with a metal ring within it to prevent the sealing element from wearing a groove in the axle spindle.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips that seal against the axle spindle or against the outside or inside edge described above.

The garter spring is a loop of coiled wire spring that presses the sealing element against the sealing surface.

Chicago Rawhide Scotseal Plus XL

The Chicago Rawhide Scotseal Plus XL (see **Fig. 2**) is a unitized, one-piece seal. The outer diameter of the metallic case and the bore diameter of the seal counter face are coated with rubber. The seal is press-fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal Plus XL directly onto the axle spindle.*

Although you install the Scotseal Plus XL into the hub bore, the seal's element grips the axle spindle tightly enough that the sealing element stays stationary with the spindle, and seals against the outer cup, which turns with the hub.

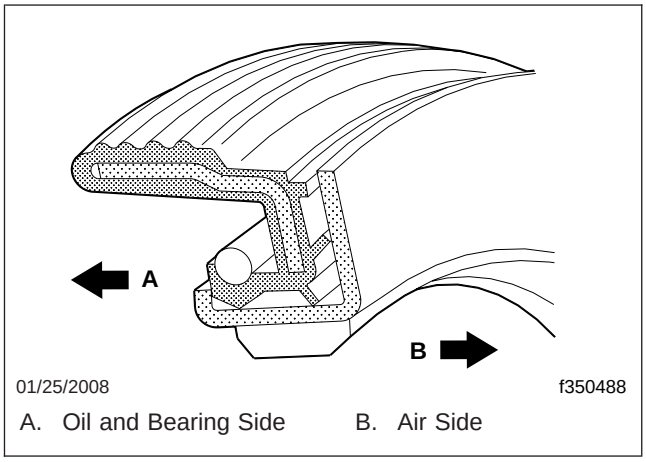


Fig. 2, Chicago Rawhide Scotseal Plus XL

Seal Replacement, Chicago Rawhide Scotseal Plus XL

IMPORTANT: Make sure the required tools are available before beginning the service procedures described here. See **Fig. 1** for a diagram of the installation tool. Ensure that the **flat side** of the driver plate faces the seal. See **Specifications, 400** for tool and seal numbers.

Replacement

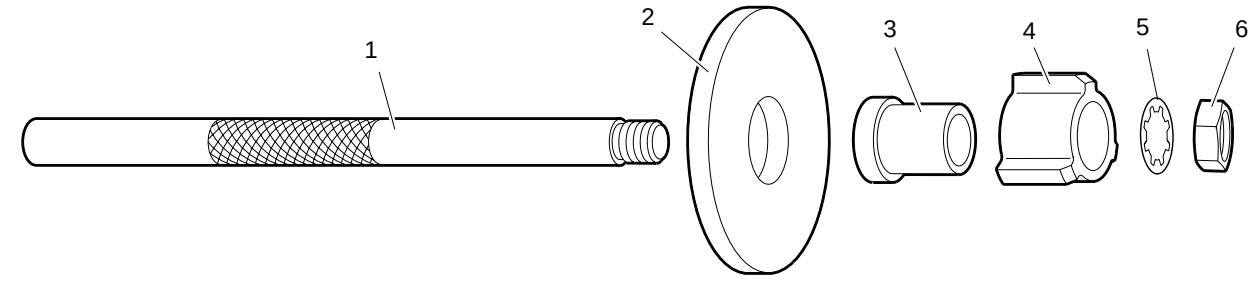
1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01**.
2. Remove the inner wheel bearing assembly from the axle. Handle the bearings with clean dry hands, and wrap the bearings in clean oil-proof paper or lint-free cloths. Occasionally, the inner wheel bearing cone assembly will remain in the hub after the hub is removed from the axle. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing and seal out of the inner wheel bearing cup. Discard the seal.
3. Clean the spindle, spindle threads, seal bore, and hub cavity. See **Fig. 2** and **Fig. 3**.
4. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.

NOTICE

Do not spin bearing rollers at any time. Dirt or grit can scratch the roller surface and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

5. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
6. Coat the wheel bearing cones with oil.
7. Install the inner wheel bearing cone in the inner wheel bearing cup.
8. Inspect a new seal for damage (such as cuts or being out of round) and contamination. If damage is evident, discard it and use a suitable seal.
9. Apply a thin layer of lubricant to the inside and outside diameters of the seal using the same lube used in the hub.
10. Using the appropriate driver plate and centering tool, assemble the installation tool so that the flat side of the plate is the seal installation surface. See **Fig. 4**. To determine which driver plate to use, see **Specifications, 400**.



1. Handle
2. Driver Plate
3. Bushing
4. Centering Tool
5. Washer
6. Nut

Fig. 1, Installation Tool

Seal Replacement, Chicago Rawhide Scotseal Plus XL

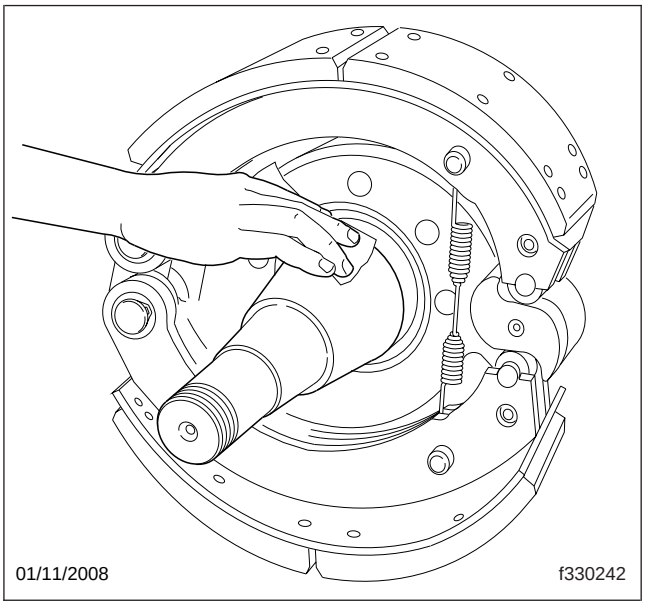


Fig. 2, Cleaning the Spindle

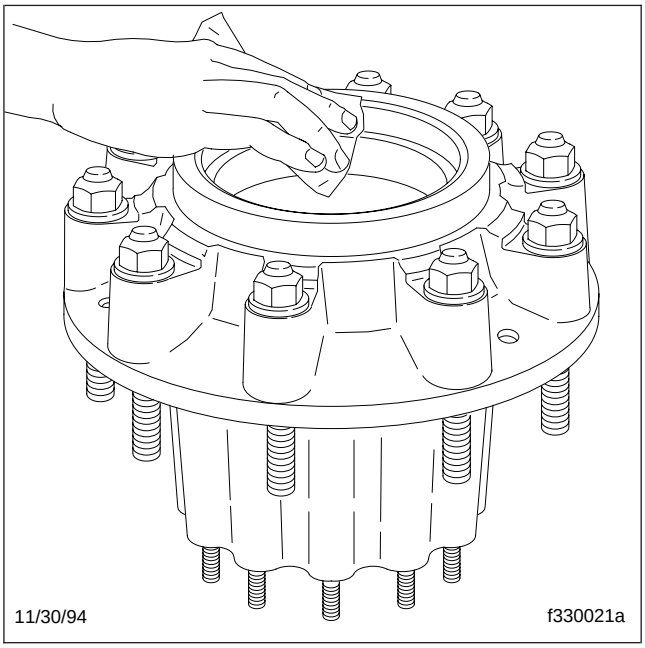


Fig. 3, Cleaning the Hub

11. Seat the seal in the seal bore with the "air side" facing outward ("air side" is stamped on the sleeve flange of the seal).
12. Insert the centering tool into the bore of the inner bearing cone (to prevent cocking of the seal), and press the seal down firmly with the flat side of the driver plate. See **Fig. 5**.
13. To avoid bounce or unseating of the seal, hold the tool handle firmly, and strike it until the seal bottoms out. See **Fig. 6**.

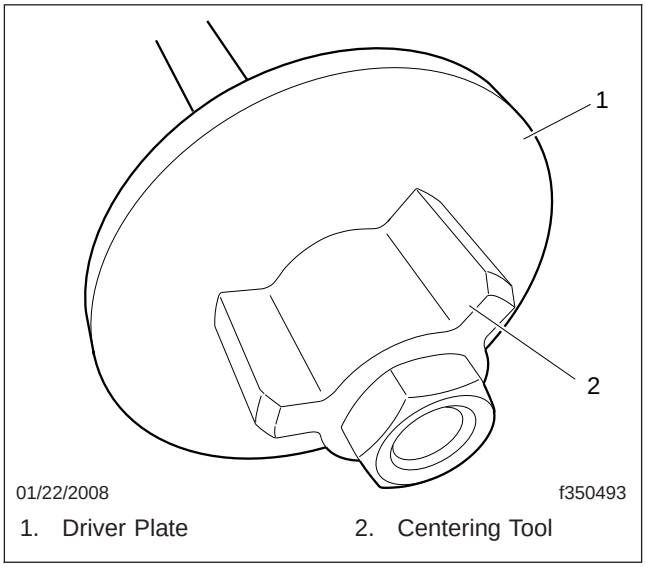


Fig. 4, Installation Tool

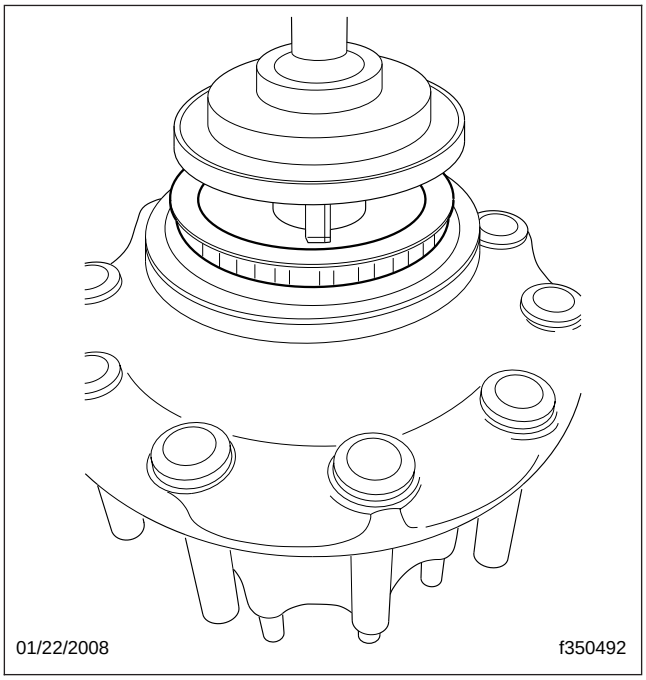


Fig. 5, Inserting the Centering Tool into the Hub Bore

Seal Replacement, Chicago Rawhide Scotseal Plus XL

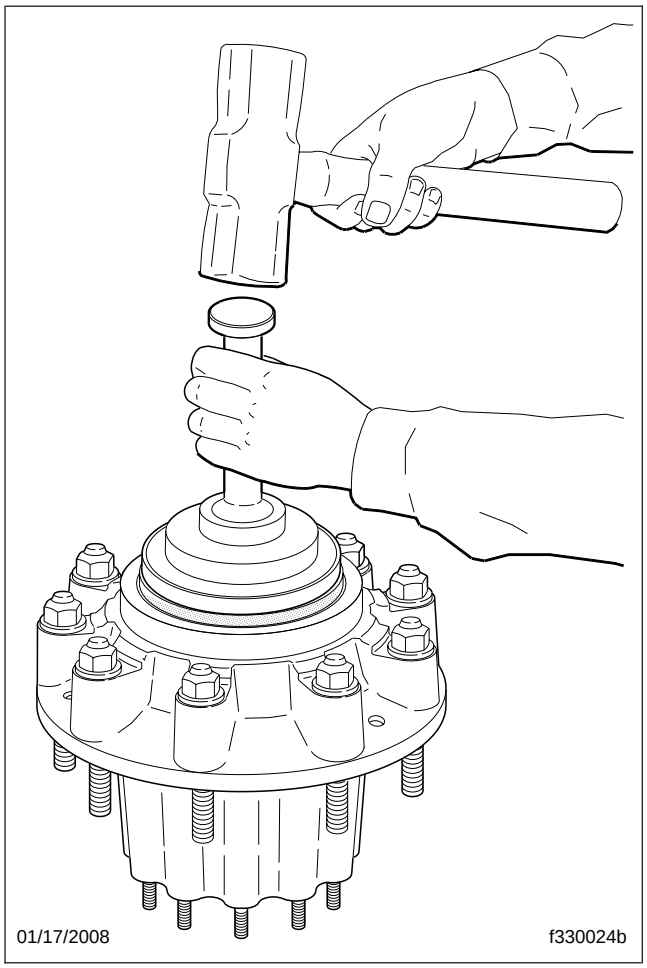


Fig. 6, Striking the Tool

14. After the seal is bottomed in the bore, check for freedom of movement by manually moving the interior rubber part of the seal back and forth. A slight movement indicates a damage-free installation. If any damage is visible, remove the seal and install a new one.
15. Install the hub and drum on the axle, adjust the wheel bearings, then install the wheel. For instructions, see **Section 35.01**.

Specifications

For Scotseal Plus XL seal stock number 47691, see **Table 1** to identify the installation tool parts needed to install the seal. The seal stock number is listed on the air-side flange of the seal.

Scotseal Plus XL Seal and Tool Numbers			
Bearing Cone	**Seal Stock Number**	**Centering Tool Number**	**Driver Tool**
594A	47691	715	435*

* The number 435 driver tool is the same one used for the Scotseal Classic.

Table 1, Scotseal Plus XL Seal and Tool Numbers

General Information

Detroit rear axles are compatible with industry-standard brakes, hubs, and wheel bearings.

The following explains an example of the number found on a Detroit rear axle identification tag, which is located on the carrier. See **Fig. 1**.

Typical Model Number: ART-40.0-4

- *ART* = tandem rear axle
- *40.0* = weight rating (times 1000 lb)
- *4* = basic model number

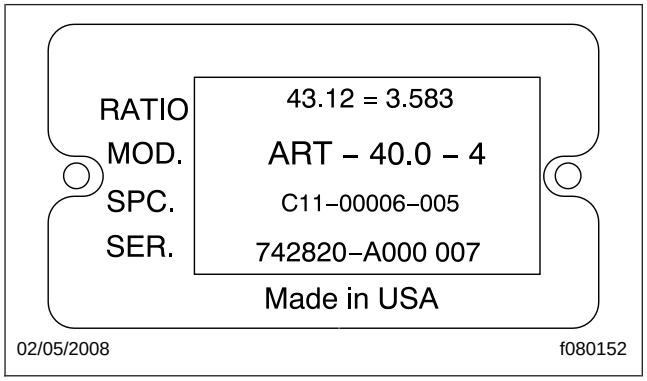


Fig. 1, Rear Axle ID Tag

Detroit rear axles may have a main differential lock, which is commonly known as the "DCDL" (Driver-Controlled Differential Lock). The DCDL is an optional feature that can lock the differential assembly to improve traction on icy road conditions. When the differential lock is engaged, the clutch collar completely locks the differential case, gearing, and axle shafts together to maximize traction of both wheels and protect against spinout. Each part of the DCDL is replaceable; see **Subject 180**.

On tandem axles there are three possible differential lock options: forward-rear carrier only, rearmost carrier only, or both rear carriers.

NOTE: Detroit axles are a proprietary product, though in some applications they may be referred to as "Freightliner" or "Axle Alliance" axles or "MB components."

Warranty

To assist in the determination of warrantable and non-warrantable failures for these axles, warranty evaluation guides are available through WarrantyLit on **www.accessfreightliner.com**. These guides help determine whether or not pre-approval is needed for a repair. The following evaluation guides are available:

- **Warranty Evaluation Guide**
- **Submission Guidelines - Differential Cross Failure**
- **Submission Guidelines - Pinion Bearing Cage Damage**
- **Submission Guidelines - Pinion Nut Failure**
- **Submission Guidelines - Thrust Bearing Failure**
- **Submission Guidelines - Yoke (Pinion) End Play**

Single or Rearmost Axle Removal and Installation

Removal

For rear axle components, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.
4. Continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the tire and wheel assemblies.
7. Drain the oil from the differential housing. Install the drain plug.
8. Disconnect the driveshaft from the differential carrier; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
9. Release the parking brakes.
10. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
11. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
12. Place a basin under the axle shaft flanges to catch any oil, then remove the axle shafts; see **Subject 120**.
13. Drain the air system.
14. Disconnect the DCDL air line from the carrier housing, if installed.
15. If necessary, back off the slack adjusters, then remove the brake drums.
16. Remove the hubs from the axle spindles; see **Section 35.01, Subject 100**.
17. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
18. If applicable, disconnect the leveling valve rod(s) from the suspension.
19. At the frame rail or crossmember, disconnect the wiring for the ABS sensors. Remove any tie straps that hold the wires to the frame rails.
20. Disconnect the air lines from the rear brake chambers.
21. Remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
22. Remove the ABS sensors and wiring, and the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
23. Using a suitable jack, support the axle housing.
24. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
25. Remove the suspension components that attach the axle to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
26. Lower the axle enough to clear the suspension components.
27. Remove the axle from the vehicle.
28. If you are going to replace the differential carrier, place the axle on a secure axle stand.

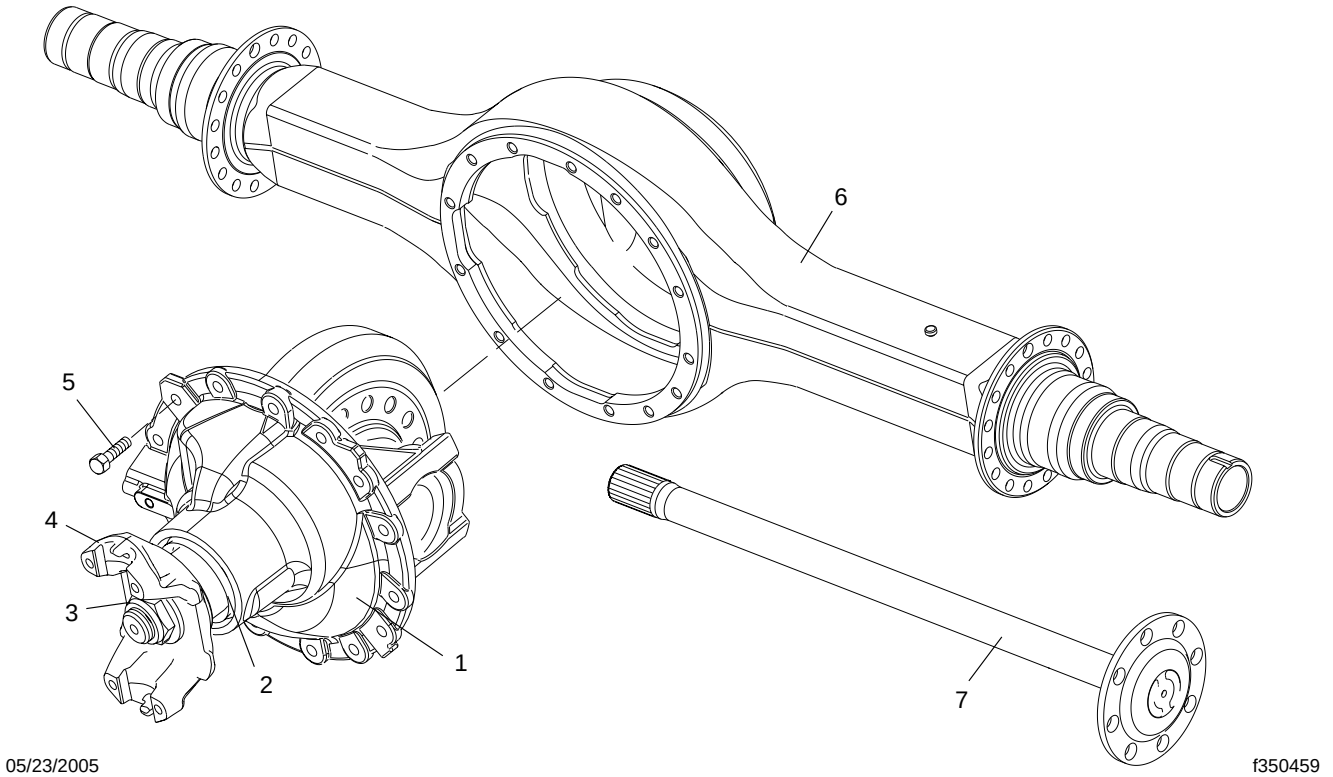
Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets,

Single or Rearmost Axle Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

Fig. 1, Single or Rearmost Axle Components

new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

On vehicles without U-bolts, install the walking beams.

2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.

3. Connect the driveshaft to the differential carrier yoke; see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. Fill each hub with approved axle oil until you can see a little amount of oil trickling out of the back of the hub (use about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles. For instructions, see **Section 35.01, Subject 100**.

NOTE: See **Table 1** for approved axle oils.

10. If DCDL is installed on the vehicle, connect the DCDL air line, fill the air system, and use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged.
11. Using new gaskets, install the axle shafts; see **Subject 120**.
12. Install the brake drums on the hubs.
13. Install the wheels and tires. For instructions, see **Group 40**.
14. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
15. Uncage the parking brake springs.
16. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.
17. If the hubs are dry, raise one side of the vehicle about 4 inches (10 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

18. Turn the wheels, wait one minute, and check the lubricant level.
19. Raise the vehicle, remove the safety stands, then lower the vehicle.
20. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
21. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
22. Set the parking brake.

Single Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	10.6 (10.0)	12.2 (11.5)
75W-90 Synthetic Gear Oil		

Table 1, Single Rear Axle Oil Type and Capacity

Single or Rearmost Axle Differential Carrier Removal and Installation

When the wheel lock is removed, inspect the carrier for damage and replace it if damage is found. If no damage is found, install the carrier again.

Removal

NOTE: The differential carrier can be removed either with the rear axle installed on the vehicle, or with the rear axle removed from the vehicle.

Axle Installed on Vehicle

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a jack underneath the axle housing.
4. Remove the tires and wheels. For instructions, see **Group 40**.
5. Drain the oil from the axle housing.
6. Disconnect the driveshaft from the carrier yoke; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
7. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
8. Place a basin under the axle shaft flanges, then remove the axle shafts; see **Subject 120**.
9. Do the steps under the heading, "Axle Removed from Vehicle."

Axle Removed from Vehicle

1. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.
2. If DCDL is installed on the vehicle, ensure the lock is engaged. Turn the appropriate wheels to verify it is fully engaged.

⚠ WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

3. Remove the carrier capscrews that hold the differential carrier to the axle housing. See **Fig. 1**.
4. With the differential carrier securely supported, remove it from the axle housing.

Installation

IMPORTANT: If you replace the yoke on the differential carrier, use a **new** nut when installing the new yoke.

NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the rear axle housing and the forward carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

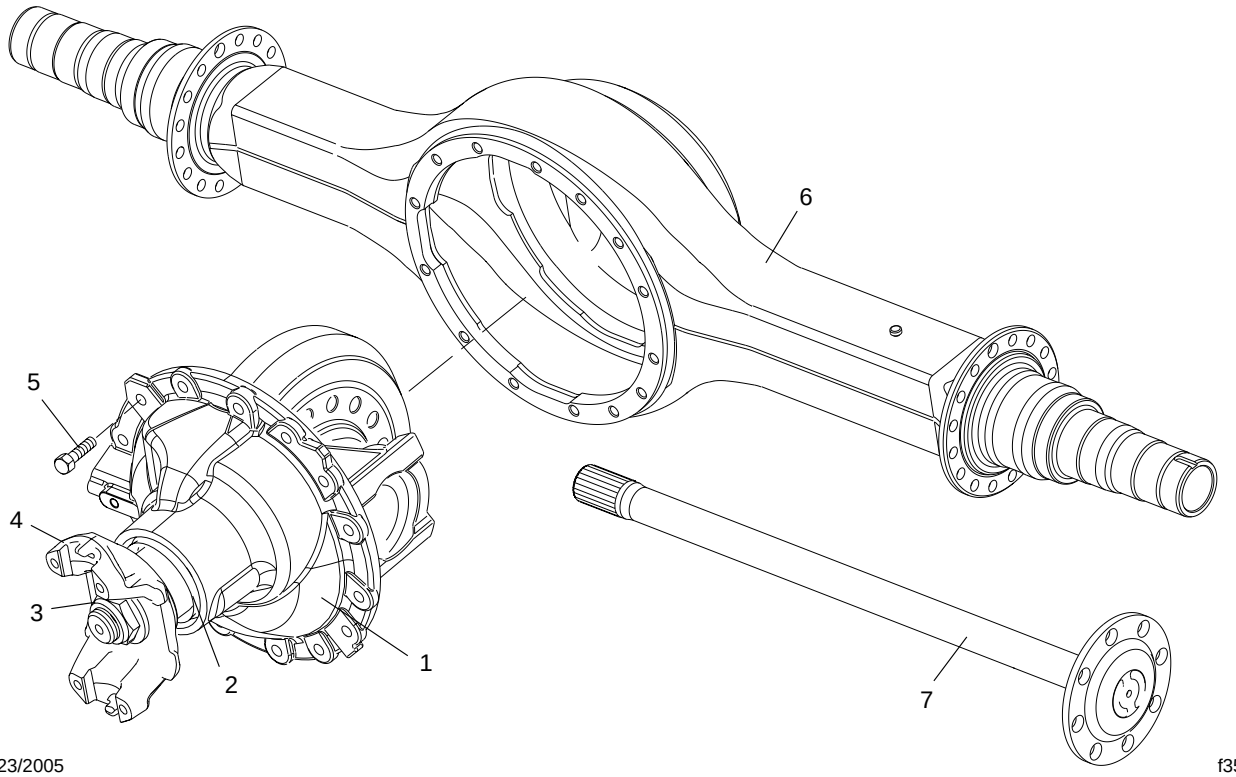
NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M16 x 1.5 x 100 mm bolts.

4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.
5. If DCDL is installed on the vehicle, ensure it is engaged.

NOTICE

Make sure the differential carrier is centered and straight on the axle housing before you install the mounting capscrews. Attempting to install the carrier when it is not centered or straight may cause damage to the carrier.

Single or Rearmost Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. Radial Shaft Seal
3. Yoke Nut
4. Carrier Yoke
5. Carrier Capscrew
6. Rear Axle Housing
7. Axle Shaft

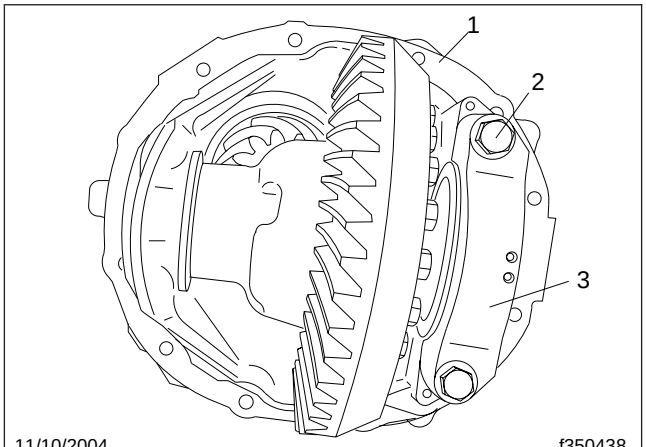
Fig. 1, Single or Rearmost Axle Components

6. Using a hoist (if the axle is removed from the vehicle) or a suitable transmission jack, install the differential carrier into the axle housing. Use the alignment dowels to center the carrier on the axle housing.
7. Install the end caps at the sides of the carrier into the corresponding slots in the axle housing. See **Fig. 2**.

   7.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

   IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

   7.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

7.3 In a star pattern, gradually tighten the M16 carrier capscrews 200 lbf·ft (270 N·m).

8. If removed, install the axle on the vehicle; see **Subject 100**.

   If the axle is already on the vehicle, go to the next step.

9. Connect the driveshaft to the carrier yoke; see **Section 41.00, Subject 120**.
10. Using new gaskets, install the axle shafts; see **Subject 120**.
11. Install the wheels and tires; see **Group 40**.
12. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Single Rear Axle Oil Type and Capacity		
Approved Oil Type	**Capacity: quarts (liters)**	
	Hubs Full	**Hubs Dry**
80W-90 Gear Oil	10.6 (10.0)	12.2 (11.5)
75W-90 Synthetic Gear Oil		

Table 1, Single Rear Axle Oil Type and Capacity

13. If the hubs are dry, raise one side of the vehicle about 4 inches (10 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

14. Turn the wheels, wait one minute, and check the lubricant level.
15. Raise the vehicle, remove the safety stands, then lower the vehicle.
16. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct.
17. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.

Removal

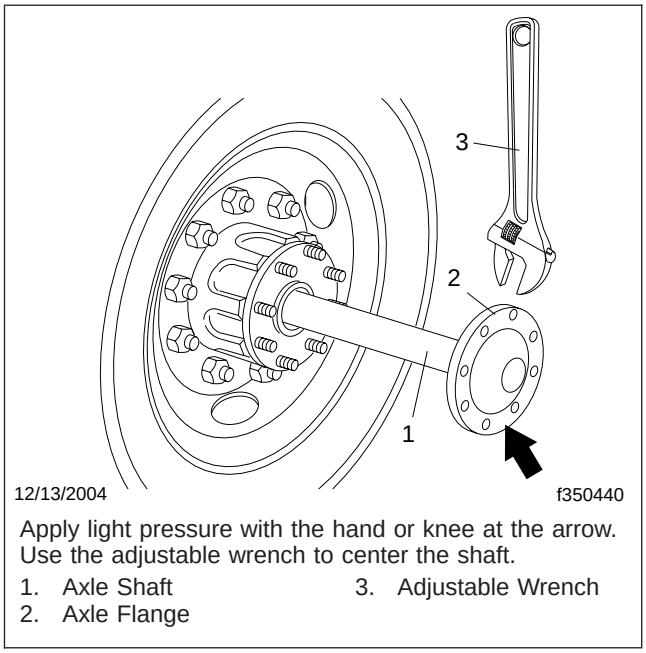
1. Chock the front tires.
2. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
3. Raise the rear of the vehicle with a suitable jack high enough to clear the axle. Support the axle with jack stands.
4. Place a basin under the axle shaft flanges to catch any oil. Dispose of used oil properly.
5. If necessary, remove the tires. For procedures, see **Group 40**.

NOTE: This procedure can be done with the wheels and tires installed or with the wheels and tires removed.

6. Remove the drive axle stud nuts that attach the axle shaft to the wheel hub.
7. Tap the axle shaft flange if necessary to loosen it, and slide the axle shaft out of the axle. Remove and discard the gasket.

Installation

1. Position a new gasket on the axle shaft flange.
2. If DCDL is installed on the vehicle, ensure it is engaged.
3. Install the axle shaft, as follows. See **Fig. 1**.
   - 3.1 Carefully raise the axle with a floor jack, and support the axle with jack stands. Slide the axle shaft into the axle.
   - 3.2 Apply light pressure with the hand or knee to the axle flange.
   - 3.3 Use an adjustable wrench to center the shaft. Turn the shaft with a slight rotating motion.
   - 3.4 Install the drive axle stud nuts and tighten them to the values given.
     - 1/2–20 nuts: 75 to 115 lbf·ft (102 to 156 N·m)
     - 5/8–18 nuts: 150 to 170 lbf·ft (203 to 230 N·m)



Apply light pressure with the hand or knee at the arrow. Use the adjustable wrench to center the shaft.

1. Axle Shaft
2. Axle Flange
3. Adjustable Wrench

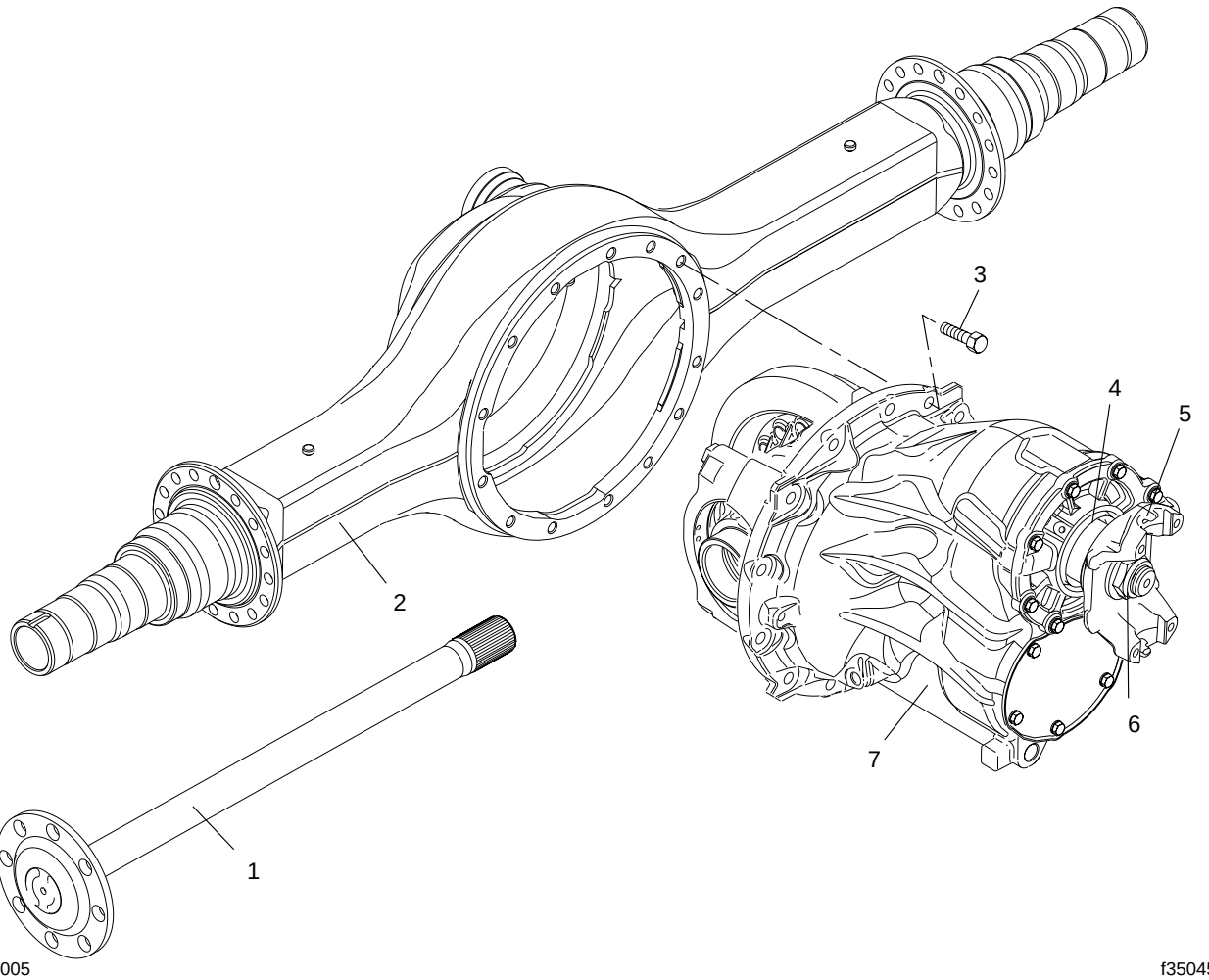
Fig. 1, Installing the Axle Shaft

4. If removed, install the tires and tighten the wheel nuts according to the procedures in **Group 40**.
5. Remove the supports and lower the vehicle.
6. As needed, replace any oil that was drained from the hub when the axle shaft was removed.

Removal

For forward-rear axle components of a tandem installation, see **Fig. 1**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. Using a suitable jack, raise the vehicle enough to take the weight off the axles, but not enough to raise the tires off the ground.
3. At both ends of the axle, loosen all the wheel nuts.



1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

Forward-Rear Axle Removal and Installation

4. Using a suitable jack, continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.

⚠ WARNING

Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the oil drain plug from the bottom of the axle housing and drain the oil from the axle housing. Install the drain plug after emptying.
7. Remove the wheels and tires. For instructions, see **Group 40**.
8. Release the parking brakes.
9. If necessary, back off the slack adjusters, then remove the brake drums.
10. If installed, make sure the optional DCDL (main differential lock) has been shifted into the engaged (locked) position.
11. If not done previously, disconnect the air lines at the interaxle lock and (if installed) the wheel lock.
12. Disconnect the main driveshaft from the forward differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
13. Disconnect the interaxle driveshaft from the output yoke of the forward-rear axle and the input yoke of the rearmost axle. For instructions, see **Section 41.00, Subject 120**.
14. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
15. Drain the air system.
16. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.
17. Remove the hubs from the axle spindles; see **Section 35.01, Subject 100**.
18. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
19. Remove the ABS sensors and wiring, and the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
20. If applicable, disconnect the leveling valve rod(s) from the suspension.
21. At the frame rail or crossmember, disconnect the wiring for the ABS sensors. Remove any tie straps that hold the wires to the frame rails.
22. Disconnect the air lines from the rear brake chambers.
23. Remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
24. Using a suitable jack, support the axle housing.
25. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
26. Remove the suspension components that attach the axle to the vehicle. If applicable, remove the U-bolt nuts from the U-bolts. Discard the U-bolt nuts and U-bolts.
27. Lower the axle enough to clear the suspension components.
28. Remove the axle from the vehicle.
29. If you are going to replace the differential carrier, place the axle on a secure axle stand.

Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

   On vehicles with air suspensions, in addition to the U-bolts, install the hexnuts that attach the air springs to the suspension brackets. For torque values, see **Group 32**.

On vehicles without U-bolts, install the walking beams.

2.2 If applicable, tighten the new U-bolt nuts in a diagonal pattern. For torque values, see **Group 32**.

3. Connect the interaxle driveshaft to the output yoke of the forward carrier and the input yoke of the rear carrier. For instructions, see **Section 41.00, Subject 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers and slack adjusters on the axle housing brackets. For instructions, see **Group 42**.
7. Connect the air lines to the brake air chambers.
8. Install the brake shoes, as removed. For instructions, see the applicable service brake section in **Group 42**.
9. Using new gaskets, install the axle shafts; see **Subject 120**.
10. Connect the main driveshaft to the forward input yoke. For instructions, see **Section 41.00, Subject 120**.
11. Connect the air hoses to the air cylinder for the interaxle lock and (if installed) the wheel lock.
12. Connect the electrical connector of the sensor unit for axles equipped with a wheel lock.
13. Fill each hub with approved axle oil until you can see a little amount of oil trickling out of the back of the hub (use about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see the applicable subject in **Section 35.01**. See **Table 1** for approved axle oils.
14. Install the brake drums on the hubs.
15. Install the wheels and tires. For instructions, see **Group 40**.
16. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
17. Uncage the parking brake springs.
18. Using approved axle oil, fill the forward-rear axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	**Capacity: quarts (liters)**	
	Hubs Full	**Hubs Dry**
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

19. Raise one side of the vehicle about 8 inches (20 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

20. Turn the wheels, wait one minute, and check the lubricant level.
21. Raise the vehicle, remove the safety stands, then lower the vehicle.
22. If applicable, connect the suspension leveling valve(s). Start the engine, build the air pressure, and make sure the suspension air bags inflate correctly. Make sure the ride height is correct. For instructions, see **Group 32**.
23. Check the operation of the wheel lock, if installed.
24. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.
25. Set the parking brake.

Forward-Rear Axle Differential Carrier Removal and Installation

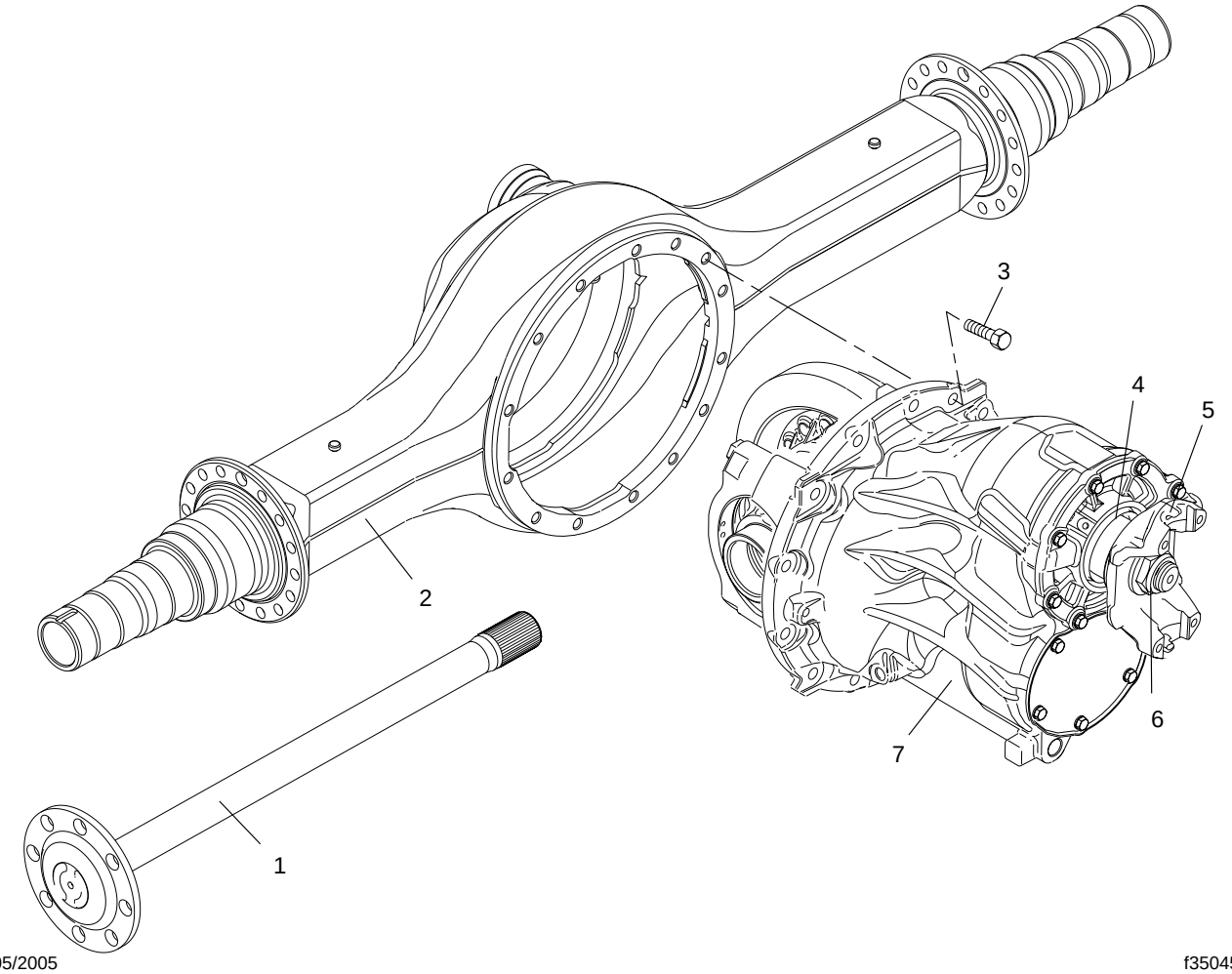
For forward-rear axle components of a tandem installation, see **Fig. 1**.

Forward-Rear Axle Differential Carrier

Do not disassemble the differential carrier. There are no serviceable parts in the differential assembly; it must be replaced as a unit. However, it is possible to remove the differential carrier to repair an oil leak.

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires. Put the transmission in neutral.
2. If applicable, release the suspension air pressure.
3. Using suitable jacks, raise the vehicle evenly until there is room to fit a jack underneath the axle housing.



1. Axle Shaft
2. Forward-Rear Axle Housing
3. Carrier Capscrew
4. Input Seal
5. Carrier Yoke
6. Input Yoke Nut
7. Forward Differential Carrier

Fig. 1, Forward-Rear Axle Components

Forward-Rear Axle Differential Carrier Removal and Installation

4. Remove the tires and wheels. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the axle housing and drain the oil from the axle housing. Install the drain plug after emptying.
6. Disconnect the driveshaft from the carrier yoke; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
7. Place a basin under the axle shaft flanges to catch any oil; then remove the axle shafts. For instructions, see **Subject 120**.
8. Using a suitable jack, support the differential carrier. Chain the differential carrier to the jack.

NOTICE

When using a pry bar, be careful not to damage the carrier or housing flange. Damage to these surfaces will cause oil leaks.

9. Remove the differential carrier from the axle housing, as follows.
   - 9.1 Remove all but the top two carrier capscrews.
   - 9.2 Loosen and back off, but do not remove, the top two carrier capscrews. The capscrews will hold the carrier in the housing.
   - 9.3 Using a pry bar, separate the mating surfaces of the differential carrier and axle housing.

   NOTE: Use a pry bar that has a round end to help separate the carrier from the housing.

   - 9.4 When the surfaces are separated, remove the top two capscrews.
   - 9.5 With the carrier on the jack, slide the carrier away from the axle housing.

⚠ WARNING

The differential carrier is heavy. Do not try to move it without a suitable support. To do so could result in the carrier falling, which could cause serious personal injury and component damage. Support the carrier with a suitable jack and chain it to the jack, or use a hoist if the axle has been removed from the vehicle.

   - 9.6 Lift the carrier assembly onto a suitable stand.

Installation

NOTE: Use a cleaning solvent and clean rags to remove dirt. Blow dry the cleaned areas with air.

1. Remove any old sealant material from the mating surfaces of the axle housing. Clean the inside of the axle housing and the carrier mating surface.
2. Inspect the axle housing for damage. Repair or replace the axle housing as necessary.
3. Apply a thin bead of Loctite® 5900 sealant all the way around the mating surface of the axle housing, and around each bolt hole.

NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M16 x 1.5 x 100 mm bolts.

4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.
5. Position the forward differential carrier in front of the axle housing, using an axle jack or other suitable lifting tool.

NOTICE

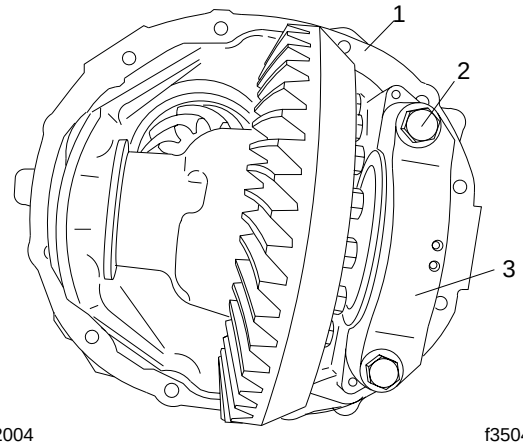
Do not use a hammer or a mallet to install the differential carrier. A hammer or a mallet will damage the mounting flange of the carrier and cause oil leaks.

6. Install the end caps at the sides of the forward differential carrier into the corresponding slots in the axle housing. See **Fig. 2**.
   - 6.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

   IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

   - 6.2 Install the forward carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.

Forward-Rear Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

6.3 In a star pattern, gradually tighten the M16 forward carrier capscrews 200 lbf·ft (270 N·m).

7. Connect the driveshaft to the carrier yoke; for instructions, see **Section 41.00, Subject 120**.
8. Using new gaskets, install the axle shafts; for instructions, see **Subject 120**.
9. Install the wheels and tires; for instructions, see **Group 40**.
10. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 1**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	Capacity: quarts (liters)	
	Hubs Full	Hubs Dry
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 1, Forward-Rear Axle Oil Type and Capacity

11. If the hubs are dry, raise one side of the vehicle about 4 inches (10 cm) to let the oil flow into the hub on the opposite side, then raise the other side in the same manner. On each side, hold the tilted position for three minutes to allow oil to run into the wheel end.

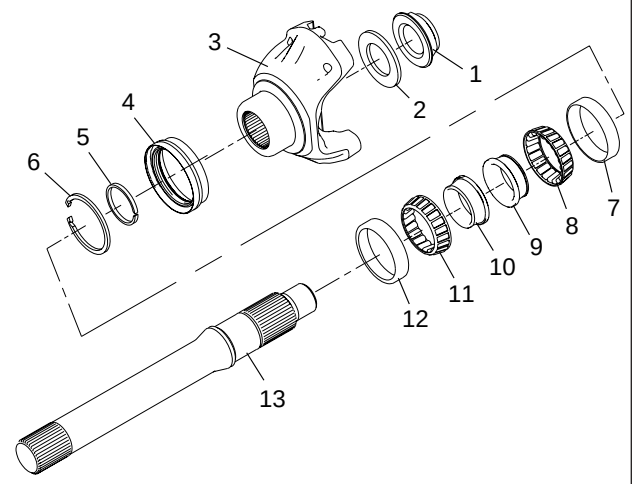
NOTICE

Make sure the hubs are filled. Driving with the hubs dry will cause bearing damage.

12. Turn the wheels, wait one minute, and check the lubricant level.
13. Raise the vehicle, remove the safety stands, then lower the vehicle.
14. Start the engine, build the air pressure, and check that the suspension air bags inflate evenly and correctly. Make sure the ride height is correct.
15. Check the oil level in the axle housing. The level should be up to the bottom of the fill hole. Add approved axle oil, if needed.

Repair

1. Remove the output yoke nut, washer, and output yoke; see **Subject 170**.
2. Remove the output oil seal from the thru-shaft bore; see **Subject 170**.
3. Remove the snap ring and spacer from the thru-shaft. See **Fig. 1**.



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1. Output Yoke Nut
2. Washer
3. Output Yoke
4. Output Oil Seal
5. Spacer
6. Snap Ring
7. Outer Bearing Race
8. Outer Bearing
9. Outer Bearing Cup
10. Inner Bearing Cup
11. Inner Bearing
12. Inner Bearing Race
13. Thru-Shaft

Fig. 1, Thru-Shaft Components

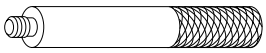
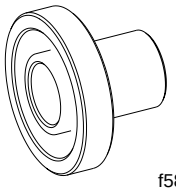
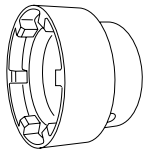
4. Using a suitable shaft puller, draw the thru-shaft out of the bore.
5. Using a suitable bearing puller on the outer races, remove both the inner and outer bearings from the thru-shaft.
6. Inspect the bearings for wear and damage. Replace both bearings if any damage is found.
7. Install the inner bearing race in the thru-shaft bore.
8. Using an arbor press or other suitable pressing tool, press the bearings and bearing cups onto the thru-shaft.
9. Insert the thru-shaft into its bore.
10. Install the outer bearing race onto the thru-shaft and bore.
11. Install the snap ring and spacer. Use the next thicker snap ring from the snap ring pack supplied with the bearings.
12. Install the output oil seal; see **Subject 170**.
13. Install the output yoke, nut, and washer; see **Subject 170**. Make sure the output yoke nut is firmly tightened, but do not tighten the nut to specifications at this time.
14. Attach a dial indicator to the flat surface of the output yoke.
15. Using a pry bar or other lever, apply force to the base of the output yoke. If the dial indicator shows a deflection of 0.0012 to 0.0024 inches (0.03 to 0.06 mm), the end play is correct.

    If the deflection is too large, use a thicker snap ring. If the deflection is too small, use a thinner snap ring.
16. Coat the threads of the nut with Loctite® 577. Tighten the output yoke nut 516 lbf·ft (700 N·m).

Single or Rearmost Axle Yoke and Seal Replacement

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools

Replacement

1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the yoke nut from the center of the carrier yoke. If the yoke nut is round and slotted, use the yoke nut socket shown in **Table 1**. See **Fig. 1**. Be careful not to damage the seal bore.
3. Remove the carrier yoke from the input shaft.
4. Pry up the seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings. See **Fig. 2**.
5. Install the rear pinion seal on the rear input shaft, as follows. See **Fig. 3**.
   - 5.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.
   - 5.2 Assemble the rear pinion seal installer onto the threaded end of the universal handle. See **Table 1**.

   IMPORTANT: Be careful not to cock the seal during installation.

   - 5.3 Using the rear pinion seal installer assembly, press the seal into the bore until the seal surface is flush with the bottom surface of the counterbore.

Single or Rearmost Axle Yoke and Seal Replacement

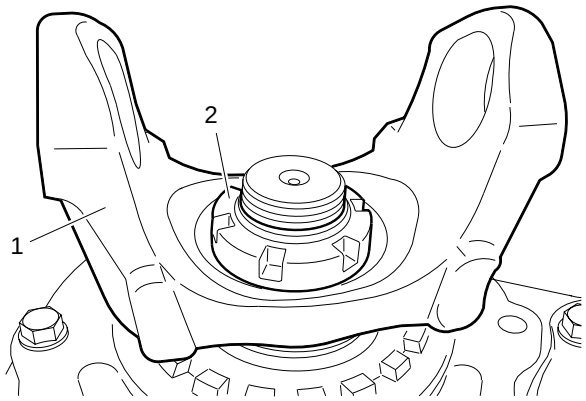
6. Install the carrier yoke on the input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

7. Install a new M45 x 1.5 yoke nut on the carrier yoke and tighten 627 lbf·ft (850 N·m).
8. Punch in the cylindrical area at the pinion groove to lock the nut in place.

IMPORTANT: The bent area has to reach the bottom of the pinion groove.

9. Connect the driveshaft. For instructions, see **Section 41.00, Subject 120**.



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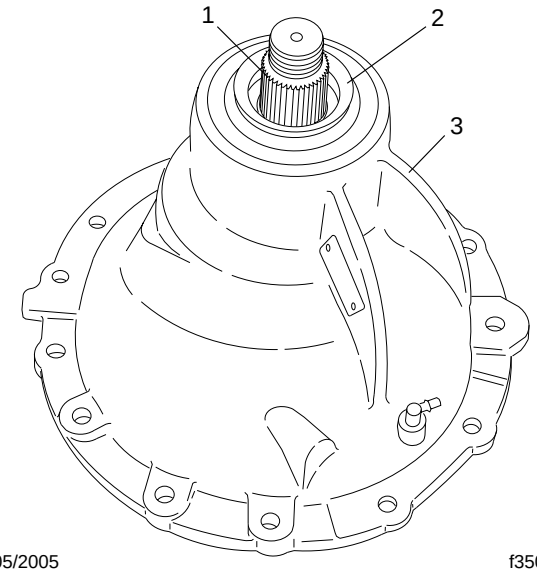
NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

Fig. 1, Yoke Nut on the Carrier



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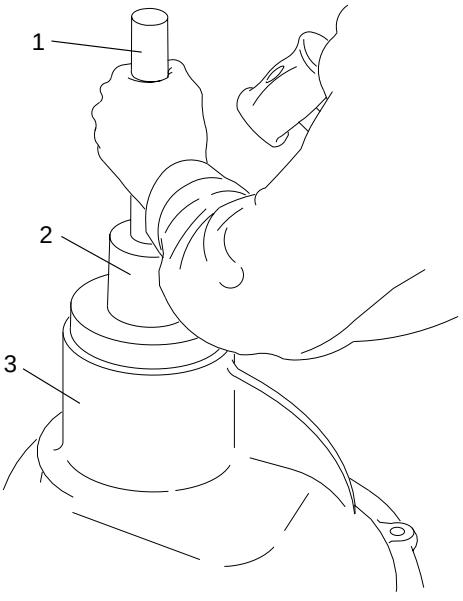
1. Input Shaft
2. Rear Pinion Seal
3. Carrier Housing

Fig. 2, Rear Pinion Seal



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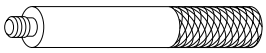
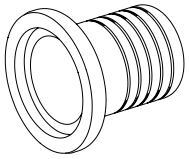
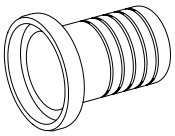
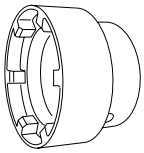
1. Universal Handle
2. Rear Pinion Seal Installer
3. Carrier Housing

Fig. 3, Installing the Rear Pinion Seal

Special Tools

Special tools are required for this procedure. See **Table 1**.

Special Tools for Forward-Rear Axle Yoke and Seal Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 1, Special Tools for Forward-Rear Axle Yoke and Seal Replacement

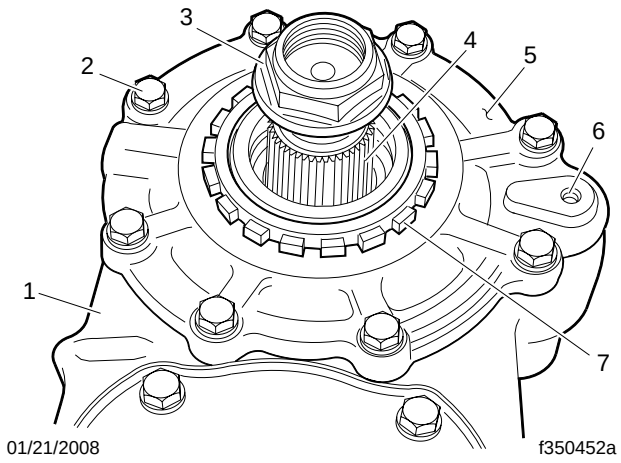
Replacement

Forward Carrier Input Yoke and Seal

1. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the input yoke nut and washer from the center of the forward carrier input yoke.
3. Remove the old forward carrier input yoke from the forward input shaft.
4. If there is an oil leak at the threaded ring, repair it; for instructions, see **Subject 200**.

Forward-Rear Axle Yoke and Seal Replacement

5. If there is a leak between the bearing cage and the carrier housing, remove the bearing cage, as follows. See **Fig. 1**.



1. Forward Carrier Housing
2. Bearing Cage Mounting Capscrew
3. Input Yoke Nut
4. Input Shaft
5. Bearing Cage
6. Interaxle Lock Bore
7. Threaded Ring

Fig. 1, Bearing Cage

5.1 Remove the bearing cage capscrews from the bearing cage.

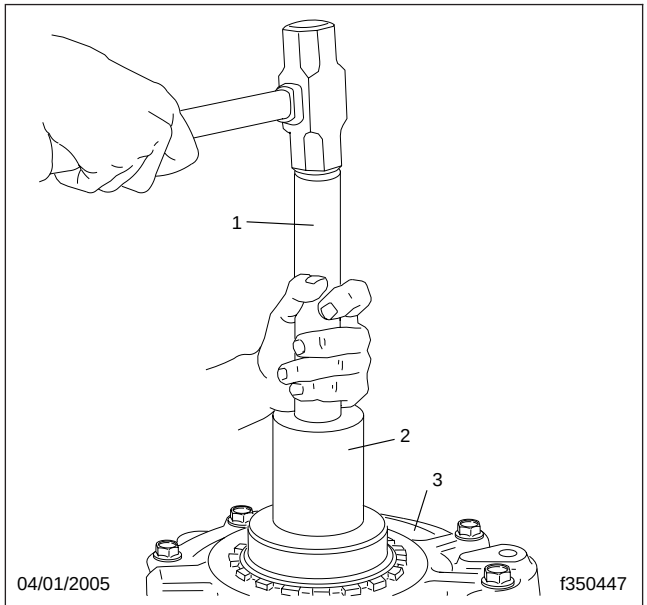
5.2 Pry the bearing cage from the forward carrier housing. Clean any remnants of sealant clinging to the mating surfaces of the carrier housing and the bearing cage.

6. Pry up the input seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings.

7. Install the seal in the input shaft bore, as follows. See **Fig. 2**.

7.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

7.2 Assemble the input seal installer onto the threaded end of the universal handle. See **Table 1**.



1. Universal Handle
2. Input Seal Installer
3. Carrier Housing

Fig. 2, Installing the Forward Carrier Input Seal

7.3 Using the input seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

8. On the mating surface of the bearing cage, lay down a bead of Loctite® 5900 sealant, or equivalent. Go around all of the bolt holes and other openings in the inside cover of the bearing cage. See **Fig. 3**.

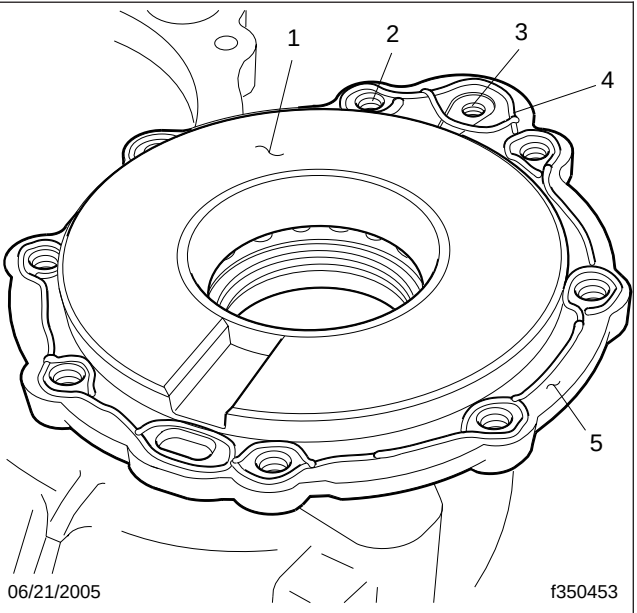
IMPORTANT: Do not allow sealant to get into the interaxle lock bore. See **Fig. 4**. Do not attempt to repair the interaxle differential lock (IAD). No repairs to this component are possible.

9. Install the bearing cage onto the forward carrier housing. Tighten the M12 bearing cage capscrews 107 lbf·ft (145 N·m).

10. Install the forward carrier input yoke on the forward input shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

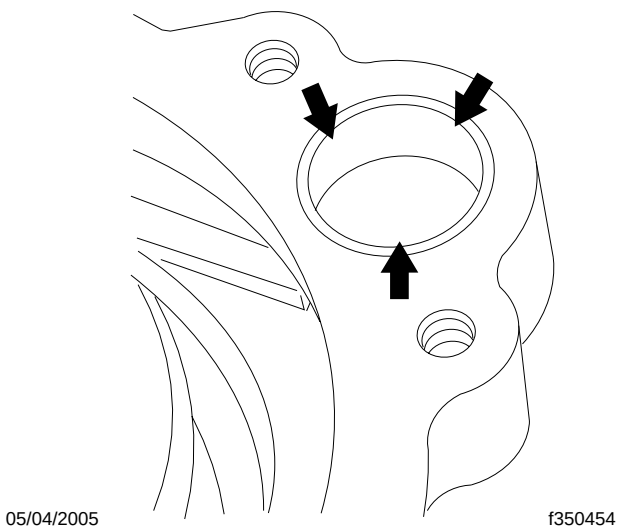
11. Coat the threads of a new M45 x 1.5 input yoke nut with Loctite® 277. Install the new washer and



Apply a bead of sealant to the inner mating surface as shown.

1. Inside Cover
2. Mounting Capscrew Hole
3. Interaxle Lock Bore
4. Sealant
5. Mating Surface

Fig. 3, Sealant Application



Keep sealant away from this bore.

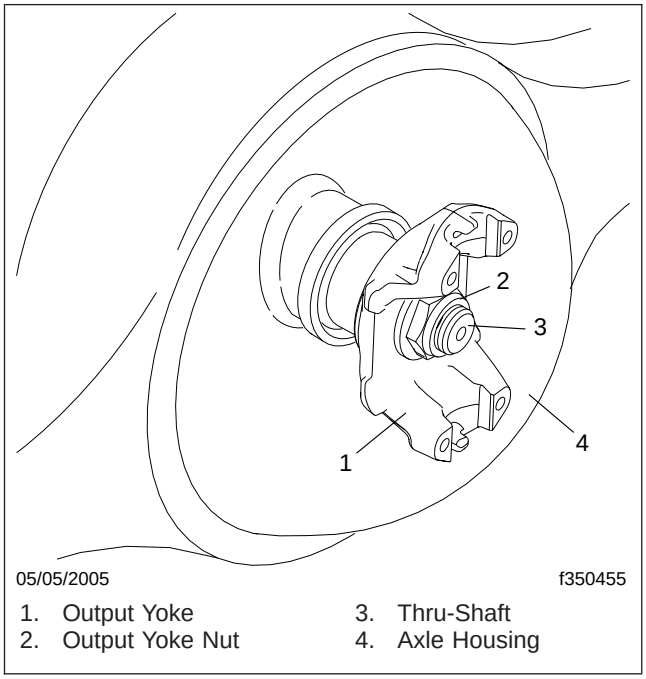
Fig. 4, Interaxle Lock Bore

input yoke nut on the forward carrier input yoke. Tighten the nut 627 lbf·ft (850 N·m).

12. Connect the main driveshaft; see **Section 41.00, Subject 120**.

Output Yoke and Seal

1. Disconnect the interaxle driveshaft from the output yoke; see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the output yoke nut and washer from the center of the output yoke.
3. Remove the output yoke from the thru-shaft. See **Fig. 5**.



1. Output Yoke
2. Output Yoke Nut
3. Thru-Shaft
4. Axle Housing

Fig. 5, Output Yoke

4. Pry up the output oil seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or thru-shaft bearings.
5. Install the seal on the thru-shaft, as follows.

   5.1 Inspect the area around the output oil seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

Forward-Rear Axle Yoke and Seal Replacement

5.2 Assemble the output seal installer onto the threaded end of the universal handle. See **Table 1**.

5.3 Using the output seal installer assembly, press the seal into the bore until the seal surface is flush with the thru-shaft receptacle.

6. Install the output yoke on the thru-shaft. If the yoke is damaged or worn, install a new yoke.

NOTE: It is not necessary to replace the yoke when replacing the seal.

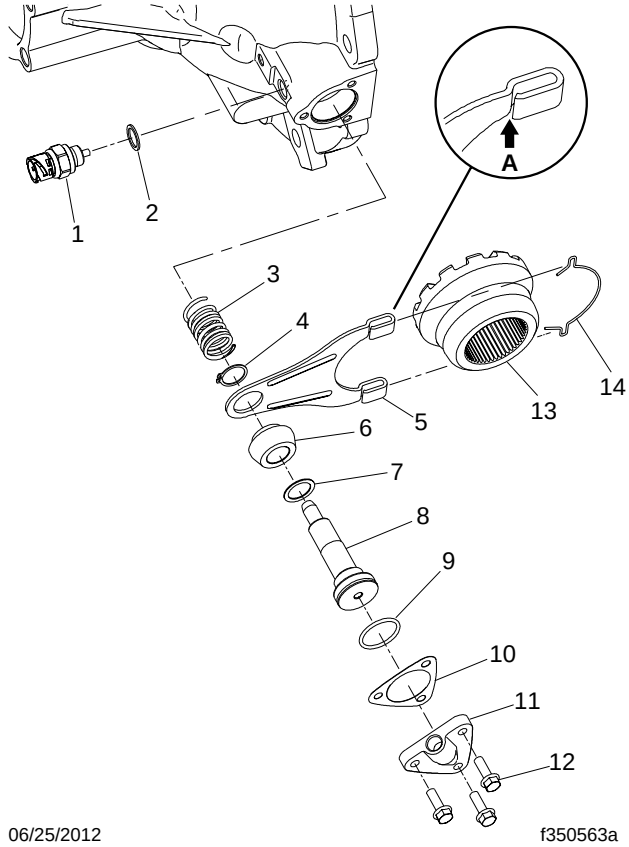
7. Coat the threads of a new M39 x 1.5 output yoke nut with Loctite® 577. Install the new washer and output yoke nut on the forward carrier output yoke. Tighten the nut 516 lbf·ft (700 N·m).
8. Connect the interaxle driveshaft; see **Section 41.00, Subject 120**.

Main Differential Lock Disassembly and Assembly

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single and tandem rear axles. On tandem rear axles DCDL is available for the forward, rear, or both axles. The following procedures only apply to Model 4 rear axles with optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.



A. Opening in fork loop faces away from the clutch collar as shown.

1. Sending Unit
2. Sending Unit Seal
3. Spring
4. Snap Ring
5. Shift Fork
6. Alignment Boss
7. Shim(s)
8. Shift Shaft Piston
9. O-Ring
10. Air Interface Gasket
11. Air Interface
12. Capscrew
13. Clutch Collar
14. Retaining Clip

Fig. 1, DCDL Components

Disassembly

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Remove the differential carrier, and place it on a work stand.

   To remove a single or rearmost axle differential carrier, see **Subject 110**.

   To remove a forward-rear differential carrier, see **Subject 140**.
3. Unlatch the retaining clip, and remove it. See **Fig. 1**.
4. Remove the clutch collar.
5. Remove the DCDL sending unit from the carrier housing.
6. Remove the three bolts that attach the air interface to the carrier housing.
7. Remove the air interface and gasket.
8. Remove the shift shaft piston from the bore in the carrier housing, and note the number of shims found on the piston. There should be at least one shim, and a maximum of three.
9. Compress the spring and pull the shift fork from the carrier housing.
10. Remove the spring from the carrier housing.

Assembly

1. Install the spring in the carrier housing, and compress it to install the shift fork in the housing. Ensure that the spring is centered in the bore.
2. Ensure the O-ring on the shift shaft piston is properly installed and lubricated. Then install the piston, being careful to properly align it in the bore. Do not force the piston into the bore.
3. Place the air interface and gasket over the air interface bore, and insert the three capscrews that attach the air interface to the carrier housing. Tighten the capscrews in a regular sequence that ensures it seats evenly. Tighten the capscrews 19 lbf·ft (25 N·m).
4. Install the clutch collar.
5. Install the retaining clip on the shift fork.

Main Differential Lock Disassembly and Assembly

6. Install the DCDL sending unit in the carrier housing, as removed.
7. Connect the DCDL air line, and engage the DCDL. Ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
8. The clearance between the clutch collar and ring gear must be between 0.4 and 1.4 mm. Engage the DCDL, and use a feeler gauge to measure the gap.

   If the gap between the clutch collar and ring gear measured between 0.4 and 1.4 mm, ensure the same number of shims are on the shift shaft piston (as when it was removed).

   If the gap between the clutch collar and ring gear was not between 0.4 and 1.4 mm, add or remove shims to vary the gap until it measures within the acceptable range. The acceptable maximum number of shims is three, and the minimum is one.
9. Install the differential carrier.

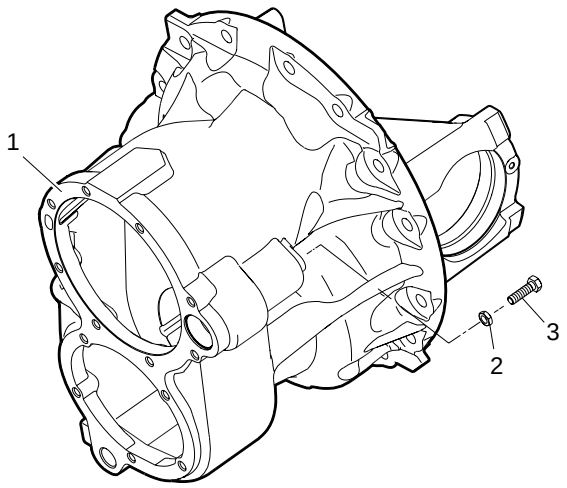
   For instructions on installing a single or rearmost axle differential carrier, see **Subject 110**.

   For instructions on installing a forward-rear axle differential carrier, see **Subject 140**.

Adjustment

The Interaxle Differential (IAD) has an adjustment screw that can become loose or even fall out, causing an oil leak, and malfunction of the IAD. To ensure the adjustment screw is properly tightened and secured, follow the steps below. The IAD is sometimes called the power divider. See **Fig. 1**.

1. Chock the front tires.
2. Use the IAD switch in the cab to engage the lock.
3. At the forward-rear axle, rotate one of the wheels to ensure the teeth of the lock fully engage the teeth of the gear inside the carrier housing.
4. Remove the adjustment screw, and using a suitable solvent (such as brake cleaner), clean the threads of the screw and bore. Dry the surfaces completely, making sure no cleaning solvent remains.
5. Coat the threads of the adjustment screw with Loctite® 577, install it, and hand-tighten it until it hits the shaft.
6. Disengage the IAD to relieve the air pressure exerted on the adjustment screw.
7. Hand-tighten the adjustment screw one quarter turn, then tighten the locknut 30 lbf·ft (41 N·m).

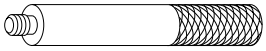
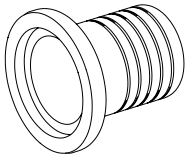


1. Carrier Housing
2. Lock Nut
3. Adjustment Screw

Fig. 1, Interaxle Differential and Adjustment Screw

Special Tools

Special tools are required for this procedure. See **Table 1**.

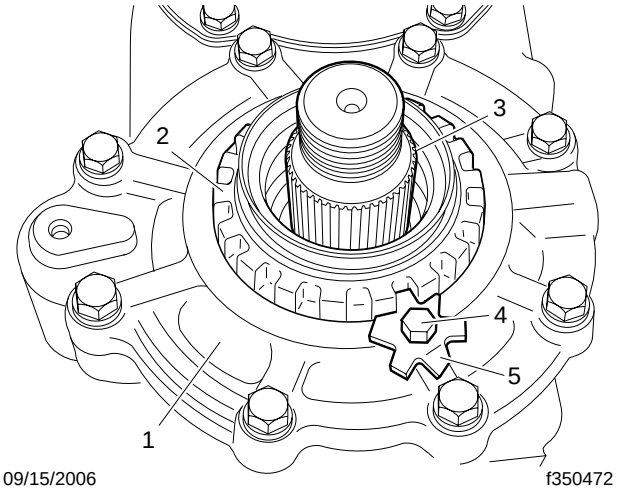
Special Tools for Threaded Ring Repair			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580410	Input Seal Installer*	Kent-Moore	J-47369

* To order Kent-Moore tools call 1-800-328-6657.

Table 1, Special Tools for Threaded Ring Repair

Repair

1. Apply the parking brakes, shut down the engine, and chock the tires.
2. Disconnect the main driveshaft from the forward carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
3. Remove the yoke nut and washer from the input shaft of the forward differential carrier, then remove the yoke.
4. Remove the capscrew and the locking plate from the bearing cage on the front of the differential carrier. See **Fig. 1**.
5. Using a spanner wrench, remove the threaded ring to expose the bearing cavity. See **Fig. 2**.
6. Using a suitable solvent, such as brake cleaner, clean the surface of the bearing cavity. See **Fig. 2**. Dry the surface, making sure no cleaning solvent remains.
7. Coat the threads of the threaded ring with Loctite® 577 sealant. Apply a 1/8-inch (3-mm) diameter bead all the way around the bottom thread, then spread the sealant evenly over the threads, so that all threads are thoroughly covered with the sealant.



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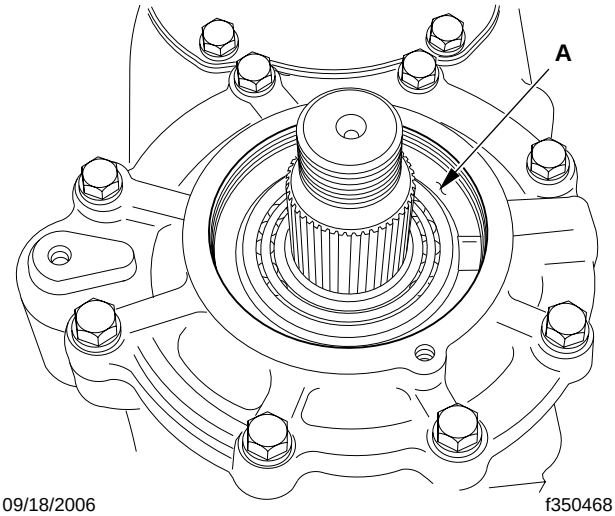
1. Bearing Cage
2. Threaded Ring
3. Input Shaft (yoke removed)
4. Capscrew
5. Locking Plate

Fig. 1, Forward-Rear Axle Differential Housing

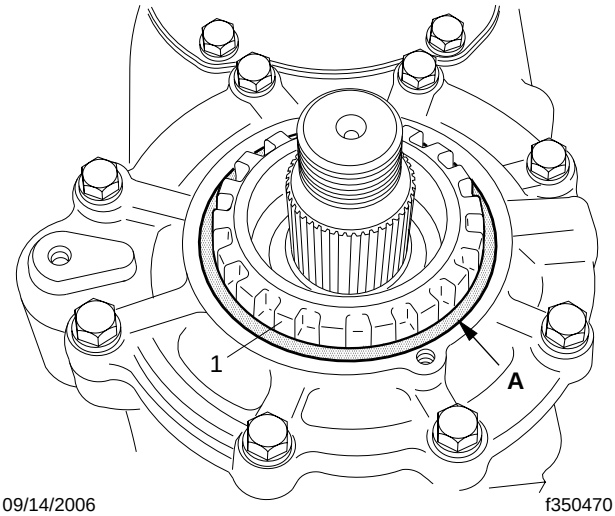
Threaded Ring Repair



A. Clean and dry this entire surface.

Fig. 2, Bearing Cavity Exposed

8. Install the threaded ring (without the new input-shaft seal) and turn it clockwise (tighten it) enough to form a uniform bead of sealant all the way around the threaded ring. See **Fig. 3**.

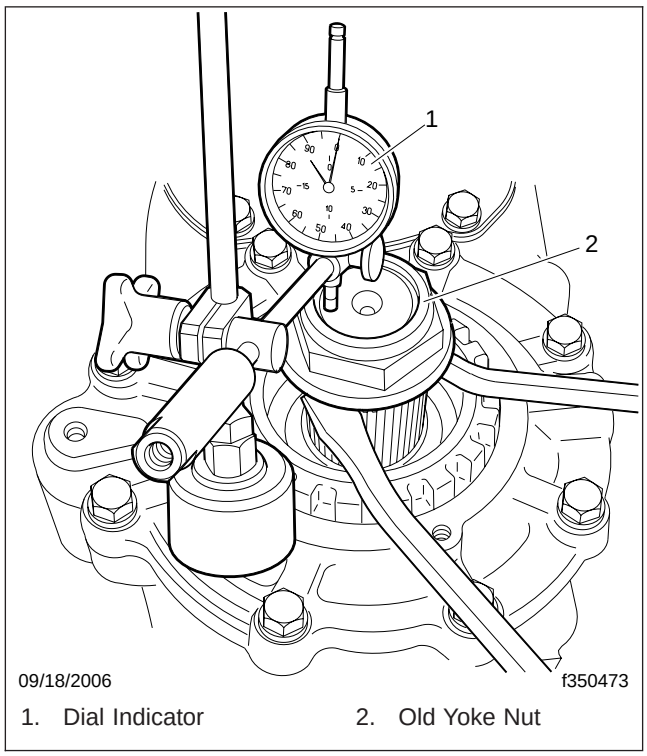


A. Loctite Bead from the Threads

1. Threaded Ring

Fig. 3, Preliminary Installation of the New Threaded Ring

9. Install the old yoke nut on the input shaft to protect the threads, then strike the nut sharply with a brass mallet to unseat the bearing.
10. Adjust the initial bearing preload to 0.002 inch (0.05 mm), as follows:
    10.1 Install a dial indicator on the bearing cage, and using two pry bars, pry up evenly on the yoke nut (and the input shaft) to determine the bearing preload. See **Fig. 4**.



1. Dial Indicator
2. Old Yoke Nut

Fig. 4, Measuring Bearing Preload

    10.2 Tighten the threaded ring until the dial indicator reads 0.002 inch (0.05 mm).
11. Using a suitable marker or paint, mark the center of one of the teeth on the threaded ring and the surface of the bearing cage. See **Fig. 5**.

IMPORTANT: The next step is critical. Tightening the threaded ring by advancing it one tooth will set the bearing preload to 0.00 to 0.0012 inch (0.00 to 0.03 mm). If you tighten the threaded ring beyond this tolerance, you cannot back it off; you will need to remove the threaded ring and repeat the entire installation procedure.

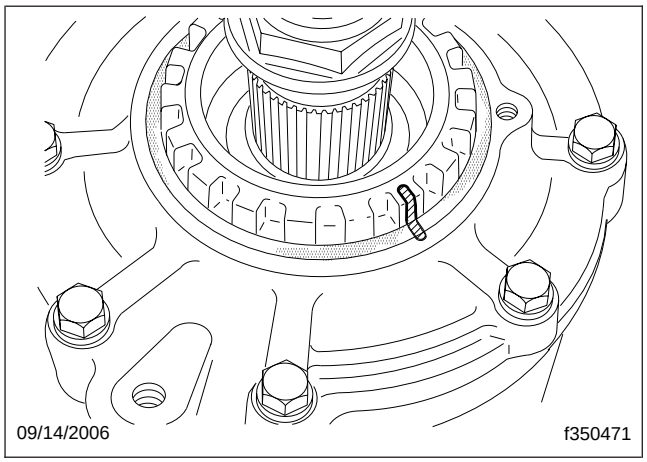


Fig. 5, Marking the Tooth and Bearing Cage

12. Very carefully advance the threaded ring one tooth while checking the paint mark. Stay close to a one-tooth advancement when making the final adjustment. Bear in mind that the new locking plate must fit into place once the correct tightness is achieved. The locking tab should fit in place either slightly before or slightly past a one-tooth advancement of the threaded ring. *You cannot back off the threaded ring once it is tightened.*

    Try fitting the new locking plate in place by turning and flipping it over as you slowly tighten the threaded ring. Tighten the threaded ring so the bearing preload is 0.00 to 0.0012 inch (0.00 to 0.03 mm). When the correct tolerance is reached, the mark on the surface of the bearing cage should line up with the center of the next tooth. See **Fig. 6**. Do not tighten the threaded ring any further.

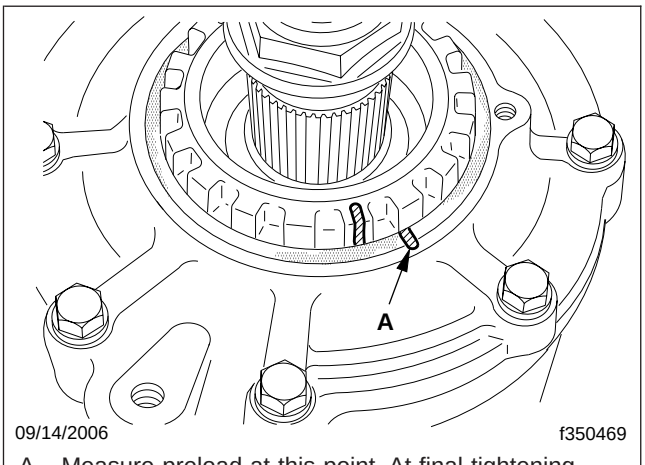
13. When the bearing preload is correct, install the new locking plate and capscrew. Tighten the capscrew 18 lbf·ft (24 N·m).

14. Install the new input-shaft seal as follows (see **Fig. 7**):

    14.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.

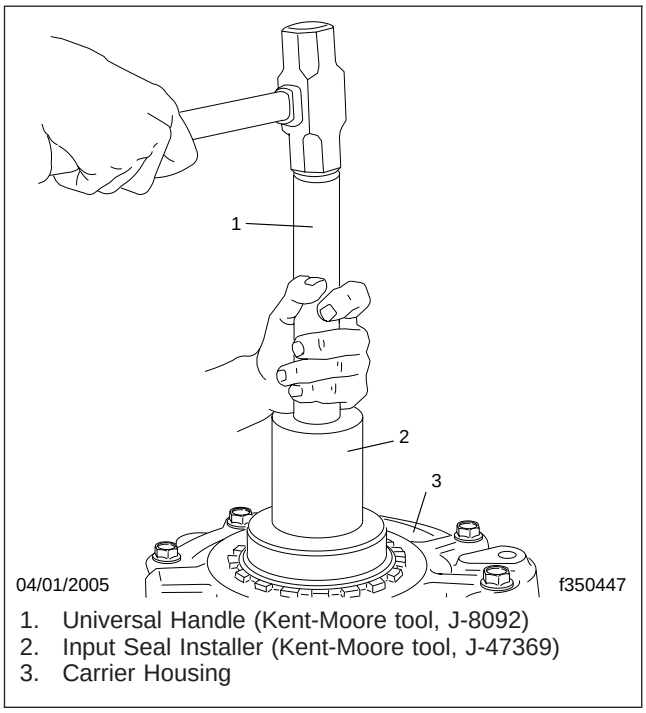
    14.2 Apply a light coating of axle oil to the seal bore.

    14.3 Coat the mating surfaces of the new seal with Loctite® 5900 sealant, or equivalent.



A. Measure preload at this point. At final tightening, this mark should be opposite the center of the next tooth, but no further.

Fig. 6, Advancing the Threaded Ring



1. Universal Handle (Kent-Moore tool, J-8092)
2. Input Seal Installer (Kent-Moore tool, J-47369)
3. Carrier Housing

Fig. 7, Installing the Forward Carrier Input Seal

14.4 Assemble the input shaft seal installer onto the threaded end of the universal handle. See **Fig. 7**.

Threaded Ring Repair

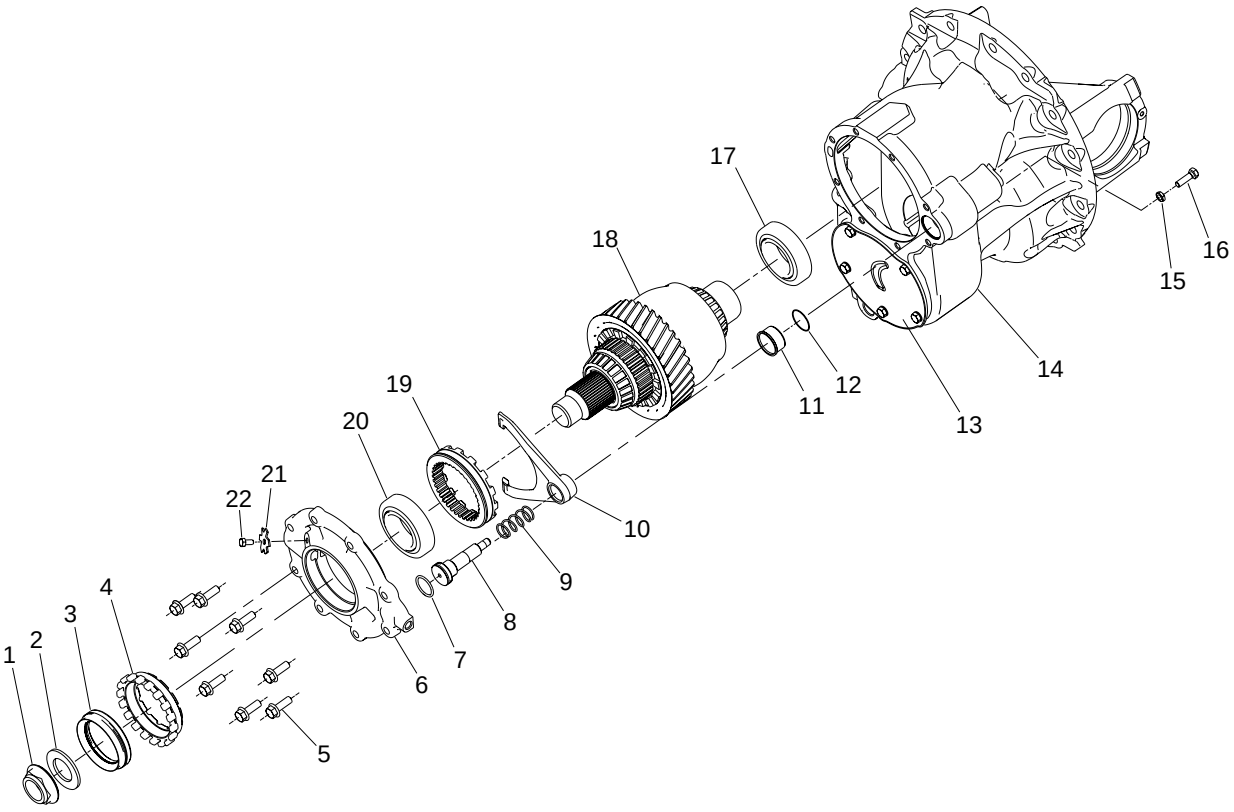
14.5 Using the input shaft seal installer assembly, press the seal into the bore until the seal surface is flush with the threaded ring.

15. Apply Loctite 242 to the threads of the new yoke nut, then using it and a new washer, install the existing yoke on the input shaft. Tighten the yoke nut 628 lbf·ft (850 N·m).
16. Connect the main driveshaft to the input shaft. For instructions, see **Section 41.00, Subject 120**.

The following on-vehicle procedure replaces the interaxle differential (IAD) assembly and accomplishes a minor carrier rebuild by replacing the bearing races and, as needed, the shift shaft bushing. The front cover is resealed and the input shaft seal is replaced. See **Fig 1**.

Special Tools

Special tools are required for this procedure. See **Table 1**.

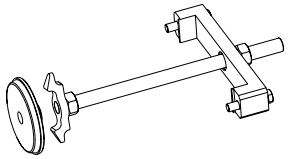
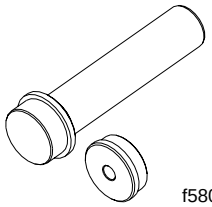
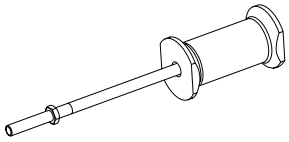
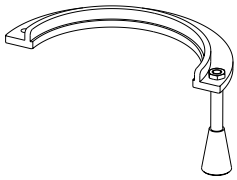
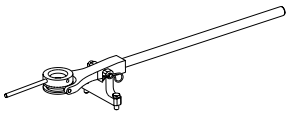


11/02/2011 f350514

1. Yoke Nut
2. Washer
3. Input Shaft Seal
4. Threaded Ring
5. Bearing Cage Capscrews
6. Bearing Cage
7. Shift Shaft Piston O-ring
8. Shift Shaft Piston
9. Piston Spring
10. Shift Fork
11. Shift Shaft Bushing
12. Shift Shaft Bushing O-ring
13. Cover Plate
14. Carrier Housing
15. Locknut
16. IAD Adjustment Screw
17. Output Bearing Race
18. IAD Assembly
19. Clutch Collar
20. Input Bearing Race
21. Locking Plate
22. Locking Plate Capscrew

Fig. 1, The Interaxle Differential and Carrier Housing Components

Interaxle Differential Replacement

Special Tools for Interaxle Differential Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580478	Output Bearing Remover and Installer	Daimler	MBA 420589003300
 f580480	Shift Shaft Bushing Remover and Installer	Daimler	MBA 420589013300
 f580476	Slide Hammer	Daimler	MBA 060589003300
 f580479	Half-Moon Device	Daimler	MBA 420589006300
 f580477	Push-Pull Device	Daimler	MBA 420589001600

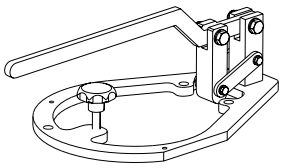
Special Tools for Interaxle Differential Replacement			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580481	Shift Shaft Piston Installer	Daimler	MBA 420589023300

Table 1, Special Tools for Interaxle Differential Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the front tires.
2. Ensure the interaxle differential is disengaged and the system is charged with air. The rear wheels will need to turn near the end of this procedure.
3. Place a suitable strap around the driveshaft and frame to hold the driveshaft out of the way after it is disconnected.
4. Disconnect the main driveshaft from the forward carrier input yoke (for instructions, see **Section 41.00, Subject 120**), and support it with the strap.
5. Clean the carrier housing and surrounding area as needed to remove any debris that could enter the housing.
6. Drain the oil from the carrier housing.
7. Disconnect the air line connected to the bearing cage.
8. Remove the yoke nut and washer from the input shaft of the forward differential carrier, then remove the yoke.
9. Remove the capscrew and the locking plate. See **Fig 1**.
10. Using a spanner wrench, remove the threaded ring by turning it counterclockwise.
11. Remove the bearing cage capscrews from the bearing cage, and pry the bearing cage from the carrier housing. It may help to tap the bearing cage loose with a chisel; see **Fig. 2**.

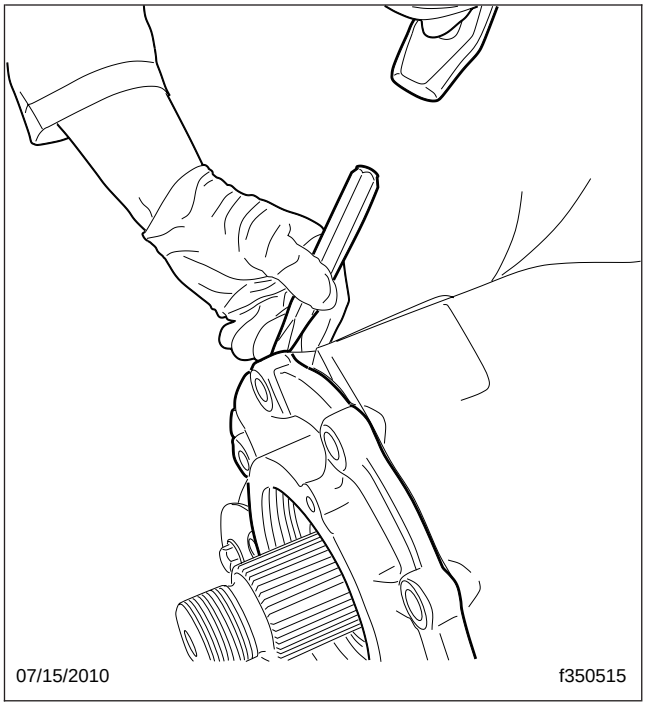


Fig. 2, Tapping the Bearing Cage Loose

12. Remove the IAD adjustment screw and locknut.

NOTICE

When unseating the shift shaft piston, multiple taps may be needed, but use moderate force only and be careful to hit the piston only (not the housing). Stop tapping it once it protrudes from the housing. The use of excessive force, or tapping it while it protrudes from the housing can damage the piston and the housing.

Interaxle Differential Replacement

13. Using a brass or plastic mallet, squarely tap the shift shaft piston to unseat it, and then remove it from the carrier housing.
14. Remove the piston spring, clutch collar, and shift fork.

NOTICE

The IAD assembly is heavy. Use appropriate support while removing and transporting it to prevent dropping and damaging it. Do not allow it to rest on the oil slinger; see Fig. 3. Resting the IAD assembly on the oil slinger could damage the oil slinger.

15. Remove the IAD assembly.
16. Align the output bearing remover (see **Table 1**) with the notches in the rear of the carrier housing, then attach it to the housing with bearing cage capscrews, and use it to remove the output bearing race. See **Fig. 4**.
17. If the brass shift shaft bushing is damaged or worn, assemble the slide hammer and shift shaft bushing remover (see **Table 1**), and slide the hammer handle to remove the bushing. See **Fig. 5**.
18. Using a suitable solvent (such as brake cleaner), clean any remaining sealant from the threaded ring and mating surfaces of the carrier housing and the bearing cage. Dry the surfaces with compressed air, ensuring no cleaning solvent remains.

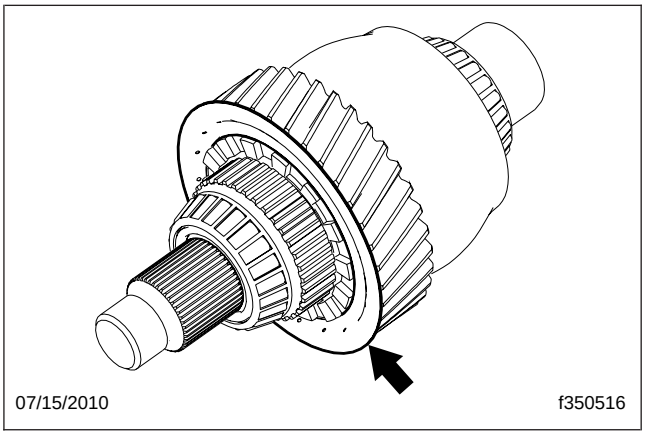


Fig. 3, Oil Slinger

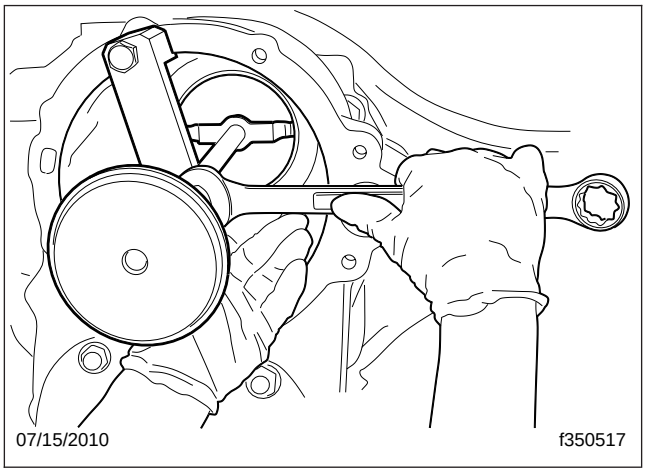
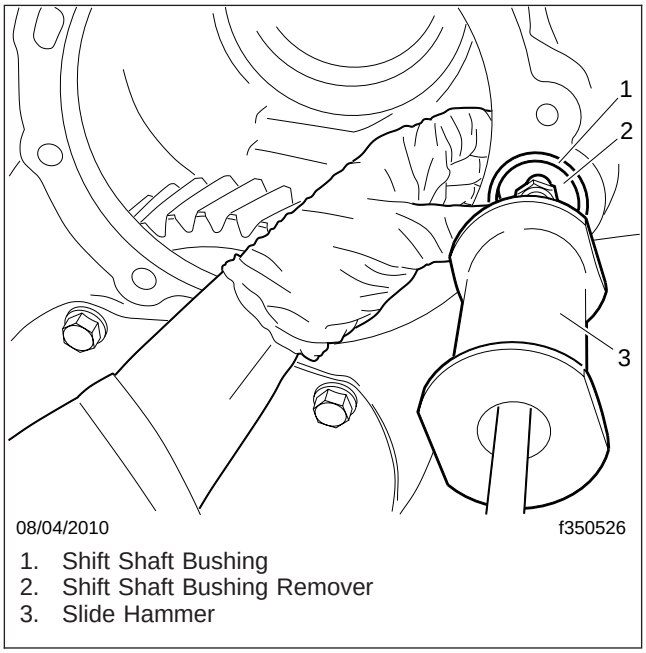


Fig. 4, Removing the Output Bearing Race

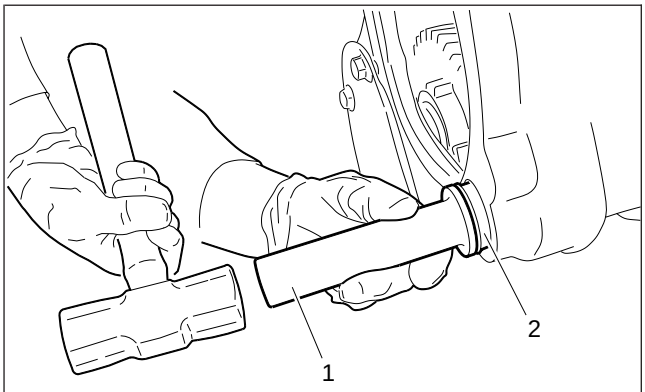


1. Shift Shaft Bushing
2. Shift Shaft Bushing Remover
3. Slide Hammer

Fig. 5, Installing the Bushing Remover

19. As in the previous step, clean the groove at the piston bushing bore.
20. If the brass shift shaft bushing was removed, install a new one using a mallet and the Shift Shaft Bushing Installer. See **Fig. 6**.
21. A new output bearing race is included with the new IAD. Install it as follows.

    21.1 To get it started, lightly tap the race into place with a hammer handle or wood



1. Shift Shaft Bushing Installer
2. Shift Shaft Bushing

Fig. 6, Installing the Bushing

block. The race must be square in the housing or damage will occur when it is pressed. See **Fig. 7**.

21.2 Fasten the output bearing installer to the carrier housing, and use it to press the race into the housing. As the race is installed, slight jerks can be felt and heard. See **Fig. 8**.

22. Lubricate the output gear and bearing of the new IAD assembly with white grease.
23. Install the IAD assembly and output gear. Do not allow the assembly to rest on the oil slinger.
24. Install the clutch collar and shift fork.
25. Apply a thin film of white grease to the shift shaft piston, and insert it with the piston spring into the housing until about 1 inch (2.5 cm) of the piston protrudes from the bore.
26. The half-moon device (see **Table 1**) helps align the shift fork and shift shaft piston. To install it, slide it between the oil slinger and the shift fork. See **Fig. 9**.
27. Install the shift shaft piston as follows.

27.1 The shift shaft piston installer (see **Table 1**) is designed to install the piston without damaging it or the carrier housing. Use two bearing cage capscrews to mount it to the carrier housing. See **Fig. 10**.

27.2 Adjust the hex screw until the shift fork is snug but not bound.

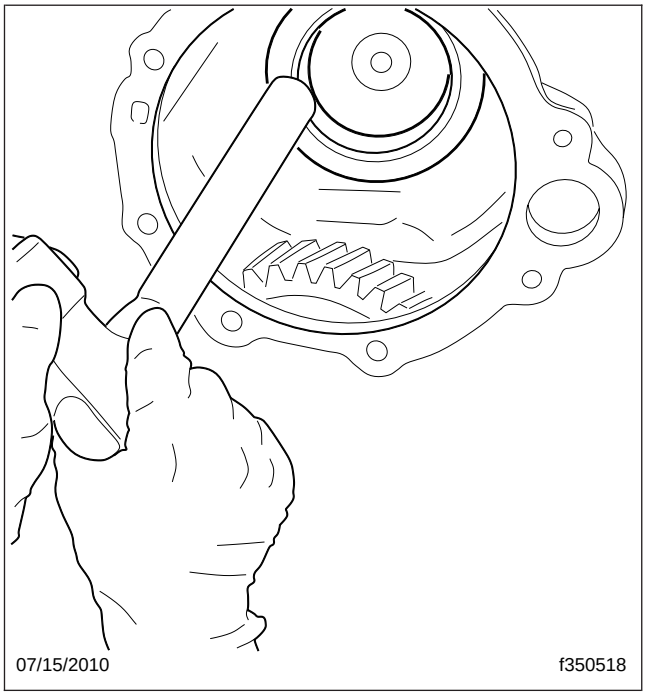


Fig. 7, Setting the Race

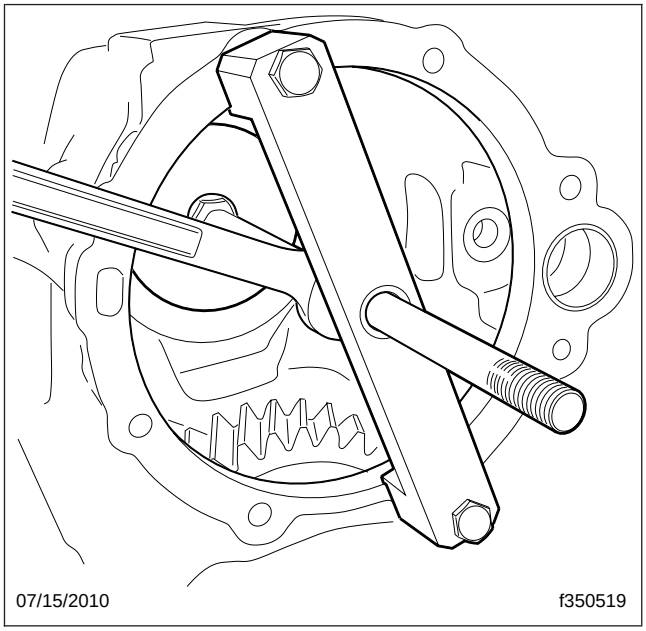


Fig. 8, Pressing a New Race into the Housing

27.3 In a single movement of moderate force, use the lever of the installer to press the piston into the bore until only about 1/8 to

Interaxle Differential Replacement

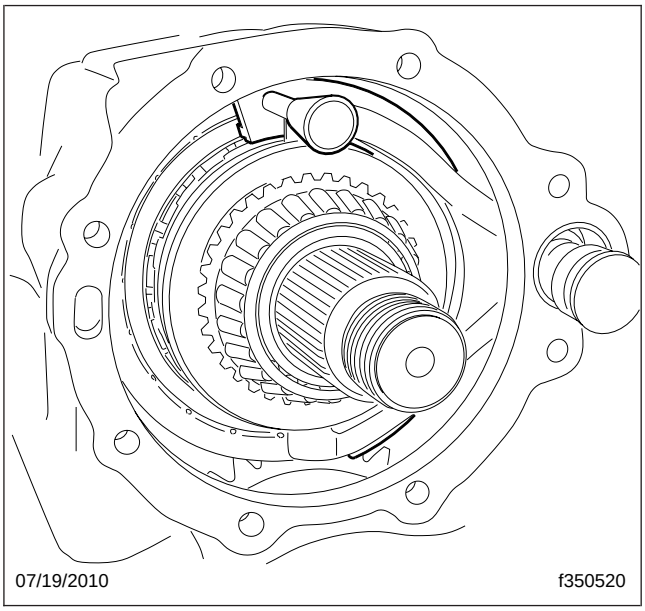


Fig. 9, The Half-Moon Device, Installed

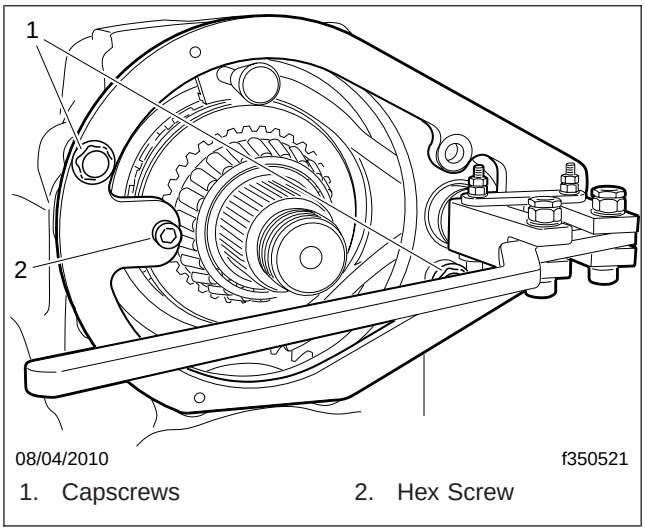


Fig. 10, Shift Shaft Piston Installer, Mounted

1/16 inch (2 to 3 mm) of the piston protrudes from the carrier housing. When the piston seats, a "click" sound may be audible. If the piston does not seat readily, adjust the hex screw, and try again.

27.4 Once the piston is seated, remove the shift shaft piston installer and the half-moon device.

28. Remove the input bearing race from the bearing cage. Place the new race into the cage so that it is more forward than in the final position. As the preload is adjusted, the race will seat to its final position.

29. Apply Loctite® 577 sealant to the threads of the threaded ring and tighten it until it is snug against the race.

IMPORTANT: Do not overapply sealant. Do not allow sealant to enter the oil return or touch the shift shaft piston.

30. Apply a small bead of Loctite 5900 to the carrier housing. See **Fig. 11**. To help ensure a good seal, spread it uniformly over the surface area.

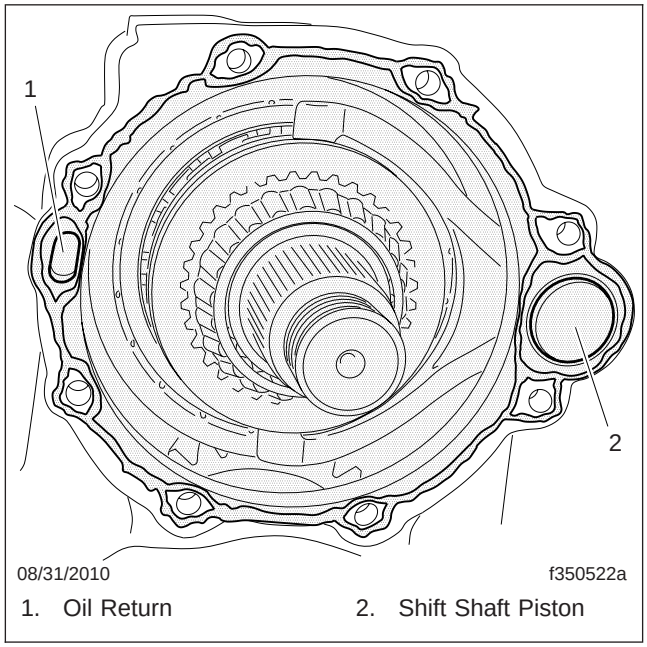


Fig. 11, Sealant Applied to Carrier Housing

31. Install the bearing cage, and using a star pattern tighten the capscrews to 103 lbf·ft (140 N·m).

32. The push-pull device (see **Table 1**) is used to set pre-load on the input bearing. Remove the two upper capscrews from the cover plate and install the device as shown in **Fig. 12**.

33. Set the correct end play as follows.

33.1 Set up a dial indicator as shown in **Fig. 13**.

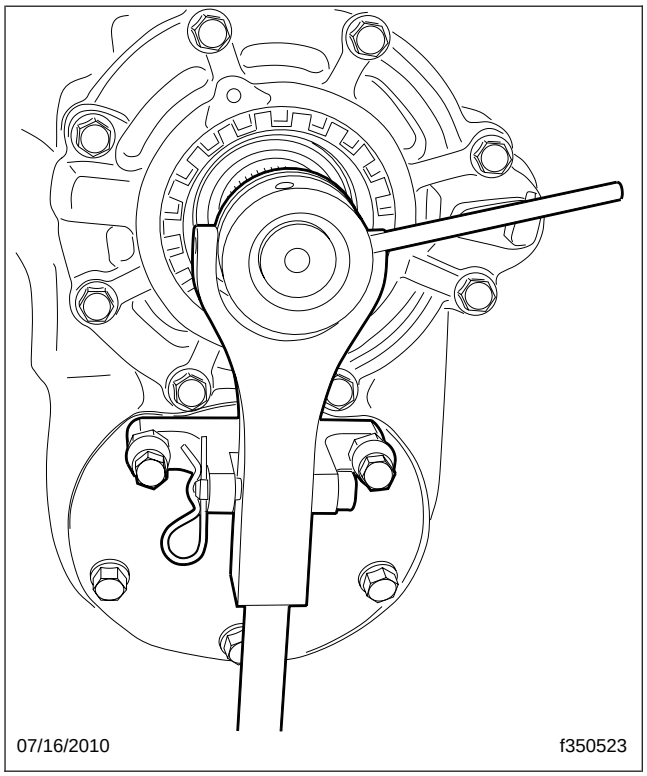


Fig. 12, Push-Pull Device, Installed

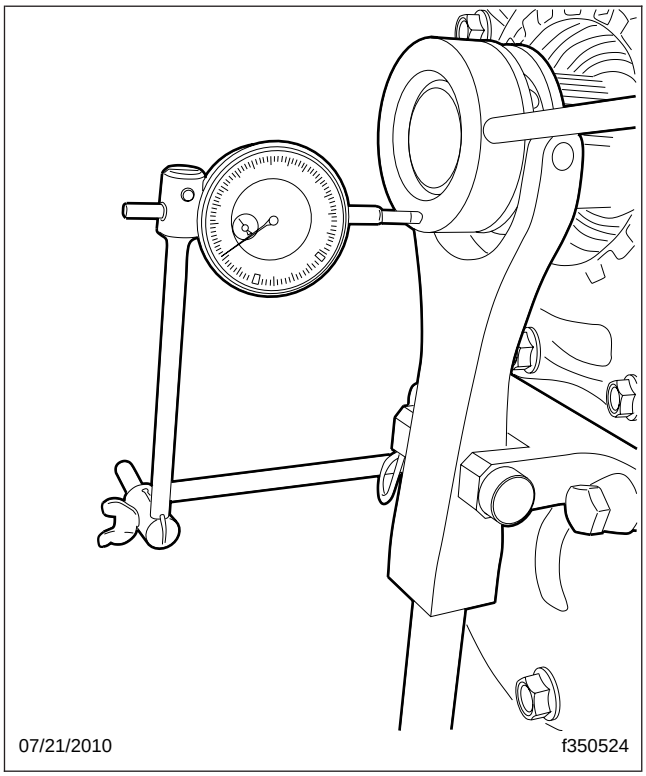


Fig. 13, Dial Indicator and Push-Pull Device

33.2 Turn the input shaft three revolutions and tighten the threaded ring until there is between 0.002 and 0.003 inch (0.05 and 0.08 mm) of end play. Turn the input shaft three more revolutions and verify the measurement.

33.3 When there is between 0.002 and 0.003 inch (0.05 and 0.08 mm) of end play, align a mark on the threaded ring with one on the bearing cage. See **Fig. 14**.

33.4 Tighten the threaded ring almost one notch.

IMPORTANT: Do not loosen the threaded ring. If the threaded ring is loosened, the bearing cage must be removed and the race re-installed.

33.5 The locking plate has six positions that can lock the threaded ring. Find the position that fits best, install it, and tighten the capscrew 18 lbf·ft (24 N·m).

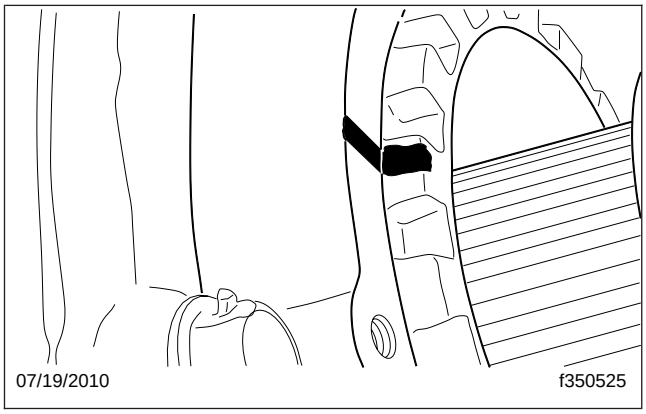


Fig. 14, Threaded Ring and Bearing Cage, Marked

33.6 Remove the push-pull device and dial indicator, and install the the two upper capscrews on the cover plate. Tighten the capscrews 63 lbf·ft (85 N·m).

34. Install a new input shaft seal and the yoke, nut, and washer; see **Subject 170** for instructions.

Interaxle Differential Replacement

35. Clean, install, and adjust the IAD adjustment screw and locknut as follows.
    - 35.1 Clean the IAD adjustment screw and locknut with a suitable solvent (such as brake cleaner). Dry the cleaned surfaces, ensuring no solvent remains.
    - 35.2 Connect an air line at the interaxle lock.
    - 35.3 Apply air, and by hand, turn the input shaft to ensure the gear cogs fully engage.
    - 35.4 Coat the threads of the adjustment screw with Loctite® 577.
    - 35.5 Install the adjustment screw, with the locknut, into the carrier housing, and handtighten the screw until it touches the engaged shift shaft piston.
    - 35.6 Disengage the IAD to relieve the air pressure exerted on the adjustment screw.
    - 35.7 Hand-tighten the adjustment screw one quarter turn, then tighten the locknut 30 lbf·ft (41 N·m).
36. Connect the main driveshaft; for instructions, see **Section 41.00, Subject 120**.
37. Using approved axle oil, fill the axle housing to the bottom of the fill hole, or until filled to capacity as shown in **Table 2**.

Forward-Rear Axle Oil Type and Capacity		
Approved Oil Type	**Capacity: quarts (liters)**	
	Hubs Full	**Hubs Dry**
80W-90 Gear Oil	14.3 (13.5)	15.9 (15.0)
75W-90 Synthetic Gear Oil		

Table 2, Forward-Rear Axle Oil Type and Capacity

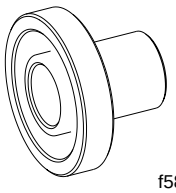
38. To lubricate the wheel ends, tilt the axle to the left and right by jacking the opposite side 8 inches (20 cm). Hold the tilted position for two minutes on each side to allow oil to run into the wheel end. Return the axle to a level position, and add oil through the axle housing filler hole. About two more pints (1 liter) of lubricant will be needed to bring the oil level even with the base of the filler hole.

Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
All Model 4 Axles		
Carrier Capscrews	M16	200 (270)
Drive Axle Stud Nuts	1/2–20	75–115 (102–156)
	5/8–18	150–170 (203–230)
Yoke Nut (model 4 axles)	M45 x 1.5	627 (850)
Forward-Rear Axles		
Bearing Cage Capscrews	M12	107 (145)
Input Yoke Nut	M45 x 1.5	627 (850)
Output Yoke Nut	M39 x 1.5	516 (700)

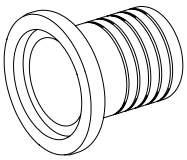
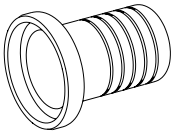
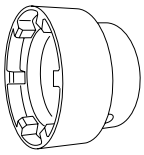
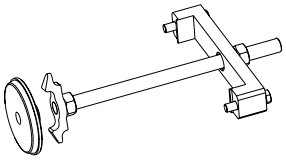
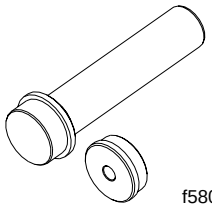
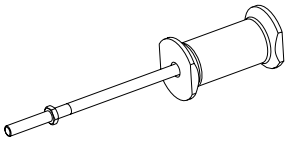
Table 1, Torque Values

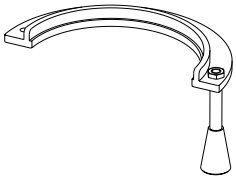
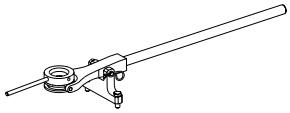
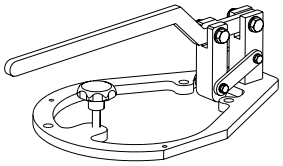
Rear Axle Lubricant Type and Capacity			
Approved Lubricant Type	**Axle**	**Oil Capacity: quarts (liters)**	
		Hubs Full	**Hubs Dry**
80W/90 Gear Oil	Forward-Rear	14.3 (13.5)	15.9 (15.0)
75W/90 Synthetic Gear Oil			
80W/90 Gear Oil	Single and Rearmost Tandem	10.6 (10.0)	12.2 (11.5)
75W/90 Synthetic Gear Oil			

Table 2, Rear Axle Lubricant Type and Capacity

Special Tools for Detroit Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354

Specifications

Special Tools for Detroit Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580410	Input Seal Installer*	Kent-Moore	J-47369
 f580408	Output Seal Installer*	Kent-Moore	J-47368
 f580450	Yoke Nut Socket†	Daimler	MBA 742589020700
 f580478	Output Bearing Remover and Installer	Daimler	MBA 420589003300
 f580480	Shift Shaft Bushing Remover and Installer	Daimler	MBA 420589013300
 f580476	Slide Hammer	Daimler	MBA 060589003300

Special Tools for Detroit Rear Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580479	Half-Moon Device	Daimler	MBA 420589006300
 f580477	Push-Pull Device	Daimler	MBA 420589001600
 f580481	Shift Shaft Piston Installer	Daimler	MBA 420589023300

* To order Kent-Moore tools call 1-800-328-6657.

† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 3, Special Tools for Detroit Rear Axles

General Description

Tires support the weight of the vehicle, and are integral parts of the transmission and braking systems. Wheels serve as load carrying members between the tires and the axle.

Disc wheels are comprised of a rim and disc. The rim, the portion of the wheel on which the tire is mounted and supported, is welded to the disc. See **Fig. 1**. After the tire is mounted on the wheel, the assembly is held in place on the hub with wheel studs and nuts. All standard and optional steel and aluminum disc wheels are hub-mounted, using ten 2-piece flanged nuts to hold single front wheels and both, inner and outer, dual rear wheels centered on the pilot pads of the hub.

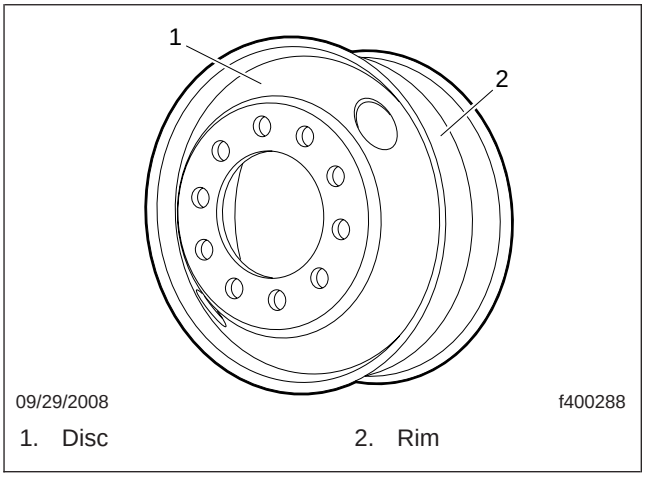


Fig. 1, Disc wheel

Radial tires have ply cords that run from bead to bead, and at a right angle to the belt plies and tire tread. See **Fig. 2**. The belt plies constrict the radial ply cords and give rigidity to the tread.

Tire body plies, breakers, and belts are made of polyester, rayon, nylon, fiberglass, steel, or aramids (fibrous reinforcements). In radial ply tires, these materials are used in various combinations, including steel body/steel belt, polyester body/fiberglass belt, or nylon body/steel belt.

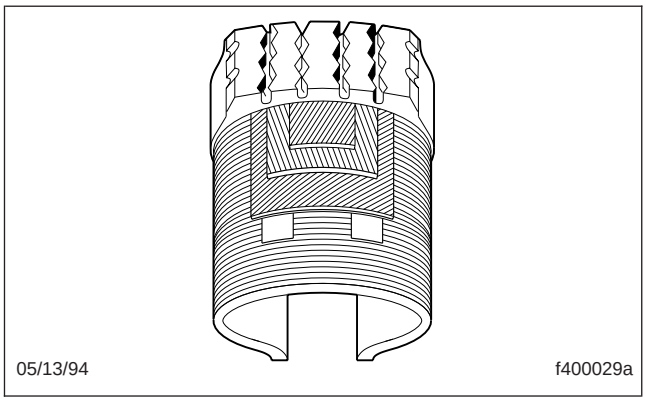


Fig. 2, Radial Ply Tire Construction

Tire Matching and Mixing

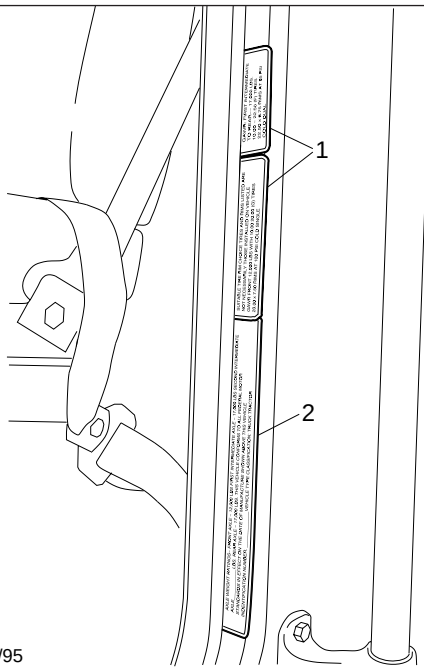
IMPORTANT: Review and follow these requirements for matching and mixing tires, before installing any tire and wheel assembly on a vehicle.

Before changing wheels and tires, consider the effect that the change may have on the Gross Vehicle Weight Rating (GVWR) of the vehicle. At the time of vehicle certification, the GVWR is calculated by adding the vehicle Gross Axle Weight Ratings (GAWR). The GVWR and each of the GAWRs are shown on a certification label (U.S.-purchased tractors) or "Statement of Compliance" label (Canadian-purchased tractors) attached to the left rear door post. See **Fig. 3**.

Tire and wheel labels certify the minimum tire and wheel combinations that can be installed on the vehicle for the given GAWRs. See **Fig. 3** and **Fig. 4**. Each GAWR is determined by considering each component of the axle system, including suspension, axle, wheels, and tires. The lowest component's capacity is the value used for the system. Therefore, the tires and wheels installed on the vehicle at the time of vehicle manufacture may have a higher load capacity than that certified by the tire and wheel label.

Tires and wheels of the minimum capacity can be installed without changing the load limitations. If tires and wheels are installed that have a lower load capacity than that shown on the tire and wheel label, then the tires and wheels determine the load limitations (the GAWRs and GVWR will be lower).

General Information



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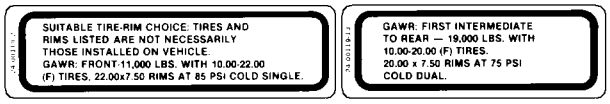
1. Tire and Wheel Labels
2. Certification Label

Fig. 3, Certification Label, U.S.



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NOTE: Examples only. Actual specifications may vary from vehicle to vehicle.

Fig. 4, Tire and Rim Labels

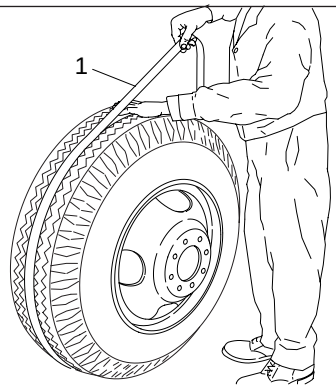
Changing to tires of a different overall diameter also negatively affects the antilock braking system, which is set to respond to the tire diameter that's programmed into the ABS when the vehicle is built. A different tire diameter can also cause speedometer and odometer readings to be too high or too low.

When pairing tires in a dual assembly, the tire diameters must not differ by more than 1/4 inch (6.4 mm), or the tire circumference by more than 3/4 inch (19 mm). The total tire circumference of one driving rear axle must match, as nearly as possible, the total tire circumference of the other driving rear axle.

NOTICE

Mismatching dual tires overloads the larger diameter tire, causing it to overdeflect and overheat. The smaller diameter tire, lacking proper road contact, wears faster and unevenly. Tread or ply separation, tire body breaks, and blowouts can occur from mismatched duals.

With an endless pi tape or square, measure the diameter of the tires 24 hours after inflation. See **Fig. 5**, and **Fig. 6**. A matching stick, string gauge, or tire straight edge can also be used to determine the difference in tire radius, which is then doubled to calculate the diameter difference. See **Fig. 7**, **Fig. 8**, and **Fig. 9**.



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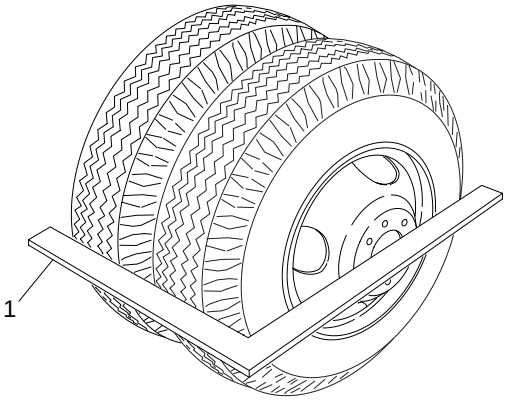
1. Endless Pi Tape

Fig. 5, Endless Pi Tape



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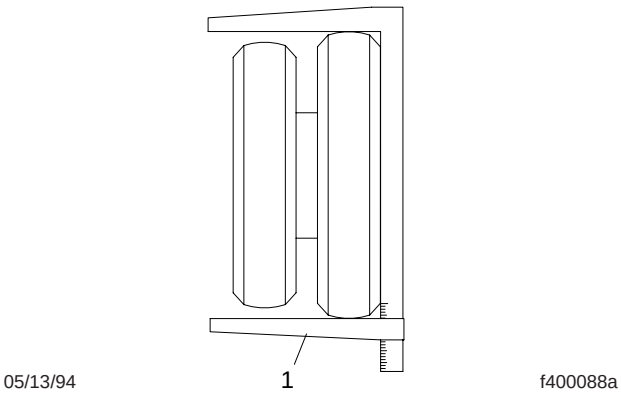
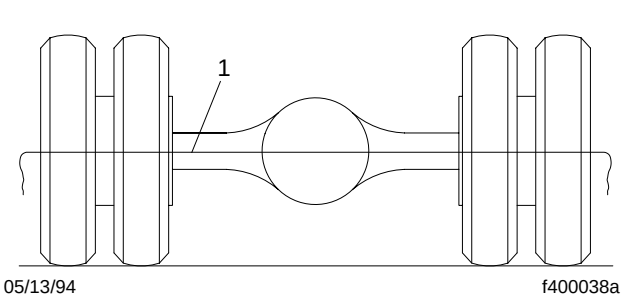
1. Square

Fig. 6, Square



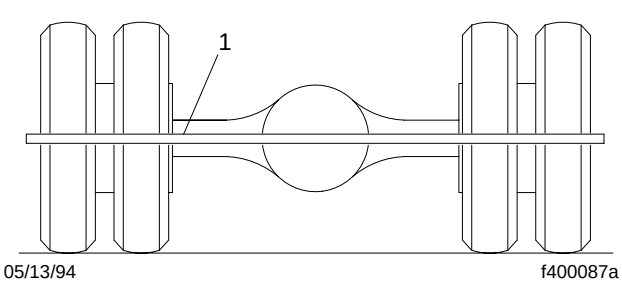
1. Matching Stick

Fig. 7, Matching Stick



1. String Gauge

Fig. 8, String Gauge



1. Tire Straight Edge

Fig. 9, Tire Straight Edge

When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

CAUTION

Driving a vehicle on one tire of a dual assembly dangerously exceeds the carrying capacity of the single tire and wheel. Operating in this manner can cause damage to the wheel and tire.

Inflate all tires on an axle, or on both axles of a tandem unit, to within 5 psi (35 kPa) of one another. For tire inflation specifications, see **Specifications, 400**.

There must be sufficient space between dual tires for air to flow and cool the tires, and to prevent them from rubbing against one another. Wheels of the same size, but of different makes and types, can have different offsets, which would affect dual spacing. If there is sidewall contact between tires, or between the inside tire and the chassis, refer to the tire manufacturer's catalog to determine the minimum dual spacing. Refer to the wheel manufacturer's catalog to determine the correct offset.

Federal Motor Carrier Safety regulations require the removal of all tires with less than 4/32 inch (3 mm) remaining groove depth on a front axle, and tires with less than 2/32 inch (1.5 mm) remaining groove depth on a rear axle.

Disc Wheel Removal and Installation

Removal

1. Park the vehicle on a level surface and set the parking brake. Chock all tires that will not be serviced.
2. If removing wheels and tires from the front axle, raise the front of the vehicle until the tires clear the floor. Place safety stands under the front axle.

   If removing wheels and tires from the rear axle, raise the rear of the vehicle until the tires clear the floor. Place safety stands under the axle being serviced.
3. If any of the following conditions apply, deflate the tire being serviced by removing the valve core. On a dual assembly, deflate both tires.
   - The wheel or tire is damaged.
   - There is suspected damage.
   - The tire has been run at 80 percent or less of its recommended operating pressure.
4. Turn the wheel until one hub-pilot pad is in the top-center position.
5. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced.

NOTICE

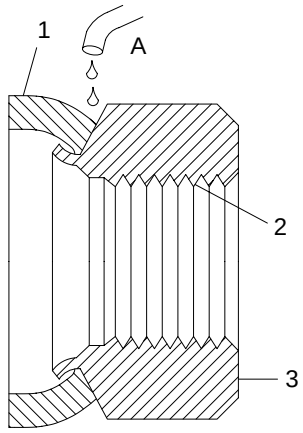
Keep the wheel square to the hub during removal. The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during removal and damage the stud threads or hub-pilot pads.

IMPORTANT: On both sides of the vehicle, the two-piece flange nuts have right-hand threads.

6. Leaving one top and one bottom nut to keep the wheel straight, remove the other eight two-piece flange nuts from the wheel, then remove the top and bottom nuts.
7. Remove the wheel. Do not let it drop on, or drag across, the stud threads.

Installation

1. Inspect the wheel and tire assembly using the instructions in **Subject 130** and **Subject 140**. Replace any damaged wheels and tires. Follow the tire matching and mixing requirements in **Subject 050**.
2. Clean the hub and wheel mounting surfaces, the fasteners, and between the rims of dual wheels.
3. Make sure the tire is correctly inflated. For instructions, see **Subject 150**.
4. Apply a few drops of light engine oil to the wheel studs, the area between the body and the flange of each nut, and the hub pilot. Wipe off any excess oil. See **Fig. 1** for lubrication of the two-piece flange nuts.



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A. Apply oil here.

1. Flange
2. Nut Threads
3. Nut Body

Fig. 1, Two-Piece Flange Nut

IMPORTANT: Freightliner "Turbo" wheel assemblies require directional mounting, as shown in **Fig. 2**.

IMPORTANT: Before installing the wheels, make sure the drum is in position on the raised step of the pilot pad. One of the hub pilot pads must be centered at the top. To help keep the drum in place, it may be necessary to adjust the brakes before installing the wheels.

5. Turn the hub until one hub-pilot pad is in the top-center position.

Disc Wheel Removal and Installation

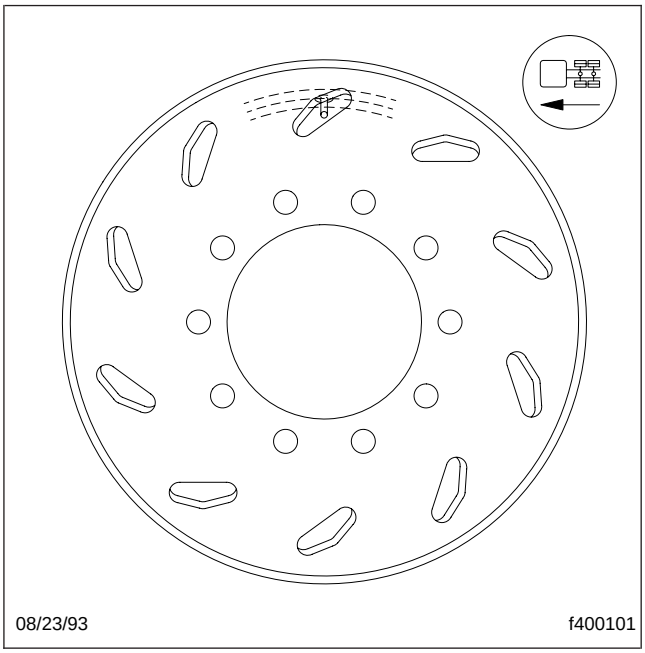


Fig. 2, Directional Freightliner "Turbo" Wheel

NOTICE

Keep the wheel square to the hub during installation. The wheel center hole and hub pilot have close tolerances. If the wheel is not kept square to the hub, it could bind during installation and damage the stud threads or hub-pilot pads.

6. Using a jack or wheel-and-tire dolly, install the wheel assembly (inner wheel on a dual wheel assembly) on the hub. Make sure the wheel is square to the hub. Be careful not to damage the threads or hub-pilot pads.

   6.1 Before placing the wheel assembly on the hub, rotate the wheel as needed until the balance weight(s) on the wheel are 180 degrees from the weight(s) on the brake drum.

   6.2 Make sure the hub-pilot pad is still centered at the top after the wheel is installed.

7. On a dual wheel assembly, repeat the previous step to mount the outer wheel against the inner wheel.

   Before placing the outer wheel assembly on the hub, rotate the wheel as needed until the balance weight(s) on the wheel are 180 degrees from the weight(s) on the brake drum. If this causes the valve stems to be in the same wheel hole, mount the outer wheel so that the outer wheel balance weight(s) are on the same side as the brake drum balance weight(s).

NOTICE

The wheel nuts have right-hand metric threads. Do not try to install a similar size SAE nut on a stud, or the stud and nut will be damaged.

8. Install and hand-tighten the two-piece flange nuts on the top and bottom studs.
9. Check that the wheel is correctly seated against the hub, and on the hub-pilot pads.
10. Install and hand-tighten the remaining nuts.

NOTICE

Use the specified torque values and follow the correct tightening sequence. Too little wheel nut torque can cause wheel shimmy, wheel damage, stud breakage, and extreme tire tread wear. Too much wheel nut torque can break studs, damage threads, and crack discs in the stud hole area.

11. Tighten the nuts in two stages. Follow the sequence in **Fig. 3**.

    11.1 Tighten the flange nuts initially to 50 to 100 lbf·ft (68 to 136 N·m).

    11.2 Tighten the flange nuts to 450 to 500 lb·ft (610 to 678 N·m).

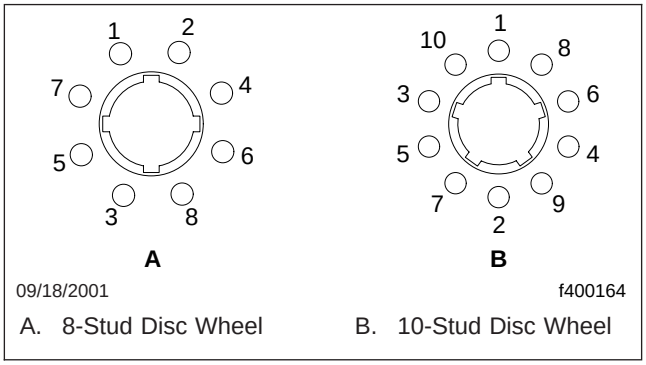


Fig. 3, Wheel Nut Tightening Sequence

IMPORTANT: If the wheel nuts cannot be tightened to minimum torque values, the studs could

be turning in the hub flange, having lost their locking ability. In this situation, the wheel hub assembly is damaged and must be replaced with a new assembly. Failure to reach minimum torque values could also be caused by stripped threads on the wheel studs or wheel nuts.

⚠ WARNING

Always replace damaged parts with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, which could cause personal injury or property damage.

12. Replace any damaged parts. Follow the instructions in **Section 33.01** to replace front-axle parts, or **Section 35.01** for rear-axle parts.
13. Remove the safety stands, lower the vehicle, and remove the chocks.

IMPORTANT: The wheel nuts seat during vehicle operation. As a result, it is necessary to periodically tighten the nuts to the specified torque.

14. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the wheel nuts to the original specification, following the tightening sequence in **Fig. 3**.
15. Tighten the wheel nuts every 50,000 miles (80 000 km) thereafter.

Tire Demounting and Mounting Service Precautions

Service Precautions

⚠ WARNING

Read the following information. Failure to follow the safety precautions, before and during tire demounting and mounting, could cause tire or rim damage while servicing or in use. An incorrectly mounted tire can burst, which could result in personal injury or equipment damage.

IMPORTANT: Do not mount or demount tires without proper training, as required in Occupational Safety and Health Administration (OSHA) Rules and Regulations 1910.177, *Servicing Multi-Piece and Single Piece Rim Wheels*.

Service information containing demounting and mounting instructions are available through your rim supplier. Charts detailing service procedures are available through OSHA area offices.

The address and telephone number of the nearest OSHA area office can be obtained by looking in the local telephone directory under U.S. Government, Labor Department of Occupational Safety and Health Administration.

Use the information from the above sources with the following precautions before and during tire demounting and mounting.

Safety

- Examine all wheel and tire parts as explained in **Subject 130** and **Subject 140**. Replace damaged, rusted, or worn parts.
- Do not reinflate a tire that has been driven flat, or has been driven at 80 percent or less of its recommended operating pressure.
- Before removing a low tire from the vehicle, make sure it is completely deflated.

Tools

- Use special tools, as recommended by tire suppliers, for demounting and mounting tires. These tools must be smooth and used with care to avoid gouging the rim.
- Loosening tire beads may be difficult, and considerable force may be required. The use of a machine designed for loosening tire beads is recommended.

Handling

- To prevent nicking or gouging the wheels, handle them on a wooden floor or rubber mat.
- Store tires indoors, or under cover outdoors, to prevent water from collecting inside the tire.

Lubrication

- Lubricate the tire with an approved tire-mounting lubricant. Never use antifreeze, silicones, petroleum-based lubricants, or any flammable material, such as ether or some other starting aid.
- When lubricating a tire prior to mounting, make sure excess lubricant does not run into the tire.
- Michelin Tire Corporation recommends applying lubricant to the valley of the tire, before using tools to break the bead.
- Michelin also recommends applying a sufficient but sparing amount of lubricant to the entire wheel face when mounting a tire on a wheel, to ensure correct bead seating and ease of mounting.

Five-Degree Full Drop Center

WARNING

Read the information in Subject 110. Failure to follow the precautions, before and during tire demounting and mounting, could cause tire damage while servicing or in use. An incorrectly mounted tire can burst, which could cause personal injury and equipment damage.

To demount or mount tubeless tires on 5-degree full drop center rims, regular or safety type, follow the same procedures used to demount or mount tubeless automobile tires.

Fifteen-Degree Tapered Drop Center

Demounting

1. Deflate the tire being serviced by removing the valve core. Check the valve stem by running a piece of wire through the stem to make sure it is not plugged.
2. Loosen both beads from the wheel.
   - 2.1 Place the wheel on a wooden floor or rubber mat with the wide side up.
   - 2.2 Drive the flat end of the tire tool between the tire bead and the wheel flange.
   - 2.3 Holding the tool upright, hammer on the neck to free the tire bead from the wheel. See **Fig. 1**.
   - 2.4 Repeat at 8-inch (20-cm) intervals around the flange, until the bead is free from the wheel.
   - 2.5 Turn the wheel over and repeat the previous substeps to loosen the second bead from the wheel.
3. Remove one bead from the wheel.
   - 3.1 Make sure the wide side of the wheel is down.
   - 3.2 Lubricate the tire bead and the wheel.
   - 3.3 Insert the curved end of two tire tools between the bead and the wheel, just to one side of the tire valve. See **Fig. 2**.

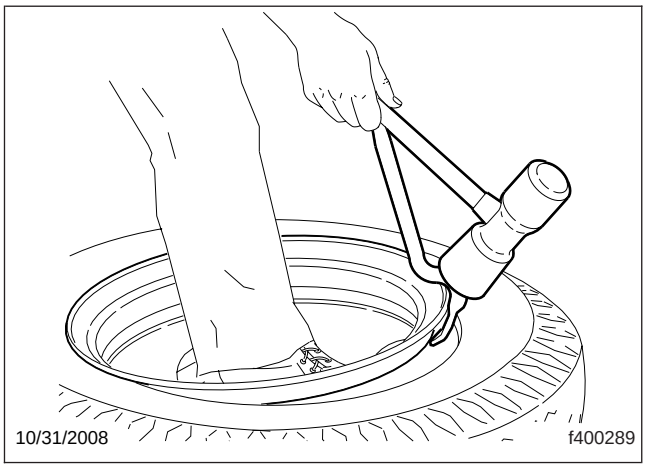


Fig. 1, Loosening the Beads

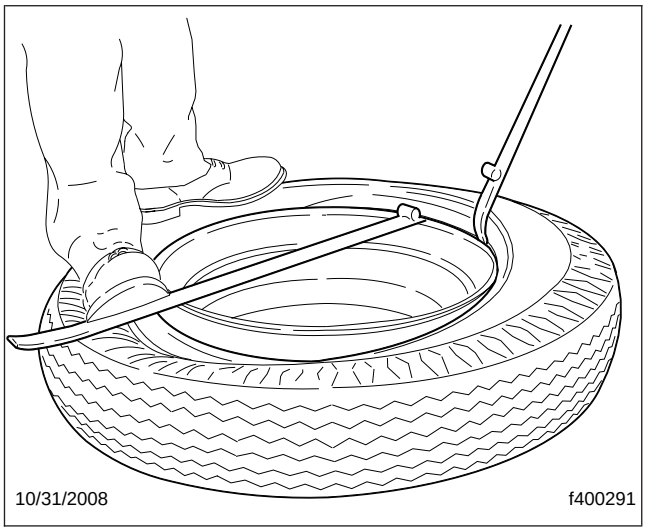


Fig. 2, Forcing First Bead From Wheel

   - 3.4 Step on the side of the tire opposite the valve to force the first bead into the wheel well.
   - 3.5 Hold one of the tools in place with your foot and pry with the second tool, to force the bead up over the wheel flange.
   - 3.6 Continue prying around the tire to work the first bead off of the wheel. Leave the second bead in the wheel well.
4. Remove the wheel from the tire.
   - 4.1 Stand the wheel and tire assembly upright, with the valve stem near the top.

Demounting and Mounting Tubeless Tires

4.2 Lubricate the second bead and wheel.

4.3 Insert the straight end of the tool between the tire bead and the back wheel flange, hooking the tool over the second flange. See **Fig. 3**.

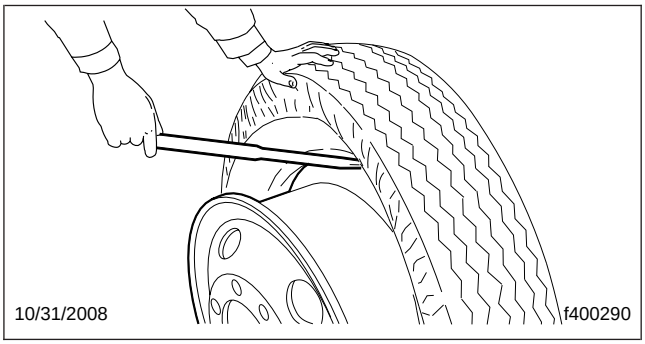


Fig. 3, Prying the Wheel Out of the Tire

4.4 Lean the tire assembly toward the tool and use a rocking or bouncing action to pry the wheel out of the tire.

5. Clean and inspect all parts. Follow the instructions in **Subject 130** and **Subject 140**.

Mounting

1. Install the valve stem in the wheel.

   1.1 Place the valve stem, with a rubber washer, through the valve hole from the tire side of the wheel.

   1.2 Screw the valve nut onto the stem from the opposite side. Make sure the rubber bushing and metal collar or nut are centered and fit snugly in the valve hole. See **Fig. 4**.

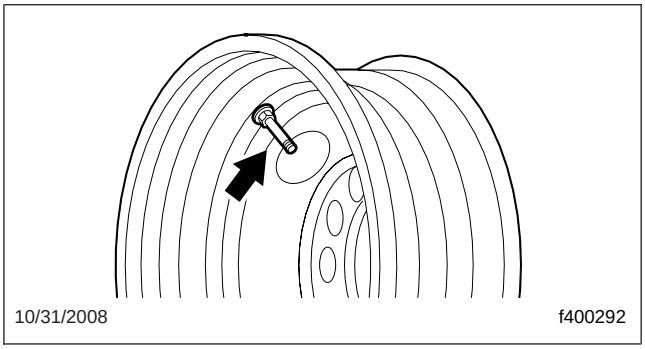


Fig. 4, Valve Stem Installation

1.3 Tighten the nut securely.

2. Lubricate the bead seats on the wheel and both tire beads.

   2.1 Place the wheel on a wooden floor or rubber mat with the wide side down.

   2.2 Using a brush or swab, lubricate both bead seats (flanges) of the wheel, and both tire beads, with an approved lubricant. Do not let excess lubricant run inside the tire.

   Apply enough lubricant to enable correct bead seating and to make mounting easier.

3. Work the lower tire bead into the wheel well.

   3.1 Lay the tire on the wheel. If there is a balance mark on the tire, align the mark with the valve stem.

   3.2 Push one area of the lower bead over the flange and into the wheel well.

   3.3 Using the straight end of the tire tool, with the stop resting on the wheel flange, work small sections until the remaining bead slips into the wheel. See **Fig. 5**.

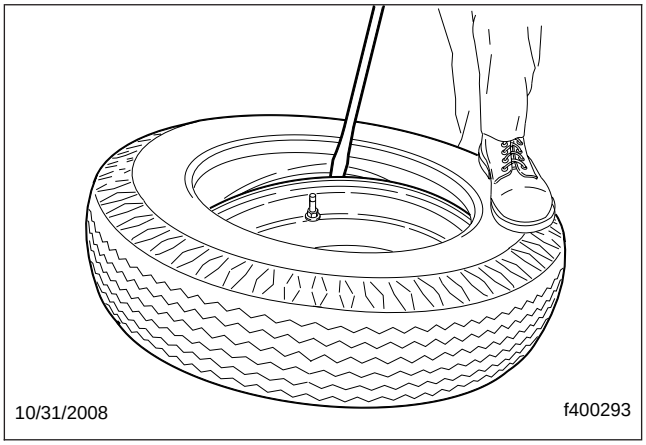


Fig. 5, Working the Lower Bead into the Wheel

4. Work the upper tire bead into the wheel well.

   4.1 Start the upper tire bead over the wheel flange and into the wheel well by standing on the tire. If necessary, push a section of the bead into the wheel well and anchor it by attaching Vise-Grip® pliers to the wheel flange with the snub side toward the tire.

Put a rag between the wheel and the pliers to avoid damaging the wheel.

4.2 Using the spoon end of the tire iron, with the stop toward the wheel, work around the bead. See **Fig. 6**. Work small sections, until the bead slips over the flange and into the wheel well.

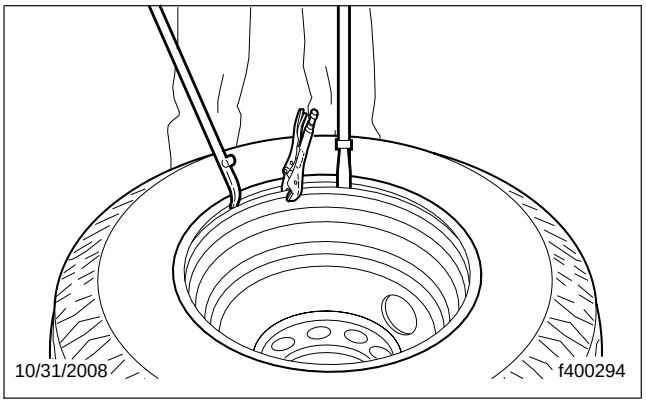


Fig. 6, Working the Upper Bead into the Wheel

4.3 If necessary, insert a second tire iron and relubricate the last 8 inches (20 cm) of the bead.

IMPORTANT: Inflate tires immediately after mounting, before the tire lubricant dries. Once the lubricant dries, bead positioning is not possible, even with increased inflation pressure.

5. Inflate the tire. Follow the instructions in **Subject 150**.

Inspection

WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire or rim damage while servicing or in use. An incorrectly mounted tire can burst, which could cause personal injury or property damage.

Examine the wheel, and all parts. Remove any grease, dirt, or rust. Using a wire brush, remove any rubber from the bead seat. Replace corroded parts. Paint the rim to prevent corrosion.

NOTE: Do not paint Alcoa aluminum disc wheels. If the wheels are corroded, contact the manufacturer for instructions.

A cracked wheel, or brake drum, damaged inner or outer wheel nuts or an out-of-round wheel, requires replacement of the damaged part.

NOTE: For inspection and service procedures for the hub, wheel studs, wheel, and brake drum assemblies, see **Section 33.01** for front-axle parts, or **Section 35.01** for rear-axle parts.

Inspect valve cores for cracks, bends, and air retention. Replace damaged or leaky cores.

Do not attempt to rework, weld, heat, or braze any wheel parts that are cracked, broken, or damaged.

Remove all foreign matter, such as grease and dirt, from the wheel mounting surface. Smooth any projections on the mounting surface to ensure even pressure when tightening the wheel nuts.

Inspection

⚠ WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire damage while servicing or in use. An incorrectly mounted tire can burst, which could cause personal injury and equipment damage.

Inspect the inside and outside of the tire for out-of-roundness, loose cords, cuts, foreign objects, and other damage. Repair as needed. Contact the tire manufacturer for repair procedures.

Do not repair tires with the following problems:

- cuts in the tread that are wire or breaker fiber deep
- tread worn to the wire or breaker fibers
- tread that is scalloped or otherwise worn unevenly
- visible, broken, deformed, or otherwise damaged bead wires
- deteriorated rubber
- rubber cracked to the wire or cord
- separations in the casing
- exposed cord (i.e.: due to weather checking or sidewall scuffing)

Inspect the tread for abnormal or excessive wear. See **Troubleshooting, 300** for possible causes of abnormal wear. Rotate the tires if they are wearing irregularly. If the front axle tires become irregularly worn, find out why they are wearing and correct the problem, then move them to the drive axle(s) or trailer axles.

Check the front-end alignment.

In a dual assembly, if one tire wears faster than its mate, find out why and correct the problem. Once this is done, the position of the two tires should be reversed.

Government regulations require the removal of any tire with less than 2/32-inch (1.5-mm) tread remaining. Retread the tire, if possible. Discard the tire if it cannot be retreaded.

Michelin Tire Corporation recommends using only new valve cores, caps, and O-rings in a new mounting.

Tire Inflation

IMPORTANT: Inflate tires immediately after mounting, before the tire lubricant dries. Once the lubricant dries, bead positioning is not possible, even with increased inflation pressure.

1. Check all parts to make sure they are correctly seated prior to inflation.

⚠ WARNING

During initial tire inflation, there is the possibility of an explosion of the assembly. Observe the following safety rules to reduce the possibility of serious physical injury in the event of an explosion.

- **Inflate tires in a safety cage or an approved portable restraining device.**
- **Always use a clip-on chuck with an inline valve and gauge.**
- **Make sure the inflation hose is long enough to permit standing to the side of the tire during inflation.**
- **Never sit on, or stand in front of, an assembly that is being inflated.**

2. Place the tire in a safety cage, or an approved portable restraining device. See **Fig. 1**.

IMPORTANT: Water in the tire can cause ply separation. During tire inflation, air tank reservoirs and lines must be dry. Use well-maintained air line moisture traps, and service them regularly.

3. Inflate the tire 10 psi (69 kPa).
4. Check the parts for correct seating. If the seating is not correct, completely deflate the tire and correct the problem. Never attempt to seat rings or other parts by hammering on an inflated or partially inflated tire.

IMPORTANT: Due to the different flex characteristics of radial sidewalls, it may be necessary to use an inflation aid, such as the following, to help seat tubeless tire beads:

- Metal rings, which use a blast of compressed air to seat the beads.

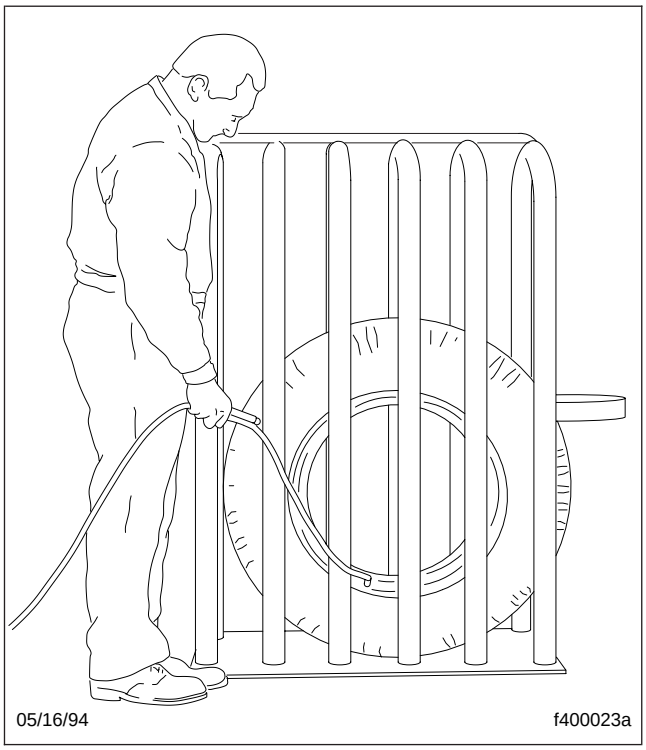
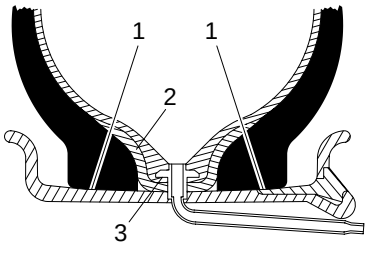


Fig. 1, Safety Cage for Tire Inflation

- Rubber rings, which seal between the tire bead and rim, allowing the bead to move out and seat correctly. A well-lubricated, heavy-duty bicycle tube can be used to help seal between the tire bead and rim.

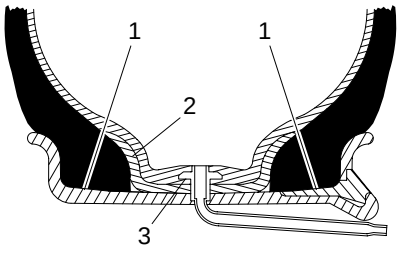
5. Continue to inflate the tire to the recommended pressure. See **Specifications, 400** for correct cold-inflation pressures.
   - Michelin Tire Corporation recommends an initial pressure of 90 to 100 psi (621 to 690 kPa) for this step to correctly seat the tire beads.
   - The position of the beads, flap, and tube with 4 to 5 psi (28 to 34 kPa) pressure is shown in **Fig. 2**. The tube is fully rounded-out within the tire, but there isn't enough pressure to move the beads on wide-base rims.
   - Depending on the tire size and rim condition, from 20 to 40 psi (138 to 276 kPa) pressure is needed to push the beads onto the bead seat. See **Fig. 3**.

Tire Inflation



1. Tapered Bead Seat
2. Flap
3. Valve Base

Fig. 2, Position of Beads, Flap, and Tube at 4 to 5 psi (28 to 35 kPa)



1. Tapered Bead Seat
2. Flap
3. Valve Base

Fig. 3, Beads Pressured Onto the Bead Seat

NOTICE

Inflating tube-type tires incorrectly can crack or tear the edge or inside of the valve base. Once seated, the tube can stretch only in the rim area. Because resistance to stretch is greatest at the valve base, there is often enough tension to break the tube at the edge of the valve base or in the valve base.

6. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating, and prevents buckling or overstretching the tube in tube-type tires.

WARNING

Inflate tires to the specified pressure. Tire underinflation or overinflation will damage wheels and tires, and could result in a blowout, which could cause personal injury and property damage.

- **Driving on overinflated tires weakens the cords by reducing their ability to absorb road shocks, and increases the danger of cuts, snags, and punctures.**
- **Overinflation overstresses and damages the rims.**
- **Driving on underinflated tires generates excessive heat, which weakens the tire body and reduces tire strength.**

NOTICE

Use tires of the same size, type, and capacity to carry the load at the recommended cold pressure. Attempting to increase the load capacity of a tire by overinflation will damage the tire assembly.

7. Inflate the tire to the recommended cold inflation pressure listed in **Specifications, 400**.
8. Install the valve cap and tighten finger-tight.
9. Check the inflation pressure 24 hours after mounting new tires.

NOTE: Testing a vehicle on a dynamometer can cause severe tire damage. Because manufacturers differ in their recommendations for preventing tire damage, refer to the manufacturer's instructions for testing a vehicle on a dynamometer.

General Information

Runout is side-to-side (lateral) or up-and-down (radial) movement when the tire/wheel assembly is rotated. Runout can be measured with a dial indicator, a tire runout gauge, or another instrument capable of measuring small movements of the tire/wheel assembly.

Lateral runout, shown in **Fig. 1**, is side-to-side movement of the rotating tire/wheel assembly. This may cause a perceived "shimmy" or "wobble".

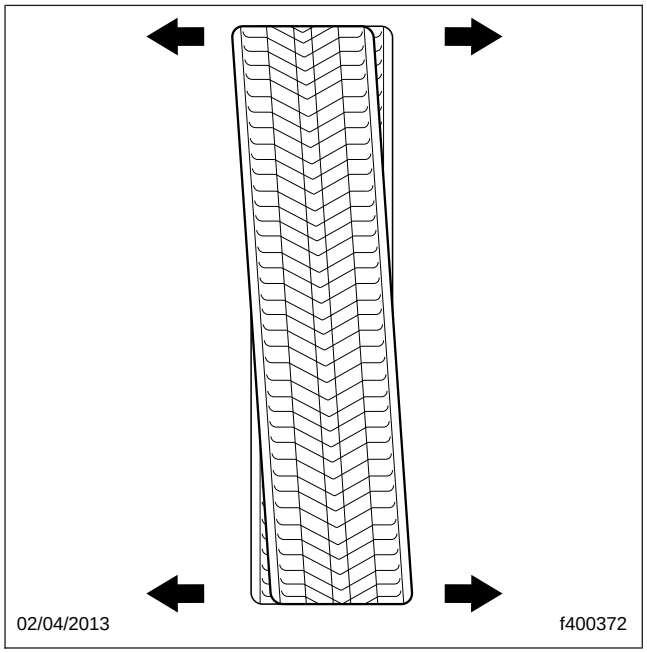


Fig. 1, Lateral Runout

Radial runout, shown in **Fig. 2**, is a changing radius of the rotating tire/wheel assembly. For a tire or wheel, its effect is to raise and lower the vehicle as it rolls along, giving the perception of a vertical "hop" or "bounce".

If a tire and wheel assembly shows visible up-and-down or side-to-side movement, it may have excessive runout. Use the inspection procedure that follows to measure runout.

Inspection

IMPORTANT: Before checking wheel runout, check the tires for proper:

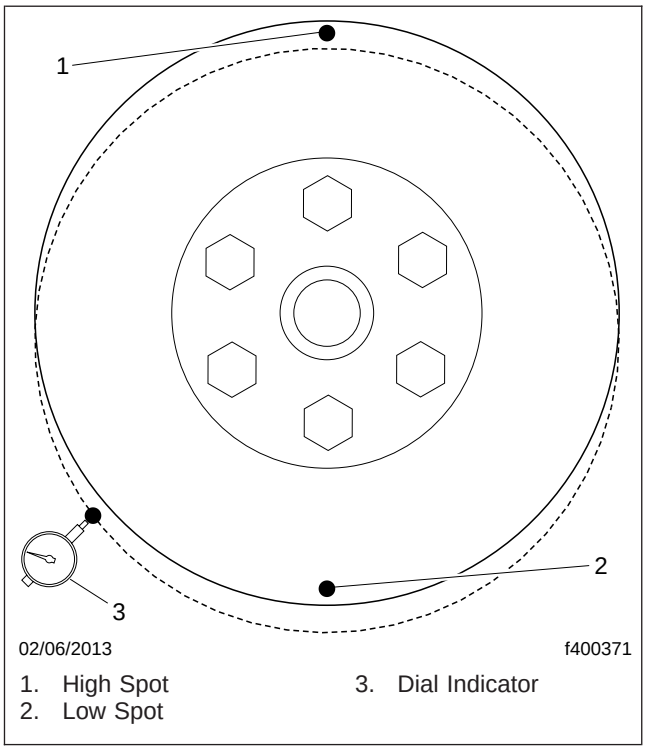


Fig. 2, Radial Runout

- inflation;
- wheel nut torque;
- bead seating on the rim.

Use a tire runout gauge, as shown in **Fig. 3**, to check lateral and radial runouts of the entire wheel end assembly.

Check radial runout on a smooth rib in the center of the tread. Check lateral runout on a smooth surface along the tire's mid-sidewall. If the wheel end assembly radial runout exceeds 0.060 inch (0.2 cm), or the lateral runout exceeds 0.150 inch (0.4 cm), the tire/wheel assembly should be removed to check the brake drum and hub runouts. Brake drum and hub runout tolerances are as follows:

- brake drum lateral runout—0.045 inch (0.11 cm)
- brake drum radial runout measured inside of the drum—0.020 inch (0.050 cm)
- hub lateral runout measured at the face of the hub—0.015 inch (0.38 cm)

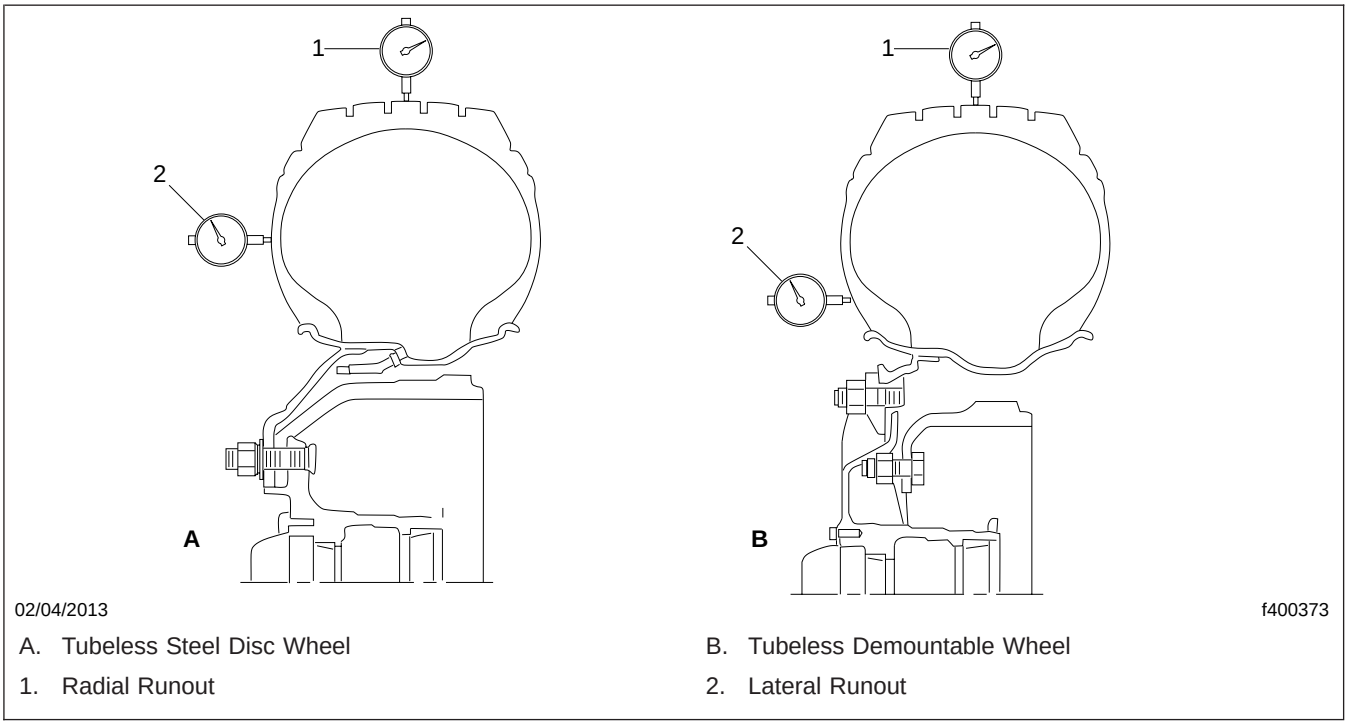
Wheel and Tire Runout Measurements

- hub radial runout measured near the hub pilots—0.015 inch (0.38 cm)

If hub and brake drum runouts are within specification, then the wheel runout will need to be checked. Demount the tire from the wheel and check lateral and radial runouts for the wheel as shown in **Fig. 4**. For tire demounting instructions, see **Section 40.00, Subject 120**. Make certain the wheel is properly fixed in a wheel balancer or remounted on the hub. See **Table 1** for wheel runout specifications.

Wheel Runout Specifications		
Wheel Type	**Lateral Runout: inches (cm)**	**Radial Runout: inches (cm)**
Aluminum	0.030 (0.08)	0.030 (0.08)
Steel	0.060 (0.15)	0.060 (0.15)

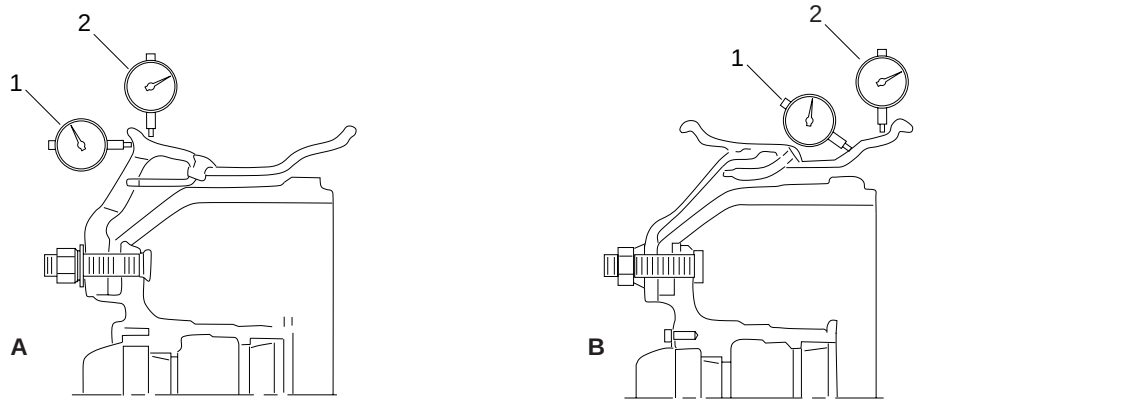
Table 1, Wheel Runout Specifications



A. Tubeless Steel Disc Wheel
1. Radial Runout
B. Tubeless Demountable Wheel
2. Lateral Runout

Fig. 3, Runout Check for Tires

Wheel and Tire Runout Measurements



A. Tubeless Aluminum Disc Wheel
B. Tubeless Steel Disc Wheel
1. Lateral Runout
2. Radial Runout

Fig. 4, Runout Check for Wheels

Troubleshooting Tables

Problem—Abnormal Tire Wear

Problem—Abnormal Tire Wear	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure.	Operate the tires at the recommended inflation pressure and use the proper size tires and wheels for the load to be carried. Refer to **Specifications, 400**.
Inflation pressures in a dual assembly are unequal.	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). Refer to **Specifications, 400** for the proper cold inflation pressures.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in **Subject 050**.
Vehicle is vibrating severely.	Follow the recommendations under "Problem—Vehicle Vibration" in this subject.
Brakes are grabbing.	Examine and adjust the brakes according to the instructions in **Group 42** in this manual.
Axles are improperly aligned.	Align the axles according to the instructions in **Section 33.00** (front-axle) and **Section 35.00** (rear-axle).
Wheel bearings are loose or damaged, or bushings are excessively worn.	Examine, and repair or replace according to the instructions in **Section 33.01** (front axle) or **Section 35.01** (rear axle).
Wear is uneven among tire sets.	Rotate the tires according to the instructions in **Subject 140**.
Driver is abusing equipment.	Caution the driver.

Problem—Vehicle Vibration

Problem—Vehicle Vibration	
Possible Cause	**Remedy**
Axles are improperly aligned.	Align the axles according to the instructions in **Section 33.00** (front-axle) and **Section 35.00** (rear-axle).
Wheels or tires are out-of-round, bent, or distorted.	Replace damaged components.
Tires, wheels, or brake drums are out-of-balance.	Determine the out of balance component and balance it.
Tire beads are not properly seated.	Demount and mount the tire. Make certain adequate lubrication is used and, if necessary, use an inflation aid to help seat tubeless tire beads.
Driveline, suspensions, or steering components are loose or worn.	Determine the location of the vibration, then repair or replace the loose or worn components.

Problem—Excessive On-the-Road Tire Failures

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Tires are not inflated to the correct pressure.	Operate the tires at the recommended inflation pressure and use the proper size tires and wheels for the load to be carried. Refer to **Specifications, 400**.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in **Subject 050**.

Troubleshooting

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
Water or foreign material is inside the casing.	Clean and dry the tires prior to mounting. Make sure excess lubricant does not flow down into the tire. Store unmounted tires indoors, or under cover, to prevent moisture from collecting inside.
Tires are contaminated with oil.	Clean the tires and inspect the engine seals, transmission seals, axle-end and drive axle seals, oil filters and oil lines for leakage. Make sure the lubricant used in mounting does not contain a petroleum derivative.
Vehicle is vibrating severely.	Follow the recommendations under "Problem—Vehicle Vibration" in this subject.
Parts are corroded, worn, or otherwise damaged.	Clean or replace parts as necessary.

Tire Pressure

Do not reduce the pressure of a hot tire if it exceeds the specified pressure. In normal driving, tire temperature and inflation pressure increase. Increases of 10 to 15 psi (69 to 103 kPa) are common. Higher pressures may be signs of overloading, underinflation, excessive speed, improper tire size, or any combination of these factors, and must be checked when the tire is cool.

IMPORTANT: The load and cold inflation pressure must not exceed the wheel manufacturer's recommendations, even though the tire may be approved for a higher load or inflation. Some wheels are stamped with a maximum load and maximum cold inflation rating. If they are not stamped, consult the wheel manufacturer for the correct tire inflation pressure for the vehicle load. If the load exceeds the maximum wheel capacity, the load must be adjusted or reduced.

For further information about tires (other than Michelin), and for inflation and load limits, refer to the "Tire and Rim Association Yearbook." Contact the Michelin Tire Corporation for further information about their tires.

Disc Wheel Fastener Torque Values

For torque values for disc wheel fasteners, see **Table 1**.

Disc Wheel Fastener Torque			
Description	**Nut Size**	**Wheel Manufacturer**	**Torque: lbf·ft (N·m)**
*8-Stud and 10-Stud Hub-Piloted Disc Wheel With Two-Piece Flange Nuts**			
Front and Rear Wheel Nut	M22 x 1.5	All	450–500 (610–678)

* Torque values for SAE 30W engine oil lubricated threads.

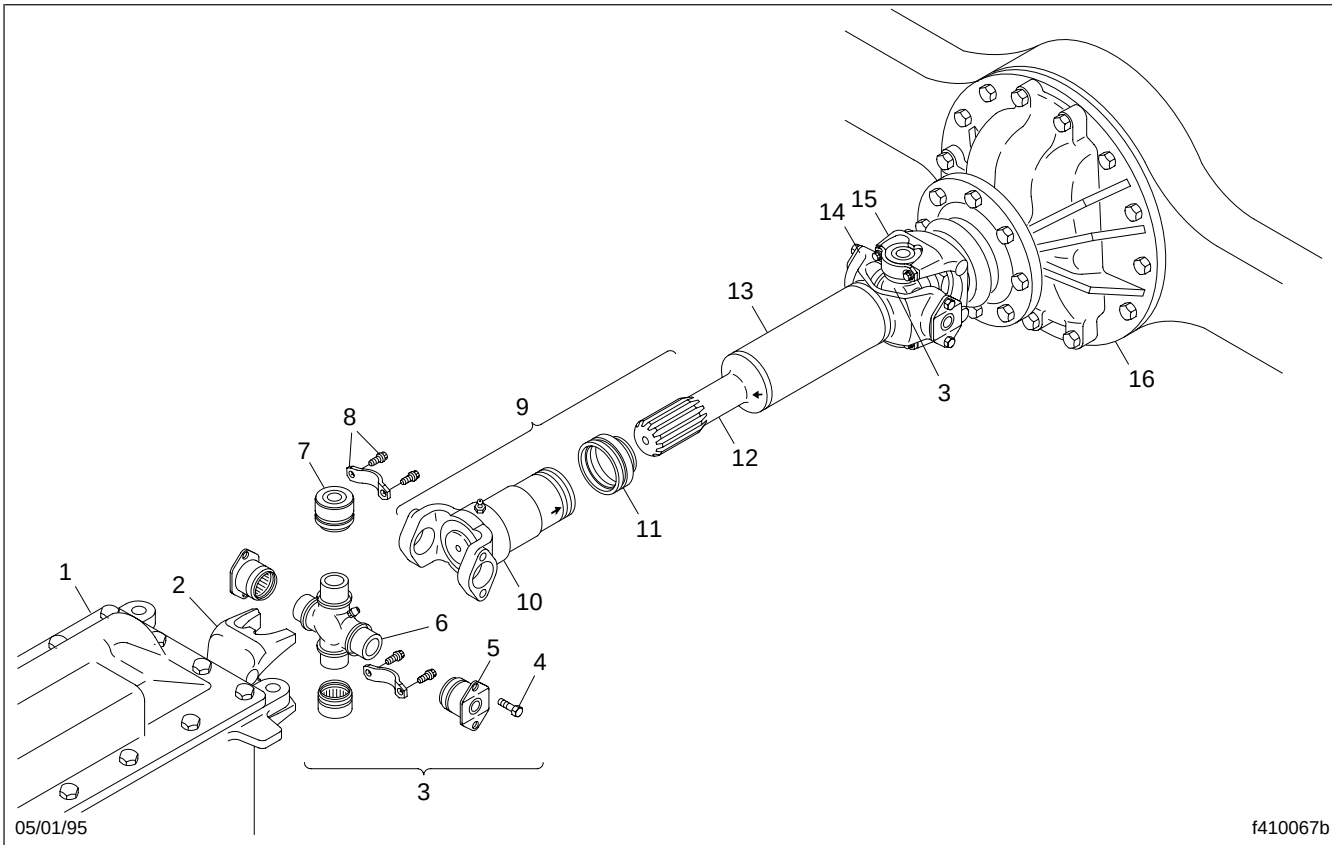
Table 1, Disc Wheel Fastener Torque

General Information

The simplest driveline consists of a transmission output-shaft end-yoke, an axle input-shaft end-yoke, and a single slip-jointed driveshaft connecting the two end-yokes. See **Fig. 1**. The driveshaft is made up of a universal joint (U-joint), a sleeve-yoke, a splined stub shaft, a driveshaft tube, a tube-yoke, and a second U-joint.

Driveline Configurations

The specific type and number of drivelines used on each vehicle depends on its number of transmissions, its number of drive axles, and its wheelbase. See **Fig. 2**. A driveline is used between each driving and driven component. A driveline connecting a main transmission (or an auxiliary transmission) to a single drive axle or forward-rear axle of a dual-drive vehicle is always referred to as a No. 2 driveline. See **Fig. 2**, examples A, B, C, D, and E. An interaxle driveline of a dual-drive vehicle is always called a No. 3 drive-



NOTE: Not all fasteners are shown.

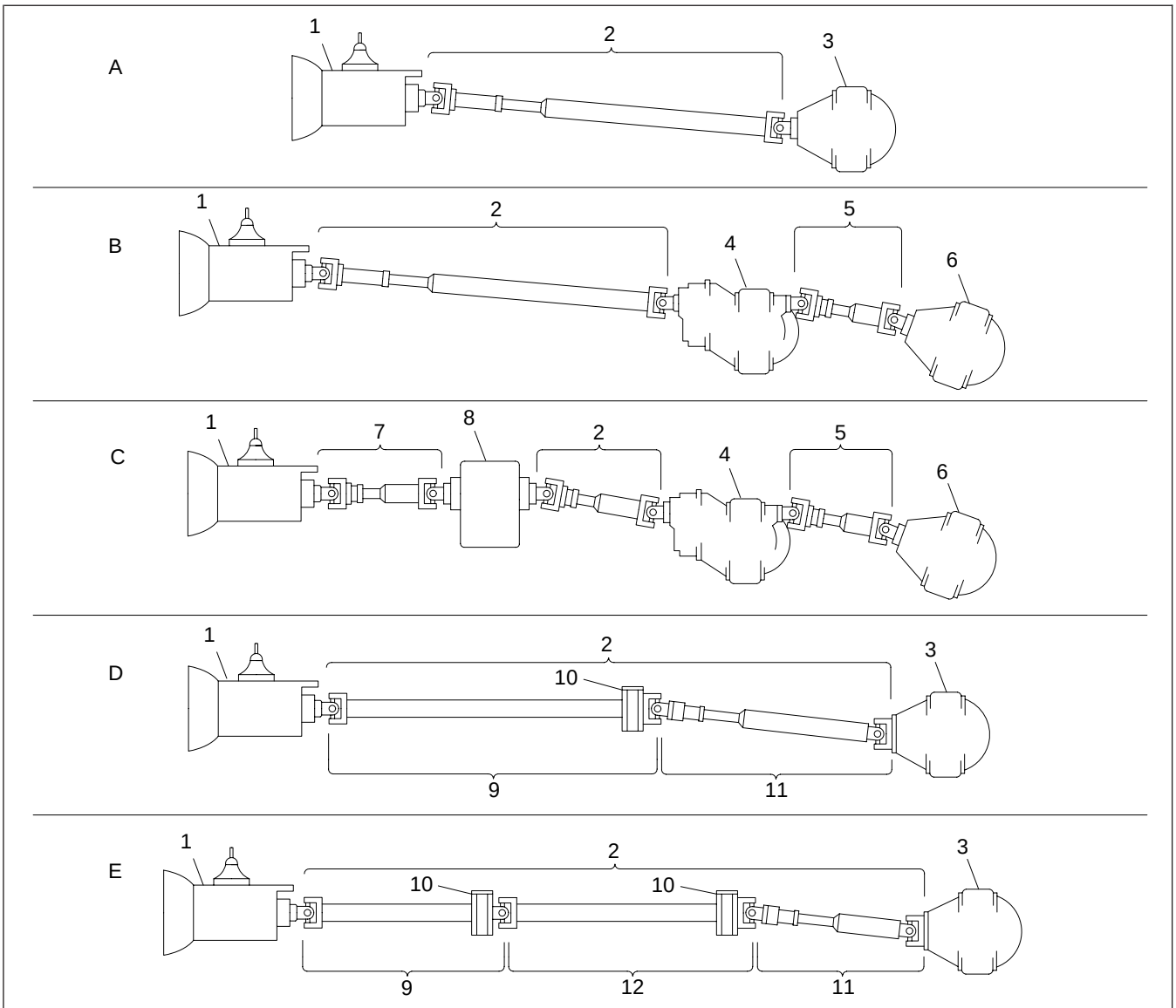
1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Bearing Plate Self-Locking Capscrew
5. Bearing Cup (for full-round yoke)
6. U-Joint Cross
7. Bearing Cup (for half-round yoke)
8. Bearing Strap and Bearing-Strap Capscrew
9. Slip-Joint Assembly
10. Sleeve-Yoke (full-round)
11. Dust Cap
12. Splined Stub Shaft
13. Driveshaft Tube
14. Tube-Yoke (full-round)
15. Axle Input-Shaft End-Yoke (half-round)
16. Rear Axle

Fig. 1, Components of a Basic Driveline

General Information

line. See **Fig. 2**, examples B and C. A driveline connecting a main transmission to an auxiliary transmission is always referred to as a No. 1 driveline. See **Fig. 2**, example C.

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at high rpm, it will flex, causing an out-of-balance vibration. Therefore, vehicles having a long wheelbase



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1. Main Transmission
2. No. 2 Driveline
3. Rear Axle
4. Forward-Rear Axle
5. No. 3 Driveline
6. Rearmost Axle
7. No. 1 Driveline
8. Auxiliary Transmission
9. Primary Coupling Shaft
10. Midship Bearing
11. No. 2 Driveshaft
12. Intermediate Coupling Shaft

Fig. 2, Driveline Configurations

use a midship bearing, mounted on a frame crossmember, for additional support. See **Fig. 2**, example D. This allows the No. 2 driveline to be separated into two, shorter shafts (a coupling shaft and a No. 2 driveshaft), thus improving balance and stability.

Vehicles having an even longer wheelbase use two crossmember-mounted midship bearings, allowing the No. 2 driveline to be separated into three short shafts, joined by four U-joints. See **Fig. 2**, example E. The first shaft is the primary coupling shaft, the second is the intermediate coupling shaft, and the third is the No. 2 driveshaft.

Slip-Joints, U-Joints, and Yokes

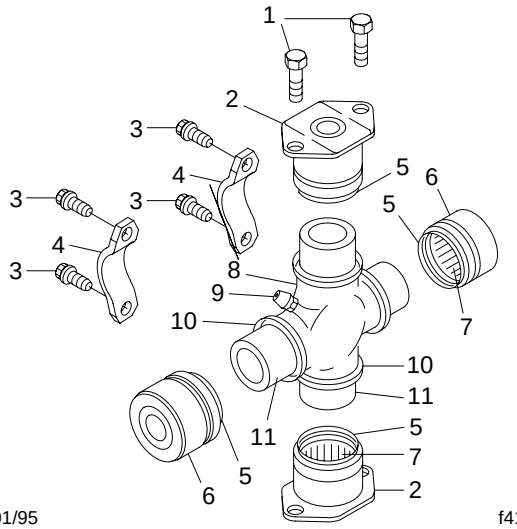
The basic function of the driveline is to send torque from the transmission to the axle in a smooth and continuous action. Because the vehicle axles are not attached directly to the frame, but are suspended by springs, they ride in an irregular, floating motion (when going over bumps or depressions), thus changing the distance between the transmission (or coupling shaft) and the rear axle, and the distance between the rear axles. The slip-joints of the No. 2 and No. 3 driveshafts, by expanding and contracting, allow for length changes between drivetrain components. Coupling shafts do not require a slip-joint.

Motion of the rear axle(s) also causes changes to the relative angles between drivetrain components. U-joints allow transfer of torque from an output shaft (or coupling shaft) to the driveshaft, and from the driveshaft to an input shaft, even though the angles between the shafts may be constantly changing.

Each U-joint consists of a cross with a close-tolerance ground cylindrical surface (trunnion) at the end of each of the four arms. Installed on each trunnion is a bearing cup lined with bearing needles. All bearing cups are sealed to retain lubricants, and to prevent entry of foreign material. See **Fig. 3**. In operation, the four bearing cups are held stationary in a pair of yokes, while the U-joint cross pivots on its trunnions.

Full-round yokes are installed at the front of coupling shafts and at both ends of the No. 2 and No. 3 driveshafts. All tube-yokes (yokes that are welded into driveshaft tubes) and all sleeve-yokes (yokes that are part of the internally splined half of slip-joints) are full-round yokes. See **Fig. 4**, items 4 and 9.

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. As standard



1. Bearing-Plate Capscrews
2. Bearing Cup (for full-round yoke)
3. Bearing-Strap Capscrew
4. Bearing Strap
5. Bearing-Cup Seal
6. Bearing Cup (for half-round yoke)
7. Bearing Needles
8. U-Joint Cross
9. Grease Fitting
10. U-Joint Cross Slinger
11. Trunnion

Fig. 3, Typical U-Joint

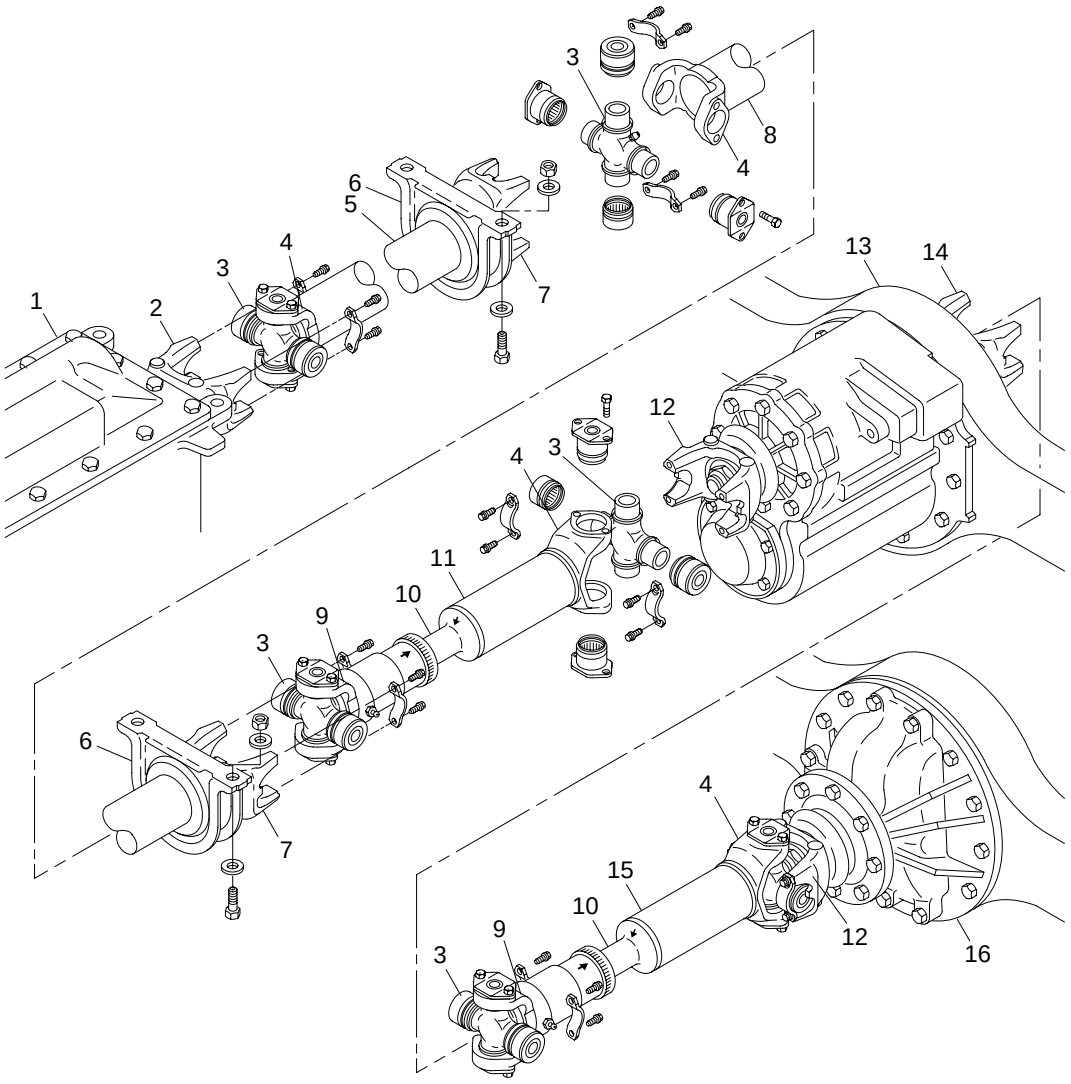
equipment, all No. 2 driveline end-yokes are half-round, with full-round optional. And, as standard equipment, all No. 3 driveline end-yokes are full-round, with half-round optional. End-yokes are installed on the transmission output shaft, on each axle input and output shaft, and behind the midship bearing of most coupling shafts. See **Fig. 4**, items 2, 7, 12, and 14.

Meritor 17T and 18T U-joints are coupled to half-round end-yokes by capscrews inserted through semicircular bearing straps that hold the bearing cups in place under tabs in the yoke cross-holes. See **Fig. 5**.

Meritor RPL Series U-joints are coupled to half-round end-yokes by capscrews inserted through the bearing cups. See **Fig. 6**.

U-joints are installed in full-round tube-yokes, sleeve-yokes, and end-yokes, by inserting the cross through from the inside of both yoke cross-holes, then install-

General Information



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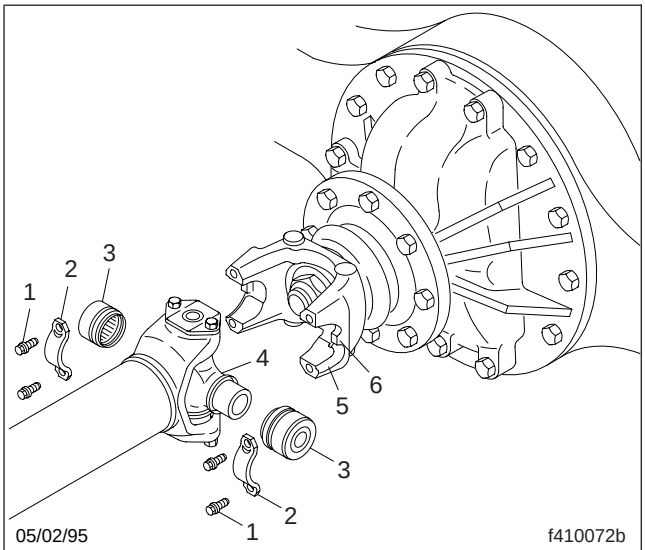
NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Full-Round Tube-Yoke
5. Primary Coupling Shaft Tube
6. Midship Bearing Assembly
7. Coupling Shaft End-Yoke (half-round)
8. Intermediate Coupling Shaft Tube
9. Sleeve-Yoke (full-round)
10. Slip-Joint Assembly
11. No. 2 Driveshaft Tube
12. Axle Input-Shaft End-Yoke (half-round)
13. Forward-Rear Axle
14. Axle Output-Shaft End-Yoke (half-round)
15. No. 3 Driveshaft Tube
16. Rearmost Axle

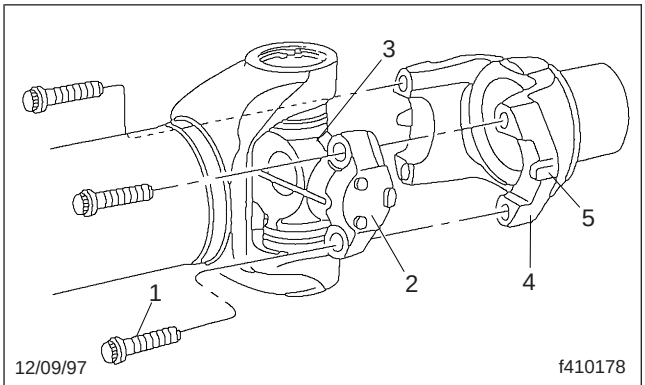
Fig. 4, Dual-Drive Installation With Primary and Intermediate Coupling Shafts

ing the bearing cups into the outsides of the yoke and over the ends of the trunnions. Snap rings or self-locking capscrews are installed into the yoke to secure the cups. See **Fig. 7**.



1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

Fig. 5, Coupling of a U-Joint With a Half-Round End-Yoke

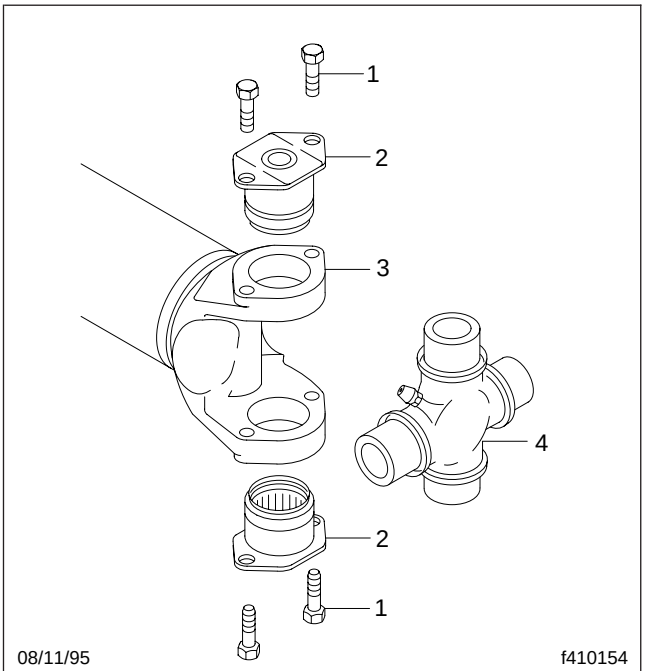


1. Capscrew
2. Bearing Cup
3. U-Joint Cross
4. Half-Round Yoke
5. Yoke Cross-Hole Tab

Fig. 6, Coupling of a RPL Series U-Joint

U-Joint Angles, Phasing, and Driveline Balance

Correct U-joint working angles, U-joint phasing, and driveline balance are vital to maintaining a quiet-running drivetrain and long life of drivetrain components (including driveline components).



1. Bearing-Plate Self-Locking Capscrew
2. Bearing Cup (bearing-plate-type)
3. Full-Round Yoke
4. U-Joint Cross

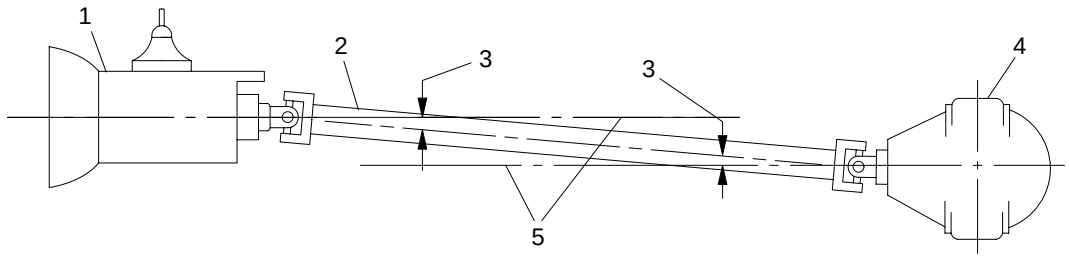
Fig. 7, Installation of a U-Joint in a Full-Round Yoke

The U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component (or other driveshaft) to which the U-joint connects. See **Fig. 8**. Because the double oscillating motion of a U-joint that connects angled shafts causes a fluctuating speed difference between the shafts, the effect created by the U-joint at one end of the shaft must cancel the effect created by the U-joint at the other end. This is done by making U-joint working angles at both ends of the driveshaft approximately equal, with the U-joints in phase. If the yoke lugs at both ends of the shaft are lying in the same plane (a plane that bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 9**.

NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.

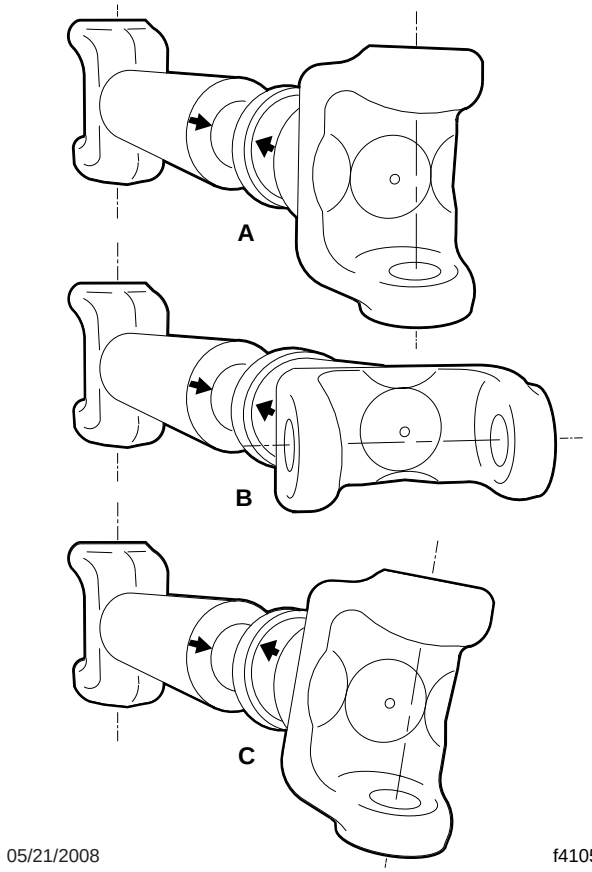
After manufacture, each driveline yoke is statically balanced. After assembly, each driveshaft and cou-

General Information



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 8, U-Joint Working Angles



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 9, U-Joint Phasing

pling shaft is checked for out-of-roundness, straightened as necessary, then dynamically balanced.

Avoiding Driveline Problems

To ensure that U-joints turn in phase, sleeve-yokes, splined shafts, coupling shaft end-yokes, and coupling shafts, should be marked for assembly reference before disassembly. A misaligned slip-joint will seriously affect driveline balance (and U-joint phasing). Even if a slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds that exceed the speed of the driveshaft's design specifications will cause an out-of-balance vibration. Any condition that allows excessive movement of a driveshaft will cause driveline imbalance: loose end-yoke nuts, loose midship bearing mounts, loose U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings, and worn slip-joint splines.

Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

To keep a vehicle operating smoothly and economically, the driveline must be carefully checked and lubricated at regular intervals. For inspection and lubrication intervals and procedures, see **Group 41** of the *108SD and 114SD Maintenance Manual*.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

U-Joint Uncoupling

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

1. Roll the vehicle forward or backward as needed to turn the rearmost end-yoke (of the driveline that is being uncoupled) until the centerline through its cross-holes is horizontal. See **Fig. 1**, Ref. A and Ref. B.
2. Apply the parking brakes, and chock the tires.
3. If the half-round bearing cups do not already have a retaining wire installed, install a bearing-cup retaining wire. See **Fig. 1**, Ref. C. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
4. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s). See **Fig. 1** and **Fig. 2**.
5. Remove the capscrews that secure the bearing cups or straps to the half-round yoke. Remove the bearing straps, if equipped.
6. Compress the slip-joint to remove the U-joint from the yoke.

NOTICE

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

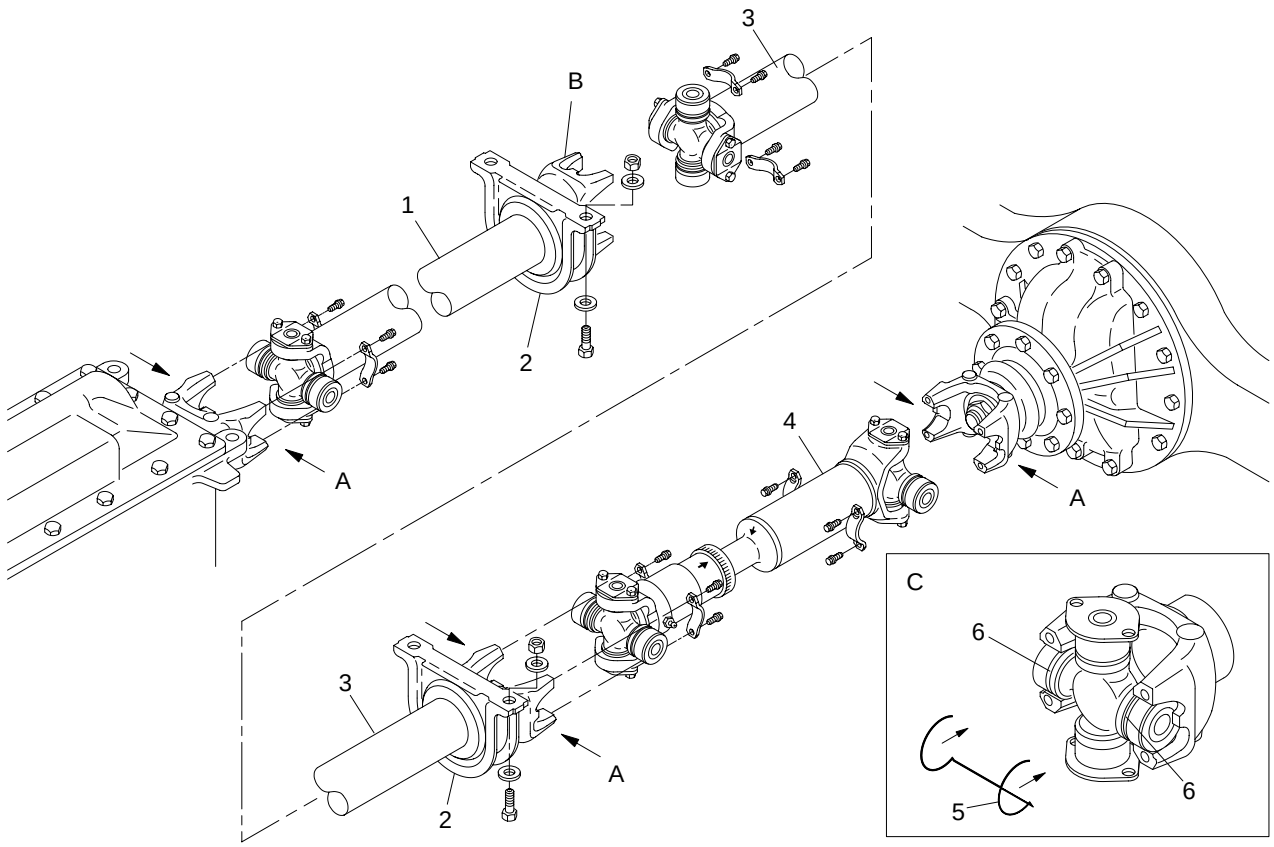
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut. See **Specifications 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes and bearing straps. See **Fig. 4**.
   - 1.4 Turn the end-yoke until its cross-holes are horizontal. See **Fig. 1** and **Fig. 2**.
2. Check, clean, and lubricate the U-joint.
   - 2.1 Remove the bearing-cup retaining wire or safety wire. See **Fig. 1**, Ref. C.

NOTICE

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.2 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 5**.
   - 2.3 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary. See **Subject 140**.
   - 2.4 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.5 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 6**.
   - 2.6 Install the bearing cups on the cross.
   - 2.7 Install a bearing-cup retaining wire. See **Fig. 1**, Ref. C. Or, install safety wire from

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



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NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Before uncoupling/coupling the U-joint, turn the end-yoke until its cross-hole centerline is horizontal.
C. Install a half-round bearing-cup retaining wire (or safety wire) before removing the bearing straps.

1. Primary Coupling Shaft
2. Midship Bearing
3. Intermediate Coupling Shaft
4. No. 2 Driveshaft
5. Half-Round Bearing-Cup Retaining Wire
6. Retaining-Wire Groove

Fig. 1, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes, Except RPL U-Joints

the retaining-wire groove of one half-round bearing cup to the other.

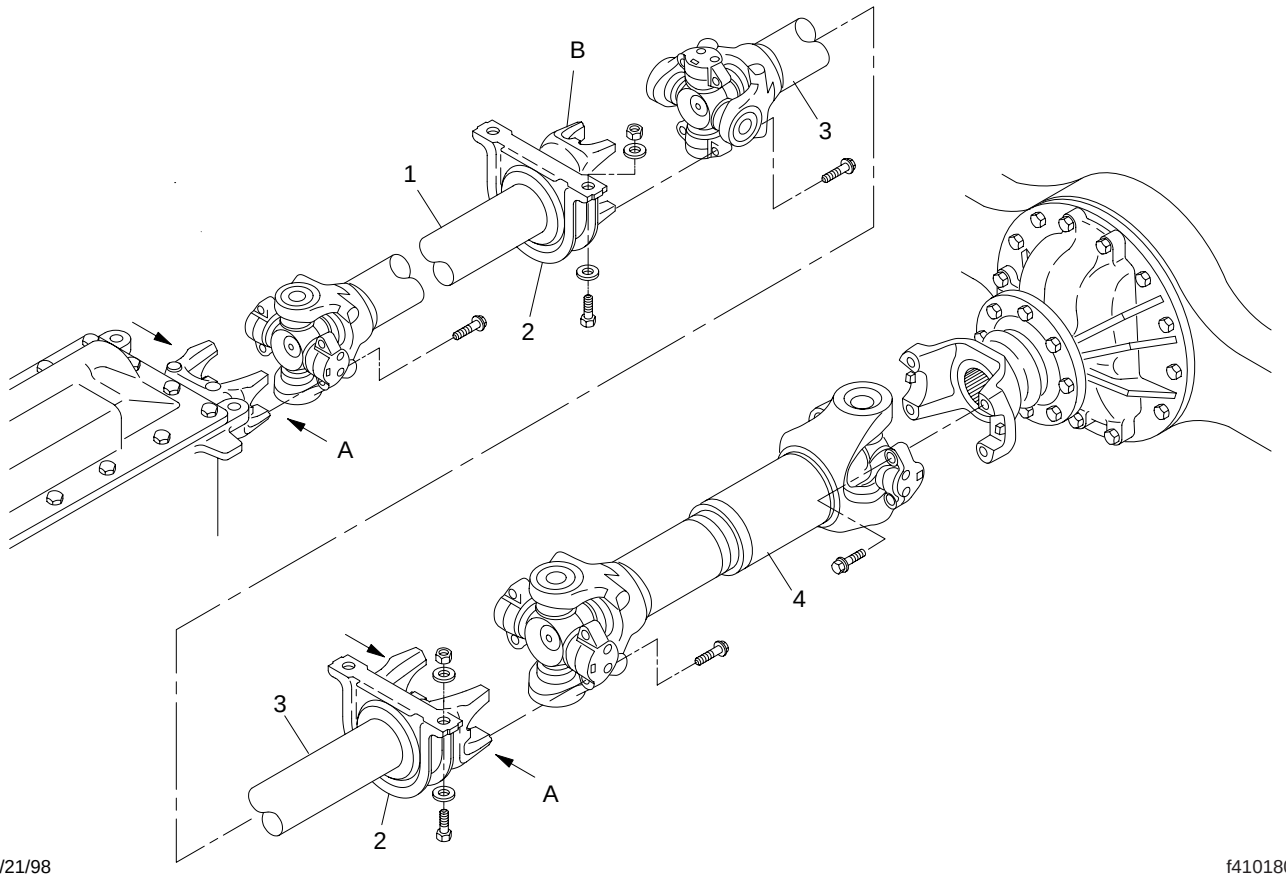
3. Extend the slip-joint, while pressing the cross and bearing cups into place in the yoke cross-holes. Using a rubber or plastic mallet, gently tap the bearing cups to seat them in the yoke. See **Fig. 7**.

NOTICE

Do not use the capscrews and bearing straps (if equipped) to seat the bearing cups in the yoke. Seating the cross by tightening the bearing straps can deform the bearing straps, allowing the bearing cups to spin, which will cause rapid wear and serious damage to the U-joint.

4. Place the bearing straps (if equipped) over the cups. Install the capscrews, finger-tight.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



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NOTE: Not all fasteners are shown.

A. End-yoke cross-hole centerline is horizontal.
B. Before uncoupling/coupling the U-joint, turn the end-yoke until its cross-hole centerline is horizontal.

1. Primary Coupling Shaft
2. Midship Bearing
3. Intermediate Coupling Shaft
4. No. 2 Driveshaft

Fig. 2, U-Joint Uncoupling/Coupling for Drivelines With Half-Round End-Yokes, RPL U-Joints

⚠ WARNING

The self-locking capscrews must not be reused. Replace the capscrews with new ones. Also, do not undertighten or overtighten the capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle. Driveline separation can cause loss of vehicle control that could result in serious personal injury or death.

Separation of the driveline can also cause damage to the driveline, driveline components, or other areas of the vehicle.

5. Alternately tighten the capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications 400**.
6. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 68 lbf·ft (92 N·m).

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

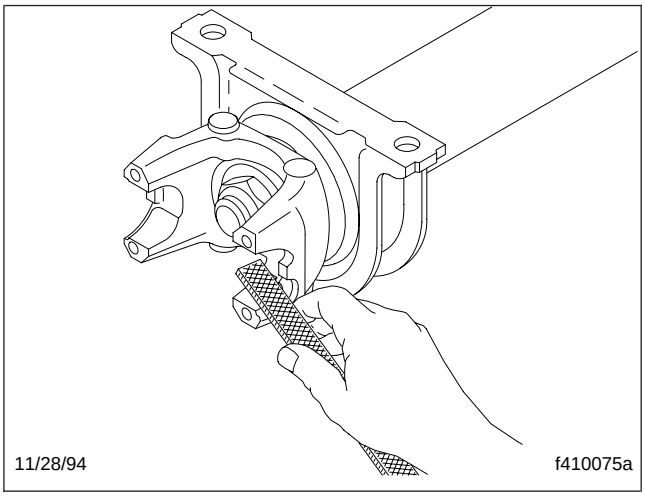
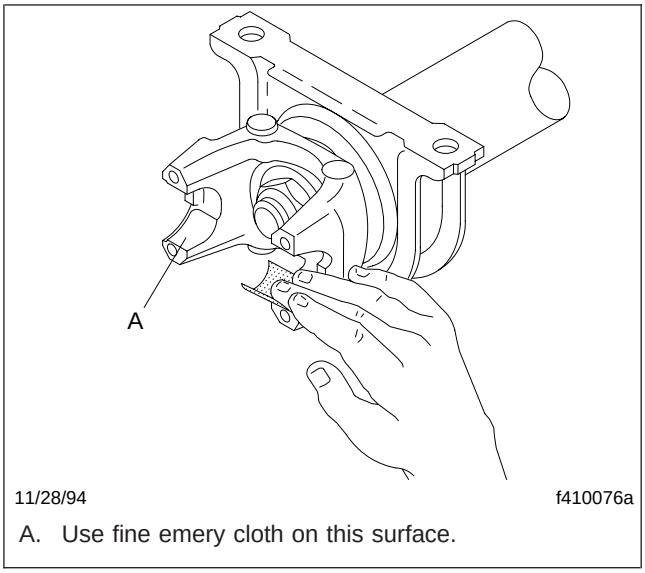


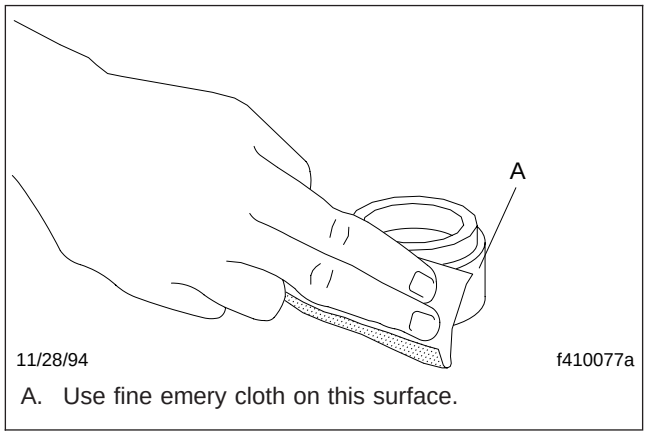
Fig. 3, Remove Burrs from a Half-Round End-Yoke Cross-Hole



A. Use fine emery cloth on this surface.

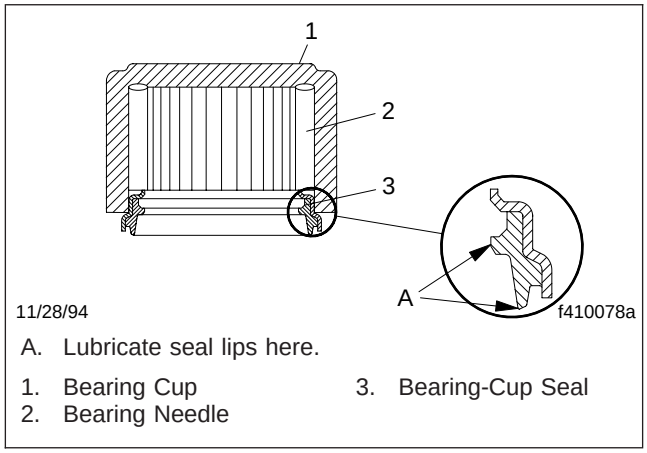
Fig. 4, Smooth a Half-Round End-Yoke Cross-Hole

7. Lubricate the U-joint, following the procedure in Group 41 of the *108SD and 114SD Maintenance Manual*.
8. Remove the nylon support straps, then remove the chocks.



A. Use fine emery cloth on this surface.

Fig. 5, Smooth a Half-Round End-Yoke U-Joint Bearing Cup

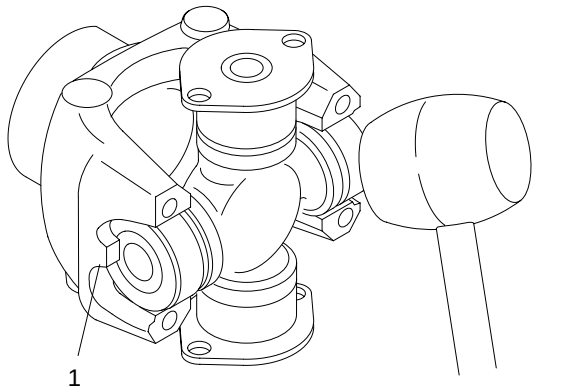


A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 6, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



1. Retaining Tab

Fig. 7, Seat a U-Joint in a Half-Round End-Yoke

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

U-Joint Uncoupling

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke. To remove the driveshaft, see **Subject 120**.

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

1. Roll the vehicle forward or backward as needed to turn the end-yoke (of the driveline that is being uncoupled) until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Apply the parking brakes, and chock the tires.
3. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s).
4. Remove and discard all four bearing-cup-plate self-locking capscrews.
5. Using one of the U-joint pullers listed in **Specifications 400**, remove both bearing assemblies from the end-yoke cross-holes. See **Fig. 2**.
6. Compress the slip-joint and pivot the end of the U-joint cross to remove it from the yoke. Install the bearing cups on the U-joint cross, and secure them with tape.

NOTICE

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

U-Joint Coupling

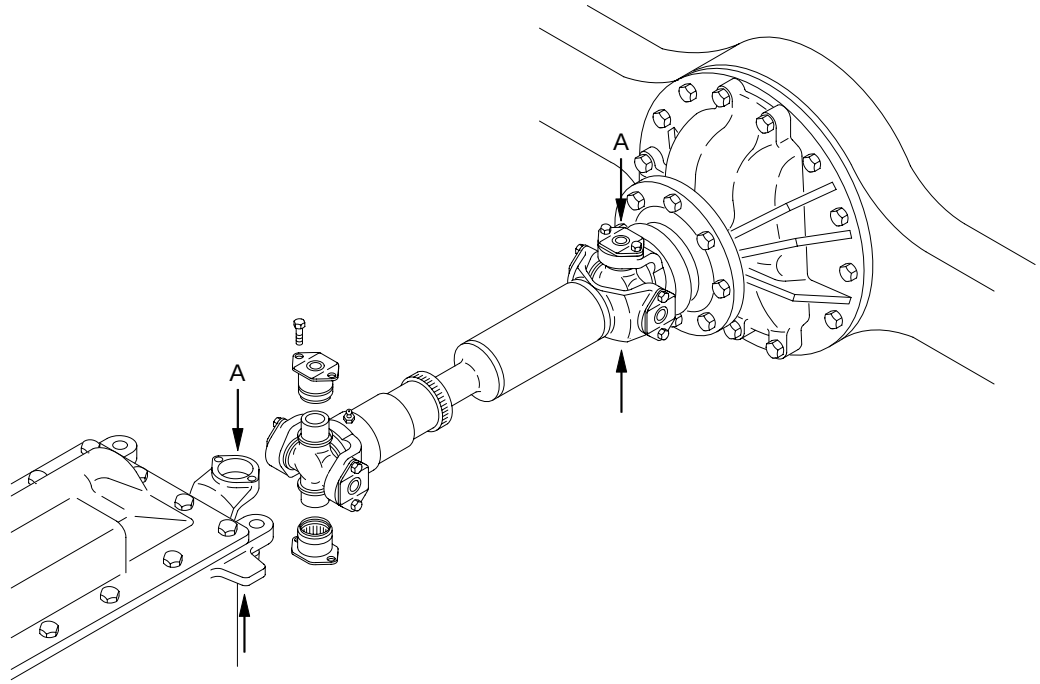
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut. See **Specifications 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using a mill file, and holding it flat against the machined surface of the yoke lug, remove any burrs or raised metal. See **Fig. 4**.
   - 1.4 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes. See **Fig. 5**.
   - 1.5 Turn the end-yoke until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Check, clean, and lubricate the U-joint.
   - 2.1 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 6**.
   - 2.2 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.

NOTICE

Do not expose the U-joint trunnions or bearing-cup needles to dirt or grit. The smallest bits of dirt or grit can cause rapid wear and serious damage to the U-joint.

   - 2.3 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.4 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 7**.
3. Couple the U-joint cross to the end-yoke.
   - 3.1 Extend the slip-joint, while pivoting the U-joint cross into place in the yoke cross-holes.
   - 3.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



NOTE: Not all fasteners are shown.
A. End-yoke cross-hole centerline is vertical.

Fig. 1, U-Joint Uncoupling/Coupling of a Driveline With Full-Round End-Yokes

Using a Spicer trunnion (journal) locator (**Specifications 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing assembly over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**.

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

3.3 By hand, press the bearing assembly flush with the face of the yoke. If the bearing assembly binds in the cross-hole, tap the *center* of the bearing plate with a rubber or rawhide mallet; do not tap the outer edges of the bearing plate. See **Fig. 9**.

3.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 10**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.

⚠ WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

3.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Repeat applicable substeps to install the opposite bearing.

3.6 Alternately tighten the bearing-cup-plate capscrews in increments of 5 lbf·ft (7 N·m), to the torque value in **Specifications 400**.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

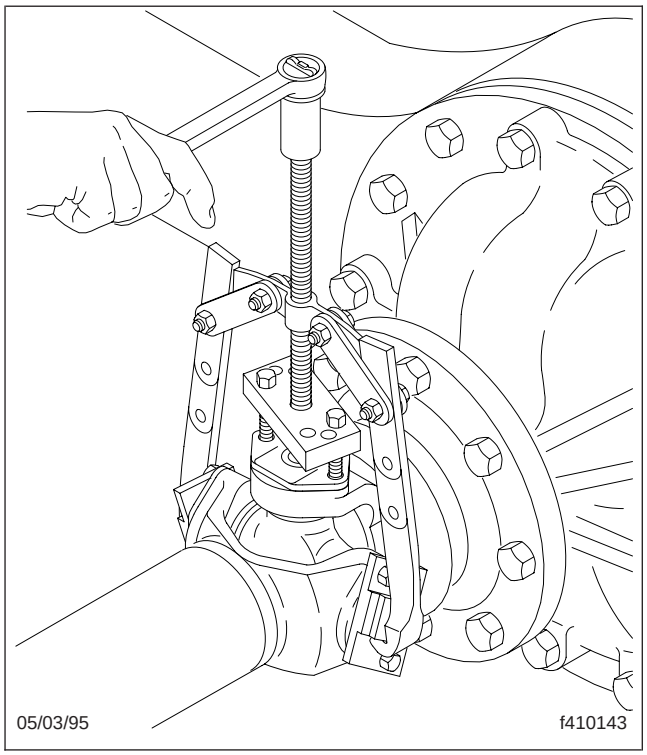


Fig. 2, Remove a Bearing Cup from a Full-Round End-Yoke

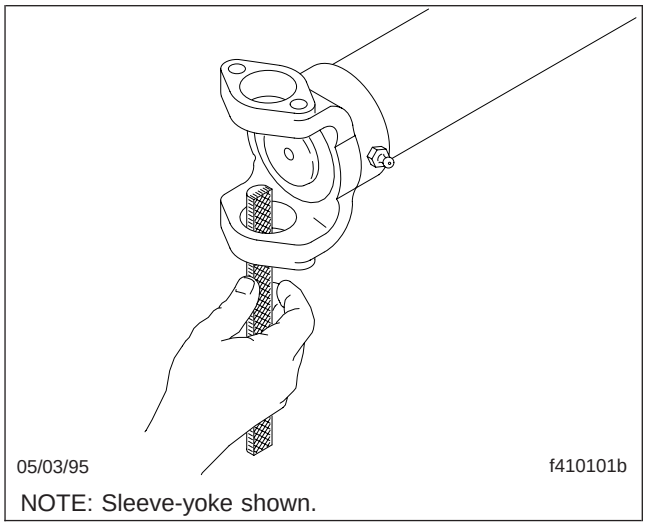


Fig. 3, Remove Burrs from a Full-Round Yoke Cross-Hole

4. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 68 lbf·ft (92 N·m).

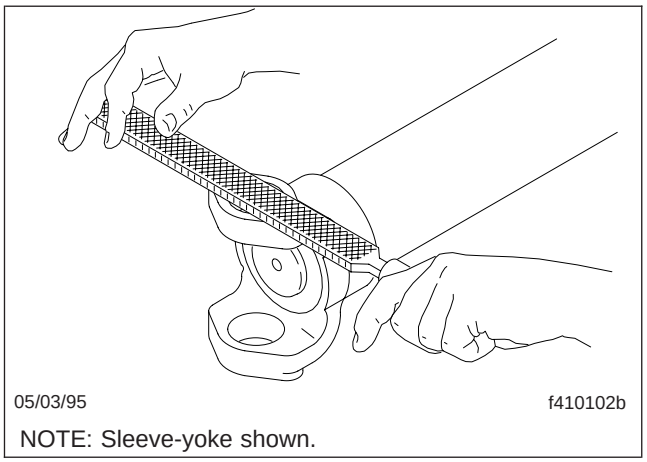


Fig. 4, Remove Burrs from the Machined Surface of a Full-Round Yoke Lug

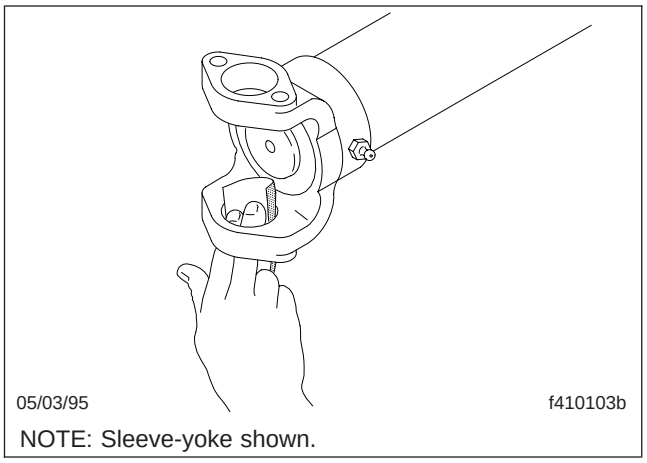
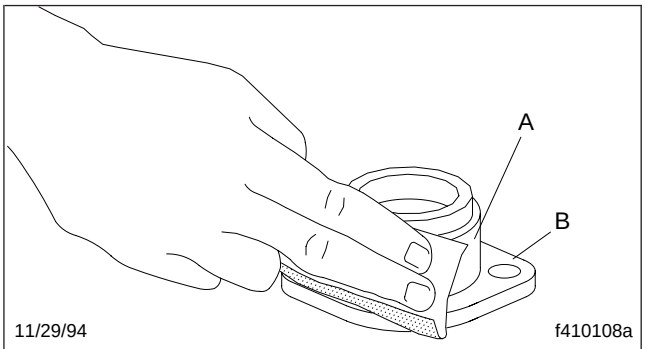


Fig. 5, Smooth a Full-Round Yoke Cross-Hole

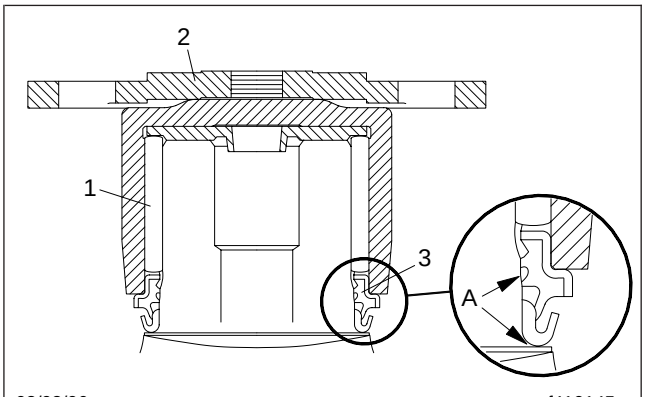
5. Lubricate the U-joint, following the procedure in Group 41 of the *108SD and 114SD Maintenance Manual*.
6. Remove the nylon support straps.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

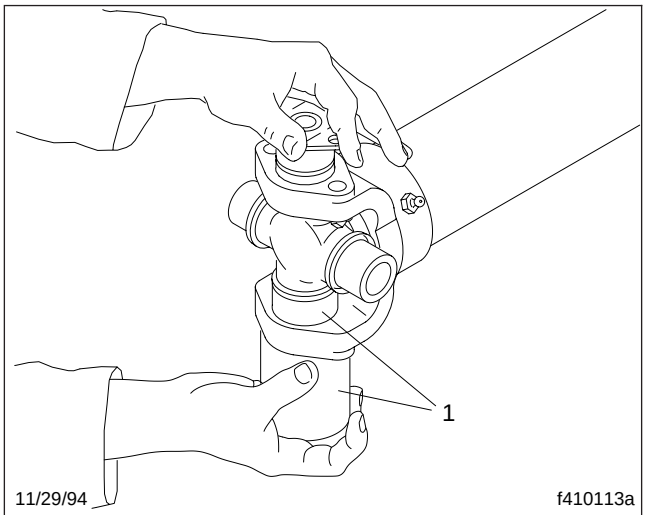
Fig. 6, Smoothing a Full-Round Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

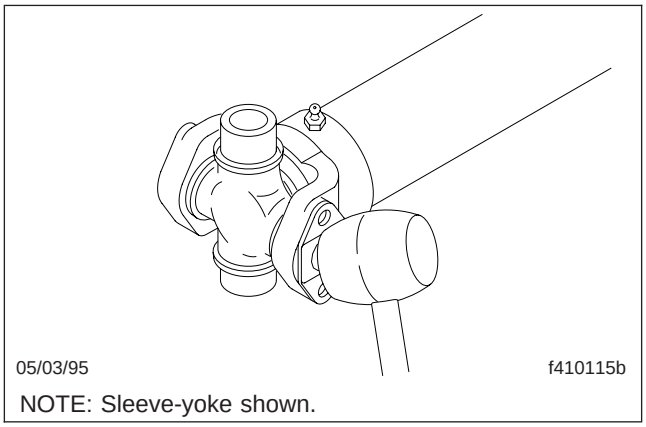
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 7, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

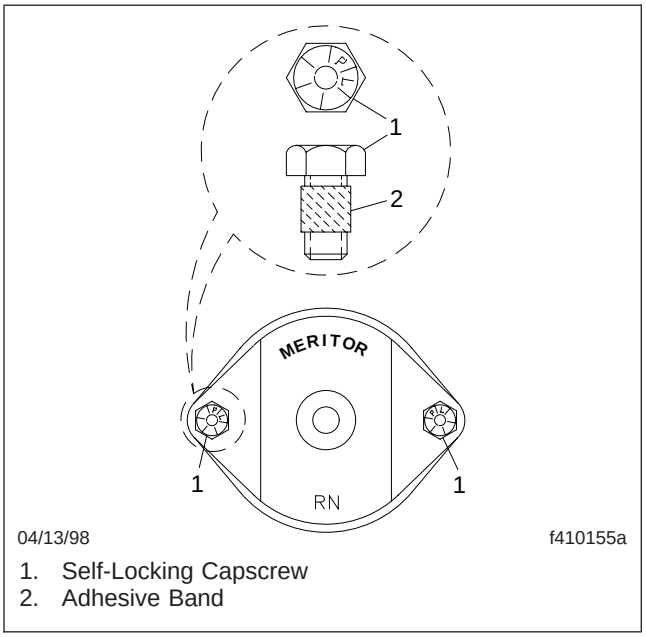
Fig. 8, Use a U-Joint Trunnion Locator



NOTE: Sleeve-yoke shown.

Fig. 9, Seat a U-Joint Bearing Cup in a Full-Round Yoke

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Meritor U-Joint Fasteners for Full-Round Yokes

Driveshaft Removal and Installation

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft. See **Subject 100** for uncoupling from a *half-round* end-yoke, or see **Subject 110** for uncoupling from a *full-round* end-yoke.

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke.

No. 3 Driveshaft Removal

1. Uncouple the No. 3 driveshaft from the rearmost axle. See **Fig. 1** and **Fig. 2**. If the No. 3 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the No. 3 driveshaft from the forward-rear axle. See **Fig. 1** and **Fig. 2**. If the No. 3 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 3 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 3 driveshaft out of the chassis.

No. 2 Driveshaft Removal

1. Uncouple the No. 2 driveshaft from the single or forward-rear axle. See **Fig. 3** and **Fig. 4**. If the No. 2 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the No. 2 driveshaft from the transmission or coupling shaft. See **Fig. 3** and **Fig. 4**. If the No. 2 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the No. 2 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the No. 2 driveshaft out of the chassis.

Intermediate Coupling Shaft Removal

1. If the No. 2 driveshaft is also being removed, remove it first.

   If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.
2. Uncouple the intermediate coupling shaft from the No. 2 driveshaft. If the intermediate coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the intermediate coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Uncouple the intermediate coupling shaft from the primary coupling shaft. See **Fig. 5** and **Fig. 6**. If the primary coupling shaft has a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.
4. Lift the intermediate coupling shaft out of the chassis.

Primary Coupling Shaft Removal

1. *For a vehicle with one coupling shaft:*

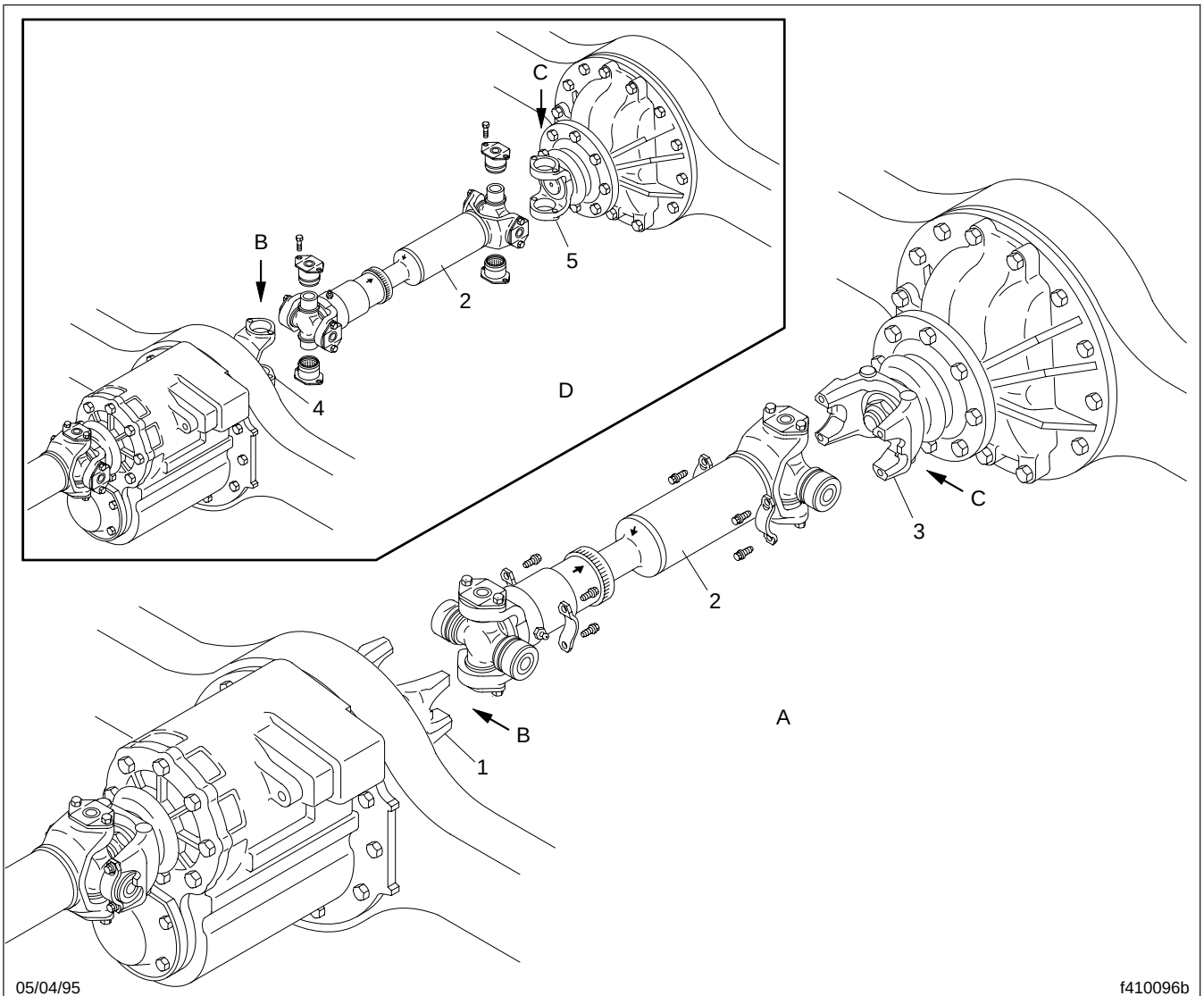
   If the No. 2 driveshaft is also being removed, remove it first.

   If the No. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.

   For a vehicle with two coupling shafts:

   If the No. 2 driveshaft is also being removed, remove it first; then, remove the intermediate coupling shaft.

Driveshaft Removal and Installation



NOTE: Not all fasteners are shown.

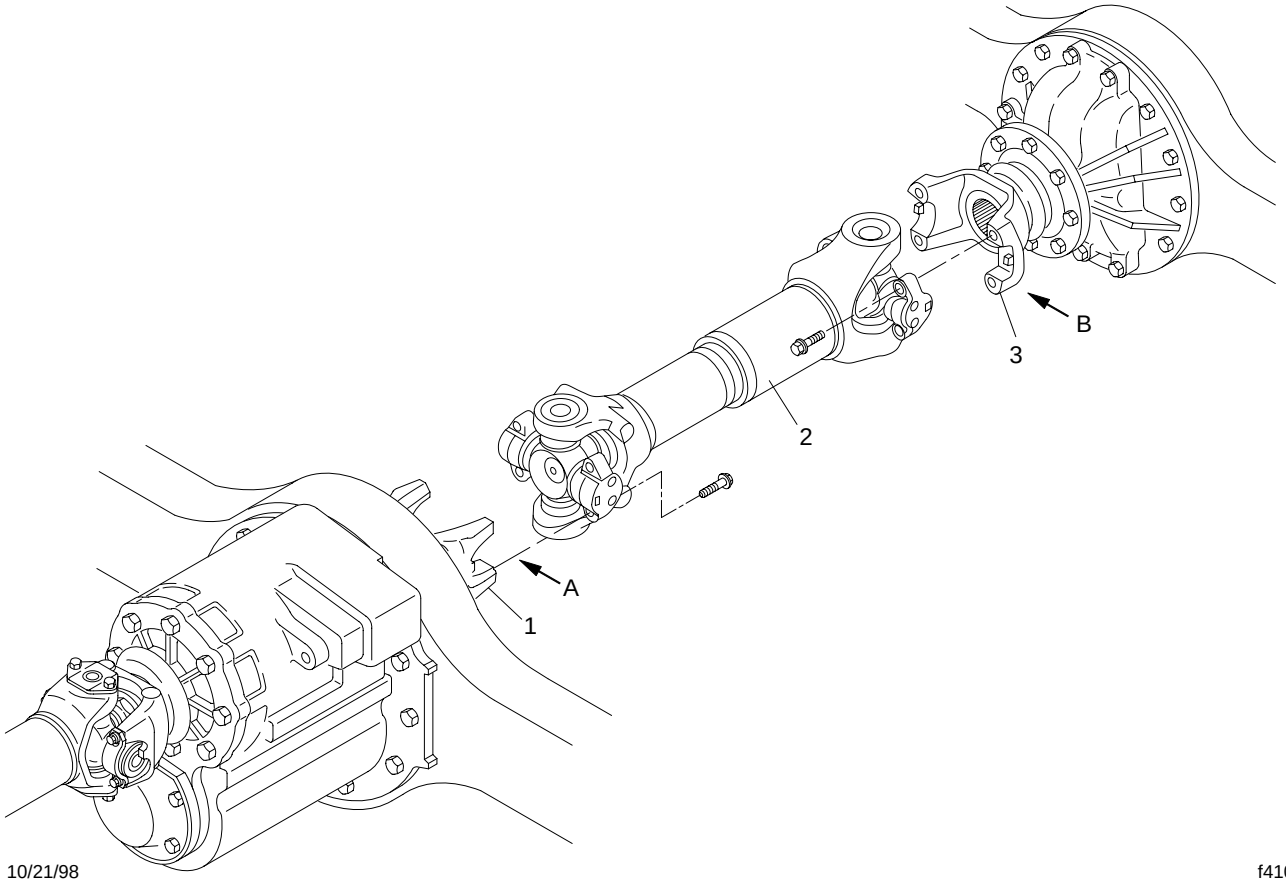
A. No. 3 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 3 Driveshaft Coupled to Full-Round End-Yokes

1. Forward-Rear Axle Output-Shaft Half-Round End-Yoke
2. No. 3 Driveshaft
3. Rearmost Axle Input-Shaft Half-Round End-yoke
4. Forward-Rear Axle Output-Shaft Full-Round End-Yoke
5. Rearmost Axle Input-Shaft Full-Round End-yoke

Fig. 1, Removal/Installation of a No. 3 Driveshaft Without RPL U-Joints

If the intermediate coupling shaft is also being removed (but not the No. 2 driveshaft), remove the intermediate coupling shaft first.

If only the primary coupling shaft is being removed, use nylon support straps to support the forward end of the No. 2 driveshaft and both ends of the intermediate coupling shaft. Then,



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.

B. Uncouple this end first; couple this end last.

1. Forward-Rear Axle Output-Shaft Half-Round End-Yoke

2. No. 3 Driveshaft

3. Rearmost Axle Input-Shaft Half-Round End-Yoke

Fig. 2, Removal/Installation of a No. 3 Driveshaft With RPL U-Joints

remove the fasteners that attach the intermediate coupling shaft midship bearing to its bracket. See **Fig. 7** and **Fig. 8**.

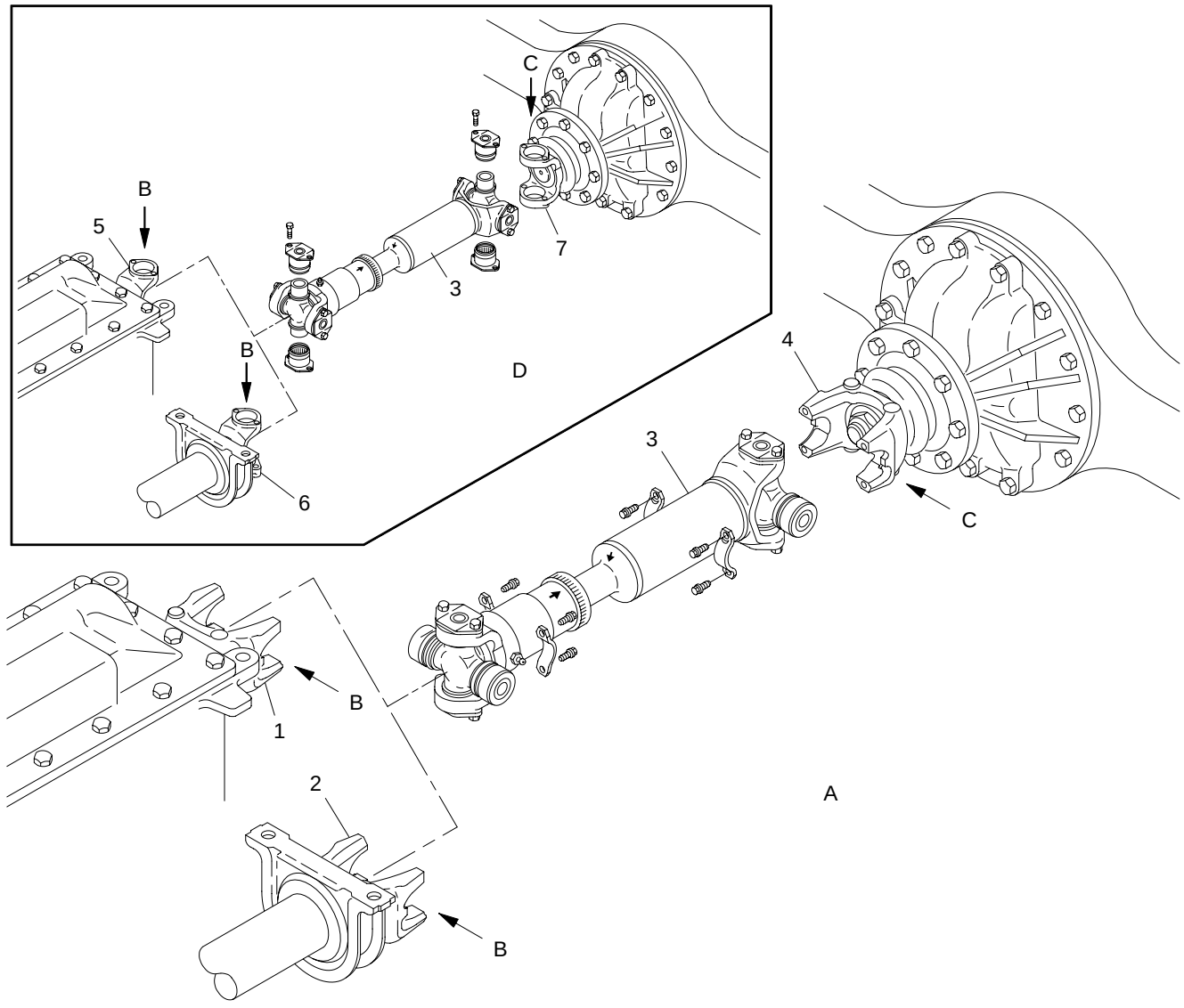
2. If not already done, uncouple the primary coupling shaft from the No. 2 driveshaft or intermediate coupling shaft. If the primary coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.

3. Using two nylon support straps, support the primary coupling shaft. Then remove the fasteners that attach the primary coupling shaft midship bearing to its bracket. See **Fig. 7** and **Fig. 8**.

4. Uncouple the primary coupling shaft from the transmission. If the primary coupling shaft is coupled to a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft is coupled to a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.

5. Lift the primary coupling shaft out of the chassis.

Driveshaft Removal and Installation



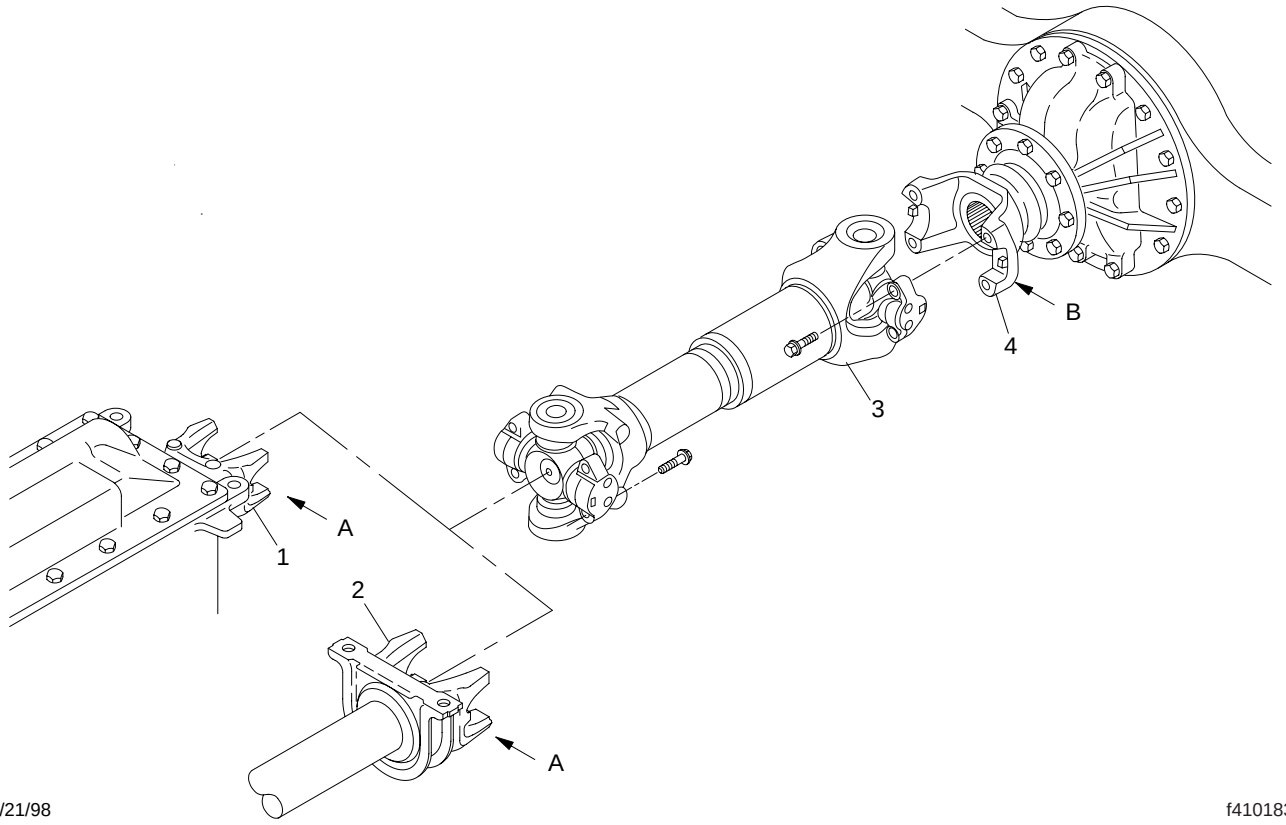
05/05/95 f410080b

NOTE: Not all fasteners are shown.

A. No. 2 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveshaft Coupled to Full-Round End-Yokes

1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke
5. Transmission Output-Shaft Full-Round End-Yoke
6. Coupling Shaft Full-Round End-Yoke
7. Single Axle or Forward-Rear Axle Input-Shaft Full-Round End-Yoke

Fig. 3, Removal/Installation of a No. 2 Driveshaft Without RPL U-Joints



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.

B. Uncouple this end first; couple this end last.

1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke

Fig. 4, Removal/Installation of a No. 2 Driveshaft With RPL U-Joints

Primary Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 9**.

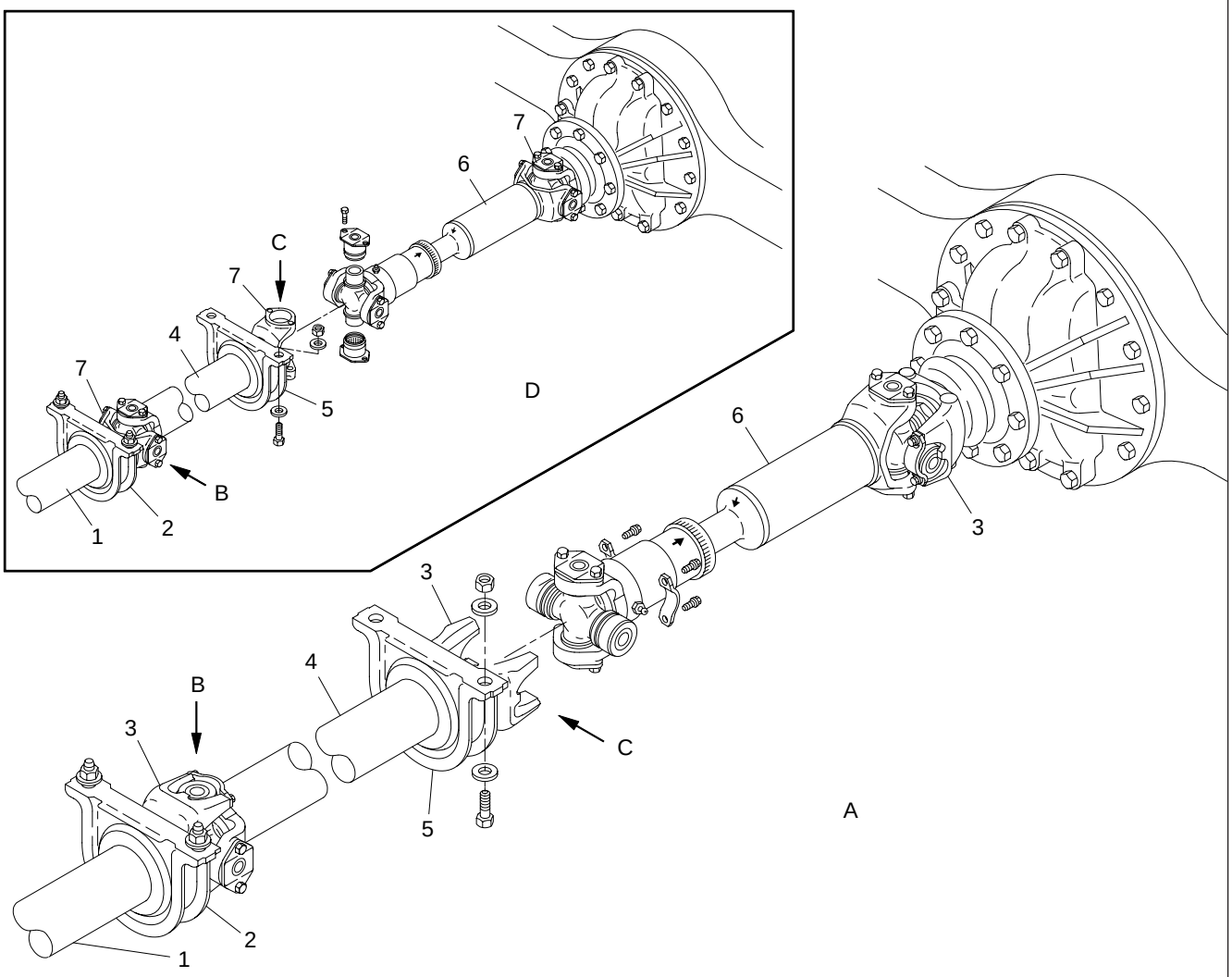
1. Place the primary coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the transmission end-yoke.
2. Couple the shaft to the transmission end-yoke. If the primary coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
3. *For a vehicle with one coupling shaft:*

   If the No. 2 driveshaft was also removed, install it, as instructed in this subject.

   If the No. 2 driveshaft was not removed, couple it to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

   For a vehicle with two coupling shafts:

Driveshaft Removal and Installation



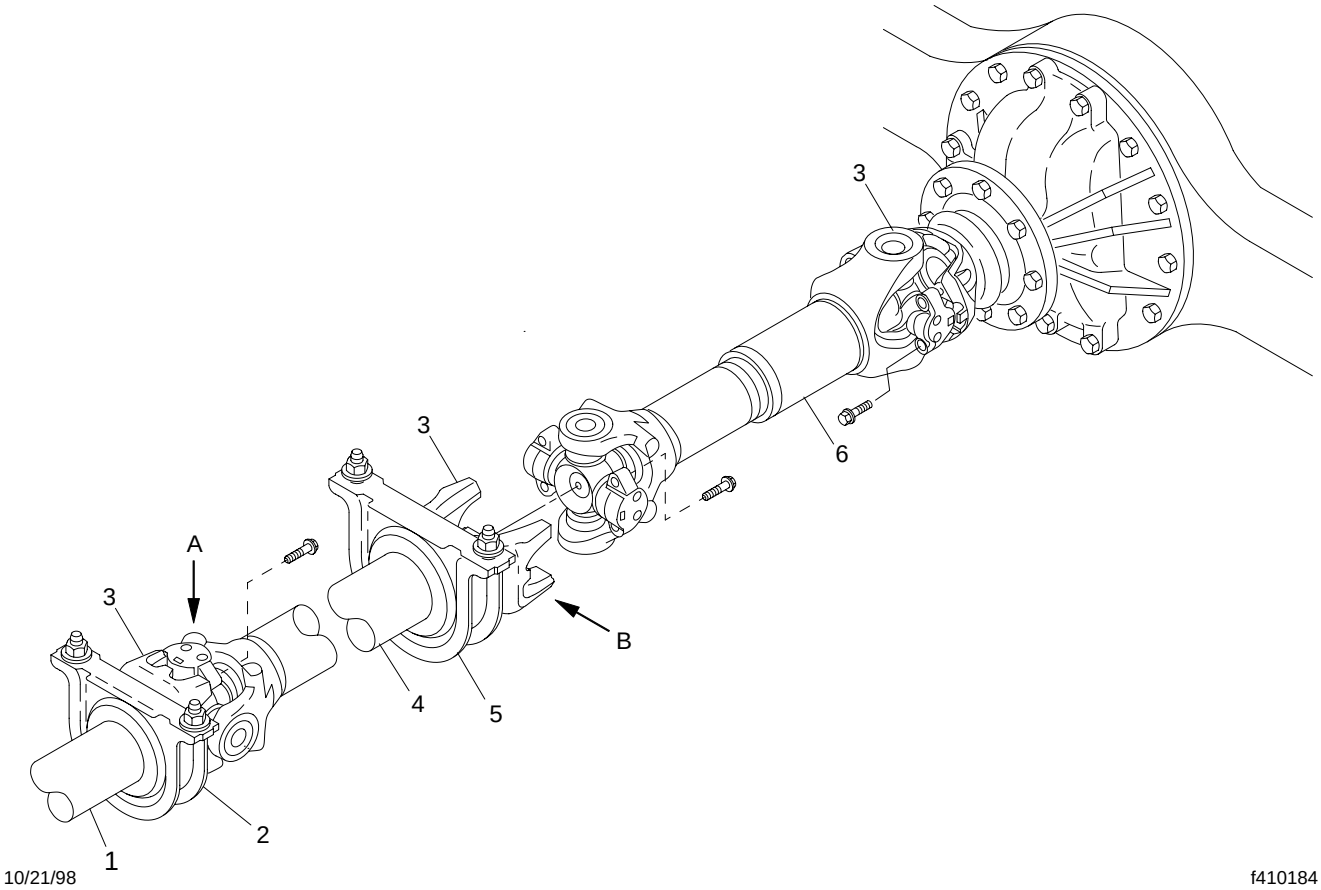
05/04/95 f410084b

NOTE: Not all fasteners are shown.

A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes

1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft
7. Full-Round End-Yoke

Fig. 5, Removal/Installation of an Intermediate Coupling Shaft Without RPL U-Joints



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
B. Uncouple this end first; couple this end last.

1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft

Fig. 6, Removal/Installation of an Intermediate Coupling Shaft With RPL U-Joints

If the intermediate coupling shaft was also removed, install it, as instructed in this subject.

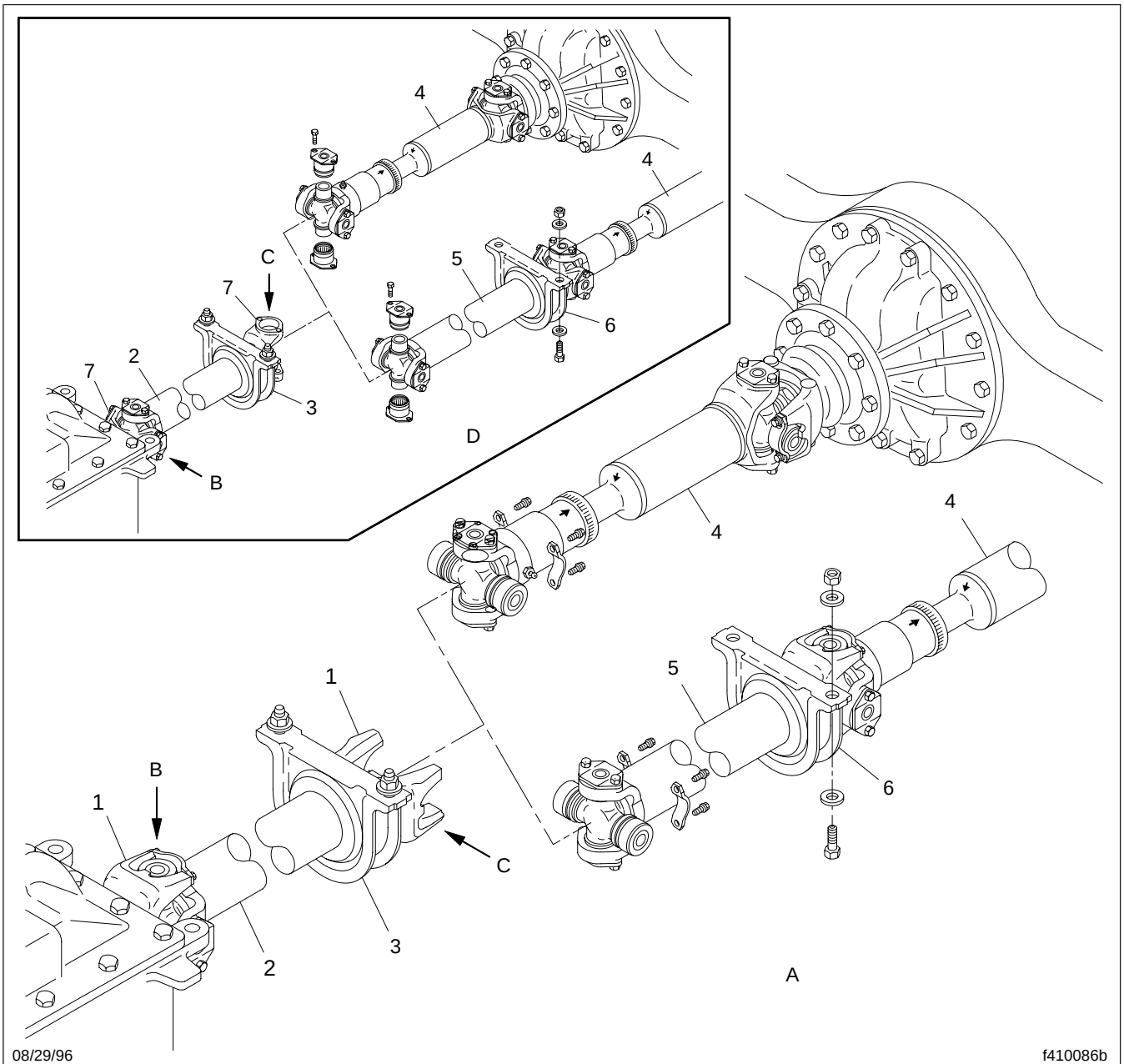
If only the primary coupling shaft was removed, couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

Intermediate Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase. See **Fig. 9**.

1. If the primary coupling shaft was also removed, install it first, as instructed in this subject.
2. Place the intermediate coupling shaft under the vehicle and support it with nylon support straps

Driveshaft Removal and Installation

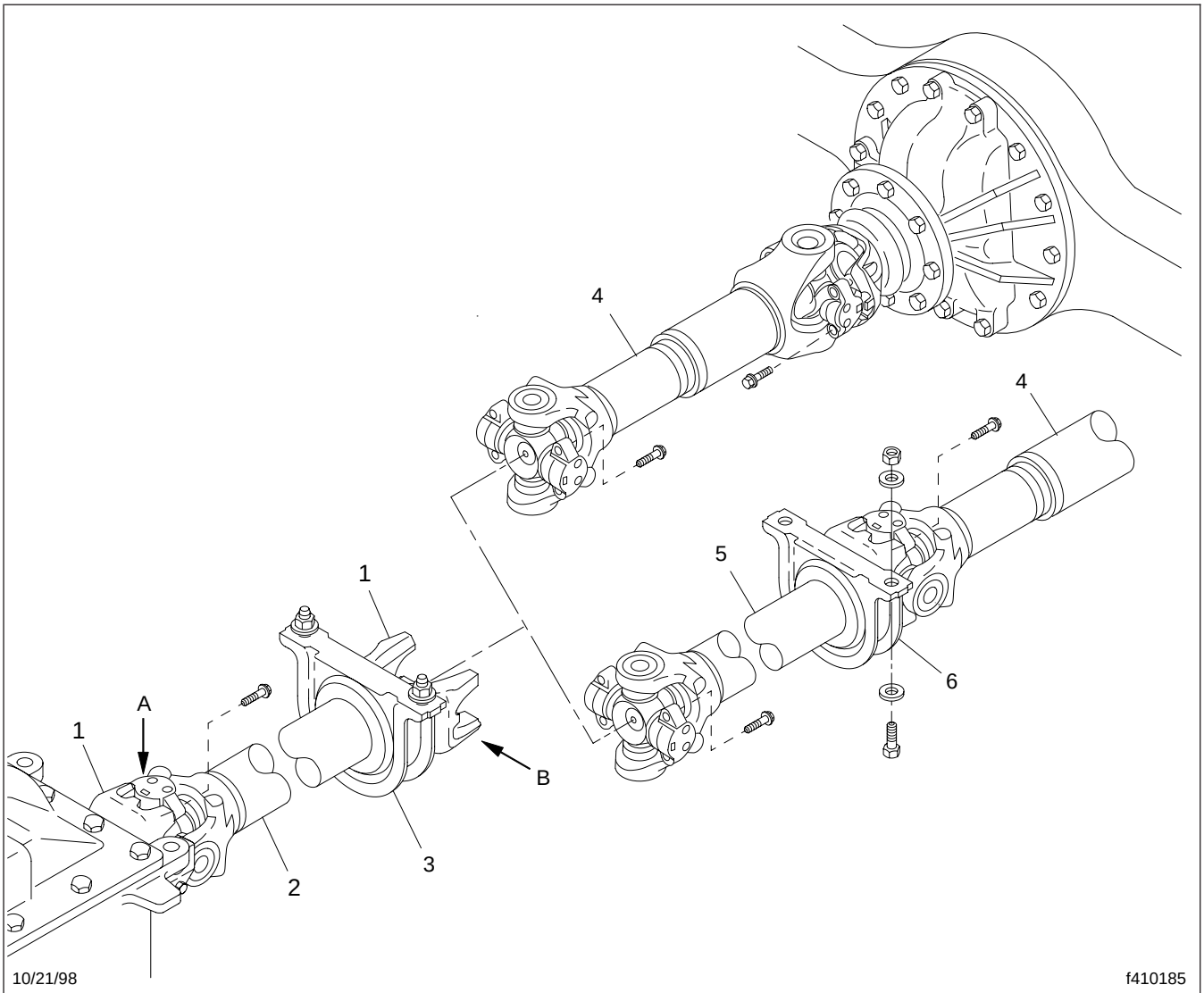


NOTE: Not all fasteners are shown.

A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes

1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing
7. Full-Round End-Yoke

Fig. 7, Removal/Installation of a Primary Coupling Shaft Without RPL U-Joints



NOTE: Not all fasteners are shown.

A. Uncouple this end last; couple this end first.
B. Uncouple this end first; couple this end last.

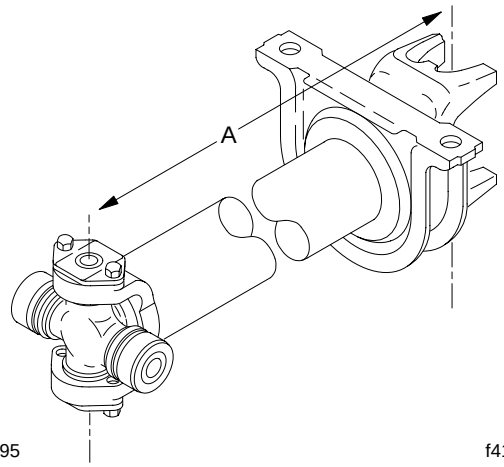
1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing

Fig. 8, Removal/Installation of a Primary Coupling Shaft With RPL U-Joints

so it can be coupled to the primary coupling shaft end-yoke.

3. Couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the intermediate coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
4. If the No. 2 driveshaft was also removed, install it, as instructed in this subject.

Driveshaft Removal and Installation



A. Cross-hole centerlines of both yokes must be in alignment.

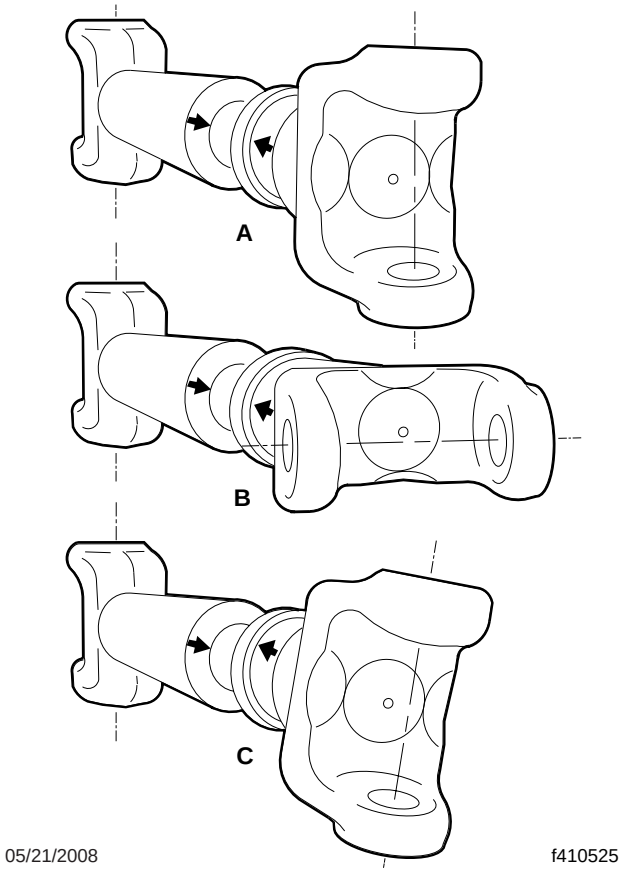
Fig. 9, U-Joint Phasing of a Coupling Shaft

If the No. 2 driveshaft was not removed, couple it to the intermediate coupling shaft end-yoke. If the intermediate coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

No. 2 Driveshaft Installation

IMPORTANT: Before installing a No. 2 driveshaft, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase; see **Fig. 10**.

1. If a primary coupling shaft was also removed, install it first, as instructed in this subject.
2. If an intermediate coupling shaft was also removed, install it before installing the No. 2 driveshaft.
3. Place the No. 2 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
4. Couple the sleeve-yoke to the coupling shaft end-yoke or transmission output-shaft end-yoke, as applicable. If the No. 2 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
5. Couple the No. 2 driveshaft to the axle input-shaft end-yoke. If the No. 2 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 2 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 10, U-Joint Phasing

No. 3 Driveshaft Installation

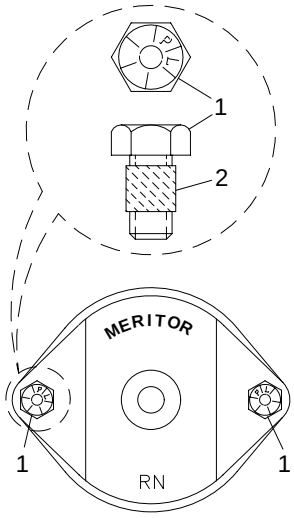
IMPORTANT: Before installing a No. 3 driveshaft, make sure the alignment marks on the slip-joint assembly are aligned, to keep the U-joints in phase; see **Fig. 10**.

1. Place the No. 3 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
2. Couple the sleeve-yoke to the forward-rear axle output-shaft end-yoke. If the No. 3 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
3. Couple the No. 3 driveshaft to the axle input-shaft end-yoke. If the No. 3 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the No. 3 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

U-Joint Removal

Full-Round Yokes

1. Remove the driveshaft from the vehicle. See **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard all four bearing-plate self-locking capscrews. See **Fig. 1**.



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1. Self-Locking Capscrew
2. Adhesive Band

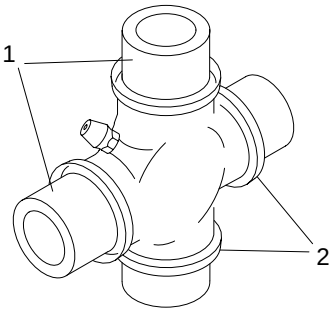
Fig. 1, Meritor U-Joint Fasteners for Full-Round Yokes

IMPORTANT: If the U-joint will be reinstalled, use care not to nick the cross trunnions or damage the slingers. See **Fig. 2**.

4. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing cups from the yoke cross-holes. See **Fig. 3**. Remove the cross from the yoke.

RPL Series U-Joint

NOTE: Do not reuse RPL U-joints. Always replace an RPL U-joint with a new one after they have been disassembled and removed from a driveshaft.



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1. Trunnions 2. Slingers

Fig. 2, U-Joint Cross

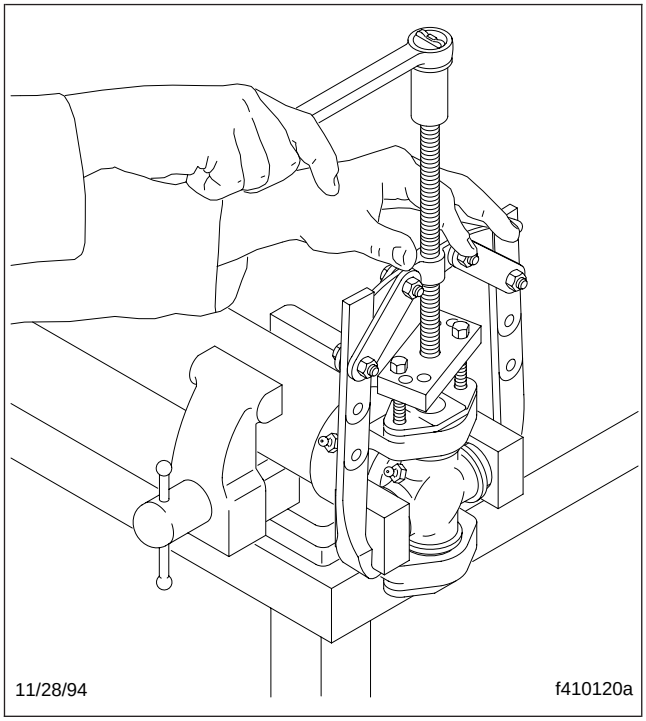

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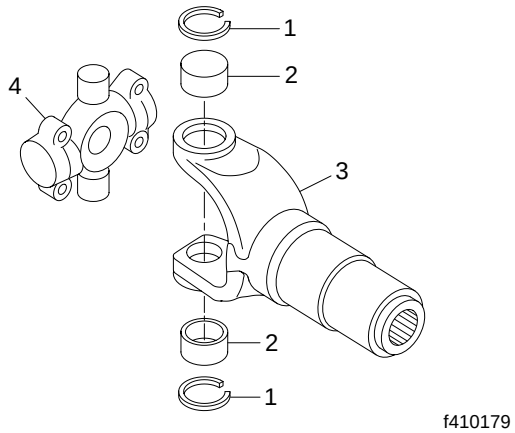
Fig. 3, Removing a Bearing Cup from a Full-Round Yoke

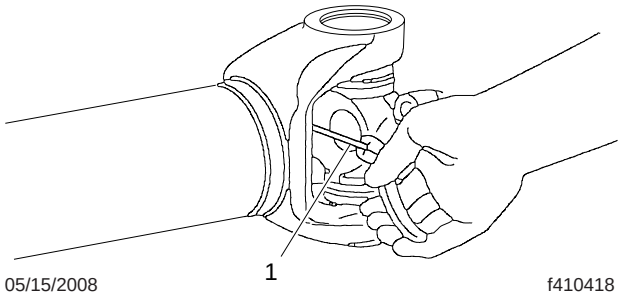
1. Remove the driveshaft from the vehicle. See **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard the snap rings. See **Fig. 4**.
4. Cut the weld strap that retains the bearing cups. See **Fig. 5**. Remove both bearing cups. See **Fig. 6**.

Driveline Component Removal/Disassembly



1. Snap Ring
2. Bearing Cups
3. Full Round Yoke
4. Bearing Cups (RPL Joint)

Fig. 4, RPL U-Joint Components



1. Weld-Strap

Fig. 5, Cutting the Weld-Strap

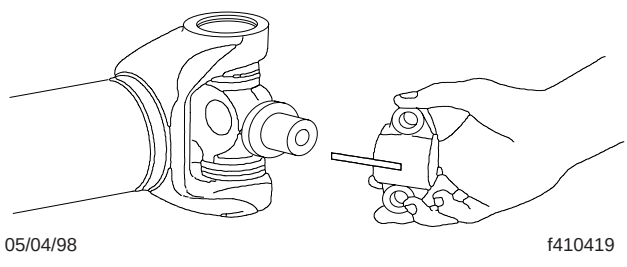
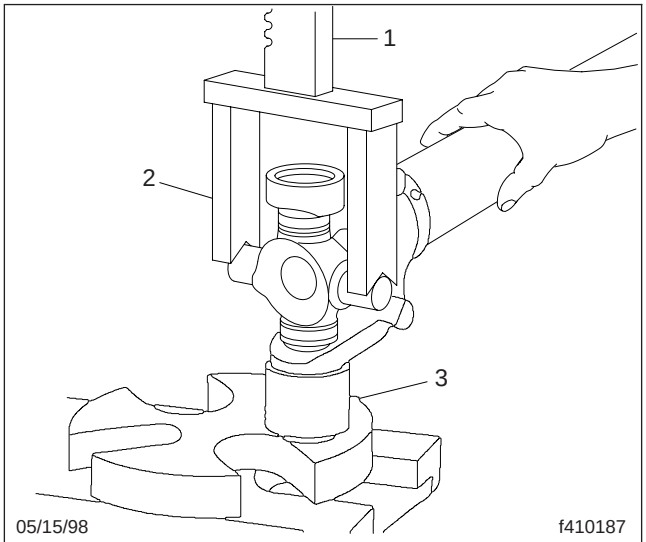


Fig. 6, Removing the Bearing Cups

5. Remove both bearing cups from the yoke cross-holes. See **Fig. 7**. Remove the cross from the yoke.



1. Press
2. Bridge
3. Bearing Cup Receiver

Fig. 7, Removing Bearing Cups from an RPL U-Joint

Slip-Joint Disassembly

Except RPL Drivelines

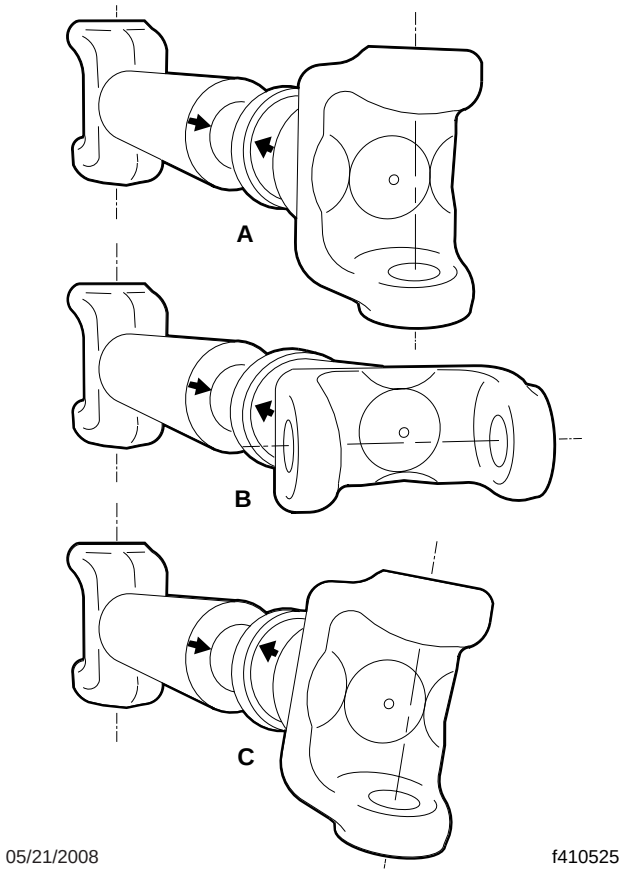
1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 8**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 9**. This will ensure proper alignment of the slip-joint components when the driveshaft is assembled.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a strap wrench to unscrew the slip-joint dust cap from the sleeve-yoke, then pull the sleeve-yoke off of the splined shaft. Remove the dust cap, and (if so equipped) the steel washer and cork seal. See **Fig. 10**.

RPL Drivelines

1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 8**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 9**. This will



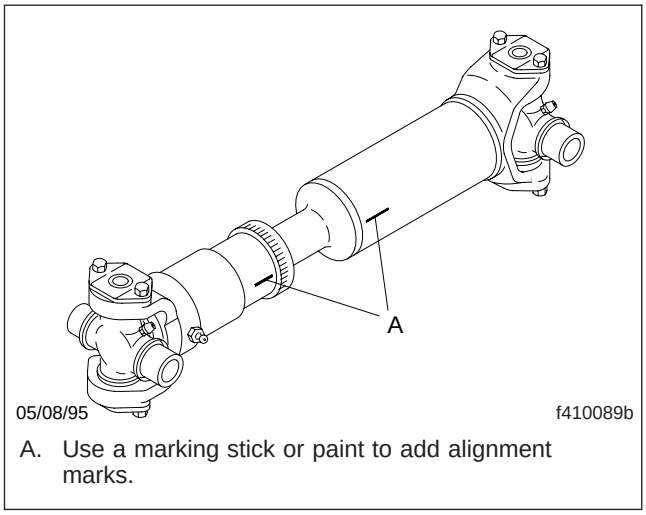
A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 8, U-Joint Phasing

ensure proper alignment of the slip-joint components when the driveshaft is assembled.

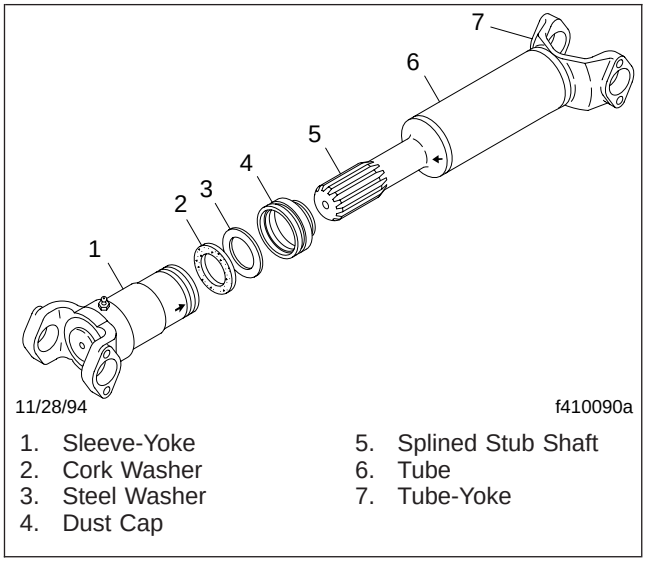
IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a brass hammer and punch to tap the shroud off the slip seal. See **Fig. 11**.
3. Use a screwdriver to pry the seal out of the groove in the slip yoke, then pull the sleeve-yoke off of the splined shaft. Remove the shroud and seal.



A. Use a marking stick or paint to add alignment marks.

Fig. 9, Slip-Joint Alignment Marks



1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 10, Slip-Joint Components

Transmission/Axle End-Yoke Removal

IMPORTANT: Before removing a transmission output-shaft end-yoke or an axle shaft end-yoke, do the steps under "End-Yoke Cleaning and Inspection," in **Subject 140**.

1. Uncouple the driveshaft from the end-yoke (**Subject 100** for a half-round yoke or **Sub-**

Driveline Component Removal/Disassembly

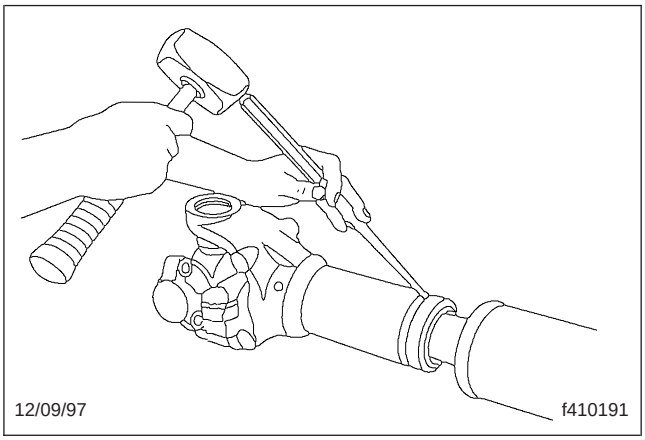


Fig. 11, Shroud Removal

ject 110 for a full-round yoke), or remove the driveshaft from the vehicle (Subject 120).

2. Remove the end-yoke locknut. See Fig. 12.
3. Using a yoke puller, remove the end-yoke. See Fig. 13 for a half-round end-yoke, or see Fig. 14 for a full-round end-yoke.

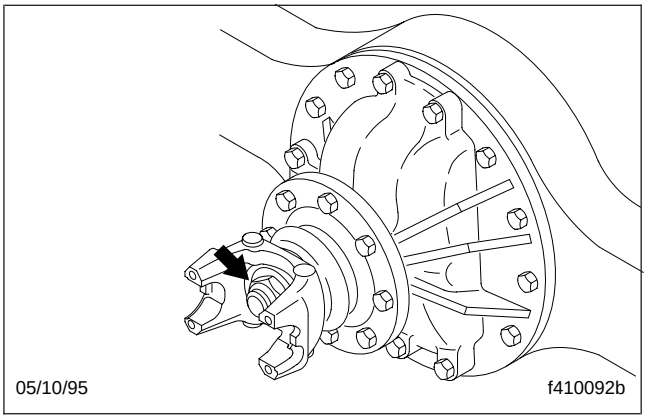
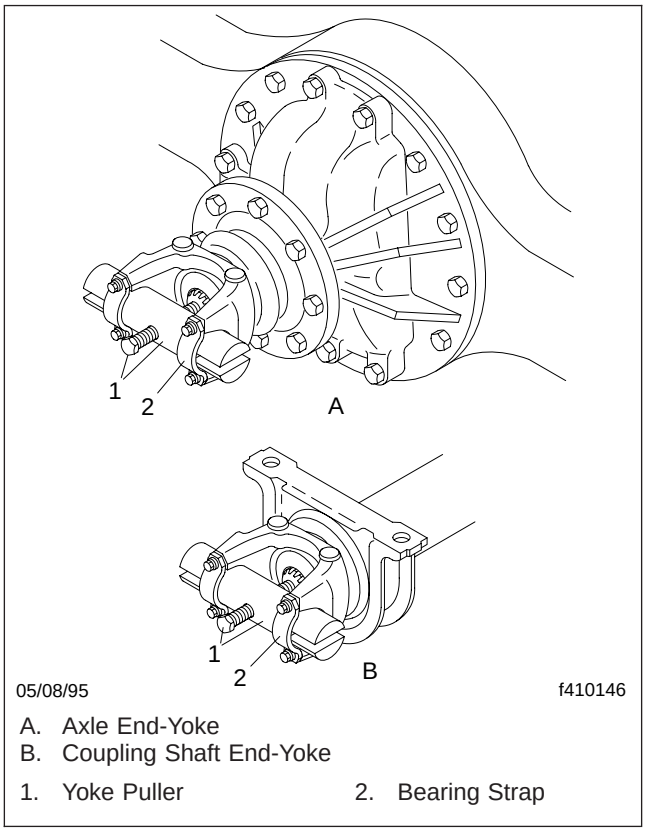


Fig. 12, Axle End-Yoke Locknut

Coupling Shaft End-Yoke and Midship Bearing Removal

1. Remove the coupling shaft from the vehicle. See Subject 120.
2. Clamp the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove the end-yoke; see Fig. 13 for a half-round end-yoke, or see Fig. 14 for a full-round



A. Axle End-Yoke
B. Coupling Shaft End-Yoke
1. Yoke Puller
2. Bearing Strap

Fig. 13, Removing a Half-Round End-Yoke

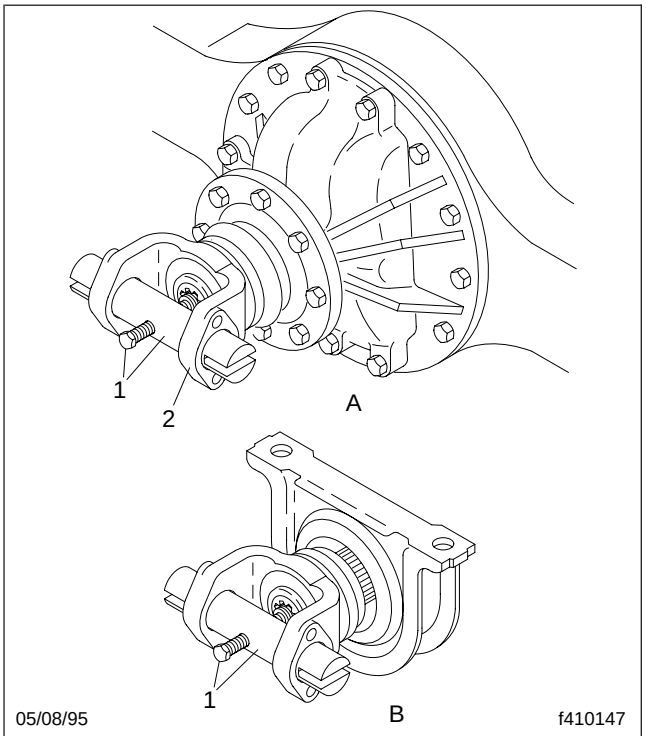
end-yoke. Then, remove the midship bearing as follows. See Fig. 15.

3.1 Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks. See Fig. 16.

3.2 Remove the coupling shaft end-yoke locknut.

3.3 Using a yoke puller, remove the end-yoke. See Fig. 13 for a half-round end-yoke, or see Fig. 14 for a full-round end-yoke.

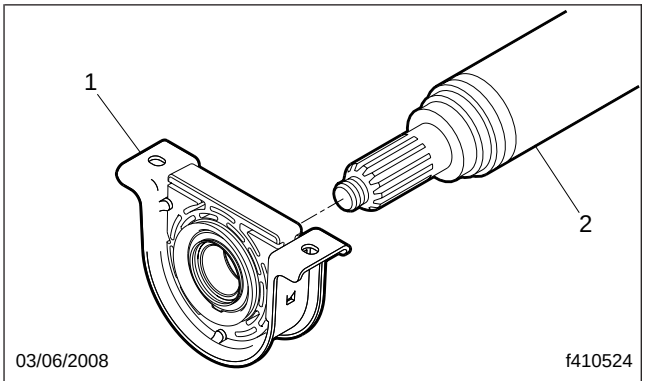
3.4 Use a hammer and a brass drift to remove the midship bearing. See Fig. 15.



A. Axle End-Yoke
B. Coupling Shaft End-Yoke

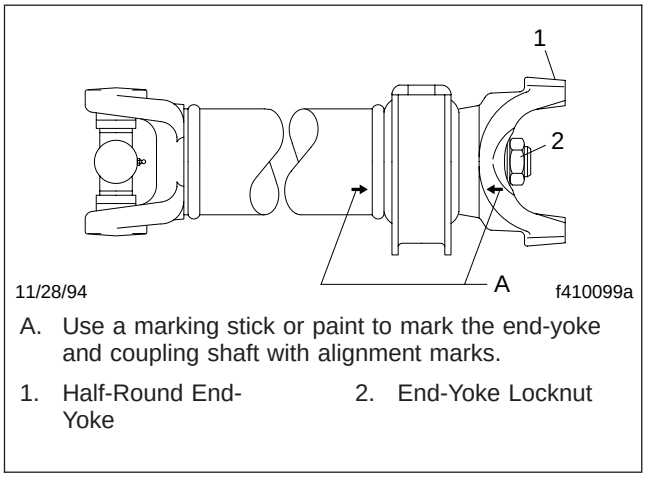
1. Yoke Puller
2. Full-Round End-Yoke

Fig. 14, Removing a Full-Round End-Yoke



1. Midship Bearing
2. Midship Bearing Shaft

Fig. 15, Midship Bearing



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.

1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 16, Alignment Marks on a Coupling Shaft With an End-Yoke

Driveshaft Tube, Slip-Joint, Sleeve-Yoke, and Tube-Yoke Cleaning and Inspection

1. With the driveshaft removed, scrape or soak away any foreign material.
2. Examine the driveshaft tube for dents, bends, twists, splitting weld-seams, and signs of missing balance weights.

   Replace the driveshaft tube if damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. If balance weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
3. Clean the slip-joint (male and female) splines, then check them for twisting and galling. See **Fig. 1**. Replace both the sleeve-yoke and the splined shaft if the slip-joint is damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. Remove any burrs or rough spots using fine emery cloth.

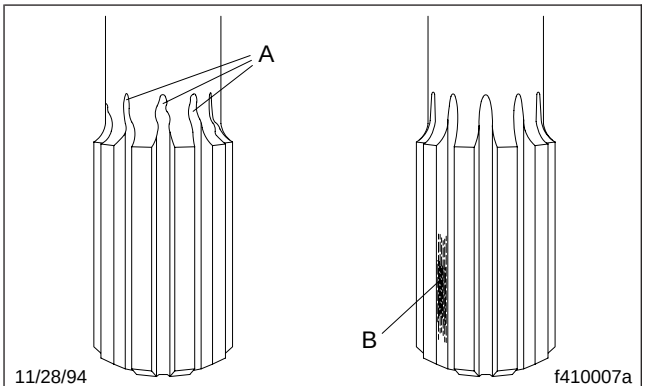


Fig. 1, Damaged Slip-Joint Splines

4. Check for a loose or missing sleeve-yoke plug. See **Fig. 2**. Repair or replace the plug as needed.
5. With the U-joint assemblies removed, check all driveshaft yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.

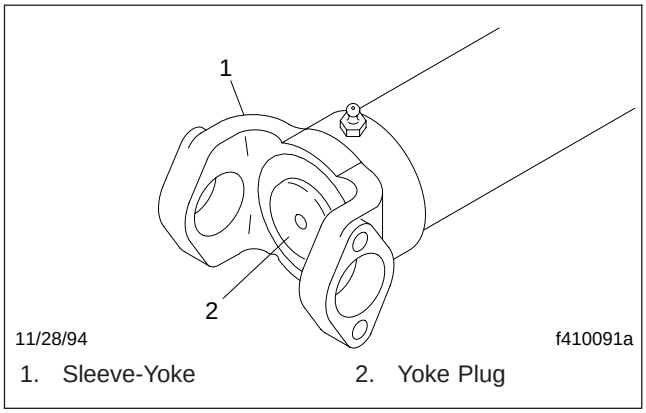


Fig. 2, Sleeve-Yoke Plug

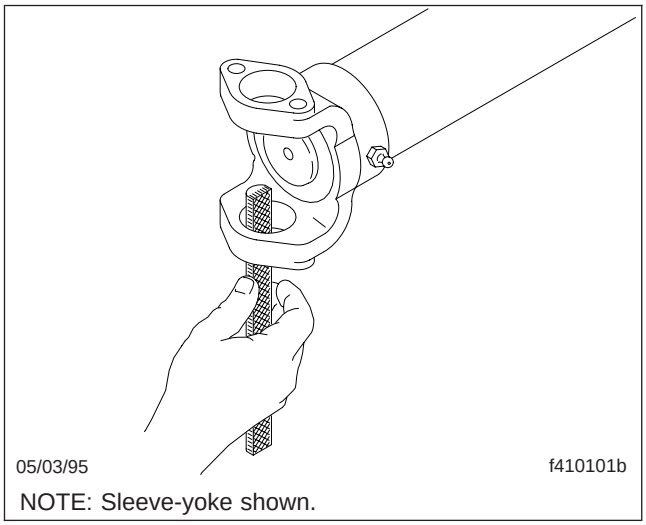


Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

6. Using a mill file, and holding it flat against the machined surface of the driveshaft yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.
7. Using fine emery cloth, smooth and clean the entire surface of all driveshaft yoke cross-holes. See **Fig. 5**.

Midship Bearing Cleaning and Inspection

1. With the midship bearing removed from the coupling shaft, use clean rags or paper towels to

Driveline Component Cleaning and Inspection

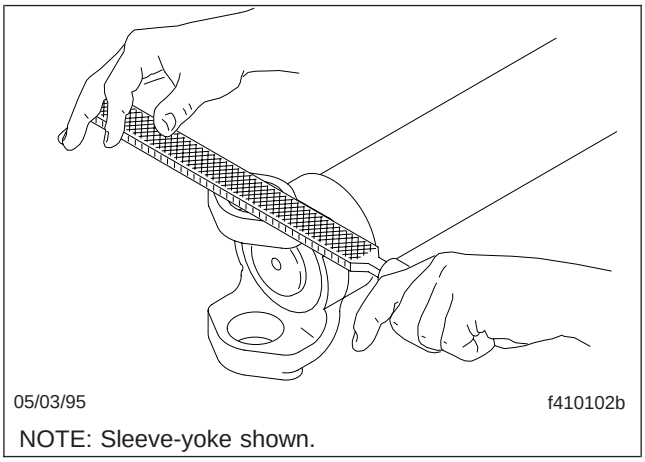


Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug

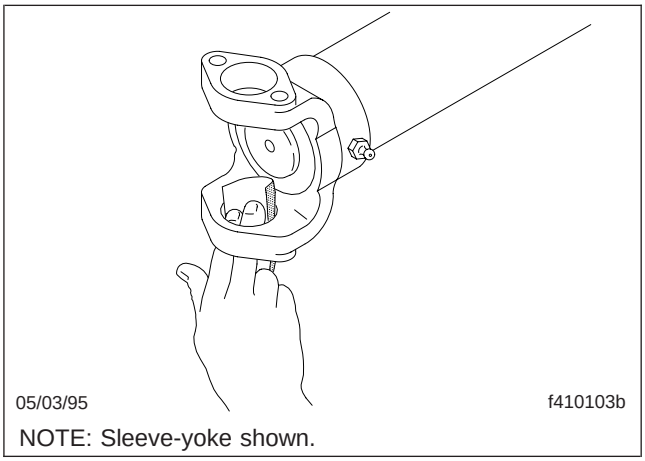


Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

wipe off the outside of the midship bearing and rubber cushion.

IMPORTANT: Do not immerse the midship bearing in cleaning solvent. The solvent will wash out the lubricant, requiring bearing-assembly replacement.

2. Check the midship bearing for roughness or rattles by holding the outside of the bearing while manually turning the inner bearing race. Replace the bearing assembly if there are any rough spots or rattles.
3. Check the rubber cushion for deterioration or oil-soaking, and replace the midship bearing assembly if needed.

End-Yoke Cleaning and Inspection

1. With the transmission output-shaft and axle shaft end-yokes installed, check them for cracks and looseness.

   Replace cracked yokes. If the end-yoke can be moved in or out on its shaft, or can be rocked on its shaft, uncouple the driveshaft from the end-yoke. Check the drive component's shaft seal for leakage or other visible damage that may have been caused by the loose yoke. Replace the shaft seal if needed. Tighten the end-yoke nut to the torque value given in **Specifications 400**. If the end-yoke is still loose after tightening the yoke nut, install a new yoke and yoke nut.

NOTE: If the end-yoke locknut is removed for any reason, install a new one.

2. With the U-joints uncoupled from the end-yokes, check all driveshaft and input/output shaft end-yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3** for full-round yokes, or see **Fig. 6** for half-round yokes.

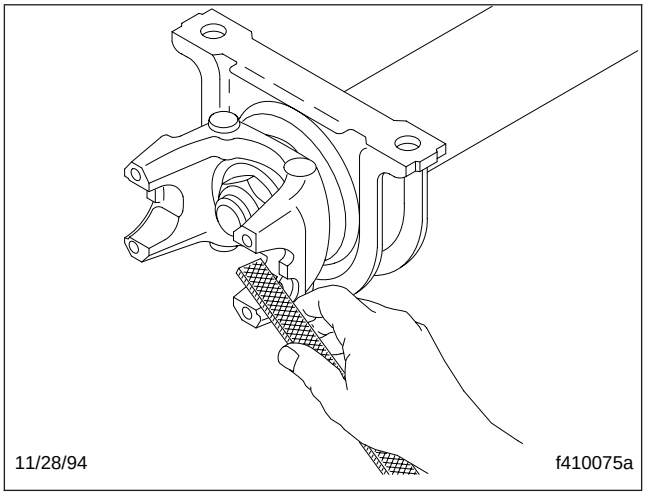
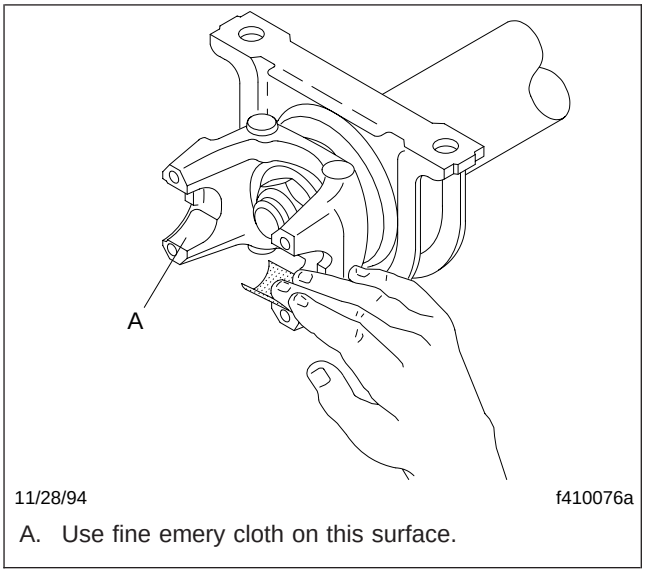


Fig. 6, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Using a mill file, and holding it flat against the machined surface of the *full-round* end-yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.

4. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See **Fig. 5** for full-round yokes, or see **Fig. 7** for half-round yokes.



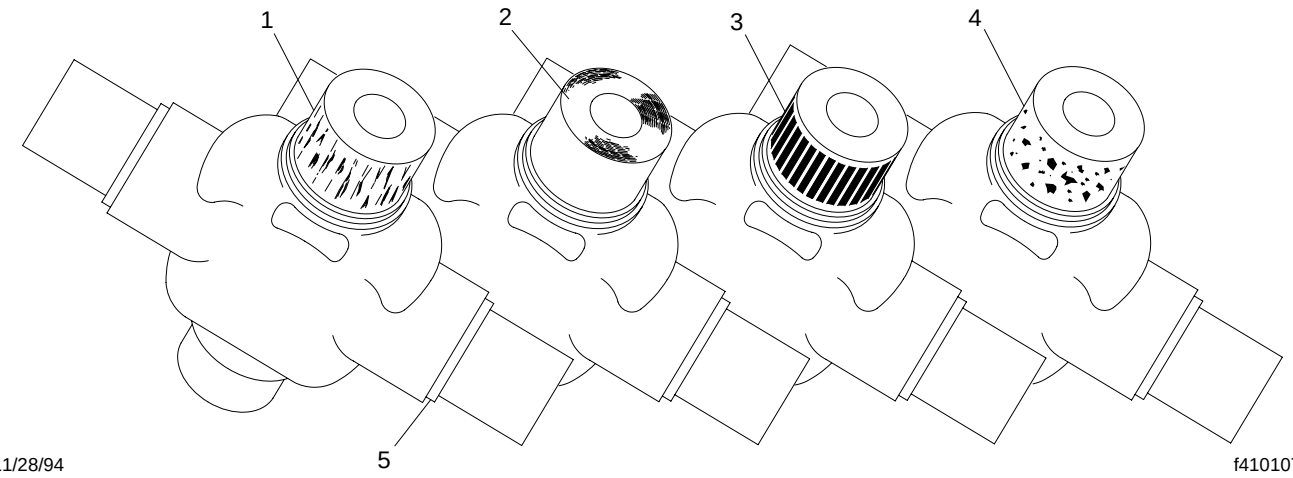
A. Use fine emery cloth on this surface.

Fig. 7, Smoothing a Half-Round End-Yoke Cross-Hole

U-Joint Cleaning and Inspection

1. With the U-joints removed from the yokes, and the bearing cups removed from the crosses, inspect the U-joint cross slingers for damage, then inspect the U-joint trunnions for spalling (flaking metal), end galling (displacement of metal), brinelling (grooves caused by bearing needles), and pitting (small craters caused by corrosion). See **Fig. 8**. If damaged, replace the U-joint assembly.
2. Using a hand-type grease gun, apply multipurpose chassis grease to the fitting on each U-joint cross until all old lubricant is forced out. See **Fig. 9**. Examine the old lubricant. If it appears rusty, gritty, or burnt, replace the U-joint assembly.
3. Soak the bearing cups in a non-flammable cleaner until particles of grease and foreign matter are loosened or dissolved. Do not disassemble the bearing cups; clean the bearing needles with a short, stiff brush, then blow them dry with compressed air. Check for minute particles of dirt or grit, and clean again if necessary.
4. Check each bearing cup for missing bearing needles. Check the bearing-cup seals for nicks. See **Fig. 10** for a half-round-yoke U-joint bearing cup, or see **Fig. 11** for a full-round-yoke U-joint bearing cup. Replace the U-joint assembly if any bearing needles are missing or any seals are damaged.
5. Apply a small quantity of multipurpose chassis grease to the bearing needles in each cup, then apply a small amount of light-weight oil to the lips of the bearing-cup seals. Rotate each bearing cup on the cross to check for wear. Replace the U-joint assembly if any bearing surfaces are worn.
6. Check the underside of each bearing-cup plate for burrs or raised metal. Use a mill file to remove any burrs or raised metal. See **Fig. 12**.
7. Using fine emery cloth, smooth and clean the outside surfaces of all bearing cups. See **Fig. 12** and **Fig. 13**.

Driveline Component Cleaning and Inspection



1. Spalling
2. End Galling
3. Brinelling
4. Pitting
5. Slinger

Fig. 8, Damaged U-Joint Crosses

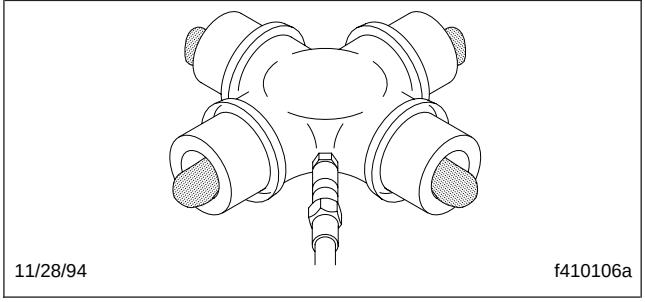
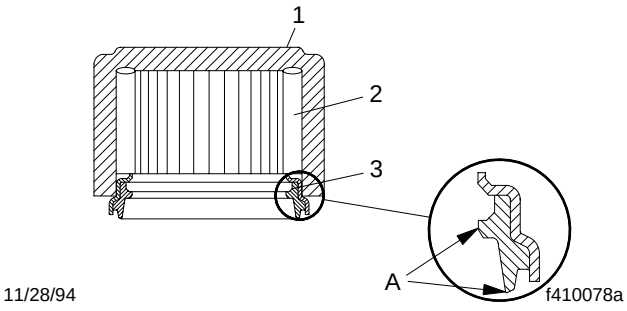


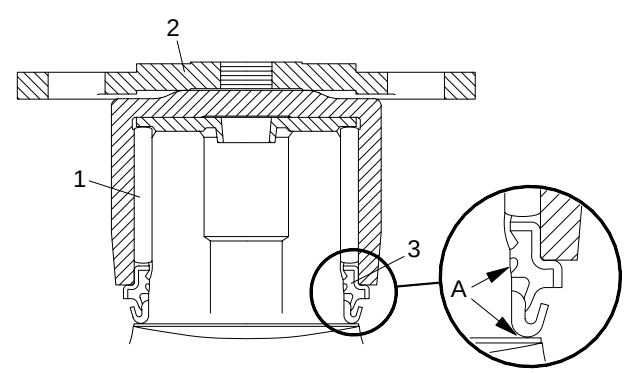
Fig. 9, Forcing Out Old Lubricant From a U-Joint Cross



A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

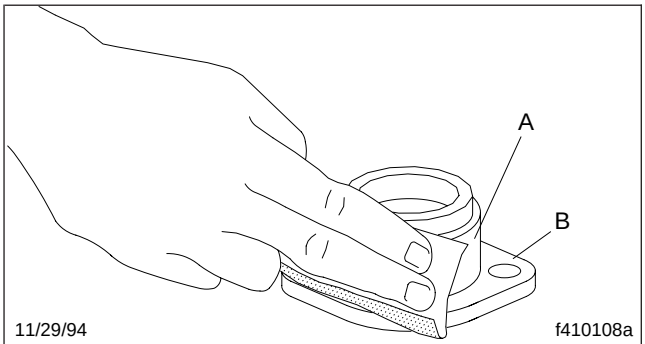
Fig. 10, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

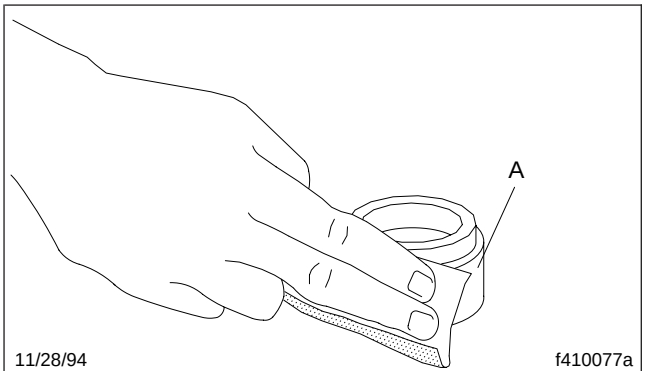
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 11, Sectional View of a Full-Round Yoke U-Joint Bearing Cup



A. Use fine emery cloth on this surface.
B. Use a mill file on this surface.

Fig. 12, Smoothing a Full-Round Yoke U-Joint Bearing Cup



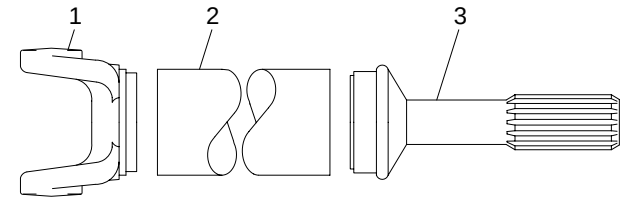
A. Use fine emery cloth on this surface.

Fig. 13, Smoothing a Half-Round Yoke U-Joint Bearing Cup

Driveshaft Tube, Stub Shaft (Slip-Joint), and Tube-Yoke Replacement

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

To replace a driveshaft tube, a tube-yoke, or a stub shaft (**Fig. 1**), the driveshaft must be chucked in a lathe, so the welds can be removed. Driveshaft rebuilding should be done by a machine shop that specializes in driveline repair.



1. Tube-Yoke
2. Driveshaft Tube
3. Stub Shaft

Fig. 1, Driveshaft Tube, Stub Shaft, and Tube-Yoke

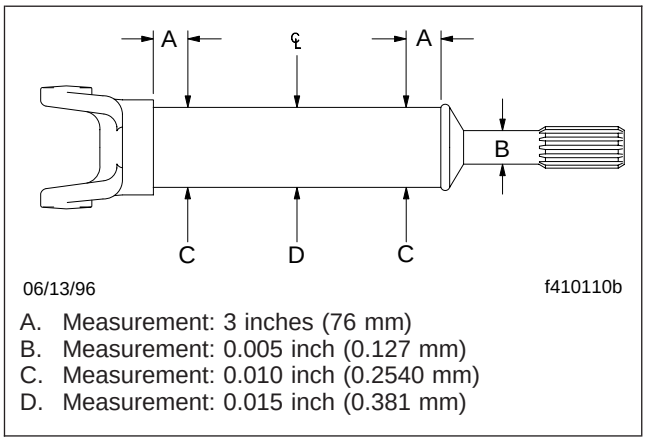
Runout limits for a new (rebuilt) driveshaft (**Fig. 2**) are:

- 0.005 inch (0.127 mm) T.I.R. (Total Indicator Reading) on the smooth portion of the stub shaft neck;
- 0.010 inch (0.254 mm) T.I.R. on the tube 3 inch (76 mm) from the front and rear welds;
- 0.015 inch (0.381 mm) T.I.R. at the center of the tube.

Balance the rebuilt driveshaft to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

Slip-Joint Replacement or Assembly

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled



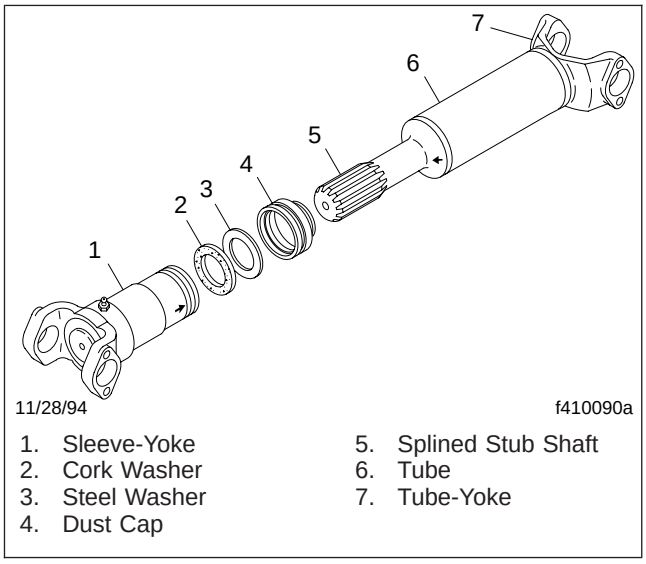
A. Measurement: 3 inches (76 mm)
B. Measurement: 0.005 inch (0.127 mm)
C. Measurement: 0.010 inch (0.2540 mm)
D. Measurement: 0.015 inch (0.381 mm)

Fig. 2, Runout Specifications for a Rebuilt (or New) Driveshaft

or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Except RPL Drivelines

1. Place the slip-joint dust cap, and (if so equipped) steel washer and cork seal, over the splined shaft. See **Fig. 3**.



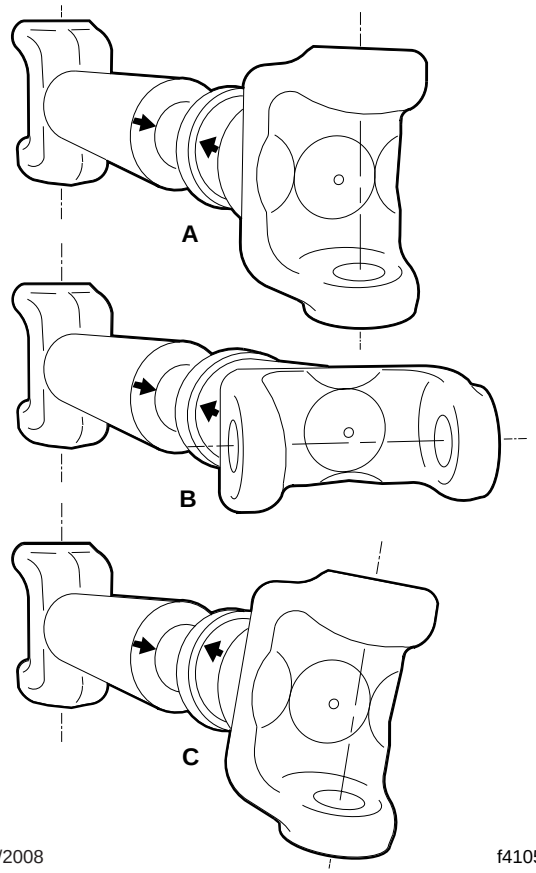
1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 3, Slip-Joint Components

2. Coat the splines of the shaft with multipurpose chassis grease.

Driveline Component Replacement or Installation/ Assembly

3. Insert the splined shaft in the sleeve-yoke, so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

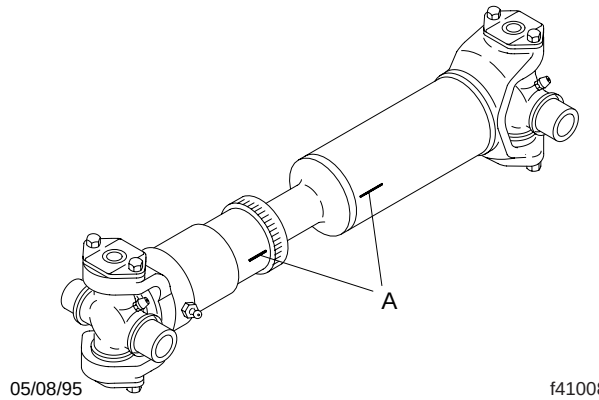


A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 4, U-Joint Phasing

IMPORTANT: If no alignment marks are visible, or new slip-joint components have been installed, align the yokes, assemble the slip-joint, then have the driveline balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

4. Install the slip-joint dust cap. Use only enough torque to seat the steel washer and cork seal (if so equipped) snug against the end of the sleeve-yoke; do not overtighten.



A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks

NOTE: The splines should slide freely, with only a slight drag from the slip-joint dust cap.

RPL Drivelines

1. Remove the grease plug from the sleeve-yoke.
2. Coat the splines of the sleeve-yoke with multipurpose chassis grease.
3. Install the shroud on the splined shaft.
4. Install the seal onto the shroud.
5. Insert the splined shaft in the sleeve-yoke so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

IMPORTANT: If no alignment marks are visible, or new slip-joint components have been installed, align the yokes, assemble the slip-joint, then have the driveline balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

6. Install the seal into the shaft groove.
7. Install the shroud. Use a brass hammer to tap the shroud over the seal.
8. Install the grease plug in the sleeve-yoke.

NOTE: The splines should slide freely, with only a slight drag from the slip-joint dust cap.

Midship Bearing and Coupling Shaft End-Yoke Replacement or Assembly

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

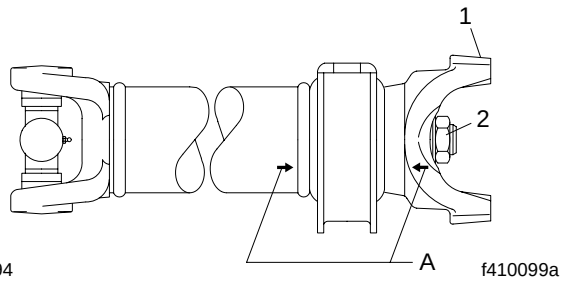
1. Place the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.

NOTE: Midship bearings are permanently lubricated when manufactured; it is not necessary to pack the bearing with grease.

2. Install the midship bearing on the coupling shaft. Press the bearing on by hand, as far as it will go.
3. Install the end-yoke. See **Fig. 6**.

   3.1 Apply Loctite® 242 to the shaft threads where the end-yoke locknut will be installed.

   3.2 Align the marks added to the coupling shaft and end-yoke during removal, then place the end-yoke on the shaft so the yoke bores are aligned at both ends of the shaft. See **Fig. 6**.



A. Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks.

1. Half-Round End-Yoke
2. End-Yoke Locknut

Fig. 6, Alignment Marks on a Coupling Shaft With an End-Yoke

   3.3 Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Then back the nut off slightly, and tighten it to the same torque.

U-Joint Replacement or Installation

IMPORTANT: Parts for different series drivelines must not be intermixed. Also, components of the various makes of U-joints may not be interchangeable, and must be assembled only with compatible products. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Worn bearing assemblies used with a new cross, or new bearing assemblies used with a worn cross will wear rapidly, making another replacement necessary in a short time. Always replace the cross and all four bearing assemblies at the same time.

If the slip-joint of a No. 2 or No. 3 driveshaft has been disassembled, assemble the slip-joint before installing the U-joints.

Full-Round Yokes

1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 or No. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 6**.

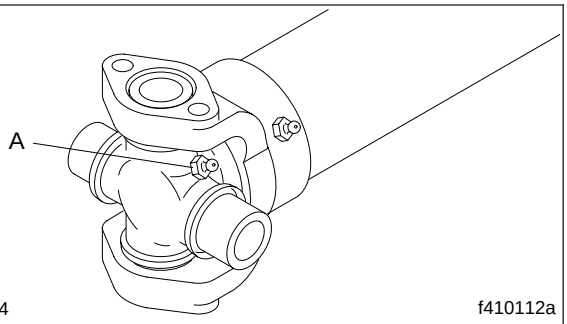
IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect and lubricate the U-joint; see **Subject 140**.
4. Install the U-joint cross and bearing assemblies in the yoke.

   4.1 Position the U-joint cross in the driveshaft yoke so one grease fitting points toward

Driveline Component Replacement or Installation/ Assembly

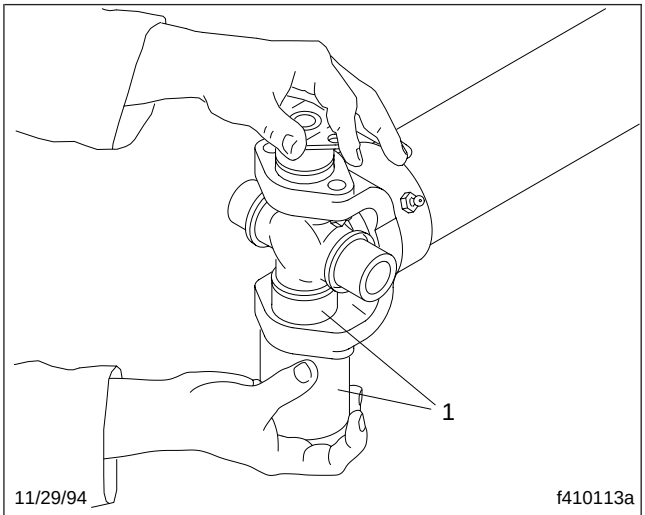
the driveshaft, and aligns with the grease fitting on the sleeve-yoke (if so equipped). See **Fig. 7**.



A. Install the cross with grease fitting pointing toward the driveshaft, and aligned with the sleeve-yoke grease fitting.

Fig. 7, U-Joint Grease Fitting Positioning

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator (see **Specifications 400**), hold the trunnions in alignment with the cross-holes, while placing a bearing cup (plate-type) over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**.



NOTE: Sleeve-yoke shown.

1. Trunnion Locator

Fig. 8, Using a U-Joint Trunnion Locator

IMPORTANT: A Spicer trunnion (journal) locator should be used to prevent damage to the U-joint trunnions and slingers.

4.3 By hand, press the bearing-cup-plate flush with the face of the yoke. If the bearing cup binds in the cross-hole, tap the *center* of the bearing-cup plate with a leather or rubber mallet; do not tap the outer edges of the plate. See **Fig. 9**.

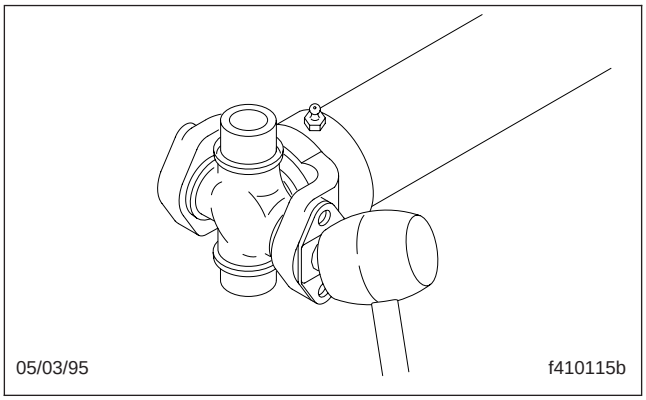


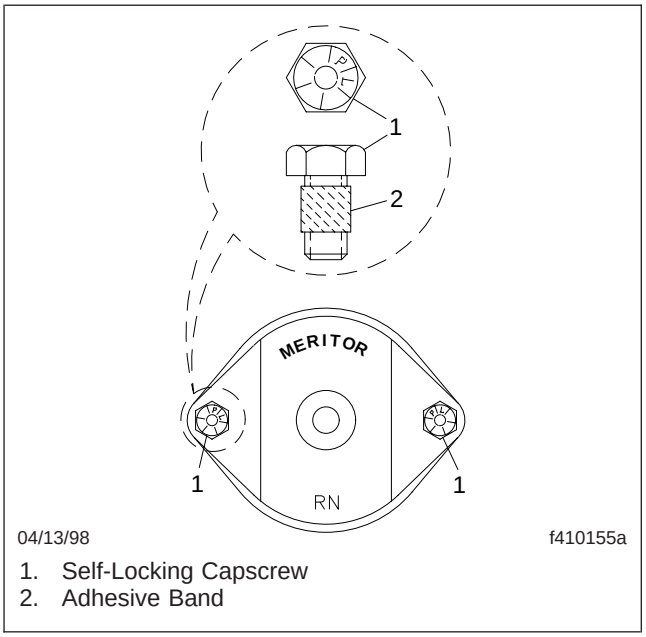
Fig. 9, Seating a U-Joint Bearing Cup In a Full-Round Yoke

4.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 10**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not tighten the capscrews to their final torque value.

⚠ WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

4.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Using the above procedure, install the opposite bearing assembly and its fasteners.



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Meritor U-Joint Fasteners for Full-Round Yokes

4.6 Slightly back off all four capscrews, then alternately tighten them in increments of 5 lbf·ft (7 N·m), to the applicable torque value in **Specifications 400**.

NOTE: The U-joint should flex, and be free of excessive bind. A slight drag is the most desirable condition for new U-joints. Excessive looseness is not desirable, and may result in an unbalanced driveshaft.

RPL Series U-Joint

NOTE: Do not reuse RPL U-joints. Always replace an RPL U-joint with a new one if they have been disassembled and removed from a driveshaft.

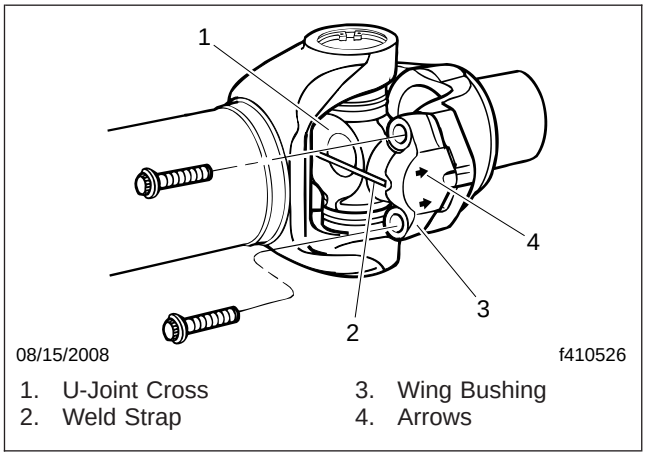
1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a No. 2 or No. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 6**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect the U-joint. See **Subject 140**.
4. Install the U-joint cross and bearing assemblies in the yoke.

   4.1 Position the U-joint cross in the driveshaft yoke so that the wing bearing weld strap faces inboard, and the arrows point toward the end of the coupling yoke. See **Fig. 11**.



1. U-Joint Cross
2. Weld Strap
3. Wing Bushing
4. Arrows

Fig. 11, Fitting the U-Joint

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Place a bearing cup over the projected trunnion, and align it with the cross-hole.

4.3 Press the bearing cup into the yoke slightly past the snap ring groove. See **Fig. 12**. Check that the bearing cup is aligned with the universal joint trunnion.

4.4 Install the snap ring into the snap ring groove. See **Fig. 13**.

4.5 Use a snap ring installation gauge to check that the snap ring is fully seated in the snap ring groove. See **Fig. 14**.

4.6 Move the cross until it projects beyond the machined surface of the opposite yoke

Driveline Component Replacement or Installation/ Assembly

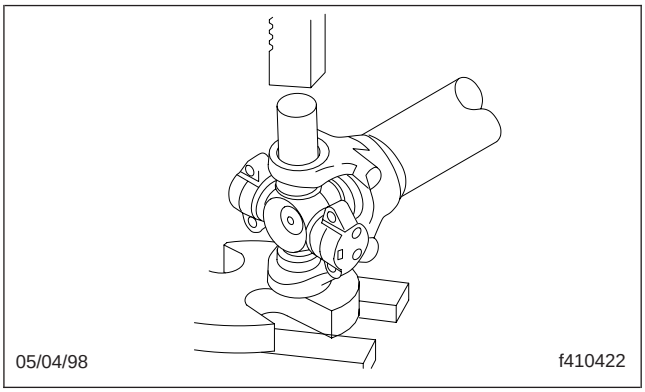
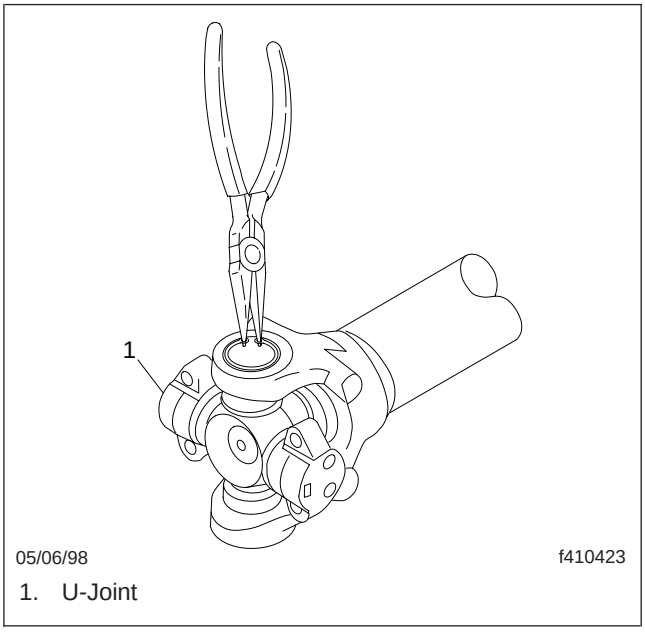


Fig. 12, Installing Bearing Cups, RPL Series U-Joint



1. U-Joint

Fig. 13, Installing the Snap Rings

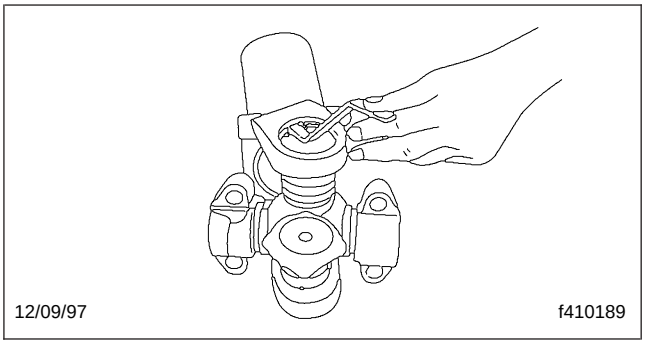
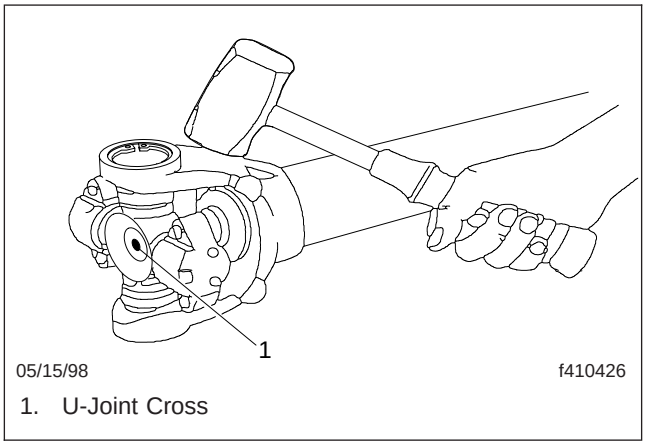


Fig. 14, Checking Snap Ring Installation

lug. Using the above procedure, install the opposite bearing cup assembly.

NOTE: The U-joint should flex, and be free of excessive bind. A slight drag is the most desirable condition for new U-joints. Excessive looseness is not desirable, and may result in an unbalanced driveshaft.

4.7 If the universal joint does not move freely, strike the yoke ear with a brass or copper hammer. See **Fig. 15**.



1. U-Joint Cross

Fig. 15, Striking the Yoke Ear

Transmission/Axle End-Yoke Replacement or Installation

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

1. Apply Loctite® 242 to the input- or output-shaft threads where the end-yoke locknut will be installed. See **Fig. 16**.
2. By hand, install the end-yoke on the input or output shaft as far as it will go.
3. Install a new end-yoke locknut, and tighten it to the applicable torque value in **Specifications 400**.

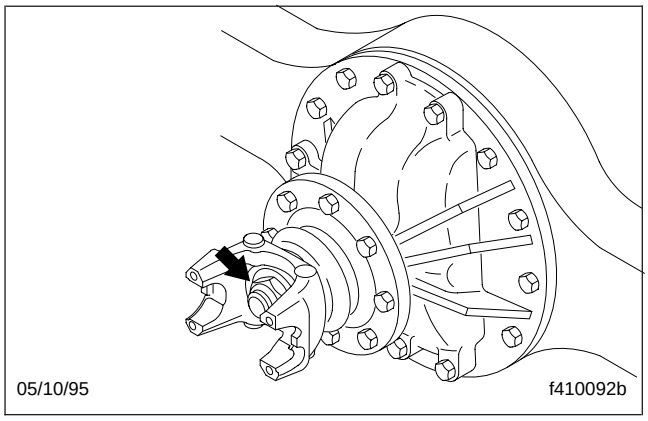


Fig. 16, Axle End-Yoke Locknut

Troubleshooting

Noise or vibration associated with the driveline can be caused by non-driveline parts. To find the cause of noise or vibration, first road test the loaded vehicle. Drive in all gears and at all speed ranges for which the vehicle was designed, including those at which problems are reported.

NOTE: Operating a vehicle at speeds that exceed its drivetrain design specifications may cause an out-of-balance vibration.

The following is a troubleshooting elimination process; checks should be made in the order listed. At each step where a problem is found, correct the problem before proceeding to the next step, then test drive the vehicle to see if other problems still exist. If no other problems exist, the elimination process may be ended at that step.

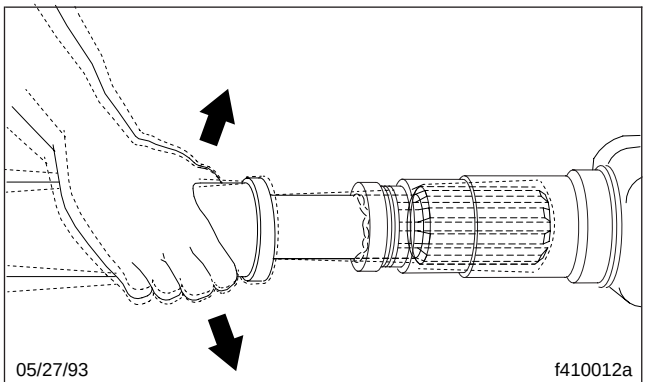
1. Check all tires for uneven wear and for out-of-roundness. Check for mismatched tires. Look for wheels and rims that are out of alignment. For instructions, see **Group 40**.
2. Check the rear suspension for loose or broken U-bolts; broken, shifted, or mismatched rear springs; or broken spring seats. If so equipped, check the air suspension for incorrect air spring height. Look for anything that could cause angular misalignment of the rear axle pinion(s). For instructions, see **Group 32**.
3. Check the frame rails and crossmembers for bends, twists, or breaks; for frame-alignment-checking and crossmember-replacement instructions, see **Group 31**.
4. Check the engine and transmission mounts; see **Group 01** (Engine) and **Group 26** (Transmission). Check the coupling shaft's midship bearing mounts. Replace mountings that are deteriorated or oil-soaked; tighten loose mounting bolts. Oil-soaked or deteriorated mountings,or loose mounting bolts, can cause driveline angular misalignment.
5. Check for loose U-joint bearing-cup-plate and bearing-strap capscrews. Tighten any loose fastener to the applicable torque value in **Specifications 400**.

NOTICE

Do not overtighten the bearing-cup-plate or bearing-strap capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could result in serious vehicle damage.

6. Check all U-joint assemblies, slip-joint splines, and midship bearings for wear.
   - 6.1 Try to move each driveshaft up and down, and from side to side. If movement is greater than 0.006 in (0.15 mm) of a U-joint cross in its bearings,replace the U-joint assembly.
   - 6.2 If the midship bearing rattles or is loose on its shaft, replace it.
   - 6.3 Try to bend the sleeve-yoke and splined shaft up and down, and from side to side. See **Fig. 1**. If looseness is greater than 0.007 in (0.18 mm), replace the sleeve-yoke and splined shaft.

     If driveline components must be replaced, see **Subject 150**.



Try to bend the sleeve-yoke and splined shaft up and down, and from side to side.

Fig. 1, Check for Slip-Joint Spline Wear

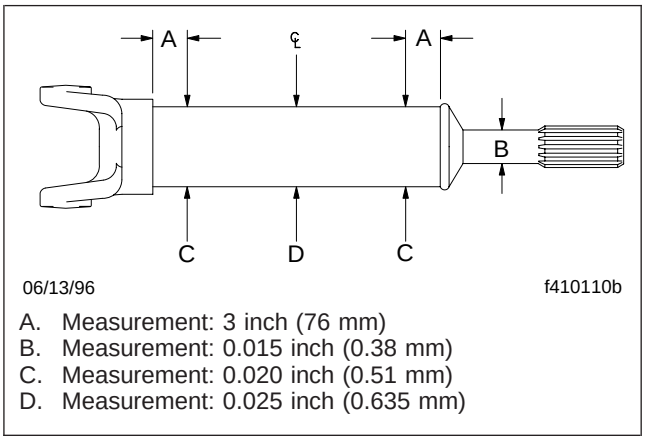
7. Check each driveshaft for an indication of missing balance weights. If any weights appear to be missing, have the driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.
8. Check each driveshaft for dents, bends, twists, or other damage.

Troubleshooting

If damaged, jack up the rear axle, support it on jackstands, place the transmission in neutral, and turn the driveshaft by hand to check runout.

The driveshaft must be straight within 0.015 inch (0.38 mm) on the slip-joint seal surface of the splined shaft, 0.020 inch (0.51 mm) on the tube 3 inch (76 mm) from the front and the rear welds, and 0.025 inch (0.635 mm) at the center of the tube. See **Fig. 2**.

If the driveshaft is not straight within specifications, replace the tube. See **Subject 150** for runout specifications for a *new* (or rebuilt) driveshaft.



A. Measurement: 3 inch (76 mm)
B. Measurement: 0.015 inch (0.38 mm)
C. Measurement: 0.020 inch (0.51 mm)
D. Measurement: 0.025 inch (0.635 mm)

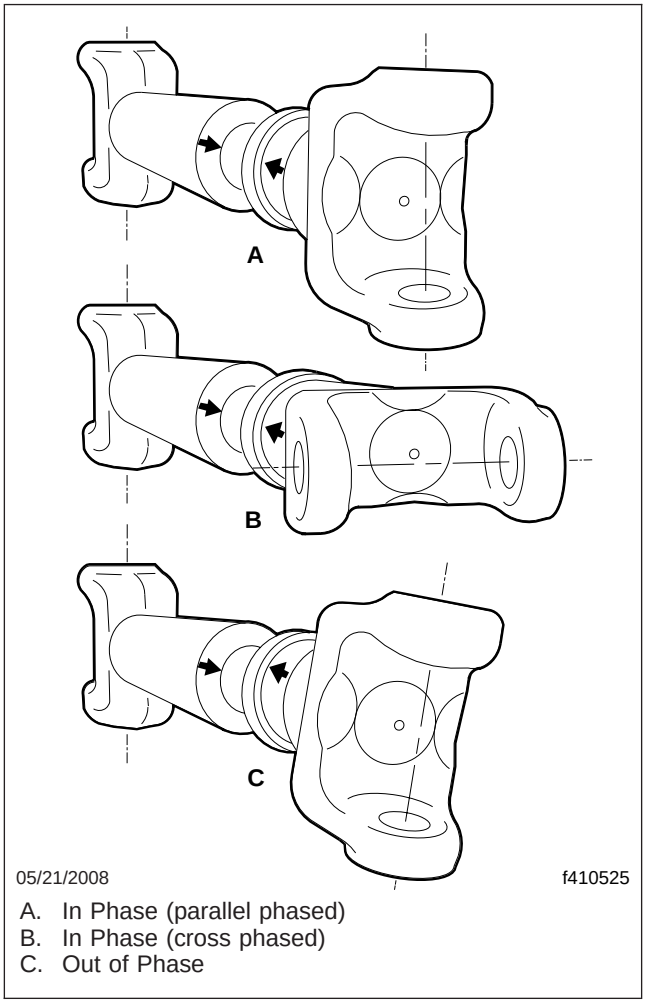
Fig. 2, Runout Specifications for a Used Driveshaft

9. Check each driveline for proper U-joint phasing. See **Fig. 3**.

9.1 On No. 2 and No. 3 driveshafts, if the U-joints are out of phase, check the slip-joint for alignment marks. If necessary, disassemble the slip-joint, and align the marks.

NOTE: To disassemble the slip-joint, uncouple the U-joint at one end of the driveshaft, unscrew the slip-joint seal from the sleeve-yoke, then pull the sleeve-yoke and splined shaft apart. Reverse the procedure to assemble the slip-joint.

9.2 If no alignment marks are present, disassemble the slip-joint, and reassemble it with the U-joints in one of the two in-phase positions (180 degrees apart).



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

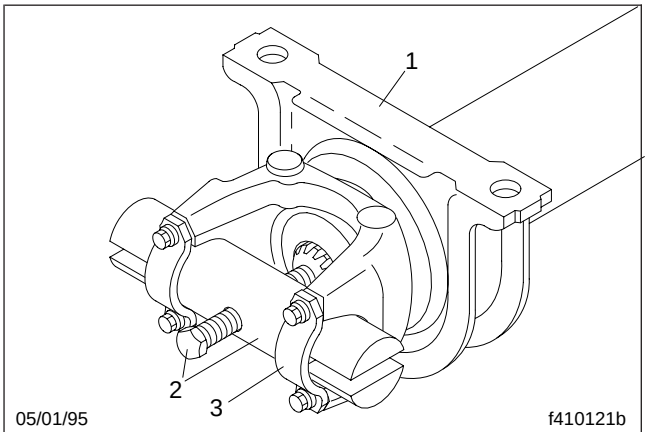
Fig. 3, U-Joint Phasing

Test drive the vehicle, then assemble the slip-joint in the other in-phase position. Test drive the vehicle again.

Determine which in-phase position provides vibration-free operation. Assemble the slip-joint in the correct in-phase position, and mark the slip-joint with alignment marks.

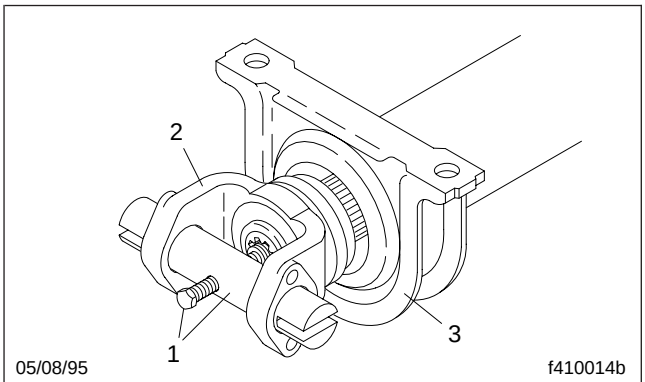
9.3 If the U-joints are out of phase on a coupling shaft, uncouple the U-joint from the coupling shaft end-yoke, then remove the end-yoke nut. Remove the end-yoke, using a yoke puller. See **Fig. 4** for a half-round end-yoke, or see **Fig. 5** for a full-round end-yoke. Align the end-yoke, then

install it by hand. Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Slightly back off the nut, and again tighten it to the same torque. Couple the coupling shaft to the driveshaft U-joint.



1. Midship Bearing
2. Yoke Puller
3. Bearing Strap

Fig. 4, Remove a Half-Round End-Yoke from a Coupling Shaft



1. Yoke Puller
2. Full-Round Yoke
3. Midship Bearing

Fig. 5, Remove a Full-Round End-Yoke from a Coupling Shaft

10. Check the torque on all of the end-yoke nuts in the drivetrain; see the applicable torque values in **Specifications 400**.

    If any yoke nut was not at its specified torque, check the yoke for wear by trying to move it up and down, and back and forth. If the yoke can be rocked on its shaft, or moved in or out on its shaft, replace the yoke and yoke nut. See **Subject 150**.

    If the yoke is not worn, tighten the yoke nut to its torque value.

11. *On single-drive vehicles:*

    Have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

    On dual-drive vehicles:

    11.1 Remove the No. 3 driveline; then, with the interaxle differential locked, test drive the vehicle.

    11.2 If vibration still exists, install the No. 3 driveline, then have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

    If *no* vibration exists, check that both rear axle gear ratios are matched. If the gear ratios do not match, replace one of the gear sets with a gear set having the correct ratio, then install the No. 3 driveline.

    11.3 Have the No. 3 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

    11.4 Have the No. 2 driveshaft balanced to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

12. If so equipped, balance the coupling shaft(s) to a maximum tolerance of 1 inch-ounce per 10 pounds weight per end, at 3000 rpm.

Transmission Output-Shaft End-Yoke Nut Fastener Torques			
Description		**Size**	**Torque: lbf·ft (N·m)**
Fuller	RT 8609	1-1/2–18	400–450 (542–610)
	T/X 14607 RT 8608 /7608LL RTO 11909MLL /14909MLL /11908LL RTX 16709 /15710 /16710 RT/X 11609 /11709 /12609 /12709 /13609 /13709 /14609 /14709 /11710 /12710 /13710 /14710 RTO/X 11708LL /14708LL RT/O/X 14715 /15715 RTLO 12610 /13610 /14610 /15610 /16610 /12713 /14713 /16713 /14718 /16718 /18718	2–16	450–500 (610–678)
Meritor	RM/O/X 9–115, –125, –135, –145, –155 RM/X 10–115, –125, –135, –145, –155, –165 RMO 13–145	2–16	450–500 (610–678)
Allison	HD Series	2–16	600–800 (813–1085)

Table 1, Transmission Output-Shaft End-Yoke Nut Fastener Torques

Midship Bearing Fastener Torques		
Location	**Size**	**Torque: lbf·ft (N·m)**
Coupling Shaft	1-1/4–18	475–525 (645–710)
Bracket to Crossmember Locknut	1/2–13	68 (92)
Bearing Mount to Bracket Locknut	1/2–13	68 (92)

Table 2, Midship Bearing Fastener Torques

Spicer U-Joint Capscrew Torque			
Series	**Thread Size**	**Style**	**Torque lbf·ft (Nm)**
1710 HD 1760 HD 1810 HD	1/2–20	Half Round	130–135 (176–183)
	3/8–24	Full Round	38–48 (52–65)
SPL100	3/8–24	Half Round	45–60 (61–81)
SPL140/HD/XL SPL170/XL SPL250/HD/XL	M12–1.25	Half Round	115–135 (156–183)

Table 3, Spicer U-Joint Capscrew Torque

Specifications

Meritor U-Joint Capscrew Torque			
Series	**Thread Size**	**Style**	**Torque lbf·ft (Nm)**
16T	3/8–24	Half Round	45–60 (61–81)
16N	5/16–24	Full Round	26–35 (35–47)
17T	1/2–20	Half Round	115–135 (156–183)
17N	3/8–24	Full Round	38–48 (52–65)
176T	1/2–20	Half Round	115–135 (156–183)
176N	3/8–24	Full Round	38–48 (52–65)
18T	1/2–20	Half Round	115–135 (156–183)
18N	3/8–24	Full Round	38–48 (52–65)
RPL20 G2 RPL250HD G2	1/2–20	Wing Yoke	115–135 (156–183)

Table 4, Meritor U-Joint Capscrew Torque

Axle End-Yoke Fastener Torques				
Position	**Brand**	**Model Number**	**Input Size**	**Torque: lbf·ft (N·m)**
Single Axle Input Shaft	Meritor	MS-21-14X	M39- 1.5	920-1130 (1250-1530)
		RS-23-160, RS-23-161, RS-23-186, RS-25-160, RS-26-185, RS-30-185,	M45-1.5	1000-1230 (1355-1670)
		RS-30-380, RS-38-380	1-1/2 -12 UNF	800-1100 (1085-1490)
	Detroit	DA-RS-17.5-4, DA-RS-19.0-4, DA-RS-21.0-4, DA-RS-23.0-4	M45-1.5	627-850 (850-1150)
First Carrier Input Shaft	Meritor	MT-40-143/4M, MT-40-14X, MT-40-14XGP, MT-40-14XP, MT-44-14X, MT-44-14XP	M 45-1.5	750-850 (1015-1150)
		RT-40-145, RT-40-145A, RT-40-145GP, RT-40-145P, RT-44-145, RT-44-145P, RT-40-160, RT-40-160P, RT-46-160, RT-46-160GP, RT-46-160P, RT-46-164, RT-46-164P		
		RT-50-160, RT-50-160GP, RT-50-160P, RZ-166, RZ-166 R-SERIES		
		RT-52-185, RT-52-185G, RT-58-185, RT-52-380G, RT-70-380, RT-70-380P, RZ-186, RZ-188, RZ-188G	1-3/4x12 UN	
	Detroit	DA-RT-40.0-4, DA-RT-40.0-4 HT, DA-RT-44.0-4, DA-RT-44.0-4 HT, DA-RT-46.0-4 HH	M45-1.5	627-850 (850-1150)
	Dana Spicer	DT463P, DD404, DD405, DD405P, DDH40, DDH40P, DS404, DS404P, DS405, DS405P, DSH40, DSH40P, DST40, DST41, DDH44P, DSH44P	M42 X 1.5	840-1020 (1140-1385)
		S23-190, D46-170, D50-170P, D52-190P, D40-170, D40-170P, D46-170P	M48 X 1.5	800-1000 (1085-1355)

Axle End-Yoke Fastener Torques				
Position	**Brand**	**Model Number**	**Input Size**	**Torque: lbf·ft (N·m)**
First Carrier Output Shaft	Meritor	MT-40-143/4M, MT-40-14X, MT-40-14XGP, MT-40-14XP, MT-44-14X, MT-44-14XP	M 39 x 1.5	600-800 (815-1085)
		RT-40-145, RT-40-145A, RT-40-145GP, RT-40-145P, RT-44-145, RT-44-145P, RT-40-160, RT-40-160P, RT-46-160, RT-46-160GP, RT-46-160P, RT-46-164, RT-46-164P		
		RT-50-160, RT-50-160GP, RT-50-160P, RZ-166, RZ-166 R-SERIES		
		RT-52-185, RT-52-185G, RT-58-185, RT-52-380G, RT-70-380, RT-70-380P, RZ-186, RZ-188, RZ-188G	1-1/2x12 UNF	450-650 (610-880)
	Detroit	DA-RT-40.0-4, DA-RT-40.0-4 HT, DA-RT-44.0-4, DA-RT-44.0-4 HT, DA-RT-46.0-4 HH	M39 x 1.5	520 - 700 (705-950)
	Dana Spicer	DT463P, DD404, DD405, DD405P, DDH40, DDH40P, DS404, DS404P, DS405, DS405P, DSH40, DSH40P, DST40, DST41, DDH44P, DSH44P	M39 X 1.5	680 - 832 (920-1130)
		S23-190, D46-170, D50-170P, D52-190P, D40-170, D40-170P, D46-170P	M42 x 1.5	800-1000 (1085-1355)
Second Carrier Input Shaft	Meritor	MT-40-143/4M, MT-40-14X, MT-40-14XGP, MT-40-14XP, MT-44-14X, MT-44-14XP	M 39 x 1.5	920-1130 (1250-1530)
		RT-40-145, RT-40-145A, RT-40-145GP, RT-40-145P, RT-44-145, RT-44-145P		
		RT-40-160, RT-40-160P, RT-46-160, RT-46-160GP, RT-46-160P, RT-46-164, RT-46-164P, RT-50-160, RT-50-160GP, RT-50-160P, RT-52-185, RT-52-185G, RT-58-185	M45 x 1.5	1000-1230 (1355-1670)
		RT-52-380G, RT-70-380, RT-70-380P	1-1/2 - 12 UNF	800-1100 (1085-1490)
		RZ-166, RZ-166 R-SERIES, RZ-186	M45 x 1.5	600-800 (815-1085)
		RZ-188, RZ-188G	1-3/4 - 12 UN	600-800 (815-1085)
Second Carrier Output Shaft	Meritor	RZ-166, RZ-166 R-SERIES, RZ-186	M39 x 1.5	450-650 (610-880)
		RZ-188, RZ-188G	1-1/2 -12 UNF	450-650 (610-880)
Third Carrier Input Shaft	Meritor	RZ-166, RZ-166 R-SERIES, RZ-186, RZ-188, RZ-188G	M45 x 1.5	1000-1230 (1355-1670)

Table 5, Axle End-Yoke Fastener Torques

Driveline Angularity

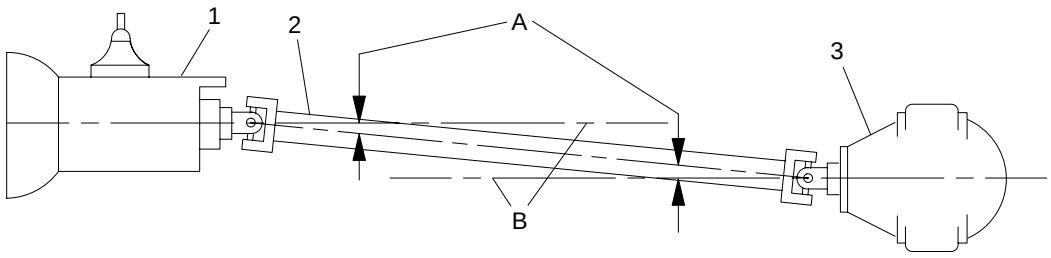
The most important consideration of driveline angularity is the U-joint working angle. A U-joint working angle is the angle formed by the intersection of the driveshaft centerline and the extended centerline of the shaft of any component to which the U-joint connects. See **Fig. 1**. Because the action of a U-joint causes a fluctuating speed difference between the shafts it connects, the effect created by the U-joint at the input-shaft end-yoke must cancel the effect created by the U-joint at the output-shaft end-yoke. This is done by making the U-joint working angles at both ends of the driveshaft approximately equal, with the U-joints in phase.

The U-joint working angles may be made approximately equal by either of two basic arrangements: a parallel arrangement (**Fig. 1**), or an intersecting arrangement (**Fig. 2**).

Driveline angularity may be adversely affected if rear suspension U-bolts are loose or broken; rear springs are broken, shifted, or mismatched; spring seats are broken; frame rails are bent, twisted, or broken; or transmission or engine mounts are loose or deteriorated.

U-Joint Phasing

The fluctuating speed difference, caused by the action of a U-joint connecting angled shafts, can be cancelled only if the U-joint at the other end of the driveshaft is in phase with that U-joint (and the U-joint working angles are approximately equal). If the yoke lugs at both ends of the driveshaft are lying in the same plane (a plane that bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 3**.



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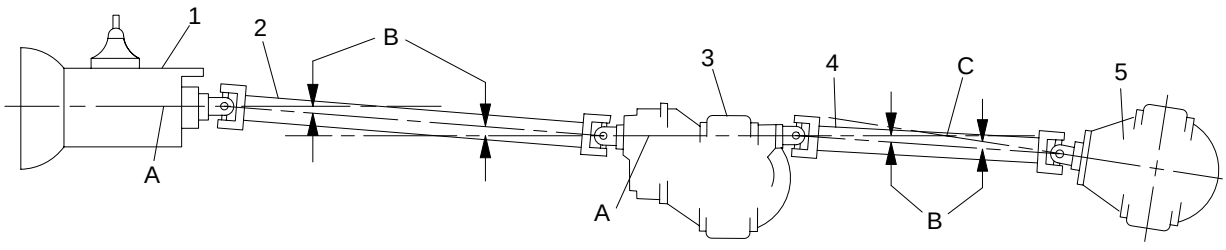
A. Equal U-Joint Working Angles
B. Parallel Centerlines
1. Transmission
2. No. 2 Driveshaft
3. Rear Axle

Fig. 1, Parallel Arrangement for Single-Drive Vehicles



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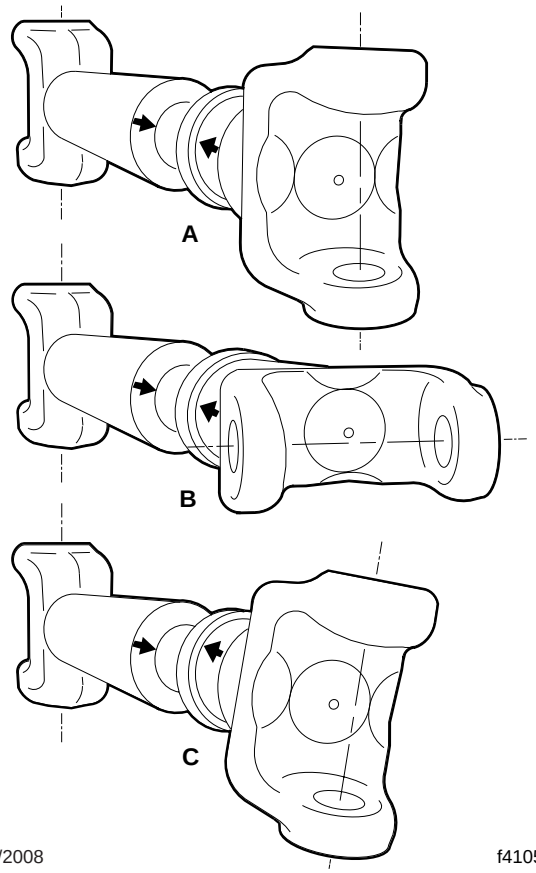
A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Intersecting Centerlines
1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 2, Intersecting Planing Arrangements for Dual-Drive Vehicles

General Information

NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 3, Driveline U-Joint Phasing

To ensure that the U-joints turn in phase, the sleeve-yoke and splined shaft of driveshaft slip-joints, and the coupling shaft and midship bearing end-yoke, should be marked for assembly reference before disassembly.

Driveline Balance

After manufacture, each driveline yoke is statically balanced. After assembly of the slip-joint, each driveshaft is checked for out-of-roundness, and straightened as necessary; then each shaft is dynamically balanced.

If the driveshaft slip-joint is disassembled for any reason, the sleeve-yoke and splined shaft should be marked for assembly alignment. Misaligned slip-joints will seriously affect the U-joint phasing and balance of the driveline. Even if the slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

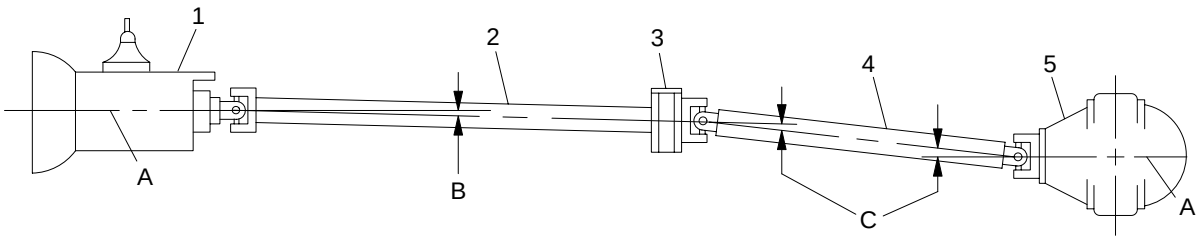
A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds that exceed the speed of the driveshaft's design specifications will cause an out-of-balance vibration. Loose end-yoke nuts, loose midship bearing or auxiliary transmission mounts, loose bearing retainer capscrews, worn U-joint trunnions or bearings, and worn slip-joint splines can lead to excessive movement of the driveshaft and cause driveline imbalance.

Midship Bearings

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at high rpm, it will flex, causing an out-of-balance vibration. Therefore, most vehicles having a long wheelbase use a midship bearing, mounted on a crossmember in the frame, for additional driveline support. See **Fig. 4**. This allows the driveshaft to be separated into two shorter shafts, thus improving balance and stability.

Angularity Standards and Drivetrain Configuration

The U-joints require a minimum working angle of 1/2 degree to ensure needle-roller movement in the U-joint bearings. Without this movement, brinelling of the trunnion bearing-contact surfaces would occur. Suspension movement causes driveshaft angles to change (and therefore, needle-roller movement) in both of the U-joints attached to driveshafts that connect to the axles. However, no angle change occurs in the U-joints attached to a driveshaft that connects the main transmission to a midship bearing or auxiliary transmission. Their working angles must be established during installation.



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A. Parallel Centerlines
B. 1/2 to 1 Degree
C. Working Angles Unequal by 1/2 to 1 Degree

1. Main Transmission
2. Coupling Shaft
3. Midship Bearing
4. No. 2 Driveshaft
5. Rear Axle

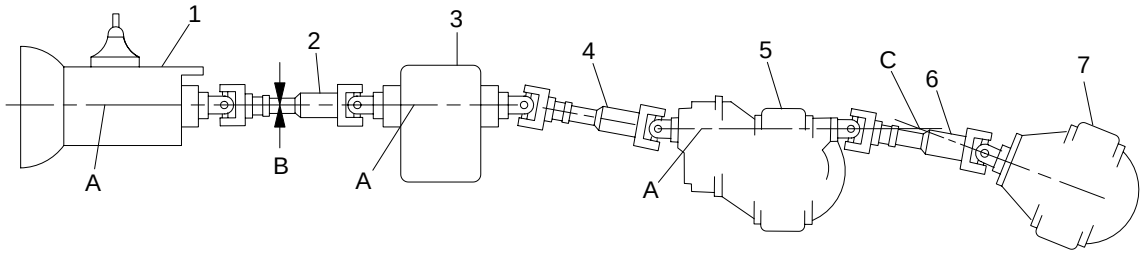
Fig. 4, Midship Bearing in a Single-Drive Vehicle

When a midship bearing is included in the drivetrain, it is installed so that the centerline of the coupling shaft is in horizontal (side-to-side) alignment within 1/2 degree, and within 1/2 to 1 degree of vertical alignment, with the centerline of the main transmission output shaft. See **Fig. 4**.

When an auxiliary transmission is included in the drivetrain, it is installed so that the centerline of the inter-transmission (no. 1) driveline is in exact horizontal (side-to-side) alignment (within 1/2 degree), and down 1/2 to 1 degree from vertical alignment, with the centerline of the main transmission output shaft. Further, the auxiliary transmission thru-shaft centerline must be parallel (horizontally and vertically) to the centerline of the main transmission output shaft, in order to achieve equal working angles. See **Fig. 5**.

Every U-joint has a maximum working angle, determined by the design and size of its cross assembly and yokes. Exceeding the maximum working angle can cause rapid U-joint wear, or in severe cases, destruction of the U-joint. For smooth operation and long drivetrain component life, the U-joint working angles must be kept small and approximately equal for each shaft.

The U-joint working angles may be made approximately equal by either of two basic arrangements: a parallel arrangement (**Fig. 1**) or an intersecting arrangement (**Fig. 2**). The parallel arrangement consists of installing the drivetrain components so that all of the input, output, and thru-shaft centerlines are approximately parallel. The intersecting arrangement (used only for some interaxle drivelines) consists of installing the drive components so that the rearmost



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A. Parallel Centerlines
B. 1/2 to 1 Degree
C. Intersecting Centerlines

1. Main Transmission
2. No. 1 Driveline
3. Auxiliary Transmission
4. No. 2 Driveshaft
5. Forward-Rear Axle
6. No. 3 Driveshaft
7. Rearmost Axle

Fig. 5, Auxiliary Transmission in a Dual-Drive Vehicle

General Information

axle pinion shaft's extended centerline intersects the forward-rear axle thru-shaft's extended centerline approximately midway between the U-joints, when all of the other shafts (including the forward-rear axle thru-shaft) are approximately parallel.

All single-drive vehicles, and the forward-rear axles of dual-drive vehicles, use the parallel arrangement. Rearmost axles of dual-drive vehicles may use the parallel arrangement or the intersecting arrangement, depending on the drivetrain configuration.

The specific drivetrain configuration of each Freightliner vehicle consists of its wheelbase, number and type of axles, axle spacing, type of suspension, and number of transmissions. The specific drivetrain configuration determines the driveline arrangement and required installation angles of all the vehicle's drivetrain components.

The simplest drivetrain configuration consists of a single short driveline connecting a main transmission to a single-drive axle, in a parallel arrangement. This driveshaft is always referred to as the no. 2 driveshaft. The parallel arrangement always used on single-drive vehicles is shown in **Fig. 1**.

On dual-drive vehicles that have both axle input shafts of approximately the same height, a parallel arrangement is used. The driveshaft connecting the main (or auxiliary) transmission to the forward-rear axle is always referred to as the no. 2 driveshaft; and the interaxle driveshaft is always referred to as the no. 3 driveshaft. See **Fig. 6**, which shows a parallel arrangement when used on dual-drive vehicles.

Most dual-drive vehicles have a high thru-shaft on the forward-rear axle, and a low pinion on the rearmost axle. When the vehicle is on level ground, the interaxle (no. 3) driveshaft may create very sharp U-joint working angles with the input and output shafts when they are parallel. In normal driving, the U-joints could momentarily exceed their maximum working angle, and driveline or drivetrain damage could result. By using an intersecting arrangement at the no. 3 driveshaft, smaller U-joint working angles are created, promoting longer U-joint life and reduced driveline vibration. An intersecting arrangement used on dual-drive vehicles is shown in **Fig. 2**.

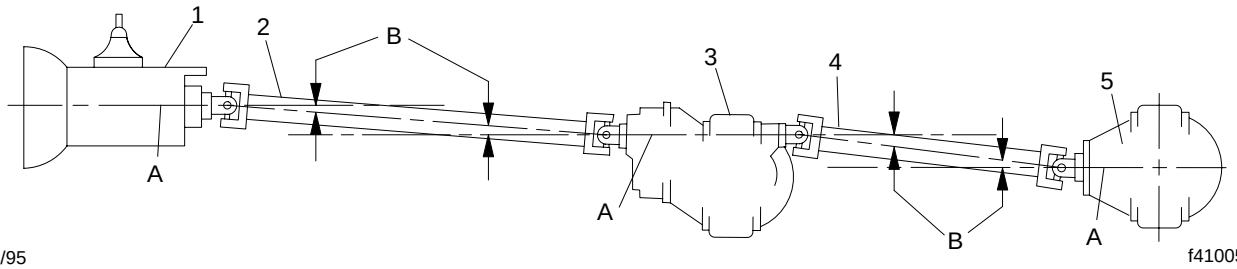
However, some axle spacings, axle models, and suspension designs allow additional axle movement or axle windup that requires additional clearances between the driveshaft and the frame or suspension components, or that creates other conditions that make the intersecting arrangement of the no. 3 driveshaft unsatisfactory. For those drivetrain configurations, it is necessary to use a modified parallel or modified-intersecting arrangement for the no. 3 driveshaft.

On drivetrain configurations that require a modified parallel arrangement, the rearmost-axle pinion shaft centerline is placed at an angle that is 2 degrees higher above horizontal than are the other input and output shafts. See **Fig. 7**.

On drivetrain configurations that require a modified-intersecting arrangement, the "proper" intersecting angle is determined, then the rearmost-axle pinion shaft centerline is placed at an angle that is 2 degrees closer to horizontal than the "proper" intersecting angle. See **Fig. 8**.

The axle pinion angles for all suspensions are factory-set for correct driveline angularity. On Freightliner spring suspensions, tapered axle planing shims at the springs maintain the correct axle pinion angle. On Hendrickson suspensions, spacers at the torque rods are used to maintain the correct axle pinion angles.

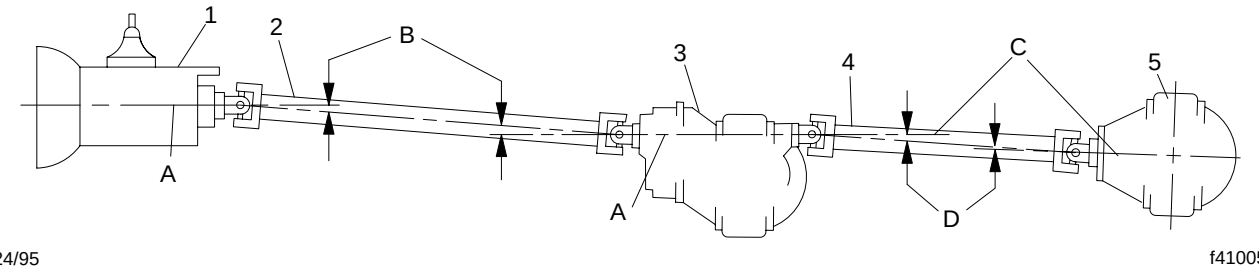
In the field, whenever axle or suspension components are changed, the axle pinion angles may also change. If this occurs, contact your district service manager for the correct axle pinion angle adjustment procedure.



A. Parallel Centerlines
B. Equal U-Joint Working Angles

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

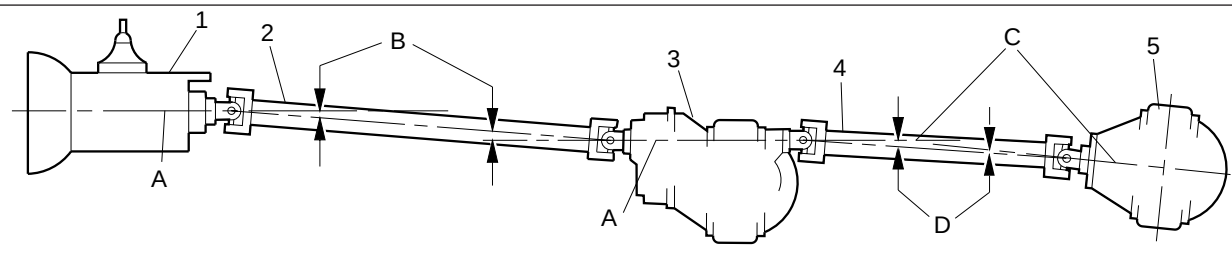
Fig. 6, Parallel Arrangement for Dual-Drive Vehicles



A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Modified-Parallel Centerlines
D. U-Joint Working Angles Not Equal by 2 Degrees

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 7, Modified-Parallel Arrangement for Dual-Drive Vehicles



A. Parallel Centerlines
B. Equal U-Joint Working Angles
C. Modified-Intersecting Centerlines
D. U-Joint Working Angles Not Equal by 2 Degrees

1. Transmission
2. No. 2 Driveshaft
3. Forward-Rear Axle
4. No. 3 Driveshaft
5. Rearmost Axle

Fig. 8, Modified-Intersecting Arrangement for Dual-Drive Vehicles

Use the procedure below for the type of tool being used. The Digital Angle Analyzer is the recommended tool.

Digital Angle Analyzer

Before checking the pinion angles or engine angle, check that the engine and transmission mounts are tight and in good condition. Loose or deteriorated mounts will cause inaccurate readings.

IMPORTANT: When using a digital angle analyzer (DAA) or digital level, be sure to always take readings from the same side of the vehicle. Also, keep the same end of the DAA pointed toward the front of the truck.

Using a DAA (**Fig. 1**), measure the engine angle, driveshaft angles, and pinion angles. Read all angles to the nearest one-tenth of a degree.

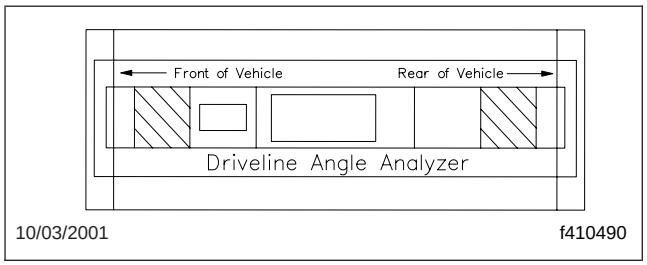
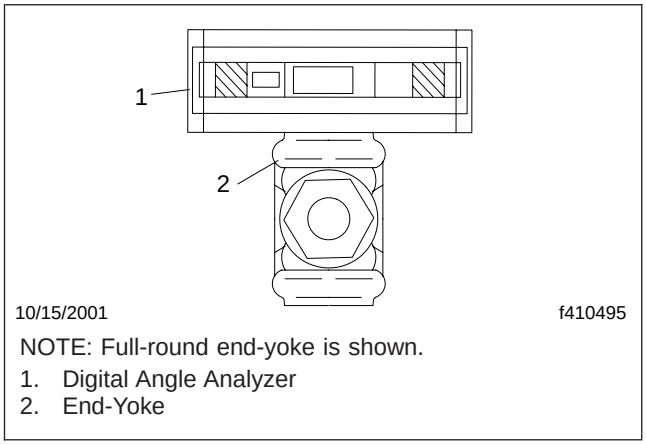


Fig. 1, Digital Angle Analyzer

After adjustment of any driveline angle, check the angle again. Also, verify ride height if the vehicle has an air suspension.

To measure the engine angle (transmission output-shaft angle) or axle pinion angles, do the following:

1. Inflate the vehicle tires to their normal operating pressure.
2. Park the unloaded vehicle on a level surface. Do not try to level the vehicle frame by jacking the front or rear axles. If the frame cannot be leveled from front to rear, determine and record the off-level inclination of the frame, and add or subtract that value from the measured values.
3. Chock the tires and place the transmission in neutral. Release the parking brakes.
4. The transmission output-shaft, coupling-shaft, and axle input- and output-yoke angles can be measured at either the top or bottom lug of the end-yoke being checked. For a full-round end-yoke, remove the bearing cup from the yoke lug. See **Section 41.00** for full-round end-yoke bearing cup removal.
5. Turn the end-yoke until the machined surface of the yoke lug is horizontal. See **Fig. 2**.



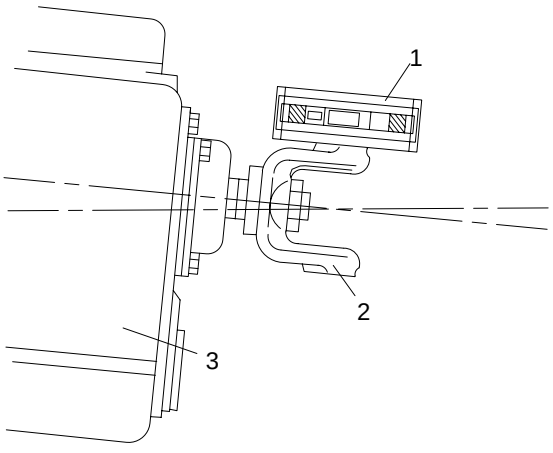
NOTE: Full-round end-yoke is shown.

1. Digital Angle Analyzer
2. End-Yoke

Fig. 2, Horizontal Positioning of Yoke Lug Machined Surface

6. To turn the driveshaft, raise one side of the rear (single-drive) or rearmost (dual-drive) axle until the tires are off the ground. Place a safety stand under the axle. With the transmission in neutral, and the interaxle differential (if equipped) unlocked, turn the tire to move the driveshaft.
7. Calibrate the digital level by placing it on the surface where the vehicle is parked at a 90-degree angle to the frame centerline. Zero the digital level.
8. Position the DAA alongside the U-joint trunnion, on the machined surface of the end-yoke, and at a 90-degree angle to the frame centerline. See **Fig. 2**. Then turn the end-yoke until the DAA reads 0 degrees. Remove the jack stand and lower the rear axle to the ground.
9. Calibrate the digital level by placing it on the surface where the vehicle is parked parallel to the frame centerline. Zero the digital level.
10. Without changing the position of the end-yoke, turn the DAA until it is parallel to the frame centerline. See **Fig. 3**. Record the measured angle of the pinion.

Engine and Pinion Angle Measurement



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NOTE: Full-round end-yoke is shown.

1. Digital Angle Analyzer
2. End-Yoke
3. Transmission

Fig. 3, Measuring Pinion Angles

11. For a full-round end-yoke, install the bearing cup. See **Section 41.00** for full-round end-yoke bearing cup installation.

Spirit Level Protractor

Before checking the pinion angles or engine angle, check that the engine and transmission mounts are tight and in good condition. Loose or deteriorated mounts will cause inaccurate readings.

Using a digital angle meter, spirit level protractor (see **Fig. 4**), or the head of a machinists's protractor, measure the engine angle, driveshaft angles, and pinion angles. Read all angles to the nearest one-tenth of a degree (6 minutes).

After adjustment of any driveline angle, check the angle again.

To measure the engine angle (transmission output-shaft angle) or axle pinion angles, do the following:

1. Inflate the vehicle tires to their normal operating pressure.
2. Park the unloaded vehicle on a level surface. Do not try to level the vehicle frame by jacking the front or rear axles. If the frame cannot be leveled from front to rear, determine and record the off-level inclination of the frame, and add or subtract that value from the measured values.

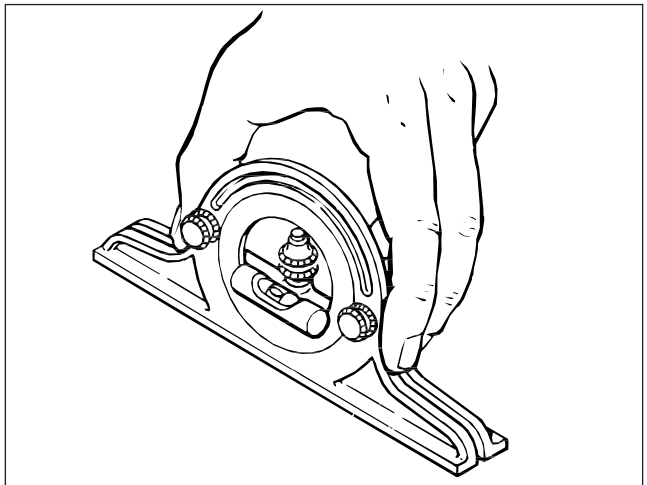

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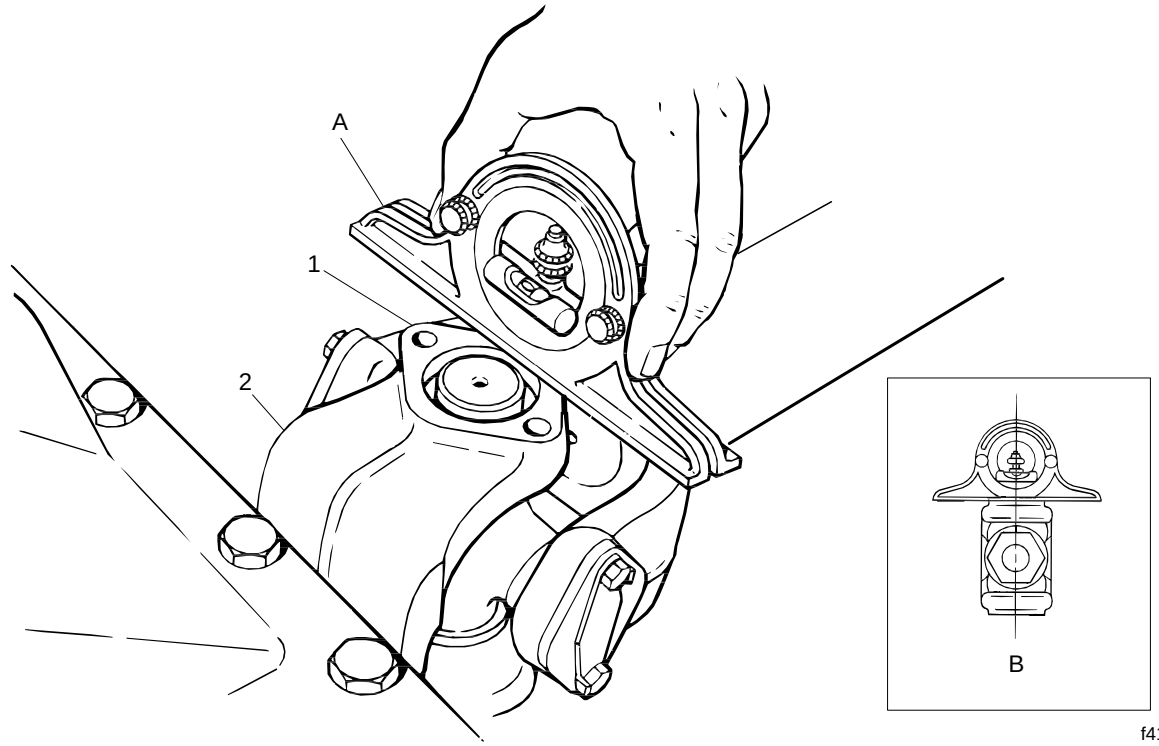
Fig. 4, Spirit Level Protractor

3. Chock the tires and place the transmission in neutral. Release the parking brakes.
4. The transmission output-shaft, coupling-shaft, and axle input- and output-yoke angles can be measured at either the top or bottom lug of the end-yoke being checked. For a full-round end-yoke, remove the bearing cup from the yoke lug. See **Section 41.00** for full-round end-yoke bearing cup removal.
5. Turn the end-yoke until the machined surface of the yoke lug is horizontal. See **Fig. 5**.

NOTE: To turn the driveshaft, raise one side of the rear (single-drive) or rearmost (dual-drive) axle until the tires are off the ground. Place a safety stand under the axle. With the transmission in neutral, and the interaxle differential (if equipped) unlocked, turn the tire to move the driveshaft.

6. Adjust the protractor scale to read 0 degrees. Position the protractor alongside the U-joint trunnion, on the machined surface of the end-yoke, and at a 90-degree angle to the frame centerline. See **Fig. 2**. Then turn the end-yoke until the bubble in the level vial is exactly between the two marks on the vial. Remove the jack stand and lower the rear axle to the ground.



NOTE: Full-round end-yoke is shown.

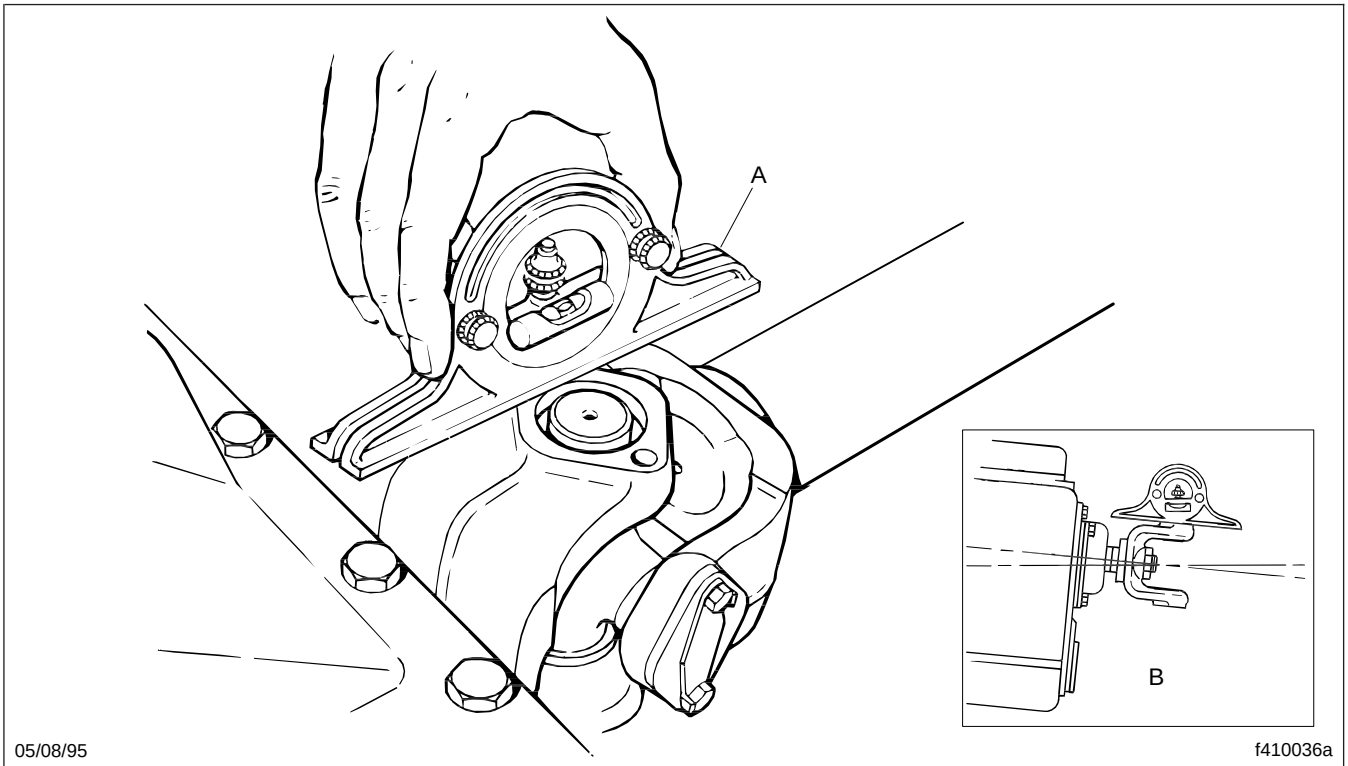
A. Protractor held at right angle to vehicle frame centerline.
B. End view of end-yoke.

1. Machined Surface of Yoke Lug
2. End-Yoke

Fig. 5, Horizontal Positioning of Yoke Lug Machined Surface

7. Without changing the position of the end-yoke, turn the protractor until it is parallel to the frame centerline. See **Fig. 6**. Adjust the calibrated scale so the bubble is exactly between the two marks on the level vial. Record the calibrated scale reading opposite the "0" mark. Correct this value for any previously recorded off-level inclination.
8. For a full-round end-yoke, install the bearing cup. See **Section 41.00** for full-round end-yoke bearing cup installation.

Engine and Pinion Angle Measurement



NOTE: Full-round end-yoke is shown.

A. Protractor held parallel to vehicle frame centerline.
B. Side view of end-yoke.

Fig. 6, Measuring Pinion Angles

Driveline Angle Checking

NOTE: Driveline suppliers have made angle checking software availble. Contact your local driveline representative or check the manufacturers website for the software. Angles need to be mearsured at the locations shown in **Fig. 1**.

If a vehicle is equipped with a Freightliner spring suspension, the axle pinion angles are factory-set using alignment shims at the rear springs. These shims have notches on the thick end of the shim. Count the number of notches in the thick end of each shim to make sure that the correct shim is used. Also, make sure the thick end of the shim is positioned correctly. See the applicable table in **Specifications, 400** for shim identification and use. If the axle pinion angles on these suspensions are incorrect, contact your district service manager for the adjustment procedure.

If the vehicle is equipped with an air suspension, verify ride height is correct. See **Group 32**.

If a vehicle is equipped with a Hendrickson suspension, spacers at the torque rods are used to maintain the correct axle pinion angles. If the measured axle pinion angles on these suspensions are not the same as the angles listed in the applicable table in **Specifications, 400**, contact your district service manager for the adjustment procedure.

NOTE: In any of the following steps, if an off-level inclination was added to or subtracted from the engine angle, the same figure must be added to or subtracted from the coupling shaft or axle pinion reading before comparing the angles. Also, avoid inperfections in paint.

IMPORTANT: DO NOT make any driveline angle adjustments before contacting your district service manager.

1. Check the engine angle at the transmission output-shaft end-yoke. The engine angle must be 3 degrees ±1/2 degree. For instructions, see **Subject 100**.

IMPORTANT: When using a digital angle analyzer (DAA), be sure to always take readings from the same side of the vehicle. Also, keep the same end of the DAA pointed toward the front of the truck.

2. If the driveline includes a midship bearing, place a digital angle analyzer (DAA) on top of the coupling shaft. Align the DAA with the shaft centerline. See **Fig. 2**. Read the scale to the nearest one-tenth of a degree (6 minutes). The centerline of the coupling shaft must be 1/2 degree out of vertical alignment with the transmission output shaft. See **Fig. 3**. Compare this reading with the measured engine angle.

   If the driveline angles are out of specification, contact your district service manager for midship bearing mount adjusting procedures.

3. On single-drive installations, measure the rear axle pinion angle at the back of the no. 2 driveline; for instructions, see **Subject 100**.

   The measured rear axle pinion angle must be equal ±1 degree to the measured engine angle. If the rear axle pinion angle does not meet the above specification, contact your district service manager.

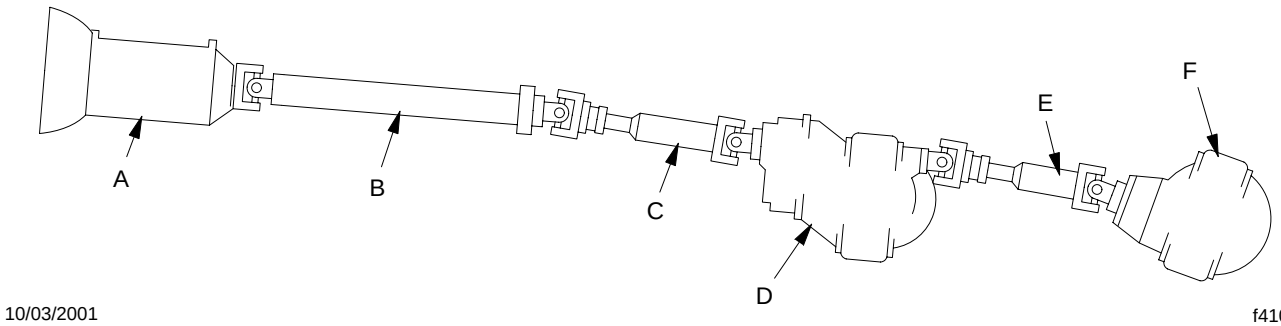
4. On dual-drive installations, measure the forward-rear-axle pinion angle (at the rear of the no. 2 driveline); for instructions, see **Subject 100**.

   The measured forward-rear-axle pinion angle must be equal ±1 degree to the measured engine angle. If the forward-rear-axle pinion angle does not meet the above specification, contact your district service manager.

   Measure the rearmost-axle pinion angle (at the rear of the no. 3 driveline); for instructions, see **Subject 100**.

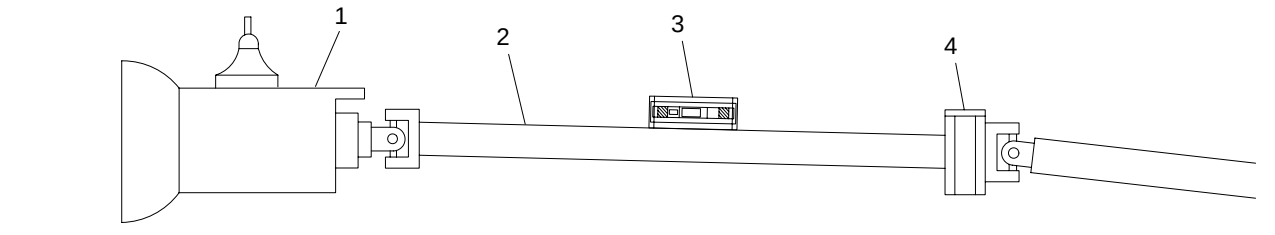
   Compare the measured angle with that shown in the applicable table in **Specifications 400**. The measured rearmost-axle pinion angle must be equal ±1 degree to the angle shown in the table. If the measured angle is incorrect, contact your district service manager.

Driveline Angle Checking



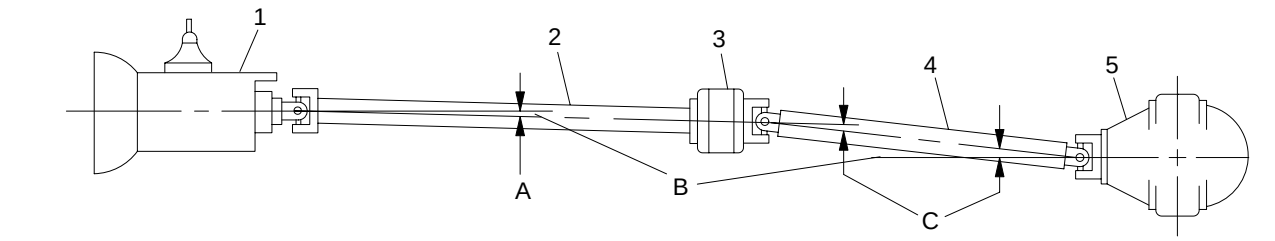
A. Tranmission
B. First Driveshaft
C. Second Driveshaft
D. Rear Drive Axle
E. Inter-Axle Driveshaft
F. Rear Drive Axle (rear-most)

Fig. 1, Driveline Angle Analysis (measuring locations)



1. Transmission
2. Coupling Shaft
3. Digital Angle Analyzer (DAA)
4. Midship Bearing

Fig. 2, Coupling Shaft Angularity



A. 1/2-Degree Minimum
B. Parallel Centerlines
C. Working Angles Unequal by 1/2 to 1 Degree

1. Transmission
2. Coupling Shaft
3. Midship Bearing
4. No. 2 Driveshaft
5. Rear Axle

Fig. 3, Midship Bearing in a Single-Drive Vehicle

Planing Angle Specifications

Engine Angle (for All Single-Drive-Axle Suspensions): Adjust to 3 or 5 degrees ±1/2 degree depending on vehicle specification in modules 101 and 109.

Engine Angle (for All Dual-Drive-Axle Suspensions): Adjust to 3-1/2 or 5 degrees ±1/2 degree depending on vehicle specification in modules 101 and 109.

Single-Drive-Axle Suspensions (All): Adjust rear axle pinion angle to 3 or 5 degrees ±1 degree depending on vehicle specification in modules 420 and 431.

Dual-Drive-Axle—Freightliner AirLiner Suspensions With Meritor RT–40/–44/–46 Axles: Adjust axle pinion angles to the values in **Table 1**, ±1 degree.

Dual-Drive-Axle—Freightliner Spring Suspensions (with Meritor RT–40/–44/–46 Axles): Adjust axle pinion angles to the values in **Table 2**, ±1 degree. See **Table 3** for shim notch decoding.

Dual-Drive-Axle—Hendrickson Suspensions With 52-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 4**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 54-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 5**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 56-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 6**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 60-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 7**, ±1 degree.

Dual-Drive-Axle—Hendrickson Suspensions With 72.5-Inch Axle Spacing: Adjust axle pinion angles to the values in **Table 8**, ±1 degree.

108SD and 114SD Single Spring Suspension Ride Heights and Planning Angles in **Table 9**.

Freightliner AirLiner Suspensions With Meritor RT–40/–44/–46 Axles												
Axle Seat Angle (degrees)		Measured Suspension Height * (Inches)	Rear Suspension Load (pounds)									
			Unladen		30,000		34,000		36,000		40,000	
			Axle Pinion Angle (degrees)									
Fwd	Rear		Fwd	Rear	Fwd	Rear	Fwd	Rear	Fwd	Rear	Fwd	Rear
3.0	5.5	2.375 (min)	2.1	10.6	3.0	11.5	3.2	11.7	3.3	11.8	3.5	12.0
		2.5	2.4	10.9	3.3	11.8	3.5	12.0	3.6	12.1	3.7	12.2
		2.625	2.7	11.2	3.6	12.1	3.8	12.3	3.8	12.3	4.0	12.5
		2.75	2.9	11.4	3.9	12.4	4.0	12.5	4.1	12.6	4.3	12.8
		2.87 (max)	3.2	11.7	4.2	12.7	4.3	12.8	4.4	12.9	4.6	13.1

* Measure suspension height at the forward drive-axle stop on the driver's side; see **Section 32.02** for complete instructions.

Table 1, Freightliner AirLiner Suspensions With Meritor RT-40/-44/-46 Axles

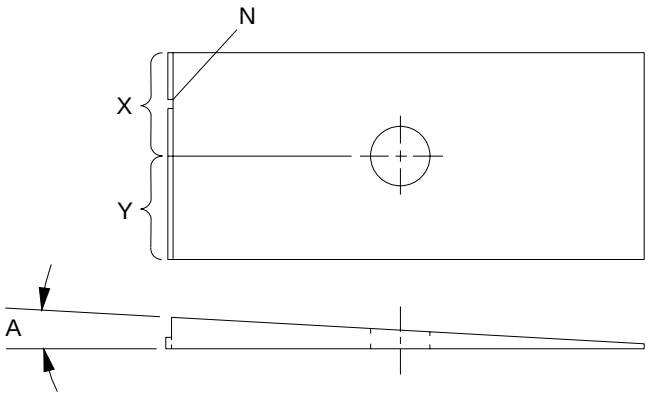
Freightliner Spring Suspensions (with Meritor RT–40/–44/–46 Axles)										
Axle Model	Forward-Rear Axle					Rearmost Axle				
	Pinion Angle (degrees)	Spring Seat Spacer	Shim Angle (degrees)	Orientation of Shim's Thick End	Number of Shim Notches *	Pinion Angle (degrees)	Spring Seat Spacer	Shim Angle (degrees)	Orientation of Shim's Thick End	Number of Shim Notches †
RT–40/–44/–46	3.0	Yes	None	—	—	11.0	None	1.0	Aft	2

* See **Table 3** for shim notch decoding.

† See **Table 3** for shim notch decoding.

Table 2, Freightliner Spring Suspensions (with Meritor RT-40/-44/-46 Axles)

Specifications



Shim Angle *A* (degrees)	Notches (N) at *X*	Notches (N) at *Y*
0.5	One (total at x plus y)	
1.0	Two	none
1.5	Three	none
2.0	Four (total at x plus y)	
2.5	Five (total at x plus y)	
3.0	Six (total at x plus y)	
3.5	Zero	Zero
4.0	One	One
4.5	Two	One

Table 3, Shim Notch Decoding

Hendrickson Suspensions With 52-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	12.88	3.2	11.6	3.0	11.8	22.5	—	25.75	0.125
RT40/44–145(P)	RS–400, –460	14	3.3	11.5	3.0	11.8	22.5	—	25.75	—
RT40/44–145(P)	RT2–400	7.19	4.2	12.6	3.0	11.8	22.25	—	25.75	—
RT40/44–145(P)	RT2–460	6	4.4	12.6	3.0	11.8	22.5	0.125	25.75	—
RT40/44–145(P)	RT2–460	7.19	2.8	10.8	3.0	11.8	22.5	—	26	0.125

Specifications

Hendrickson Suspensions With 52-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RTE2–400	7.19	4.6	12.9	3.0	11.8	22	0.125	26.25	0.125
RT40/44–145(P)	RTE2–460	7.19	4.8	12.9	3.0	11.8	22.25	—	26	—
RT46–160(P)	RS–400, –460	12.88	3.1	11.3	3.0	11.4	22.5	0.125	25.75	0.125
RT46–160(P)	RS–400, –460	14	3.2	11.1	3.0	11.4	22.5	—	25.75	0.125
RT46–160(P)	RT2–400	7.19	4.1	12.2	3.0	11.4	22.25	—	25.75	—
RT46–160(P)	RT2–460	6	4.3	12.3	3.0	11.4	22.5	0.125	25.75	—
RT46–160(P)	RT2–460	7.19	2.8	10.5	3.0	11.4	22.5	0.125	25.75	—
RT46–160(P)	RTE2–400	7.19	4.5	12.6	3.0	11.4	22	0.125	26.25	0.125
RT46–160(P)	RTE2–460	7.19	4.7	12.5	3.0	11.4	22.25	0.125	26	—

Table 4, Hendrickson Suspensions With 52-Inch Axle Spacing

Hendrickson Suspensions With 54-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	14	3.3	10.8	3.0	11.1	23.5	—	26.5	—
RT40/44–145(P)	RS–400, –460	12.88	3.1	10.9	3.0	11.1	23.5	—	26.5	0.125
RT40/44–145(P)	RT2–400	7.19	4.2	11.9	3.0	11.1	23.25	—	26.5	—
RT40/44–145(P)	RT2–460	6	4.4	12.0	3.0	11.1	23.5	0.125	26.5	—
RT40/44–145(P)	RTE2–400	7.19	4.6	12.2	3.0	11.1	23	—	27	—
RT40/44–145(P)	RTE2–460	7.19	4.8	12.2	3.0	11.1	23.25	0.125	26.75	—
RT46–160(P)	RS–400	14	3.2	10.6	3.0	10.8	23.5	—	26.5	0.125
RT46–160(P)	RS–460	14	3.2	10.6	3.0	10.8	23.5	—	26.5	—
RT46–160(P)	RS–400, –460	12.88	3.1	10.7	3.0	10.8	23.5	0.125	26.5	0.125
RT46–160(P)	RT2–400	7.19	4.1	11.7	3.0	10.8	23.25	—	26.5	—
RT46–160(P)	RT2–460	6	4.3	11.7	3.0	10.8	23.25	—	26.5	—
RT46–160(P)	RTE2–400	7.19	4.5	12.0	3.0	10.8	23	0.125	27	0.125
RT46–160(P)	RTE2–460	7.19	4.7	11.9	3.0	10.8	23.25	0.125	26.75	—

Table 5, Hendrickson Suspensions With 54-Inch Axle Spacing

Specifications

Hendrickson Suspensions With 56-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RTE2–460	7.19	4.4	11.7	3.0	10.6	24.25	0.125	27.75	0.125
RT46–160(P)	RTE2–460	7.19	4.7	11.4	3.0	10.3	24.25	0.125	27.5	—

Table 6, Hendrickson Suspensions With 56-Inch Axle Spacing

Hendrickson Suspensions With 60-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–400, –460	12.88	3.1	9.5	3.0	9.7	26.5	—	29	0.125
RT40/44–145(P)	RS–400, –460	14	3.2	9.4	3.0	9.7	26.5	—	29	—
RT40/44–145(P)	RT2–400	7.19	4.2	10.5	3.0	9.7	26.25	—	29	—
RT40/44–145(P)	RT2–460	6	4.3	10.6	3.0	9.7	26.5	0.125	29	—
RT40/44–145(P)	RTE2–400	7.19	4.6	10.9	3.0	9.7	26	—	29.5	—
RT40/44–145(P)	RTE2–460	7.19	4.7	10.8	3.0	9.7	26.25	0.125	29.25	—
RT46–160(P)	RS–400, –460	12.88	3.1	9.4	3.0	9.5	26.5	0.125	29	0.125
RT46–160(P)	RS–400, –460	14	3.2	9.3	3.0	9.5	26.5	—	29	—
RT46–160(P)	RT2–400	7.19	4.1	10.4	3.0	9.5	26.25	—	29	—
RT46–160(P)	RT2–460	6	4.3	10.4	3.0	9.5	26.25	—	29	—
RT46–160(P)	RTE2–400	7.19	4.5	10.7	3.0	9.5	26	0.125	29.5	—
RT46–160(P)	RTE2–460	7.19	4.6	10.8	3.0	9.5	26.25	0.125	29.25	—

Table 7, Hendrickson Suspensions With 60-Inch Axle Spacing

Hendrickson Suspensions With 72.5-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT40/44–145(P)	RS–460	12.88	3.1	7.5	3.0	7.6	32.75	0.125	34.5	0.125
RT40/44–145(P)	RS–460	14	3.2	7.4	3.0	7.6	32.75	—	34.5	—
RT40/44–145(P)	RT2–460	6	4.3	8.5	3.0	7.6	32.75	0.125	34.5	—
RT40/44–145(P)	RTE2–460	7.19	4.6	8.6	3.0	7.6	32.5	0.125	34.75	—

Specifications

Hendrickson Suspensions With 72.5-Inch Axle Spacing										
Axle Model	Suspension Model	Saddle Height (inches)	Planing Angle (degrees)				Suspension Control Rod			
			Unladen		Laden		Forward Axle		Rear Axle	
			Front	Rear	Front	Rear	Rod Length (inches)	Spacer Thickness (inches)	Rod Length (inches)	Spacer Thickness (inches)
RT46–160(P)	RS–460	12.88	3.1	7.3	3.0	7.4	32.75	0.125	34.5	0.125
RT46–160(P)	RS–460	14	3.1	7.2	3.0	7.4	32.75	0.125	34.5	—
RT46–160(P)	RT2–460	6	4.2	8.4	3.0	7.4	32.5	—	34.5	—
RT46–160(P)	RTE2–460	7.19	4.6	8.6	3.0	7.4	32.5	0.125	34.75	—

Table 8, Hendrickson Suspensions With 72.5-Inch Axle Spacing

108SD and 114SD Single Spring Suspension Ride Heights / Planing Angles		
Description	Ride Height *	Available Planing Angles †
10k M2 52" Vari-Rate Spring	260 mm (unladen)	3, 5 Degrees
12.5k M2 52" Vari-Rate Spring	260 mm (unladen)	
16k M2 52" Vari-Rate Spring w/ RS 13/15-120 axles	270 mm (unladen)	
16k M2 52" Vari-Rate Spring w/ RS 17-145 axles	285 mm (unladen)	
18k w/ & w/o Helper	300 mm (unladen)	
21k w/ & w/o Helper	310 mm (unladen)	
23k w/ & w/o Helper	310 mm (unladen)	
18k 60" Taper leaf 2 stage spring	235 mm (laden)	
21k 60" Taper leaf 2 stage spring	235 mm (laden)	
23k 60" Taper leaf 2 stage spring	235 mm (laden)	

* Ride height taken from the bottom bolt of the forward suspension hanger.

† Check the vehicle specification in module 421 to determine if the suspension is 3 or 5 degrees.

Table 9, 108SD and 114SD Single Spring Suspension Ride Heights / Planing Angles

General Description

CAUTION

The size of the tires installed at the factory is programmed into the electronic control unit (ECU). Installing different size tires could result in a reduced braking force, leading to longer stopping distances and possibly resulting in personal injury or property damage.

108 and 114 severe duty vehicles are equipped with a Meritor WABCO E-Version Antilock Braking System (ABS) with a cab-mounted electronic control unit (ECU).

The ABS is an electronic wheel speed monitoring and control system that works with the standard air brake system. It passively monitors vehicle wheel speed at all times, then controls wheel speed during emergency stops. As a result, the driver has full control of braking until the ECU senses that a lockup is about to occur.

The ABS includes signal-generating sensors activated by tone (tooth) wheels located on the hubs of the monitored wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. According to programmed specifications, the control unit signals the appropriate modulator valve to increase, reduce, or maintain air pressure in the brake chamber. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

Vehicles with a 4 x 2, 6 x 2, or 6 x 4 wheel configuration normally have the standard four-channel ABS with four wheel speed sensors and four modulator valves (4S/4M). Vehicles with tandem rear axles may be optionally equipped with a 6S/4M or 6S/6M ABS.

During normal braking conditions, the standard air brake system is in effect. If the vehicle is equipped with Automatic Traction Control (ATC), wheel spin is controlled during reduced-traction startup and acceleration.

Principles of Operation

The ABS has an electronic control unit that serves as the information processing and command center for the antilock braking system. The ECU is a digital microcomputer that receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the modulator valves.

The major components of the Meritor WABCO pneumatic ABS system include the following:

- Wheel speed sensors
- An electronic control unit (ECU)
- Modulator valves (solenoid control valves)
- Automatic Traction Control (ATC) valve (optional)
- ABS warning and wheel-spin indicator lights

Wheel Speed Sensors

The wheel speed sensor assembly is a signal-generating device. The assembly includes a sensor (coil wrapped around a magnet), a tone wheel, and a sensor clip that holds the sensor in position near the tone wheel. See **Fig. 2**.

Each ABS-controlled wheel has a wheel speed sensor assembly with a tone wheel mounted on the hub. When the vehicle is moving, the teeth on the tone wheel cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the electronic control unit where they are used to determine the wheel speed.

Electronic Control Unit (ECU)

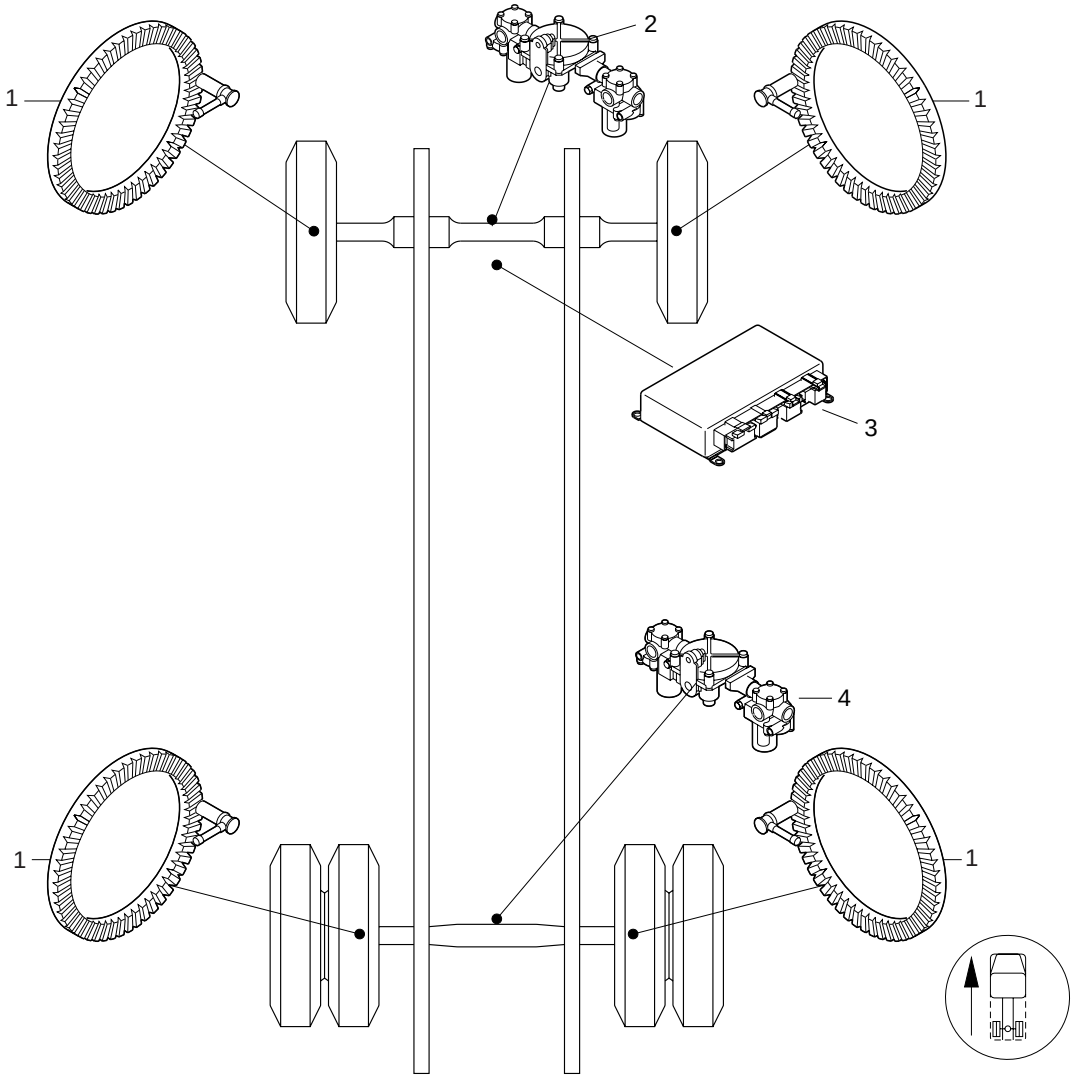
The ECU is cab mounted and contains microcomputers to monitor the front and rear control channels. See **Fig. 3**.

The ECU receives signals from the wheel speed sensors and uses them to calculate wheel speed and a vehicle reference speed. The unit is programmed to determine whether the wheels are slowing at a normal braking rate or at a higher rate, requiring ABS braking control. If the ECU senses wheel slip or lockup, the appropriate control circuit signals the modulator valve(s) to release, hold, or reapply braking pressure.

The ECU also shuts down the engine brake and the exhaust brake, if equipped, when a wheel approaches a slip or lockup condition. When the wheels return to a normal rate of speed, the engine and exhaust brakes are reactivated automatically.

The ECU constantly monitors the wheel sensors, modulator valves, Automatic Traction Control valve (if

General Information



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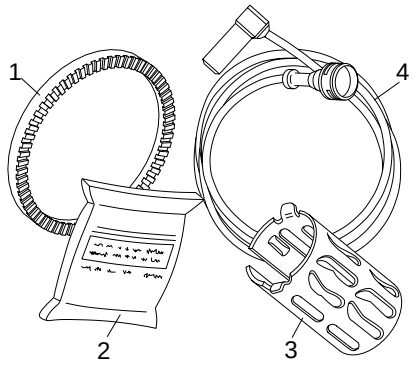
1. Tone Wheel and Sensor
2. Front Modulator Valve Assembly
3. Electronic Control Unit (ECU)
4. Rear Modulator Valve Assembly

Fig. 1, ABS Component Location (4-channel, 4S/4M system shown)

equipped), and the electrical circuitry. After the ignition switch is turned on, the ABS warning light (TRACTOR ABS) and the ATC wheel spin indicator light (WHEEL SPIN) on the dash illuminate for about 3 seconds. See **Fig. 5** for a typical instrument cluster.

IMPORTANT: If the vehicle is equipped with a stability system, the WHEEL SPIN light becomes a triangle with an exclamation point, as shown in **Fig. 4**.

During the self-test, the modulator valves and the ATC valve cycle on and off, creating clicking noises that may be heard inside the cab. These clicking noises are normal and do not indicate an ABS prob-



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1. Tone Wheel
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components

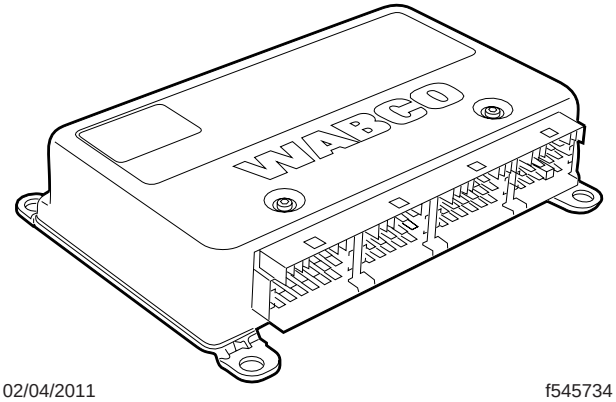

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Fig. 3, Cab Mounted ECU

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NOTE: This telltale will only appear if the vehicle is equipped with a stability system.

Fig. 4, Stability System Telltale

lem. After about 3 seconds, the lights go off only if all of the ABS and ATC components are functioning correctly.

On vehicles with Automatic Traction Control, after the self-test, the ATC indicator light comes on if a drive wheel spins during startup or acceleration.

IMPORTANT: If the ABS warning light and the ATC indicator light do not work as described above, repair the ABS/ATC system. See **Troubleshooting 300**.

If, during vehicle operation, the safety circuit senses a failure in any part of the ABS system (such as a sensor, modulator valve, wiring connection, or short circuit), the ABS warning light comes on, a fault code is stored in ECU memory, and the control circuit where the failure occurred is switched to normal braking action. The remaining control circuit retains the ABS effect.

Even if the ABS system is completely inoperative, normal braking is maintained. An exception would be if a modulator valve or valve assembly is damaged and inoperative. These components are an integral part of the air brake system so normal braking may be impaired or inoperative.

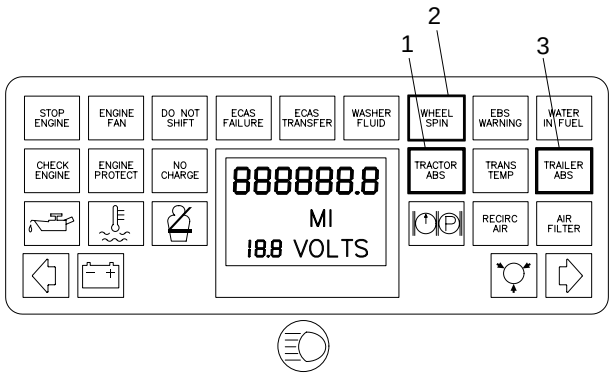
For troubleshooting purposes, the ECU can communicate with the Meritor WABCO PC Diagnostics (recommended), ServiceLink, a hand-held Pro-Link electronic diagnostic tool through the J1587 diagnostic datalink connector or blink codes. The connector is located near the B-pillar on the driver's side and the diagnostic switch is on the B-pillar panel. Fault codes can be retrieved through the datalink connection, when necessary.

IMPORTANT: Do not open the ECU. Opening the ECU to gain access to the internal components will void the warranty.

Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Depending on the signal received from the ECU, modulator valves prevent wheel lockup by reducing, maintaining, or increasing brake pressure. During normal braking applications, the ABS system is inactive and compressed air flows freely through the modulator valves to the brake chambers.

General Information



1. Tractor ABS Warning Light
2. Wheel Spin Warning Light
3. Trailer ABS Warning Light

Fig. 5, ABS and Wheel Spin Lights

Each ABS-monitored wheel has its own modulator valve. The front and rear modulator valve assemblies are mounted on a crossmember near the brake chambers. See **Fig. 1**. The assembly includes two modulator valves, one mounted on each side of a service relay valve. If the vehicle has an ATC system, the ATC valve is mounted on the control port of the service relay valve.

Vehicles with tandem rear axles and a 4S/4M ABS share modulator valves. One wheel is sensed but the modulator valve controls both wheels on a side.

Each modulator valve assembly includes two solenoid control valves (one supply and one exhaust) and two diaphragms. See **Fig. 6**.

- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust diaphragm opens and closes an air passage between the exhaust port and the delivery port. It is controlled by the exhaust solenoid valve.

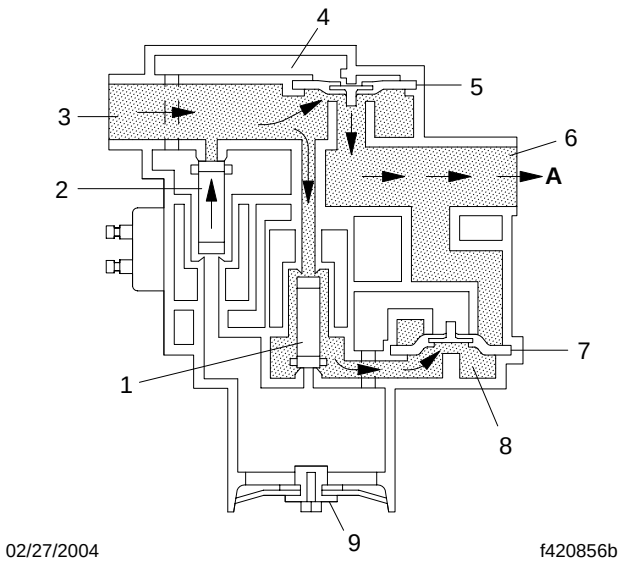
The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release (exhaust), ABS brake hold, and normal brake reapply.

Normal Brake Control

The normal brake function (without ABS control) operates as follows:

- Before braking, the supply pilot chamber is open to the atmosphere through the exhaust port.
- When the brakes are applied, both solenoid valves in the ABS modulator valve are closed (de-energized). See **Fig. 6**.
- Increased air pressure entering the supply port unseats the supply diaphragm by increasing the pressure under the diaphragm. This opens the passage to the delivery port and allows air to flow directly through the valve and into the brake chamber.
- Air also flows through the exhaust valve. The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port.
- When the brake pedal is released, air pressure at the supply port decreases and the higher pressure in the brake chamber reverses the flow of air in the modulator valve. Air now flows from the delivery port to the supply port until the pressure is balanced. This releases the supply diaphragm and closes the passage between the two ports.

- The reduced pressure unseats the exhaust diaphragm and air is vented through the exhaust port to the atmosphere.



NOTE: Both solenoid valves are closed. The modulator valve is shown in the braking configuration with increased air pressure at the supply port (supply diaphragm unseated, exhaust diaphragm seated).

A. Air to brake chamber.

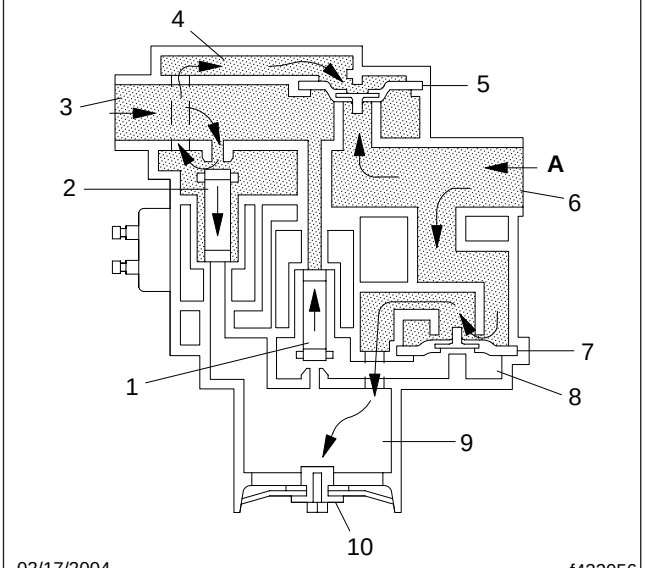
1. Exhaust Valve (closed)
2. Supply Valve (closed)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Pilot Chamber
9. Exhaust Port

Fig. 6, Modulator Valve, Normal Brake Control (brake applied)

Brake Release (ABS Active)

The ABS brake release (exhaust) function is triggered when the ECU determines that the brakes are about to lock.

- When a wheel is going to lock, the ECU opens (energizes) both solenoid valves in the ABS modulator valve. See **Fig. 7**.
- The open supply valve allows compressed air to enter the supply pilot chamber above the supply diaphragm. The increased pressure seats the diaphragm and stops air from entering the brake chamber.
- The open exhaust valve shuts off the supply of air entering the exhaust pilot chamber. It also creates an opening between the pilot and exhaust chambers.
- Air from the brake chamber enters through the delivery port. The pressure unseats the exhaust diaphragm, creating an opening between the delivery and exhaust chambers. Brake-chamber air is then released through the exhaust port.



NOTE: Both solenoid valves are open.

A. Air from brake chamber.

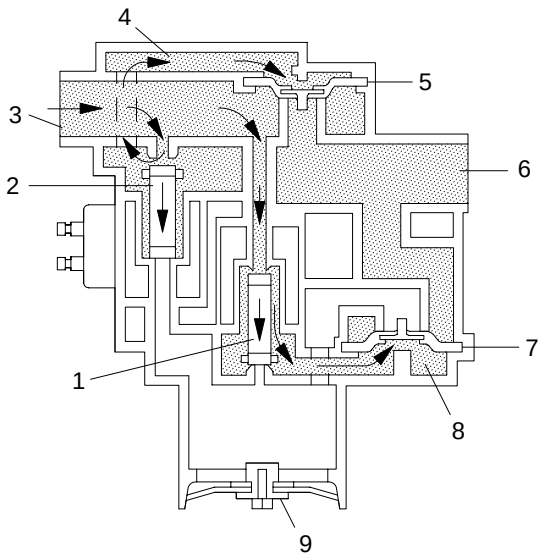
1. Exhaust Valve (open)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (unseated)
8. Exhaust Pilot Chamber
9. Exhaust Chamber
10. Exhaust Port

Fig. 7, Modulator Valve, Brake Release (exhaust)

Brake Hold Control (ABS Active)

The ABS brake hold function takes control during an emergency stop when the pedal control valve delivers more air than the brakes can handle without locking. The hold function occurs after the ABS has started to control the pressure in the brake chamber by releasing some of the air.

- When enough air is released through the exhaust port to stop the wheel from locking (ABS brake release), the exhaust valve is closed and air pressure is allowed to flow into the exhaust pilot chamber. See **Fig. 8**.



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NOTE: The supply valve is open; the exhaust valve is closed.

1. Exhaust Valve (closed)
2. Supply Valve (open)
3. Supply Port
4. Supply Pilot Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Pilot Chamber
9. Exhaust Port

Fig. 8, Modulator Valve, Brake Hold Control

- The increased pressure under the exhaust diaphragm seats the diaphragm, which closes the passage between the exhaust port and the delivery port. This stops the flow of air from the brake chamber to the exhaust port.
- The supply valve stays open to maintain pressure in the supply pilot chamber and keep the supply diaphragm seated. This prevents further buildup of pressure in the brake chamber.
- The remaining air pressure in the brake chamber is held and remains constant for stopping the vehicle in the minimum distance.

Reapply Brake Control (ABS Active)

The last ABS function is the reapply brake control. To achieve maximum braking, the ECU determines when to reapply the air pressure that the pedal control valve is delivering. When appropriate, both ABS solenoid valves are closed, which returns the system to the normal brake control state shown in **Fig. 6**.

During an ABS event, the ECU cycles the modulator valve(s) through the sequence of ABS valve states (brake release, hold, and reapply) very rapidly in order to control wheel speed. The effect is similar to manually pumping the brakes on a vehicle without an ABS.

NOTE: The driver always controls the maximum amount of pressure applied to the brakes. Pressure to the brake chamber can never be more than the driver applies with the foot pedal. The ABS can override the pedal pressure to provide less brake pressure, but not more.

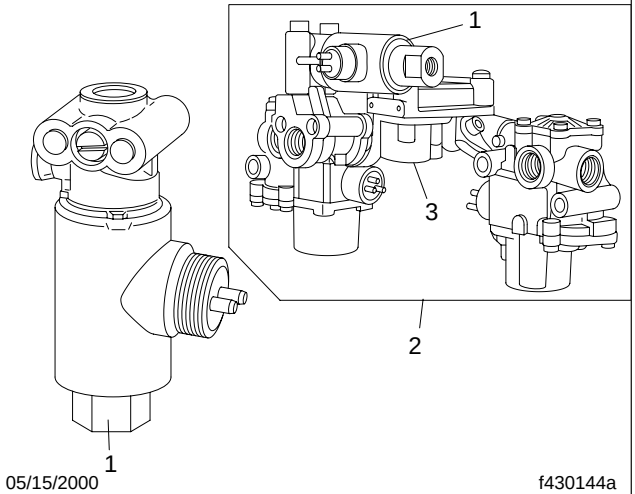
Automatic Traction Control

If the vehicle is equipped with Automatic Traction Control (ATC), the ABS/ATC system automatically reduces wheel spin during low-traction startup or acceleration.

If a drive wheel starts to spin faster than the steer-axle wheels, the ATC system applies air pressure to brake that drive wheel. This transfers engine torque to the wheel or wheels that have better traction (differential braking). If two or more drive wheels spin, the ATC reduces the engine torque to provide improved traction, overriding the throttle pressure from the driver.

The ATC valve controls only the brake chambers for the drive wheels. It is mounted on the service relay valve (rear modulator valve assembly). See **Fig. 9**.

The solenoid in the ATC valve controls an on/off air valve, which allows or prevents air flow to the control side of the service relay valve.



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1. ATC Valve
2. Rear Modulator Valve Assembly
3. Service Relay Valve

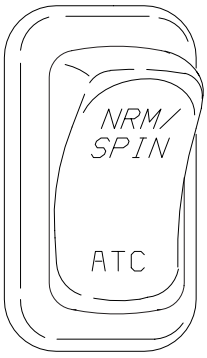
Fig. 9, ATC Valve

If a wheel spin from one side of the vehicle is detected, the ECU signals the ATC valve to open. This allows compressed air to enter the service relay valve and the normal ABS control system determines which brake to apply.

Figure 10 shows an ATC function switch on the dash that allows the driver to select from two levels of drive-axle traction control:

- In the default position, the ATC reduces drive-axle wheel spin on icy, wet, or sand-covered roads.
- Pressing the NORM/SPIN switch increases the available traction on extra soft surfaces like snow, mud, or gravel by slightly increasing the permissible wheel spin. The greater wheel spin may also be used to help burn through a thin layer of ice.

The ATC function turns on and off automatically; drivers do not have to select this feature. If a drive wheel spins during startup or acceleration, the ATC indicator lamp comes on, indicating the ATC is active. It goes out when the drive wheel stops spinning.



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NOTE: This is a momentary rocker switch, shown in the ATC (default) position.

Fig. 10, ATC Switch for Soft Surfaces

The NORM/SPIN mode overrides the ATC function. It must be manually selected by pressing the NORM/SPIN spring-loaded switch briefly after the vehicle is started. The ECU indicates the activation by a constant flashing of the WHEEL SPIN lamp. This mode is disengaged by pressing NORM/SPIN on the switch again or turning the ignition switch off.

ABS Warning and ATC Indicator Lights

The ABS warning light (TRACTOR ABS) receives power whenever the ignition switch is turned on. The ground paths for this indicator are through the ABS ECU, the blink-code switch, and relay. During the self-test, and whenever a malfunction occurs, the ECU completes the ground path and the ABS indicator on the dash comes on. See **Fig. 5**. The light is also used to display blink code diagnostics.

The warning light alerts the driver that the self-test is working or that an ABS system malfunction exists. After a wheel-sensor-related fault has been repaired, if the stored faults are cleared, the ABS warning light remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

The ATC indicator light also receives power whenever the ignition switch is on. If the drive-axle wheels spin, the ATC indicator light turns on.

On vehicles equipped with Automatic Traction Control, if the NORM/SPIN switch is activated, the ABS

General Information

ECU allows more wheel spin than normal and the ATC indicator blinks continuously until the switch is deactivated. See **Fig. 10**.

If the ATC wheel-spin indicator light stays on during normal vehicle operation, there is a malfunction in the ATC system.

Tire Size

For proper ABS/ATC operation with the standard ECU, the front and rear tire sizes must be within 14 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on.

Call Meritor WABCO at 1-800-535-5560 if you plan a tire-size difference greater than 14 percent.

Calculate the percentage difference of the tire sizes with the following equation:

Percentage Difference = {(steer-axle tire RPM ÷ drive-axle tire RPM) – 1} x 100, where RPM equals tire revolutions per mile.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires before working under the vehicle. Releasing air from the system can cause the vehicle to roll.
- Keep hands away from brake chamber push rods and slack adjusters; they will apply as the air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes.
- Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed the recommended air pressure.
- Always wear safety glasses when working with compressed air. Never look into air jets or direct them toward anyone.
- Never attempt to disassemble a component until you have read and understood the recommended procedures. Some components contain powerful springs, and injury can result if they are not correctly disassembled. Use only the correct tools and observe all precautions regarding use of those tools.
- Before performing any electric welding on a vehicle, disconnect the battery power, ground cables, and the electrical harness connectors at the ABS electronic control unit (ECU). Electric currents produced during electric welding can damage various electronic components on the vehicle.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

IMPORTANT: Do not attempt to repair the wheel sensor wire (the wire that comes with the sensor). If the wire is damaged, replace the sensor assembly.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. Refer to **Section 54.03** for information on special terminals and connectors, and on ordering tools for them.

Front Axle

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the steering knuckle. See **Fig. 1**.

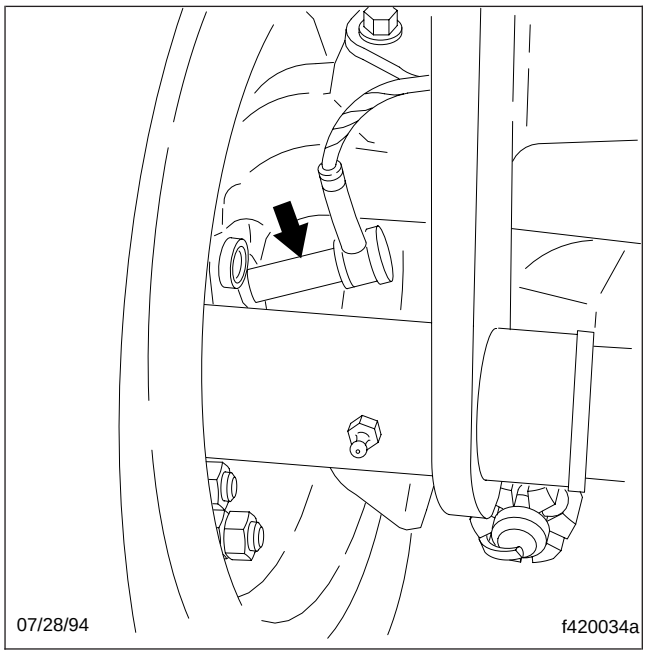


Fig. 1, Front Wheel Speed Sensor Removal

3. Remove the sensor cable from the steering knuckle top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the clamping bushing from the steering knuckle.
6. Connect the new sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Press the clamping bushing into the brake spider hole until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP 633, Pennzoil 707L, or an equivalent. Press the sensor into the clamping bushing until it is stopped by the tone wheel.
10. Remove the chocks from the rear tires.

Rear Axle

1. Park the vehicle on a flat surface, set the parking brake, and shut down the engine. Chock the front tires to prevent vehicle movement.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.
4. Remove the wheel and tire assembly from the rear axle. For instructions, see **Group 40**.
5. Remove the brake drum. For instructions, refer to **Section 35.01**.
6. Twist and pull the sensor to remove it from the mounting block in the axle housing.
7. Remove the clamping bushing.
8. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
9. Disconnect the sensor cable from the chassis harness.
10. Connect the new sensor cable to the chassis harness.
11. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.

Wheel Speed Sensor Replacement

12. Press the clamping bushing into the mounting block until it stops.
13. Coat the sensor with Mobil HP, Valvoline EP633, Pennzoil 707L, or an equivalent. Using your hand, push the sensor into the clamping bushing until it is stopped by the tone wheel.
14. Install the brake drum on the wheel hub. For instructions, refer to **Group 35**.
15. Adjust the rear axle brakes. For instructions, refer to the applicable brake section in this group.
16. Install the wheel and tire assembly, and tighten the wheel nuts. Use the tightening sequence and torque values listed in **Group 40**.
17. Remove the safety stands and lower the vehicle.

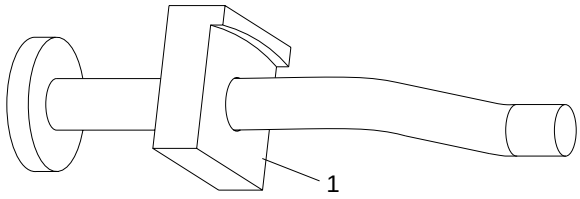
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Adjustment

NOTE: The following adjustment procedure requires the use of special tool T11-17556-000. Use of this tool, available through the PDCs, eliminates the time-consuming task of removing the wheel and tire assembly, and the brake drum. See **Fig. 1**.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the front tires.



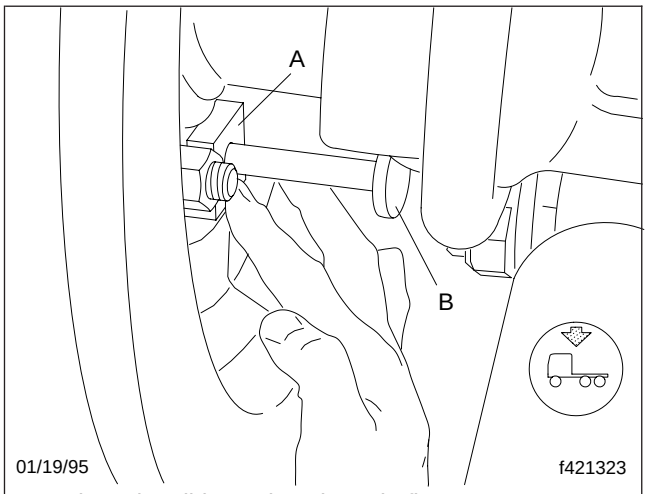
1. Adjustment Tool Slide

Fig. 1, ABS Sensor Adjustment Tool

2. Find the sensor access hole in the rear-axle flange, as follows.
   - 2.1 View the inboard side of the brake drum and axle from the rear. The ABS sensor wiring harness should be visible through a hole in the 12 o'clock position.
   - 2.2 Find the S-cam at either the 3 or 9 o'clock position.
   - 2.3 The sensor access hole is opposite the S-cam. The hole is approximately 3/4 inch (19 mm) in diameter.

IMPORTANT: Do not pry or push the sensor with sharp objects.

3. Insert service tool T11-17556-000 in the sensor access hole.
4. Place the slide of the tool on the axle flange to align the tool. See **Fig. 2**.



A. Place the slide against the axle flange.
B. Tap the handle with your hand.

Fig. 2, Positioning the Tool

5. Tap the tool handle lightly with the palm of your hand. This ensures that the sensor is touching the tone wheel.
6. Remove the tool from the wheel and repeat the procedure on the other rear-axle speed sensor.

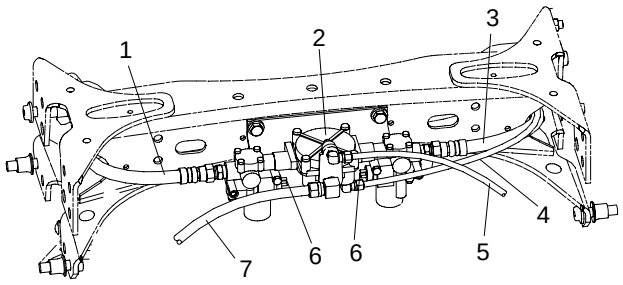
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Section 54.03** for information on special terminals and connectors, and on ordering tools for them.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the front and rear tires.
2. Release the pressure from the air reservoirs.
3. Mark the electrical connectors for ease of installation. Disconnect the wiring from the applicable modulator valve assembly. The assembly includes two modulator valves and a service relay valve. See **Fig. 1**.



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1. Delivery Air Line (to RH brake chamber)
2. Service Relay Valve
3. Delivery Air Line (to LH brake chamber)
4. Anti-Compounding Line (black, to park brake quick-release/relay valve)
5. Control Air Line (green, from foot pedal valve)
6. Modulator Valve Electrical Connection
7. Supply Air Line (green, from primary air reservoir)

Fig. 1, Modulator Valve Assembly

4. Mark the air lines for ease of installation. Disconnect the air lines.
5. Remove the fasteners that attach the front modulator valve or rear valve assembly to the mounting bracket. Remove the valve or assembly.

NOTE: The modulator valve assemblies can be disassembled if replacement of the service relay valve, automatic traction control valve (if equipped), or one of the modulator valves is needed. For disassembly and assembly instructions, see **Subject 140**.

Installation

1. Install the new front modulator valve or rear modulator valve assembly on the mounting bracket. Tighten the fasteners 18 lbf·ft (24 N·m).
2. Connect the air lines to the valves, as marked during removal.
3. Connect the electrical cable connectors to the valves. Tighten only hand-tight.

Installation Checkout

1. Apply the brakes, turn the ignition switch on, and wait for the ABS indicator light to come on.
2. Listen to the modulator valves cycle one by one, then together diagonally as follows:
   - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together followed by 3 and 4.
   - 6-Channel valve cycle: 1, 2, 3, 4, 5, 6; then 1, 2, and 3 together followed by 4, 5, and 6.
3. If a valve fails to cycle, turn the ignition switch off and make sure the electrical connections are tight. Then, turn the ignition switch on and listen to the valve cycle again.

   If a valve still fails to cycle, check for fault codes. See **Troubleshooting 300** for fault-code identification.
4. Apply the brakes and check the modulator valve fittings for leaks. No air leakage is permitted.
5. Remove the chocks from the tires.
6. Test drive the vehicle to verify that the ABS warning light is functioning correctly.

⚠ WARNING

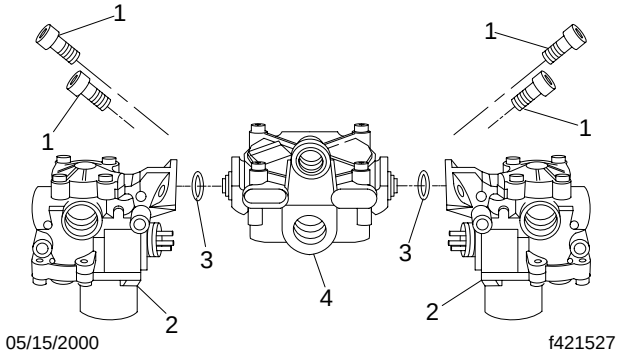
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

NOTE: On vehicles equipped with Automatic Traction Control (ATC), the ATC valve can be replaced without removing the modular valve assembly if there is enough room to work.

1. Remove the modulator valve assembly from the crossmember. See **Subject 130** for instructions.
2. Remove the modulator valves from the service relay valve, as follows.

   2.1 Using a 6-mm Allen wrench, remove two Allen-head capscrews that attach each modulator valve to the service relay valve. See **Fig. 1**.



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1. Capscrew, Allen-Head, M8
2. Modulator Valve
3. O-Ring
4. Service Relay Valve

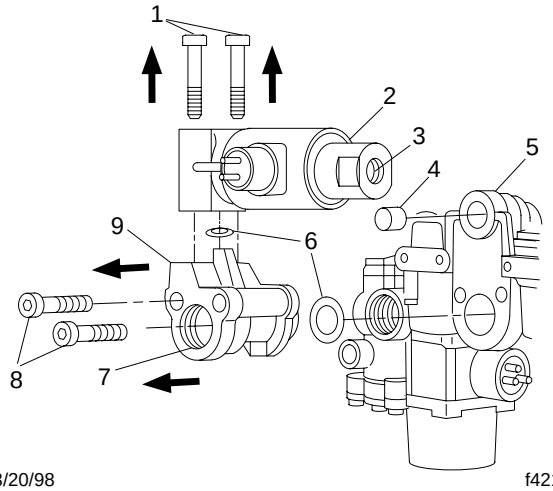
Fig. 1, Modulator Valve Assembly

   2.2 Carefully separate the modulator valves from the service relay valve.

   2.3 Remove and discard the O-rings.

3. If the vehicle is equipped with Automatic Traction Control (ATC), remove the ATC valve from the service relay valve, as follows. See **Fig. 2**.

   3.1 Using a 5-mm Allen wrench, remove two Allen-head capscrews that attach the adaptor to the service relay valve. Remove the adapter/ATC valve assembly.



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1. Capscrew, Allen-Head, M8
2. ATC Valve
3. Control Port
4. Seal
5. Service Relay Valve
6. O-Ring
7. Supply Port
8. Capscrew, Allen-Head, M6
9. Adaptor

Fig. 2, ATC Valve Mounting

   3.2 Using a 6-mm Allen wrench, remove two Allen-head capscrews that attach the ATC valve to the adaptor. Separate the valve from the adaptor.

   3.3 Remove and discard the seal and two O-rings.

Assembly

1. If the vehicle is equipped with Automatic Traction Control (ATC), install the ATC valve on the service relay valve, as follows.

   1.1 Clean the O-ring grooves on the adaptor. Lubricate the small replacement O-ring and install it in the top port in the adaptor.

   1.2 Using two new M8 Allen-head capscrews, install the ATC valve on the adaptor. Tighten the capscrews 12 to 13 lbf·ft (16 to 18 N·m).

Modulator Valve Disassembly and Assembly

1.3 Lubricate the replacement seal and install it in the control port (upper port) of the service relay valve.

1.4 Lubricate the large replacement O-ring and install it in the groove in the supply port (lower port) of the service relay valve.

1.5 Using two new M6 Allen-head capscrews, install the adaptor on the service relay valve. Tighten the capscrews 48 to 60 lbf·in (542 to 678 N·cm).

2. Install the modulator valves on the service relay valve, as follows.

2.1 Plug any unused ports on the replacement modulator valves.

2.2 Clean the O-ring surfaces on the modulator and service relay valves. Lubricate the replacement O-rings and place them in the applicable grooves in the valves.

2.3 Install each modulator valve on the service relay valve with two M8 Allen-head capscrews. Tighten the capscrews 13 to 15 lbf·ft (18 to 20 N·m).

3. Install the modulator valve assembly on the bracket on the crossmember. For instructions, see **Subject 130**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Installation

IMPORTANT: Some ABS service hubs do not have a tone (tooth) ring installed on the hub. The tone ring must be ordered separately and installed on the hub before installation of the hub onto the axle. Tone rings are made of a special material and require a specific installation procedure for proper installation.

WARNING

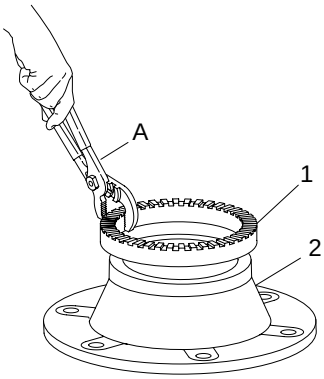
When installing an ABS system, special ABS hubs must be ordered. Machining older hubs to accommodate the installation of tone rings can cause problems due to insufficient hub bore wall thickness. Machining an older hub with insufficient hub bore wall thickness could result in cracking, causing bearing damage and wheel loss. This could cause an accident resulting in personal injury and property damage.

1. Submerge the tone ring in boiling water or place it in an oven at 250°F (121°C) for approximately 15 minutes.

NOTICE

Do not attempt to heat the tone ring with a torch as this can damage the ring.

2. Using pliers, remove the tone ring from the boiling water or oven and center it on the machined area of the hub bore. See **Fig. 1**.
3. While the tone ring is still hot, make sure it is properly centered on the machined surface. Using a rubber mallet, tap the tone ring until it bottoms out around the machined surface on the hub. See **Fig. 2**.
4. Install the hub on the axle. Place a dial indicator with a magnetic base so the dial indicator is against the tone-ring teeth. See **Fig. 3**.



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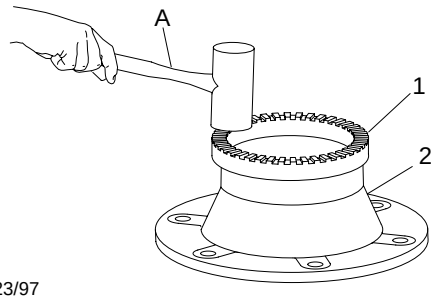
A. Use pliers to apply the ring.
1. Tone Ring 2. Hub

Fig. 1, Centering the Ring on the Hub



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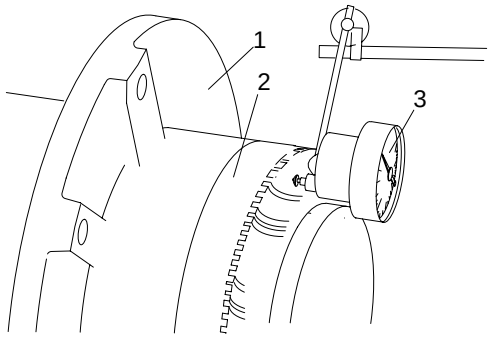
A. Use a rubber mallet.
1. Tone Ring 2. Hub

Fig. 2, Installing the Tone Ring

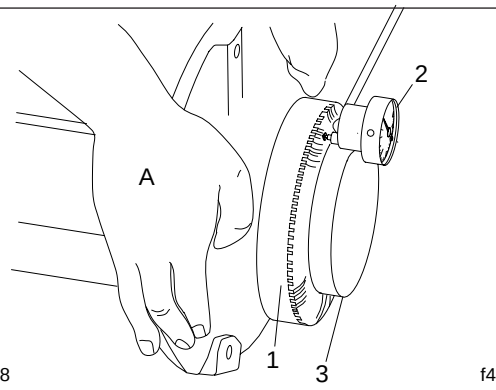
5. Rotate the hub and check the ring for runout. The runout should be less than 0.005 inch (0.13 mm). See **Fig. 4**.
6. Install the wheel. For instructions, see **Group 40**.

ABS Tone Ring Installation on Service Hubs



1. Hub
2. Tone Ring
3. Dial Indicator

Fig. 3, Positioning the Dial Indicator



A. Rotate the hub.

1. Tone Ring
2. Dial Indicator
3. Axle

Fig. 4, Checking Tone-Ring Runout

⚠ WARNING

Do not test a vehicle equipped with Automatic Traction Control (ATC) on a dynamometer unless the ATC system is disabled. Activation of the ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Vehicles with ATC must have the ATC disabled before testing the vehicle on a dynamometer. Use one of the following methods to disable the ATC:

- Use the Meritor PC Diagnostics or the Pro-Link electronic diagnostic tool to disable the ATC.
- Press and hold the blink code switch for at least three seconds. Once the system identification code begins, the ATC system has been disabled. See **Table 1** for system ID codes.
- Removing the ABS circuit breaker or fuse, or removing the ECU power connector will disable both the ABS and ATC.

The ATC light on the dash comes on and stays on when the ATC is disabled.

System Identification Blink Codes*		
Blink Code	**Sensors/ Modulators**	**Wheel Positions**
1 Blink	6S/6M	6 x 2
2 Blinks	4S/4M	4 x 4
4 Blinks	6S/4M	6 x 4
5 Blinks	6S/6M	6 x 4

* The system identification blink code, followed by a 4-second pause, repeats until the ignition switch is turned off.

Table 1, System Identification Blink Codes

General Information

⚠ WARNING

Before testing a vehicle equipped with Automatic Traction Control (ATC) on a dynamometer, the ATC system must be disabled. See Subject 160 for instructions. Activation of the vehicle ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

Before testing a wheel speed sensor, modulator valve, or ATC valve, make sure the supply voltage to the antilock braking system (ABS) electronic control unit (ECU) is sufficient (see "ECU Supply Voltage Test") and check for leaks in the ABS pneumatic system.

The sensor and valve resistance tests are given in two steps. First, disconnect the applicable cable from the ECU and measure the resistance across the terminals in the cable connector. If the resistance is within the specified range, both the cable and the sensor or valve are good.

Next, if the resistance reading is not acceptable, disconnect the cable from the sensor or valve and measure the resistance across the sensor or valve terminals. This two-step procedure quickly determines whether the problem is in the cable or the component.

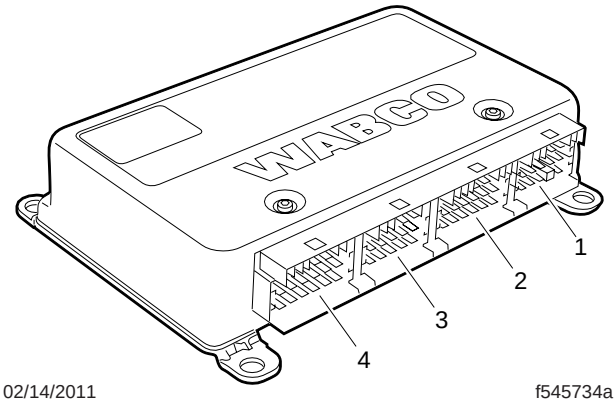
NOTE: The valve circuits and wheel sensors can be tested by Meritor PC diagnostics. If PC diagnostics indicate a problem, test the individual component to determine whether the component or the wiring has failed.

Wire Numbers and Connector Pin Locations

NOTICE

The ignition switch must be off when connecting or disconnecting connectors from the ECU. Power applied to the ECU during connector installation or removal could damage the pins.

The WABCO cab-mounted ECU has several multi-pin connectors that must be disconnected to test the wheel speed sensors, modulator valves, or ATC valve. To disconnect the electrical connectors from the ABS ECU, remove the capscrews and lift the covers. See **Fig. 1** to identify the pin locations on the ECU connector. **Table 1** provides the wire numbers and circuit descriptions for testing the ABS/ATC components.



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1. X1 Connector (gray)
2. X2 Connector (black)
3. X3 Connector (green)
4. X4 Connector (brown—6S/4M, 6S/6M only)

Fig. 1, Cab-Mounted ECU

ECU Supply Voltage Test

Use Meritor WABCO PC Diagnostics system to check the supply voltage to the ABS ECU. If the PC Diagnostics is not available, use the following procedure to check the voltage.

1. Park the vehicle on a level surface, set the parking brake, shut down the engine, and chock the rear tires.
2. Disconnect the X1 (gray) connector at the ABS ECU.
3. Turn the ignition switch on.
4. Connect a voltmeter between pin 1 and a good chassis ground. The voltmeter must indicate 9.5 to 14 volts.
5. Connect a voltmeter between pin 2 and a good chassis ground. The voltmeter must indicate 9.5 to 14 volts.

Testing

ABS/ATC Circuit Pin and Wire Numbers			
Pin Connector	**Pin Number**	**Wire Number**	**Circuit Description**
X1 Gray	1	1939–	1939–
	2	376F	Trailer ABS Indicator Lamp
	3	1939+	1939+
	4	XGRD	ECU Ground
	5	—	Not used
	6	376T	ATC Switch
	7	376C1	ECU Ignition Supply
	8	376A	ECU #1 Positive 12 Volt Supply
	9	XGRD	ECU Ground
	10	1587–	1587–
	11	1587+	1587+
	12	—	Not used
	13	376S	ATC Indicator Lamp
	14	—	Not used
	15	376L	Tractor ABS Indicator Lamp
X2 Black	1	378RF	Right Front Sensor, High
	2	378LR	Left Rear Sensor, High
	3	378LF	Left Front Sensor, High
	4	378RF0	Right Front Sensor, Low
	5	378LR0	Left Rear Sensor, Low
	6	378LF0	Left Front Sensor, Low
	7	378T–	ATC Valve Return (or Ground)
	8	378RR	Right Rear Sensor, High
	9	378RR0	Right Rear Sensor, Low
	10	377RF–	Right Front Wheel Sensor Return
	11	377LR–	Left Rear Wheel Sensor Return
	12	377LF–	Left Front Wheel Sensor Return
	13	377RF+	Right Front Wheel Sensor Signal
	14	377LR+	Left Rear Wheel Sensor Signal
	15	377LF+	Left Forward Wheel Sensor Signal
	16	378T+	ATC Valve Power
	17	377RR–	Right Rear Wheel Sensor Return
	18	377RR+	Right Rear Wheel Sensor Signal

ABS/ATC Circuit Pin and Wire Numbers			
Pin Connector	**Pin Number**	**Wire Number**	**Circuit Description**
X3 Green	1	—	Not used
	2	—	Not used
	3	—	Not used
	4	—	Not used
	5	—	Not used
	6	—	Not used
	7	—	Not used
	8	378RS–	RSC Valve Return (or Ground)
	9	—	Not used
	10	—	Not used
	11	—	Not used
	12	—	Not used
	13	378RS+	RSC Valve Power
	14	—	Not used
	15	—	Not used
X4 Brown (third axle)	1	508G	System CAN, Low
	2	—	Not used
	3	508E	System CAN, High
	4	—	Not used
	5	—	Not used
	6	—	Not used
	7	376A	ESC Module Power
	8	376C1	Pressure Sensor Power
	9	—	Not used
	10	XGRD	ESC Module Ground
	11	XGRD	Pressure Sensor Ground
	12	—	Not used
	13	378TF–	ATC Valve, Front Axle Return (or Ground)
	14	402	Pressure Sensor
	15	—	Not used
	16	378TF+	ATC Valve, Front Axle Power
	17	—	Not used
	18	—	Not used

Table 1, ABS/ATC Circuit Pin and Wire Numbers

6. Turn the ignition switch off.
7. If the voltage at the ECU is not within the specified range, check the battery voltage and test the wiring to the ECU and to ground.
8. Connect the X1 connector to the ECU and remove the chocks from the tires.

ABS Pneumatic System Test

To check for air leaks in the ABS pneumatic system, listen for the sound of escaping air at each valve. To confirm a slow air leak, apply a soap-and-water solution to air line fittings and watch for bubbles.

Wheel Speed Sensor Tests

Wheel Speed Sensor and Circuit Resistance

To check the resistance in a wheel speed sensor circuit, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the sensor cable connector from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the sensor connector terminals and read the resistance.
    - If the resistance is 900 to 2000 ohms, the cable and the sensor circuit are good. Proceed to the "Wheel Speed Sensor Voltage" test.
    - If the resistance is less than 900 ohms or greater than 2000 ohms, perform the next test, "Wheel Speed Sensor Resistance."

Wheel Speed Sensor Resistance

To check the resistance in a wheel speed sensor, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the wheel sensor cable from the chassis harness.
3. Connect ohmmeter probes to the pins on the sensor and read the resistance.
    - If the resistance reading is 900 to 2000 ohms but the resistance noted in the previous test, "Wheel Speed Sensor and Cable Resistance" was not, repair or replace the chassis harness wiring.
    - If the resistance is less than 900 ohms or greater than 2000 ohms, clean the terminals and check the resistance again.
    - If the resistance reading is still not correct, replace the sensor. See **Subject 110** for instructions.
4. Install the connectors and remove the chocks from the tires.

Wheel Speed Sensor Voltage

NOTE: PC diagnostics can be used for this test to compare speed signal output of all sensors. A problem will be indicated by low or erratic output.

To check the voltage output of a wheel speed sensor:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine.
2. Chock the tires of the axle not being tested. Raise the vehicle and put jack stands under the axle so the wheels can rotate.
3. Disconnect the applicable connector from the ABS ECU for the sensor being tested. See **Table 1**.
4. Set a digital multimeter to the AC voltmeter mode. Connect the probes to the cable connector terminals for the sensor being tested.
5. Rotate the wheel by hand at a speed of 30 rpm (one-half revolution per second) and read the voltage output. The wheel speed sensor must generate a minimum of 0.2 volt AC.
    - If the voltage is at least 0.2 volt AC, skip to the next step.
    - If the voltage reading is less than 0.2 volt AC, push the sensor in its holder until the sensor touches the tooth wheel. See **Subject 120** for instructions. Repeat the voltage test.

- If the sensor output is still less than 0.2 volt AC, replace the sensor.

6. Install the connector on the ECU. Remove the jack stands, lower the vehicle, and remove the chocks from the tires.

Modulator Valve Tests

Modulator Valve Function Check

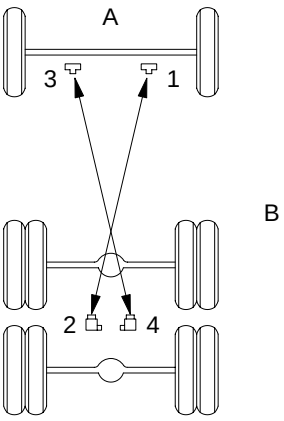
NOTE: Valves can be tested using the Meritor WABCO PC Diagnostics software or the following procedure.

Modulator valves control the air pressure to each affected brake during an ABS function. To make sure the modulator valves are working, listen to them cycle during the ABS self-test.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Turn the ignition switch on.
3. When the ABS warning light comes on, listen for the modulator valves to cycle one by one, then together diagonally. See **Fig. 2**.
   - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together followed by 3 and 4.
   - 6-Channel valve cycle: 1, 2, 3, 4, 5, 6; then 1, 2, and 3 together followed by 4, 5, and 6.
4. If the valves do not all cycle correctly, turn the ignition off and check the connectors for tightness. Repeat the self-test.
5. If the valves still do not cycle correctly, start the engine and check the air line connections to the valves for leaks. Shut down the engine and tighten the air line fittings. Repeat the self-test.
6. If the valves still do not cycle correctly, check for fault codes. Perform the next test, "Modulator Valve and Cable Resistance."

Modulator Valve and Cable Resistance

To check the resistance in a modulator valve and cable circuit, perform the following test:



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NOTE: During the self-test, the valves cycle one by one in order (1–2–3–4), then in pairs diagonally (1/2 and 3/4). A 4-channel valve cycle is shown.

A. Cab B. Curbside

1. Right Front Modulator Valve
2. Left Rear Modulator Valve
3. Left Front Modulator Valve
4. Right Rear Modulator Valve

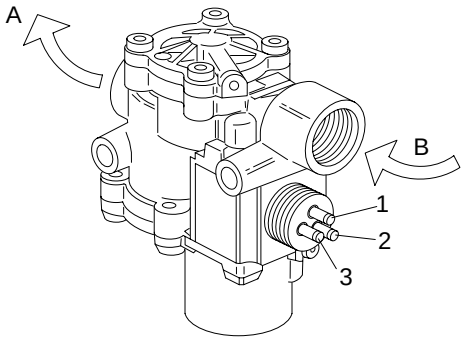
Fig. 2, Modulator Valve Self-Test Sequence

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the modulator valve connector from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the cable connector pins for the modulator valve "In" solenoid and "Ground." Read the resistance. Then, move the probes to the "Out" and "Ground" pins and read the resistance.
4. The resistance in each solenoid coil and cable circuit must be 4 to 8 ohms.
   - If the resistance in each solenoid circuit is 4 to 8 ohms, the cable and modulator valve are good. Install the connector on the ECU and remove the chocks from the tires.
   - If the resistance in either solenoid circuit is less than 4 ohms or greater than 8 ohms, go to the next test, "Modulator Valve Resistance."

Modulator Valve Resistance

To check the resistance in the solenoid coils in an ABS modulator valve, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the cable connector from the modulator valve being tested. See **Table 1**.
3. Connect ohmmeter probes to the modulator valve "In" solenoid and "Ground" terminals and read the resistance. Then, move the probes to the "Out" and "Ground" terminals and read the resistance. See **Fig. 3** for the modulator terminal locations.



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A. Delivery Port
B. Supply Port
1. Ground (Common)
2. Exhaust Solenoid (Out)
3. Supply Solenoid (In)

Fig. 3, Modulator Valve Terminals

4. The resistance in each solenoid coil must be 4 to 8 ohms.
    - If the resistance in each solenoid coil is 4 to 8 ohms but the resistance noted in the previous test, "Modulator Valve and Cable Resistance" was not, repair or replace the chassis harness.
    - If the resistance is less than 4 ohms or greater than 8 ohms, clean the terminals on the modulator valve and check the resistance again.
    - If the resistance is still not correct, replace the valve. See **Subject 130** for instructions.
5. Install the cable connectors and remove the chocks from the tires.

ATC Valve Tests

ATC Valve and Cable Resistance

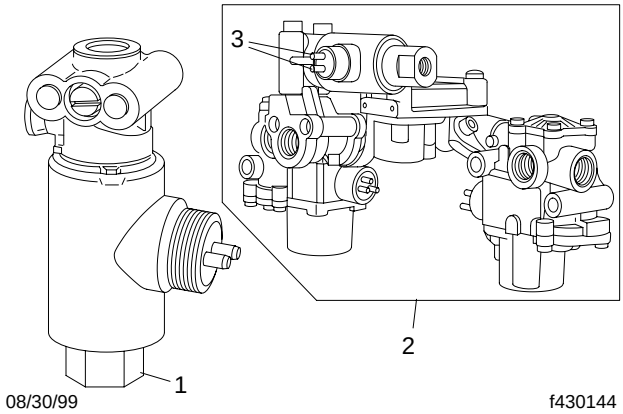
To check the resistance in the ATC valve and cable circuit, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the ATC valve connector (X3) from the ABS ECU. See **Table 1**.
3. Connect ohmmeter probes to the cable connector pins 5 and 6 for the ATC valve and read the resistance.
4. The resistance in the ATC solenoid coil and cable circuit must be 6.4 to 12 ohms.
    - If the resistance is 6.4 to 12 ohms, the ATC valve and cable are good. Install the cable connector on the ECU and remove the chocks from the tires.
    - If the resistance is less than 6.4 ohms or greater than 12 ohms go to the next test, "ATC Valve Resistance."

ATC Valve Resistance

To check the resistance in the solenoid coil in the ATC valve, perform the following test:

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Disconnect the cable connector from the ATC valve. See **Table 1**.
3. Connect ohmmeter probes to the ATC valve terminals and read the resistance. See **Fig. 4**.
4. The resistance of the ATC solenoid coil and its wiring must be 6.4 to 12 ohms.
    - If the resistance is 6.4 to 12 ohms but the resistance noted in the previous test, "ATC Valve and Cable Resistance" was not, repair or replace the electrical cable.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. ATC Solenoid Terminals

Fig. 4, ATC Valve Terminals

- If the resistance is less than 6.4 ohms or greater than 12 ohms, clean the terminals on the ATC valve and check the resistance again.
- If the resistance is still not correct, replace the valve. See **Subject 140** for instructions.

5. Install the connectors and remove the chocks from the tires.

Troubleshooting for E-Version ABS

⚠ WARNING

Before testing a vehicle equipped with Automatic Traction Control (ATC) on a dynamometer, the ATC system must be disabled. See Subject 160 for instructions. Activation of the vehicle ATC on a dynamometer will cause unequal drive-wheel torque that can result in loss of vehicle control and personal injury or death.

This subject includes troubleshooting procedures for diagnosing problems indicated by the ABS warning light(s) or the ATC wheel spin indicator light (if equipped) on the instrument panel. If any of these lights come on after the initial self-test, use one of the following methods to identify the problem:

- Troubleshoot using the Meritor WABCO PC Diagnostics software.
- Troubleshoot using J1587 codes viewed on a computer with Freightliner's ServiceLink installed.
- ProLink 9000®
- Troubleshoot using the instrument panel blink codes.

The J1587-code method provides more information about the specific problem than can be obtained from the blink codes.

The ABS (and ATC, if equipped) system has built-in diagnostics to ensure that all components are operating correctly. The first step is an automatic self-test. Under normal conditions, the ABS warning light(s) (TRACTOR ABS and TRAILER ABS, if equipped) and ATC wheel spin indicator light (WHEEL SPIN) light up on the instrument cluster when the ignition is turned on. After about 3 seconds, these lights should go out if all of the vehicle's ABS/ATC components are working.

If any of the lights stay on, or come back on later, a problem within the ABS/ATC system has occurred. The driver can continue to drive the vehicle, but the ABS system could be partially or completely inoperative.

NOTE: The WHEEL SPIN indicator stays lit when the ATC is controlling wheel spin and blinks continuously if the ATC switch (NORM/SPIN) is activated. These are normal conditions and do not indicate a fault.

To check the type of fault code recorded, stop the vehicle and turn off the engine. Then, turn on the ignition switch, but don't start the engine. If the light stays on after the 3-second self-test, there is an active system fault that must be repaired to ensure proper system operation.

If the light does not stay on, a stored or intermittent fault has been recorded in the ABS electronic control unit (ECU) memory. Stored (historical) faults are faults that occurred during a previous operation of the vehicle but are not still active when the ignition switch is turned on. Intermittent faults may indicate a loose connector or broken wire.

If either light does not come on during the self-test, check the bulb, all related circuit breakers in the electrical panel, or the batteries (the ABS/ATC system requires at least 9.5 volts to function correctly).

If a fault has been corrected since the ABS warning light originally came on, the system must be calibrated by driving the vehicle a short distance at 4 mph (6 km/h) or more before the light will go out.

Using Meritor WABCO PC Diagnostics

Use Meritor PC diagnostics to view fault codes, test component operation, and clear historic faults. If more detailed fault troubleshooting is required, note the J1587 fault codes in PC diagnostics and look it up in the troubleshooting tables.

Using J1587 Fault Codes

Use Freightliner's ServiceLink to diagnose the ABS/ATC system if detailed fault codes are needed or if the diagnosis must be done remotely. Connect a computer, with ServiceLink installed, to the J1587 datalink connector located near the driver's side B-pillar. Follow the instructions found in the ServiceLink manual.

On vehicles equipped with an ICU1 or ICU2 instrument control unit with the optional MODE/RESET button, the J1587 fault codes can be seen on the driver's display screen. When the MODE/RESET button is pressed, the three parts of the J1587 fault codes (MID, SID, and FMI) appear on the screen in sequence.

Troubleshooting

The J1587 fault codes are eight-digit numbers.

- The first three digits refer to the message identifier (MID) that indicates the ECU reporting the fault. The MID is 136 for the ABS/ATC ECU.
- The next three digits (preceded by a lowercase "s") represents the subsystem identifier (SID), which indicates the component at fault.
- The last two digits, the Failure Mode Identifier (FMI), represent the specific problem with the component.

The tables provided in "Troubleshooting Tables" all have an MID code of 136. Each table lists all the FMI codes for a specific component (SID). See **Table 1** for a list of the first six digits of the fault codes with their corresponding components and troubleshooting table references.

Active faults cannot be cleared until they are repaired. A wheel sensor fault that has been repaired will not be cleared from memory until the vehicle has been driven at least 4 mph (6 km/h) to calibrate the system.

To erase all the stored fault codes from the ECU memory, refer to the ServiceLink manual. Make sure to make a note of all the stored fault codes before clearing them. Stored faults cannot be cleared if active faults exist.

Using the Instrumentation Panel Blink Codes

NOTE: If troubleshooting the system with the Pro-Link 9000, use the instruction booklet that is supplied with the WABCO E-Version ABS cartridge.

Use the ABS CHECK switch and the ABS warning light to:

- Display any active or stored faults (press the ABS CHECK switch 1 second for the Diagnostic mode).
- Erase stored faults from the ECU memory or display the system identification code (press the ABS CHECK switch 3 seconds for the Clear All mode).

NOTE: For simplicity, the ABS warning light will be referred to as the ABS light in this procedure. The warning light(s) on your vehicle may indicate TRACTOR ABS (and TRAILER ABS, if equipped).

J1587 Fault Code Cross-Reference		
MID-SID	**Description**	**Troubleshooting Table**
	Wheel Sensor	
136-001	Left Front	**Table 4**
136-002	Right Front	**Table 5**
136-003	Left Rear	**Table 6**
136-004	Right Rear	**Table 7**
136-005	Left Third Axle *	**Table 8**
136-006	Right Third Axle *	**Table 9**
	Modulator Valve	
136-007	Left Front	**Table 10**
136-008	Right Front	**Table 11**
136-009	Left Rear	**Table 12**
136-010	Right Rear	**Table 13**
136-013	Retarder	**Table 14**
136-014	Ground, Diagonal 1	**Table 15**
136-015	Ground, Diagonal 2	**Table 16**
136-018	ATC Valve (if equipped)	**Table 17**
136-019	Not Used	**Table 18**
136-023	ABS Warning Lamp	**Table 19**
136-231 136-248	J1939 Datalink	**Table 20**
136-249	J1922 Datalink	**Table 21**
136-251	Voltage Diagonal 1 or 2	**Table 22**
136-253	Configuration Errors	**Table 23**
136-254	Miscellaneous Faults	**Table 24**

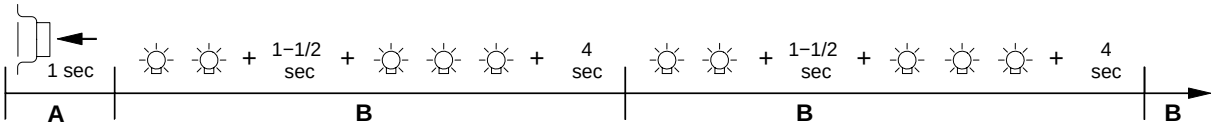
* Tag axle; 6S/4M and 6S/6M only.

Table 1, J1587 Fault Code Cross-Reference

Displaying Fault Codes

Fault codes are displayed as follows:

- With the ignition switch on, press the ABS CHECK switch for about 1 second (Diagnostic mode), then release. The ABS light should go out during the 1-1/2 second pause. See **Fig. 1**.



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NOTE: An active fault code repeats until the ignition switch is turned off.

A. Press the ABS CHECK switch 1 second. The ABS light goes out during a 1-1/2 second pause.
B. Blink code 2–3: two blinks, a 1-1/2 second pause, three blinks, and a 4-second pause.

Fig. 1, Active Fault Codes Repeat (blink code 2-3 shown)

- The ABS light will blink (flash) a number equal to the first digit of the two-digit fault code. The first digit is a number from one to eight.
- After a 1-1/2 second pause, the light will blink the second digit. The number of blinks for the second digit is from one to six.
- After a 4-second pause, the cycle repeats an active fault code until it is repaired.
- If there are no active faults but one or more stored faults are in the ECU memory, the system will display all recorded faults in sequence starting with the most recent, with a 4-second pause between codes.

For example, after the ABS CHECK switch is pressed 1 second and released, fault code 2–3 is indicated by two blinks, a pause of 1-1/2 seconds, followed by three blinks and a 4-second pause.

- If it is an active fault, the same fault code will repeat until the ignition switch is turned off. See **Fig. 1**.
- If it is a stored fault, the next fault in the ECU memory will be displayed after the 4-second pause. See **Fig. 2**. The last fault stored in memory is displayed first; each stored fault is displayed only once.
- If there are no fault codes in the ECU memory, blink code 1–1 is displayed, meaning the system is clear. See **Fig. 3**.

Identifying Blink Codes

The first digit in a blink code identifies the type of fault; the second digit indicates the specific location of the fault. See **Table 2** to identify the blink codes.

NOTICE

The ignition switch must be off when connecting or disconnecting connectors from the ECU. Power applied to the ECU during connector installation or removal could damage the pins.

Once a fault code has been identified, use a multimeter to check the electrical harness at the ABS ECU connectors. See **Testing, 170** for wire numbers and connector pin locations on the frame-mounted ECU.

Refer to the applicable table in "Troubleshooting Tables" for fault codes, pins to be tested, and the correct multimeter readings. Repair or replace the components and/or wiring if the readings are not correct.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. Refer to **Section 54.03** for information on special terminals and connectors, and ordering tools for them.

Refer to the wiring diagrams in **Specifications, 400** when troubleshooting the ABS system.

After the repair is complete, drive the vehicle at least 4 mph (6km/h) to calibrate the ABS/ATC system. Then, shut down the engine and turn the ignition switch on to verify the fault is no longer active. After pressing the ABS CHECK switch 1 second, a 1–1 "no fault" blink code should be displayed if there are no stored faults in the ECU memory.

Erasing Stored Faults

An active fault code cannot be erased from ECU memory but stored faults can be erased all at once without being repaired. Make sure that all stored fault codes are recorded before they are erased because they should be repaired as soon as possible.

Troubleshooting

Blink Code Cross-Reference		
Blink Code	**Description**	**Trouble-shooting**
1	No Faults	—
	Modulator Valve	
2-1	Right Front	**Table 11**
2-2	Left Front	**Table 10**
2-3	Right Rear	**Table 13**
2-4	Left Rear	**Table 12**
2-5	Not Used (6M only)	—
2-6	Not Used (6M only)	—
	Wheel Sensor Air Gap	
3-1	Right Front	**Table 5**
3-2	Left Front	**Table 4**
3-3	Right Rear	**Table 7**
3-4	Left Rear	**Table 6**
3-5	Right Third Axle (6S/4M only)	**Table 9**
3-6	Left Third Axle (6S/4M only)	**Table 8**
	Sensor Short or Open Circuit	
4-1	Right Front	**Table 5**
4-2	Left Front	**Table 4**
4-3	Right Rear	**Table 7**
4-4	Left Rear	**Table 6**
4-5	Right Third Axle (6S/4M only)	**Table 9**
4-6	Left Third Axle (6S/4M only)	**Table 8**
	Sensor Erratic Signal	
5-1	Right Front	**Table 5**
5-2	Left Front	**Table 4**
5-3	Right Rear	**Table 7**
5-4	Left Rear	**Table 6**
5-5	Right Third Axle (6S/4M only)	**Table 9**
5-6	Left Third Axle (6S/4M only)	**Table 8**
	Tone Wheel	
6-1	Right Front	**Table 5**
6-2	Left Front	**Table 4**
6-3	Right Rear	**Table 7**
6-4	Left Rear	**Table 6**
6-5	Right Third Axle (6S/4M only)	**Table 9**

Blink Code Cross-Reference		
Blink Code	**Description**	**Trouble-shooting**
6-6	Left Third Axle (6S/4M only)	**Table 8**
	System Function *	
7-1	J1922 or J1939 Datalink	**Table 21**
		Table 22
7-2	ATC Valve	**Table 19**
7-3	Retarder Relay † (third brake)	**Table 16**
7-4	ABS Warning Light	**Table 20**
7-5	ATC Configuration	**Table 24**
7-6	Not Used	—
	ECU	
8-1	Low Power Supply	**Table 17**
		Table 18
8-2	High Power Supply	**Table 23**
8-3	Internal Fault	**Table 25**
8-4	System Configuration	**Table 24**
8-5	Not Used	—

* Reconfigure the ECU if fault messages appear for components not installed on the vehicle.

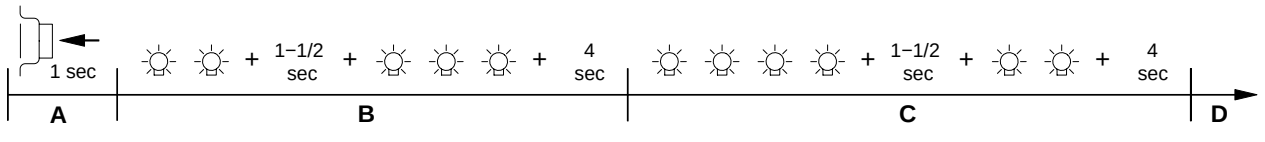
† The ECU detects only fault code 136 S013 03, indicating the retarder relay is shorted to power. See "Troubleshooting Tables," **Table 1**. If the retarder relay circuit is open or if it is shorted to ground, the system will not indicate a fault.

Table 2, Blink Code Cross-Reference

Stored faults can be erased from the ECU memory as follows:

- Press the ABS CHECK switch for 3 to 6 seconds (Clear All mode).
- After releasing the switch, the ABS light will go out during the 1-1/2 second pause.
- If there were stored faults but no active faults, the ABS light will blink eight times meaning all stored faults have been cleared. See **Fig. 4**. (If there are active faults, only the system identification code will be displayed. See **Fig. 5**.)
- After 4-second pause, the ABS light will display the system identification code followed by another 4-second pause repeatedly until the ignition switch is turned off.

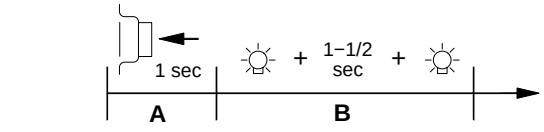
If there are active faults, only the system identification code will be displayed. See **Fig. 5**.



NOTE: The last fault stored is displayed first; each stored fault is displayed only once.

A. Press the ABS CHECK switch 1 second. The ABS light goes out during a 1-1/2 second pause.
B. The newest stored fault is displayed (blink code 2–3 is shown).
C. The second newest stored fault is displayed if one exists (blink code 3–2 is shown).
D. The third newest stored fault is displayed if one exists.

Fig. 2, Stored Fault Codes Display in Sequence



A. Press the ABS CHECK switch 1 second. The ABS light goes out during a 1-1/2 second pause.
B. Blink code 1–1: one blink, a 1-1/2 second pause, and 1 blink.

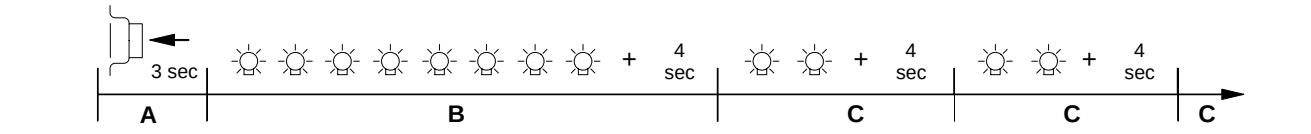
Fig. 3, No Faults, System OK

The system identification code indicates the number of ABS wheel speed sensors (S) and modulator valves (M) installed on the vehicle. See **Table 3** for a list of system identification codes.

If a fault cannot be repaired or erased from ECU memory, contact your Meritor district service manager or call Meritor WABCO at 1-800-535-5560.

System Identification Blink Codes		
Blink Code	**Sensors/ Modulators**	**Vehicle Wheel Positions**
1 Blink	6S/6M	6 x 2
2 Blinks	4S/4M	4 x 4
4 Blinks	6S/4M	6 x 4
5 Blinks	6S/6M	6 x 4

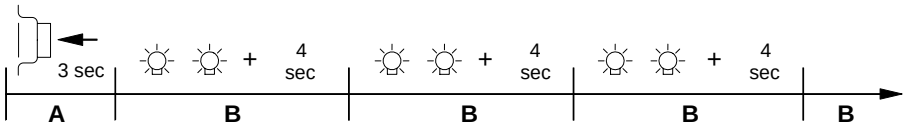
Table 3, System Identification Blink Codes



A. Press the ABS CHECK switch 3 seconds. The ABS light goes out during a 1-1/2 second pause.
B. Eight quick blinks followed by a 4-second pause. (Faults cleared.)
C. The system ID code followed by a 4-second pause repeats until the ignition switch is turned off. (The system ID code for a 4 x 4 vehicle is two quick blinks.)

Fig. 4, Stored Faults Cleared

Troubleshooting



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A. Press the ABS CHECK switch 3 seconds. The ABS light goes out during a 1-1/2 second pause.
B. The system ID code followed by a 4-second pause repeats until the ignition switch is turned off.

Fig. 5, Faults Not Cleared (active faults still exist)

Troubleshooting Tables

J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 7 and 8 of the black X2 ECU connector while rotating the LF wheel 30 rpm.	Voltage is 0.2 Vac or greater.	Sensor adjustment solved the problem.	3-2
					Voltage is less than 0.2 Vac.	Check for excessive wheel bearing end play and hub runout. Repair as needed.	
136	001	02	Incorrect tire size			Check for correct tire size and mixed tire sizes. Check for correct number of teeth on tone wheel. Correct as needed.	5-2
136	001	03	Sensor shorted to power	2. Measure the voltage across pins 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Measurable voltage at either pin.	Repair short to power in circuit(s) 377LF+ and 377LF– in chassis harness and sensor cable. If problem is in the sensor harness, replace the sensor.	4-2
					No voltage at either pin.	Repeat the test and check for intermittent short to power in circuits 377LF+ and 377LF–. Suspect ECU is at fault if the problem persists.	

J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	04	Short to ground	3. Measure the resistance between pin 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	Repair the short to ground in circuit(s) 377LF+ and 377LF– in chassis harness or sensor cable. If problem is in sensor harness, replace the sensor.	4-2
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377LF+ and 377LF–. Suspect ECU is at fault if the problem persists	
136	001	05	Open circuit	4. measure the resistance between pins 7u and 8 of the X2 (black) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377LF+ and 377LF–. Suspect ECU at fault if the problem persists.	4-2
					Resistance is greater than 2000 ohms OR less than 900 ohm.	Perform test 5.	
				5. Disconnect the sensor connector from the chassis harness. Measure the resistance between the pins on the sensor connector.	Resistance is 900–2000 ohms.	Repair open or short in circuit(s) 377LF+ and 377LF– in chassis harness.	4-2
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.	
136	001	06	Short circuit			Perform tests 4 and 5.	4-2
136	001	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tooth wheel is installed (100-tooth is normal application). Repair as needed.	6-2
136	001	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 sec.	3-2

Troubleshooting

J1587 Fault 136-001 Left Front Wheel Sensor							
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**	**Blink Code**
136	001	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor PC Diagnostics, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.	5-2
136	001	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor PC Diagnostics, spin the wheel or drive the vehicle and check for intermittent or erratic signal.	Signal output OK.	Adjustment solved the problem. Make sure brake chatter is not causing the problem.	3-2
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. Cause could be due to brake chatter. Repair as needed.	5-2
136	001	11	Erratic signal			Perform test 7.	
136	001	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	Suspect ECU is at fault if the problem persists.	5-2
					Wiring incorrect.	Repair wheel sensor circuit, as needed.	

Table 4, Left Front Wheel Sensor Troubleshooting (SID = s001)

Right Front Wheel Sensor Troubleshooting (SID = s002)					
J1587 Fault Code			**Problem**	**Diagnostic Procedure**	**Blink Code**
MID	**SID**	**FMI**			
136	002	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 5 and 6 of the X2 (black) connector. A good measurement should be above 0.2 volt AC when the tire is rotated 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–1

Table 5, Right Front Wheel Sensor Troubleshooting (SID = s002)

Left Rear Wheel Sensor Troubleshooting (SID = s003)					
J1587 Fault Code			**Problem**	**Diagnostic Procedure**	**Blink Code**
MID	**SID**	**FMI**			
136	003	01	Excessive air gap.	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 1 and 2 of the X3 (green) connector. A good measurement should be above 0.2 volt AC when the tire is rotated 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–4

Table 6, Left Rear Wheel Sensor Troubleshooting (SID = s003)

Right Rear Wheel Sensor Troubleshooting (SID = s004)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	004	01	Excessive air gap.	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 3 and 4 of the X3 (green) connector. A good measurement should be above 0.2 volt AC when the tire is rotated 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–3

Table 7, Right Rear Wheel Sensor Troubleshooting (SID = s004)

Left Third Wheel Sensor Troubleshooting (SID = s005)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	005	01	Excessive air gap.	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 3 and 4 of the X4 (brown) connector. A good measurement should be above 0.2 volt AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–6

Table 8, Left Third Wheel Sensor Troubleshooting (SID = s005)

Right Third Wheel Sensor Troubleshooting (SID = s006)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	006	01	Excessive air gap.	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 5 and 6 of the X4 (brown) connector. A good measurement should be above 0.2 volt AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–5

Table 9, Right Third Wheel Sensor Troubleshooting (SID = s006)

Left Front Modulator Valve Troubleshooting (SID = s007)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	007	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 10 and 11 of the X2 (black) connector, and between pins 2 and 11. A good measurement should be between 4 and 8 ohms.	2–2

Table 10, Left Front Modulator Valve Troubleshooting (SID = s007)

Troubleshooting

Right Front Modulator Valve Troubleshooting (SID = s008)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	008	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 3 and 9 of the X2 (black) connector, and between pins 4 and 9. A good measurement should be between 4 and 8 ohms.	2–1

Table 11, Right Front Modulator Valve Troubleshooting (SID = s008)

Left Rear Modulator Valve Troubleshooting (SID = s009)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	009	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 10 and 11 of the X3 (green) connector, and between pins 12 and 11. A good measurement should be between 4 and 8 ohms.	2–4

Table 12, Left Rear Modulator Valve Troubleshooting (SID = s009)

Right Rear Modulator Valve Troubleshooting (SID = s010)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	010	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 7 and 8 of the X3 (green) connector, and between pins 9 and 8. A good measurement should be between 4 and 8 ohms.	2–3

Table 13, Right Rear Modulator Valve Troubleshooting (SID = s010)

Left Third Modulator Valve Troubleshooting (SID = s011)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	011	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 10 and 11 of the X4 (brown) connector, and between pins 12 and 11. A good measurement should be between 4 and 8 ohms.	2–6

Table 14, Left Third Modulator Valve Troubleshooting (SID = s011)

Right Third Modulator Valve Troubleshooting (SID = s012)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	012	01	Open circuit in the inlet and/or outlet solenoid circuits.	Check the modulator valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 7 and 8 of the X4 (brown) connector, and between pins 9 and 8. A good measurement should be between 4 and 8 ohms.	2–5

Table 15, Right Third Modulator Valve Troubleshooting (SID = s012)

Retarder Troubleshooting (SID = s013)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	013	03	Shorted to power.	Measure the voltage between pin 5 of the X1 (gray) connector and ground. If the measurement indicates a voltage, the relay circuit is shorted to power.	7–3

Table 16, Retarder Troubleshooting (SID = s013)

Ground (diagonal 1–right front, left rear) Troubleshooting (SID = s014)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	014	04	Voltage, diagonal 1, low voltage/open circuit.	Check the 10A circuit breaker F43. Check pin 1 in the X1 (gray) connector for proper contact. Check circuit 16, 16E. Check the vehicle batteries and charging system.	8–1

Table 17, Ground (diagonal 1–right front, left rear) Troubleshooting (SID = s014)

Ground (diagonal 2–left front, right rear) Troubleshooting (SID = s015)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	015	04	Voltage, diagonal 2, low voltage/open circuit.	Check the 10A circuit breaker. Check pin 1 in the X1 (gray) connector for proper contact. Check circuit 16A,16F.	8–1

Table 18, Ground (diagonal 2–left front, right rear) Troubleshooting (SID = s015)

Troubleshooting

ATC Valve Troubleshooting (SID = s018)					
J1587 Fault Code *			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	018	03	ATC valve, shorted to power.	Measure the voltage between pin 5 of the X3 (green) connector and ground, and pin 6 of the X3 connector and ground. If measurements indicate a voltage, the ATC valve is shorted to power.	7–2

* Reconfigure the ECU if the fault message appears but ATC is not installed.

Table 19, ATC Valve Troubleshooting (SID = s018)

Warning Light Troubleshooting (SID = s023)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	023	05	Warning Light.	Check the bulb and continuity of the warning light circuit. Was the blink code switch activated longer than 16 seconds? If so, cycle the ignition off and on to verify the fault.	7–4

Table 20, Warning Light Troubleshooting (SID = s023)

J1939 Datalink Troubleshooting (SID = s231)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	231	02	J1939 plausibility error.	Check the speedometer calibration. Check for tire size mismatch.	7–1

Table 21, J1939 Datalink Troubleshooting (SID = s231)

J1922 Datalink Troubleshooting (SID = s249)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	249	05	The J1922 datalink has an open circuit.	Check the J1922 datalink connections. Check continuity of the datalink wires. Reconfigure the ECU if the fault message appears but no J1922 datalink is installed.	7–1

Table 22, J1922 Datalink Troubleshooting (SID = s249)

Overvoltage Troubleshooting (SID = s251)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	251	03	Overvoltage, diagonal 1 or 2.	Check the alternator output and the battery voltage. Supply voltage is greater than 14 volts for more than 5 seconds.	8–2

Table 23, Overvoltage Troubleshooting (SID = s251)

Configuration Troubleshooting (SID = s253)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	253	01	ATC configuration.	Check the wires responsible for parameter setting.	7–5
136	253	02	EEPROM or ABS configuration, wheel parameter incorrect.	Cycle the ignition off and on. If the fault detection repeats, replace the ABS ECU.	8–4
136	253	12	EEPROM, checksum.	Check the parameter setting. Diagnostic device disconnected during active diagnosis. Cycle the ignition off and on. If the fault detection repeats, replace the ABS ECU.	

Table 24, Configuration Troubleshooting (SID = s253)

Miscellaneous ABS/ATC Troubleshooting (SID = s254)					
J1587 Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	254	02	Internal error.	Cycle the ignition off and on. If the fault detection repeats, replace the ABS ECU.	8–3

Table 25, Miscellaneous ABS/ATC Troubleshooting (SID = s254)

Wiring Diagrams

For vehicle specific wiring diagrams, access Service-Pro® or PartsPro®. EZWiring™ can also be accessed from within PartsPro.

General Description

Meritor Q Plus brakes are standard for both front and rear axles. These Cam-Master® brakes are air-actuated, cam-operated, foundation brakes. The main components in each brake assembly (wheel end) include the following:

- an S-head camshaft
- a brake spider
- a camshaft-and-chamber bracket
- two brake shoe and lining assemblies
- two retaining springs
- a return spring
- two anchor pins

The S-head camshaft transfers force from the slack adjuster to the brake shoe assemblies. The camshaft passes through the brake spider and camshaft-and-chamber bracket before connecting to the slack adjuster. See **Fig. 1**.

Each brake shoe is mounted on an anchor pin on the brake spider and is displaced by either the outward force of the S-head camshaft or the inward restoring force of the return spring.

The heavy-duty, double-web brake shoes have notches on one end of the webs that fit on the anchor pins. Two retaining springs secure the brake shoes to each other near the anchor pins, creating a hinge for brake-shoe movement. This design makes quick-change brake service possible.

Q Plus MX500 brakes are extended maintenance brakes. These brakes can be identified by an identification tag affixed to the brake shoe. An additional identification tag is affixed to the brake camshaft-and-chamber bracket (on top of the plugged grease hole).

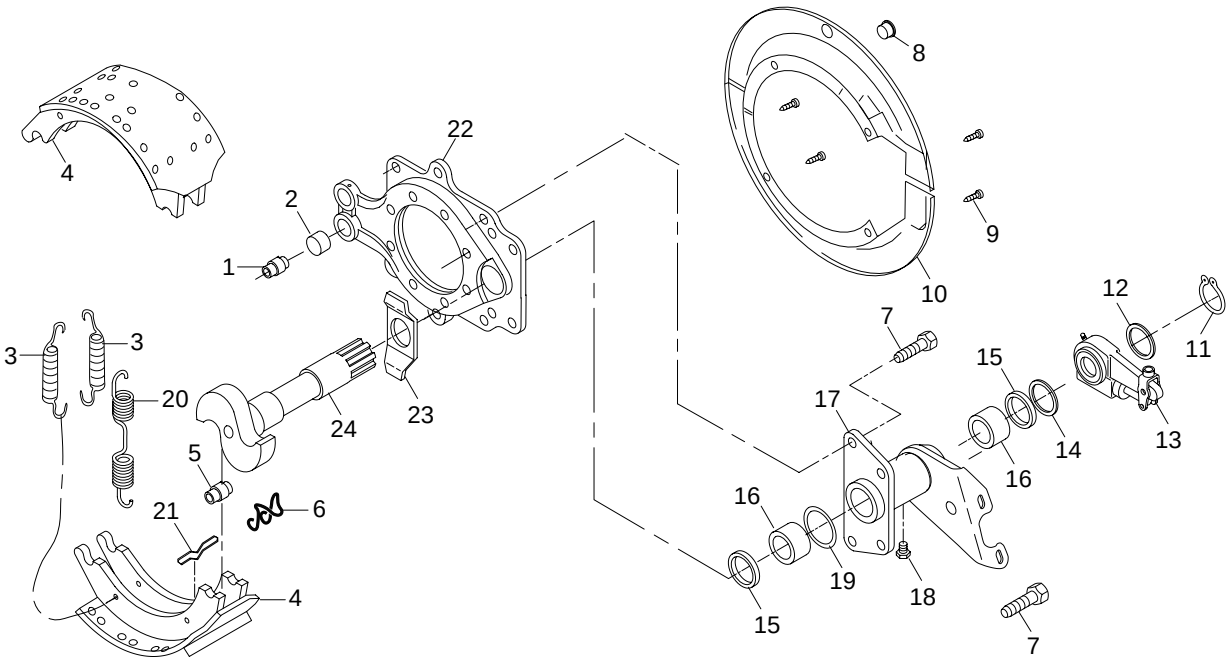
Principles of Operation

When the brake pedal is depressed, compressed air enters the brake chamber, causing the diaphragm to move a pushrod assembly.

The pushrod turns the slack adjuster and brake camshaft. As the camshaft turns, the S-type cam head forces the brake shoes against the brake drum, and braking occurs.

When the brakes are released and air is exhausted from the brake chamber, the actuator return spring (within the brake chamber) and the brake shoe return spring return the camshaft, brake shoes, slack adjuster, and pushrod to their released positions.

General Information



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1. Anchor Pin
2. Anchor-Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Plug
9. Capscrew, Dust Shield
10. Dust Shield
11. Camshaft Snap Ring
12. Washer (spacer)
13. Automatic Slack Adjuster
14. Washer (thick spacer)
15. Camshaft Grease Seal
16. Camshaft Bushing
17. Camshaft-and-Chamber Bracket
18. Grease Fitting
19. Chamber-Bracket Seal
20. Return Spring
21. Return-Spring Pin
22. Brake Spider
23. Washer, Camhead
24. S-Head Camshaft

Fig. 1, Meritor Cam-Master Q Plus Brake (typical)

General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brake. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Shoe Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: When replacing the brake linings, use a dial indicator to measure the cam-to-bushing radial free play (the up-and-down and side-to-side free play of the camshaft) and the camshaft axial end play (the in-and-out end play of the camshaft).

Replace the bushings if the cam-to-bushing radial free play exceeds 0.020 inch (0.5 mm) of movement.

Remove the snap ring from the end of the slack adjuster and add shims between the slack adjuster and the snap ring if the axial end play exceeds 0.005 to 0.030 inch (0.13 to 0.8 mm) of movement.

For detailed instructions, see **Subject 150**.

Removal

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.

WARNING

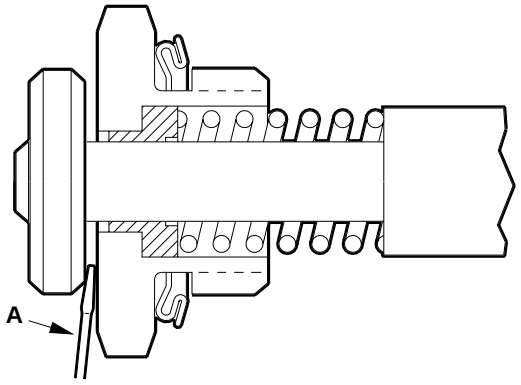
When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury or death.

3. If the brake has spring chambers, carefully cage and lock the springs so that the springs cannot actuate during disassembly.

NOTICE

For a Meritor automatic slack adjuster, disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. If your vehicle has a Meritor automatic slack adjuster, disengage the pull-pawl on the side of the adjuster, as follows.
   - 4.1 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 1**.
   - 4.2 Wedge the tool in place, and keep it there until the end of the brake shoe installation. Pull-pawls are spring-loaded. When the tool is removed, the pull-pawl will engage the teeth automatically.



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A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 1, Pull-Pawl on Meritor Automatic Slack Adjusters

NOTE: On Haldex automatic slack adjusters, an internal clutch resists turning the manual adjusting nut in the counterclockwise direction to back off the adjuster. A torque of approximately 13 lbf·ft (18 N·m) must be applied to overcome the resistance of the internal clutch.

5. For each wheel end, back off the automatic slack adjuster by turning the manual adjusting nut until the brake shoes are fully retracted and the drum clears the lining. See **Subject 130** for instructions.

Brake Shoe Removal and Installation

- On Meritor adjustors, turn the square adjusting nut clockwise (as if tightening a right-hand threaded fastener).
- On Haldex adjusters, turn the adjusting hexnut counterclockwise. You will hear a ratcheting sound.

6. Remove the wheels. For instructions, see **Section 40.00, Subject 100**.
7. Remove the brake drums. For instructions, see **Section 33.01, Subject 140**, for front axles, or **Section 35.01, Subject 140**, for rear axles.
8. Remove the brake shoes, as follows.

   8.1 Push down on the lower brake shoe, then pull on the roller retaining clip to remove the lower cam roller. See **Fig. 2**.

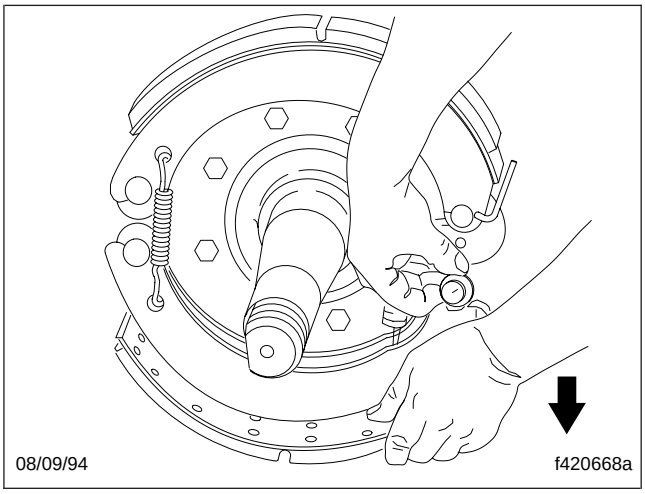


Fig. 2, Cam Roller Removal

   8.2 Lift the upper brake shoe and pull on the roller retaining clip to remove the upper cam roller.

   8.3 Lift the lower shoe to release tension on the brake return spring. Remove the spring. See **Fig. 3** and **Fig. 4**.

   8.4 Rotate the lower shoe around the anchor pin on the spider to release tension on the two retaining springs. See **Fig. 5**. Remove the brake shoes.

9. Inspect the brake shoes and linings for wear or damage. For instructions, see **Subject 120**.

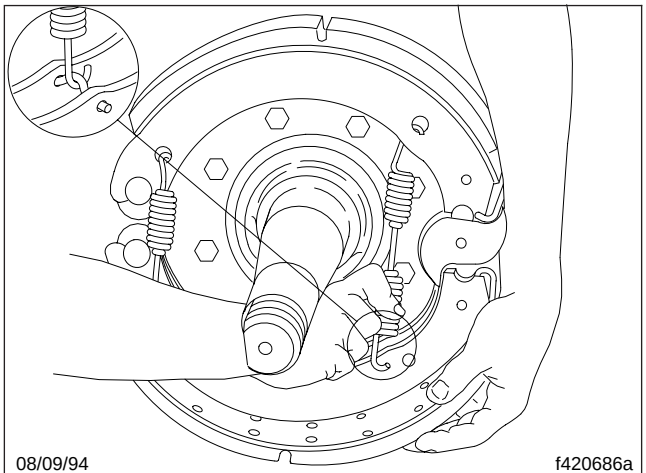


Fig. 3, Return Spring Removal/Installation, Straight Tie Bar

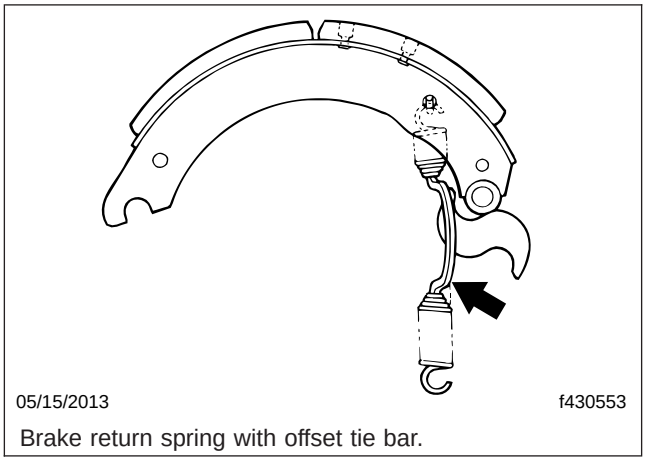


Fig. 4, Return Spring Removal/Installation, Offset Tie Bar

IMPORTANT: If the linings are being replaced, disassemble and inspect the camshaft-and-chamber bracket. For instructions, see **Subject 150**.

Installation

IMPORTANT: For best brake performance, do not mix Q Plus brakes with other brakes.

NOTE: Springs, rollers, and anchor pins should be replaced when installing new brake linings.

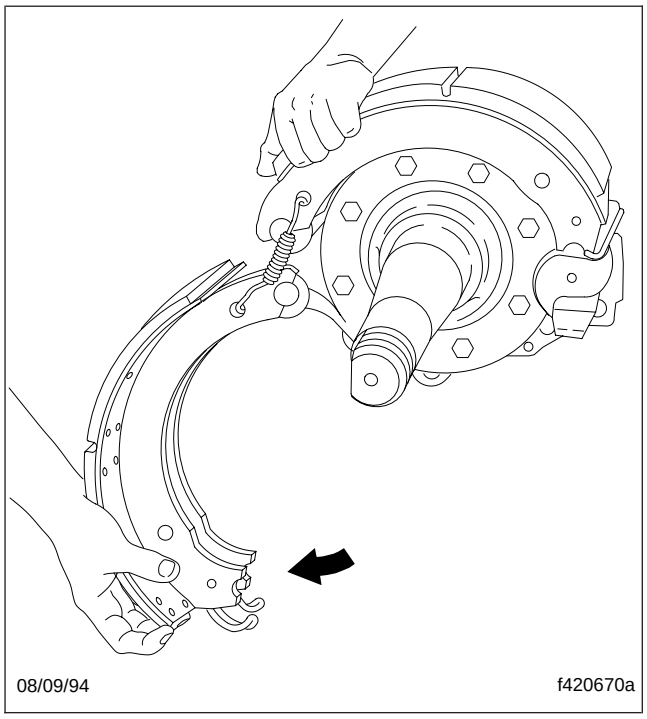


Fig. 5, Brake Shoe Removal

1. Install the brake shoes, as follows.

   IMPORTANT: Do not lubricate the cam-head surface or the center section of the cam rollers. For efficient operation, the cam interface must remain free of oil, grease, and other contaminants.

   1.1 Using an NLGI Grade 1 or 2 multipurpose chassis or temperature-resistant grease (Meritor O-616A, O-617A, O-617B, O-645, or O-692):

   - Lubricate the cam rollers on the journals where they touch the brake shoe webs.
   - Lubricate the anchor pins where they touch the brake shoe webs.

   1.2 Place the upper brake shoe in position on the upper anchor pin. Hold the lower brake shoe vertically against the lower anchor pin and install two new brake shoe retaining springs to link the upper and lower brake shoes. See **Fig. 6**.

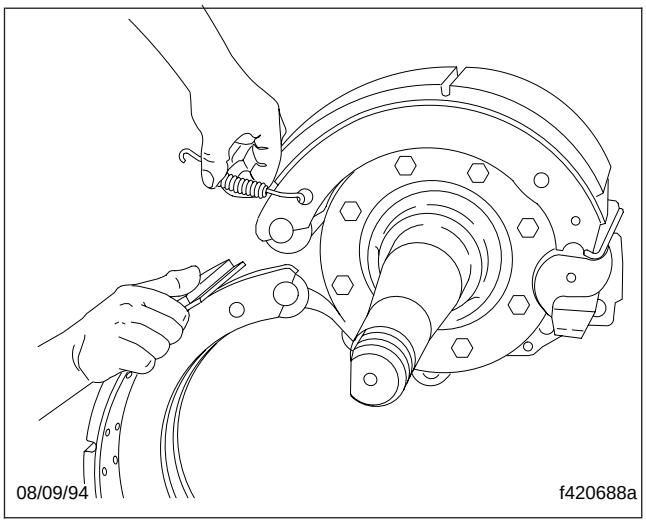


Fig. 6, Brake Shoe Retaining Spring Installation

NOTICE

If the offset tie bar shoe return spring is reversed during installation, it will rub a groove in the barrel of the hub, requiring the hub to be replaced.

1.3 Rotate the lower brake shoe forward around the hub, and install a new brake shoe return spring. Install the open end of the spring hooks toward the camshaft. See **Fig. 3** and **Fig. 4**.

1.4 Pull the lower brake shoe away from the cam to allow enough space to install a new cam roller and retainer clip.

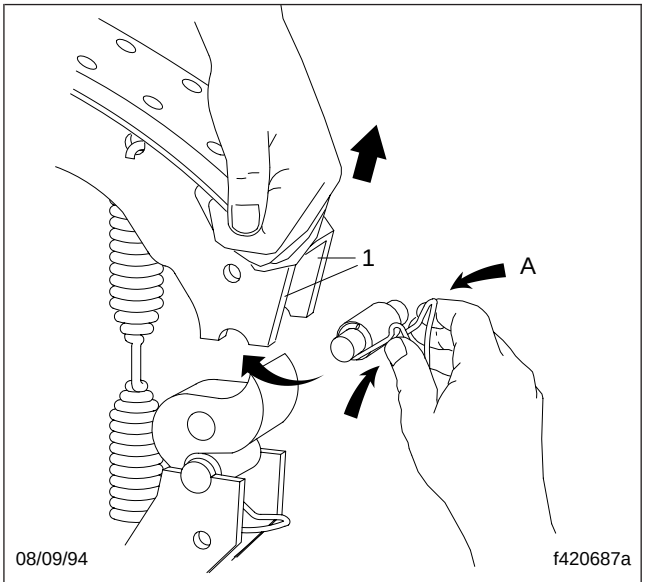
Squeeze the ears of the retainer clip together to fit between the brake shoe webs on the cam end of the brake shoes. See **Fig. 7**.

Push the retainer clips between the brake shoe webs until the ears lock in the holes in the webs. See **Fig. 8**.

1.5 Repeat substep 1.4, for the upper brake shoe.

2. Install the brake drums. For instructions, see **Section 33.01, Subject 140**, for front axles, or **Section 35.01, Subject 140**, for rear axles.
3. Install the wheels. For instructions, see **Section 40.00, Subject 100**.

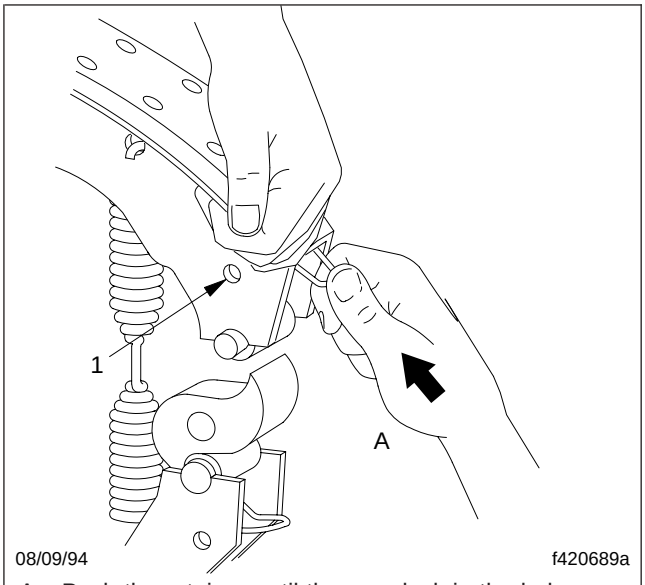
Brake Shoe Removal and Installation



A. Squeeze the ears of the retainer together.

1. Brake Shoe Webs

Fig. 7, Squeezing the Retainer



A. Push the retainer until the ears lock in the holes.

1. Web Hole

Fig. 8, Roller and Retainer Clip Installation

4. Adjust the brakes at the slack adjusters. For instructions, see **Subject 130**.
5. Remove the safety stands, and lower the vehicle.

WARNING

When work is being done on a spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury.

6. If the brakes have spring chambers, carefully release the springs.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. In a safe area, check for proper brake operation before you put the vehicle in service, as follows.
   - 7.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.
   - 7.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 7.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others show a lack of braking effort on those wheels.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Inspection

1. Remove the brake shoes as needed to perform the following inspections. Use the instructions in **Subject 110** for shoe removal.
2. Check the linings, as follows.

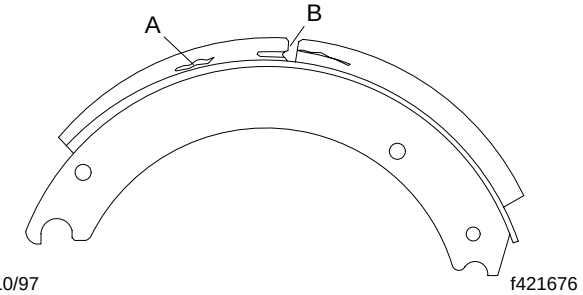
   2.1 If the linings are grease- or oil-soaked, cracked, or worn to less than 1/4-inch (6.4-mm) thickness at any point, replace them.

   2.2 Replace the linings if the lining surface is closer than 1/32 inch (0.8 mm) to any rivet head.

   If bolts are installed, the linings should not be allowed to wear to the point where bolts may contact the brake drums.

   2.3 The lining is considered worn-out and the vehicle should not be driven if:

   - Cracks on the lining surface exceed 1/16 inch (1.6 mm).
   - The lining edge shows cracks or voids over 1/16 inch (1.6 mm) in width and 1-1/2 inches (38 mm) in length. See **Fig. 1**.



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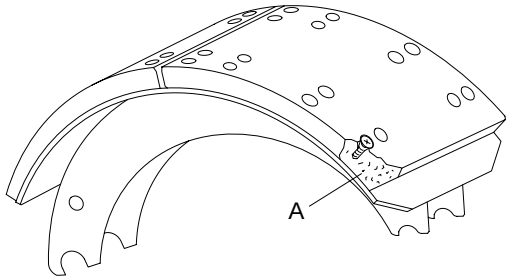
A. Cracks exceeding 1-1/2 inches (38 mm) in length.
B. Cracks or voids exceeding 1/16 inch (1.6 mm) in width.

Fig. 1, Cracks and Voids

   - Portions of the lining are missing exposing a rivet when viewed from the edge. See **Fig. 2**.



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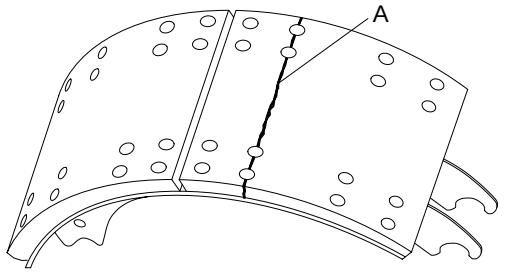
A. Exposed fastening device.

Fig. 2, Portions of Brake Lining Missing

   - Cracks extend across the lining face and through the lining edge, or the lining is loose on the shoe. See **Fig. 3**.



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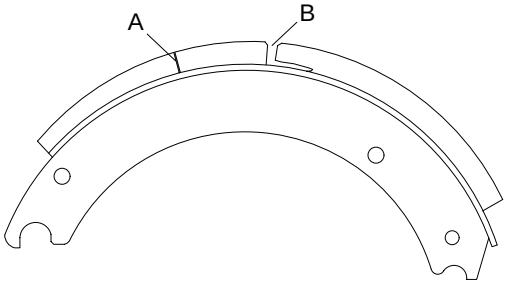
A. Cracks extending through the lining edge.

Fig. 3, Cracks in the Brake Lining

   2.4 The vehicle is still operational but the linings should be replaced as soon as possible if:

   - Horizontal or vertical cracks in the lining edge exhibit no loss of material and do not exceed 1/16 inch (1.6 mm) in width or 1-1/2 inches (38 mm) in length. See **Fig. 4**.
   - Corner portions of the lining are missing with no fastener exposed. See **Fig. 5**.

Brake Shoe and Lining Inspection



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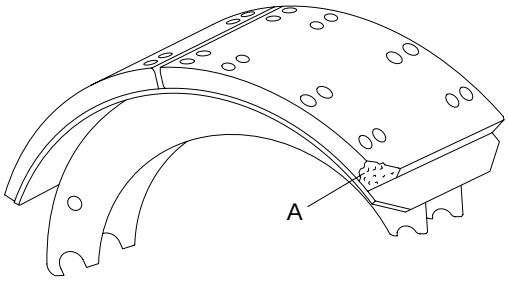
A. Cracks not exceeding 1-1/2 inches (38 mm) in length or 1/16 inch (1.6 mm) in width.
B. Voids under the lining not exceeding 1-1/2 inches (38 mm) in length or 1/16 inch (1.6 mm) in width.

Fig. 4, Cracks and Voids



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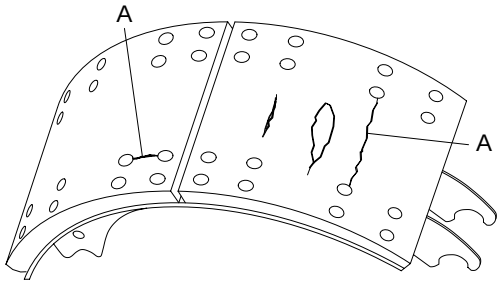
A. Corner segment is missing but no fastener is exposed.

Fig. 5, Portions of the Brake Lining Missing

- Surface cracks extend from hole to hole or if there is scoring and contamination from road debris. See **Fig. 6**.

3. Check the brake shoes for bent or cracked webs or tables, rust, broken welds, expanded or out-of-round rivet or bolt holes, and correct alignment. Replace the shoes if any of these conditions exist.
4. Check the brake shoes for visible wear (looseness) at the anchor pin holes and the camshaft roller recesses. Replace the shoe if needed.
5. Check the diameter of the anchor pin holes. The anchor pin holes must not exceed 1.009 inch (25.6 mm). Replace the shoes if needed.
6. Check the distance from the center of the anchor pin hole to the center of the cam roller hole (the shoe span). The shoe span must not exceed 12-7/8 inches (327 mm). Replace the shoes if needed. See **Fig. 7**.



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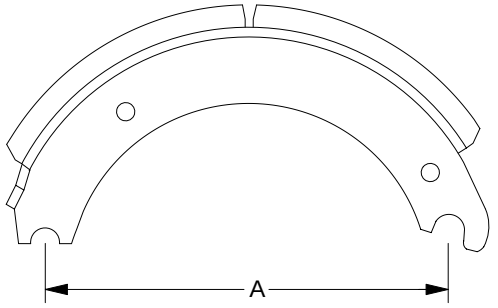
A. Cracks extending from hole to hole.

Fig. 6, Crack in the Brake Lining



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A. 12-7/8 inches (327 mm) maximum

Fig. 7, Measuring the Shoe Span

Pre-Adjustment Checks and General Adjustment Information

Before adjusting the brakes, check and adjust the following:

- Adjust the wheel bearings, if needed. For instructions, see **Section 33.01** or **Section 35.01** in this manual.
- Check the slack adjuster and the brake chamber for loose fasteners and tighten as necessary. For torque specifications, see **Specifications, 400**.

  For slack adjuster installation instructions, see **Section 42.10**, **Section 42.11**, **Section 42.12**, or **Section 42.23** for Meritor, Haldex, Dana Spicer, or Gunite slack adjusters, respectively.

Brakes with automatic slack adjusters should never have to be manually adjusted while in service. The only time automatic slack adjusters should be manually adjusted is during installation or after the brakes have been relined.

For cam brakes, there are two brake chamber stroke measurement specifications: applied chamber stroke and free-stroke.

IMPORTANT: The U.S. Department of Transportation (DOT) Federal Highway Administration has issued the applied chamber stroke specifications for cam brakes. When the applied chamber stroke is checked and adjusted, it must not be greater than the DOT specification. See **Table 1**.

The specific procedure for adjusting the brake chamber stroke at the slack adjuster's manual adjusting nut may vary, depending on which slack adjuster is installed, but there are three basic steps in completing a manual brake chamber stroke adjustment:

1. Adjusting the approximate brake chamber stroke using the manual adjusting nut on the slack adjuster (coarse adjustment).
2. Measuring and adjusting the free-stroke.
3. Measuring and adjusting the applied chamber stroke (fine adjustment).

The stroke (free or applied chamber) is the distance that the large clevis pin moves when the brakes are applied. The type of force used to move the slack adjuster from its released position to its applied position (where the brake linings contact the brake drum) distinguishes the free-stroke from the applied chamber stroke.

- The free-stroke is measured using a lever to move the slack adjuster. The length of the free-stroke equals the clearance between the brake linings and the drum when the brakes are not applied.

Brake Chamber Stroke Specifications		
Chamber Type (Size)	**Maximum Applied Stroke * inch (mm)**	**Free-Stroke, inch (mm)**
Standard Stroke		5/8 to 3/4 (16 to 19)
16, 20, and 24	1-3/4 (44)	
30	2 (51)	
36	2-1/4 (57)	
Long Stroke †		
16, 20, and 24	2 (51)	
30	2-1/2 (64)	

* Specifications are relative to a brake application with 80-90 psi (552-621 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

- The applied chamber stroke is measured using an 80 to 90 psi (552 to 621 kPa) brake application to move the slack adjuster.

With the engine off, 100 psi (690 kPa) of air tank pressure will apply the required 80 to 90 psi (552 to 621 kPa) brake application for measuring the applied chamber stroke.

The applied chamber stroke measurement can be used for diagnostic purposes. A stroke that is too long or too short may indicate excessive wear in the cam, cam bushings, return springs, or air chamber.

The applied chamber stroke should always be adjusted (minimized) to within the specified limit, but it should not be reduced to the point where the free-stroke is too short and the brakes drag. To check for brake drag, spin the wheel end, tap the rim lightly with a hammer, and listen for a drag noise (a sharp ringing sound).

Adjustment

Meritor Automatic Slack Adjuster

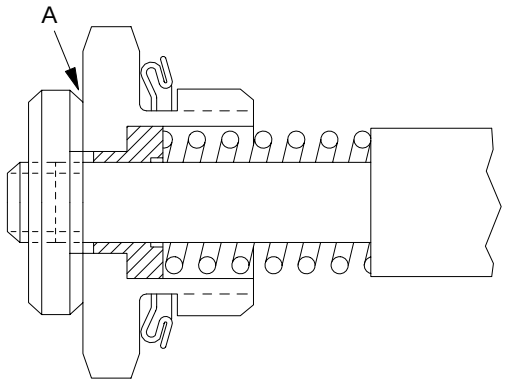
IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber push-rod must be fully retracted).
4. Check the condition of the boot on the slack adjuster. It should be held in the correct position with a retaining clip. If the boot is torn or cracked, see **Section 42.10** for slack adjuster disassembly and inspection procedures.

NOTICE

Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

5. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 1**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.



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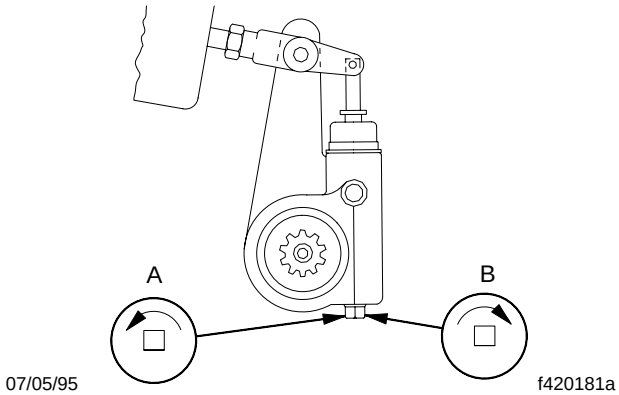
A. Insert screwdriver here.

Fig. 1, Disengage the Pull-Pawl

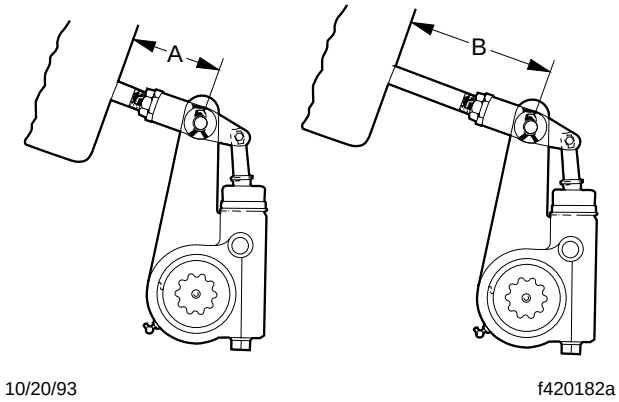
NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

6. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment). See **Fig. 2**.
   - 6.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.
   - 6.2 Then, turn the adjusting nut clockwise 1/2 turn.
7. Measure and adjust the free-stroke.
   - 7.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 3**.
   - 7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.



A. Shorten stroke. B. Lengthen stroke.

Fig. 2, Turn the Adjusting Nut



NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 3, Measuring the Stroke

7.3 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 3**.

7.4 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

7.5 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 2**. Then, measure the free-stroke again, and readjust it until it is correct.

8. Measure and adjust the applied chamber stroke (fine adjustment).

8.1 Start the engine and build the air pressure to 100 psi (690 kPa). Shut down the engine.

8.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 3**, Ref. B. Record this measurement as dimension C.

8.3 Subtract dimension A from dimension C. The difference between these measurements is the true applied chamber stroke.

8.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

NOTICE

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

8.5 If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 2**. Measure the applied stroke again and readjust it until it is correct.

8.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 150**. If necessary, replace the slack adjuster.

9. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.

10. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability,

which could cause personal injury or death, and property damage.

11. Check for proper brake operation. For instructions, see **Subject 110**.

Haldex Automatic Slack Adjuster

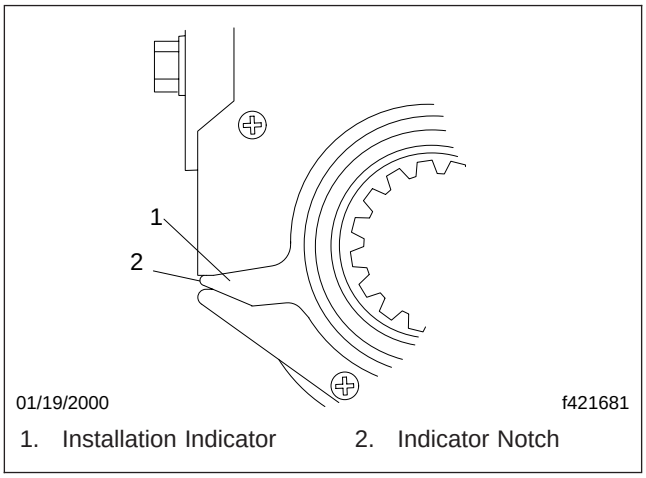
IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle. Then, place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber pushrod must be fully retracted).

NOTICE

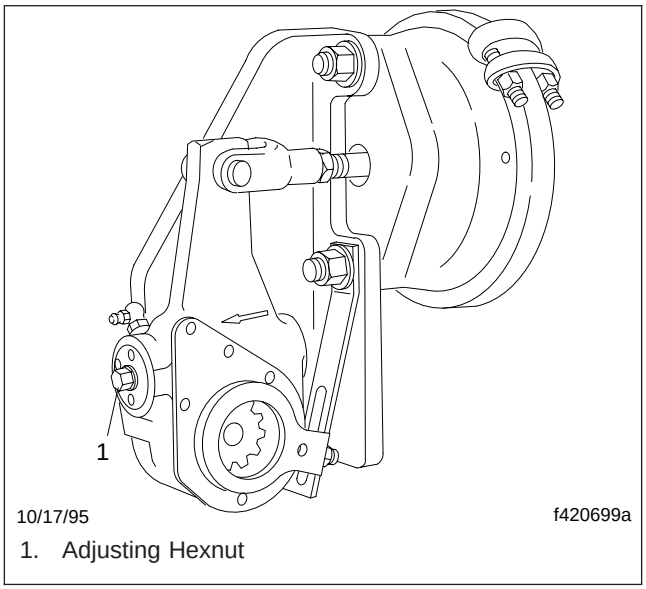
The installation indicator must be aligned with the indicator notch on the slack adjuster. If the indicator is not within the notched area, the control arm is installed in the wrong position. This may result in tight brakes, excessive lining wear, and possible brake damage.

4. Make sure the installation indicator is aligned with the indicator notch on the slack adjuster. See **Fig. 4**. If the indicator is not within the notched area, the control arm is not installed correctly.
5. Measure how much torque is required to overcome the resistance of the internal clutch (internal clutch slippage).
   - 5.1 Using a 7/16-inch torque wrench, turn the adjusting nut counterclockwise. See **Fig. 5**. You will hear a ratcheting sound.
   - 5.2 If the clutch slips with a torque less than 13 lbf·ft (18 N·m), the slack adjuster must be replaced.
6. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment).



1. Installation Indicator 2. Indicator Notch

Fig. 4, Installation Indicator



1. Adjusting Hexnut

Fig. 5, Adjusting Hexnut

   - 6.1 Turn the adjusting nut clockwise until the brake linings contact the brake drum.
   - 6.2 Then, turn the adjusting nut counterclockwise 1/2 turn. You will hear a ratcheting sound.
7. Measure and adjust the free-stroke.
   - 7.1 Measure the distance from the bottom of the brake chamber to the far side of the clevis pin. See **Fig. 6**. Record this measurement as dimension A.

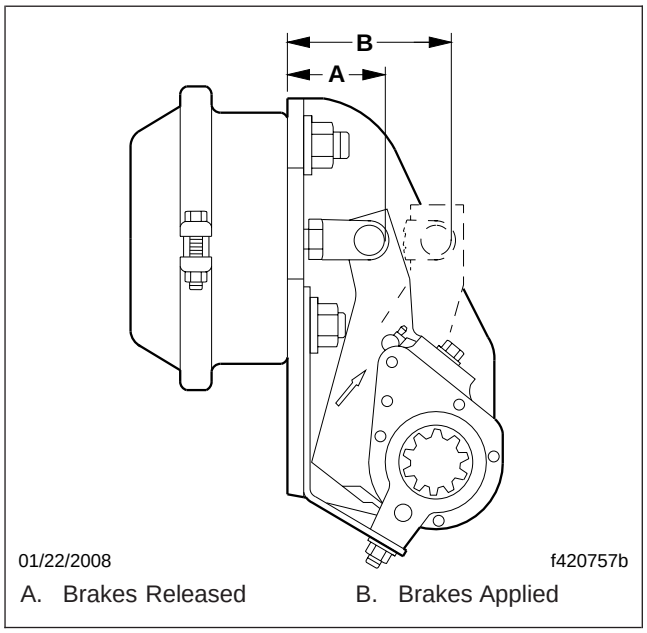


Fig. 6, Measure the Stroke

7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum. Then, measure the distance from the bottom of the brake chamber to the far side of the clevis pin. See **Fig. 6**. Record this measurement as dimension B.

7.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

7.4 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjusting nut in the required direction. Then, measure the free-stroke again and readjust it until it is correct.

8. Measure and adjust the applied chamber stroke (fine adjustment).

8.1 Start the engine and build the air pressure to 100 psi (690 kPa). Shut down the engine.

8.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the far side of the clevis pin hole. See **Fig. 6**, Ref. B. Record this measurement as dimension C.

8.3 Subtract dimension A from dimension C. The difference between these measurements is the applied chamber stroke.

8.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**. If the stroke is not correct, turn the adjusting nut in the required direction. Then, measure the applied chamber stroke again and readjust it until it is correct.

8.5 If the slack adjuster does not maintain the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 150**. If necessary, replace the slack adjuster.

9. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

⚠ WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

10. Check for proper brake operation. For instructions, see **Subject 110**.

Haldex Self-Setting Automatic Brake Adjusters (S-ABA)

IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

NOTE: To ensure a proper fit and function, always replace both adjuster and mounting bracket as a set.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Make certain the system tank pressure is above 100 psi (690 kPa).
3. Raise the front or rear axle. Then, place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.

Brake Adjustment

4. Check to be sure the push rod is fully retracted. Apply air to release the spring brake. If air is not available, the spring brake must be manually caged.
5. Install the anchor bracket loosely as shown in **Figure 7**.

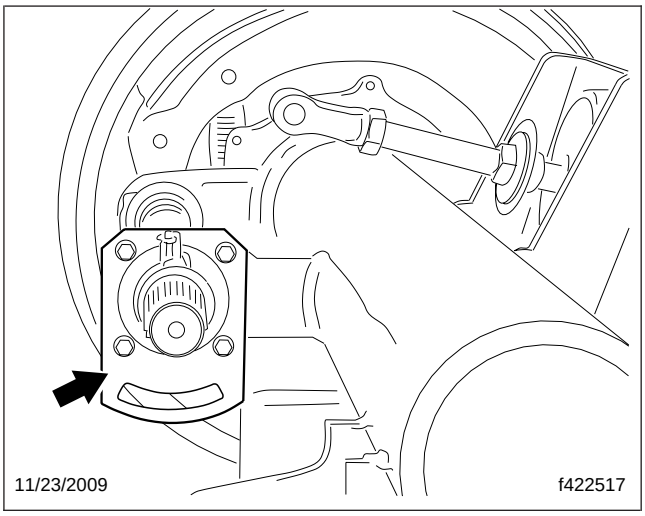


Fig. 7, Anchor Bracket Installation

6. Some strap brackets have two mounting holes. The proper mounting location is determined by the length of the adjuster arm. 5 inch and 5-1/2 inch adjuster arm lengths utilize the shorter hole location. 6 inch and 6-1/2 inch length adjusters utilize the longer hole locations.
7. Do not tighten the anchor bracket fasteners at this time. Apply antiseize lubricant to the camshaft splines.
8. Install the brake adjuster onto the camshaft *with the adjusting hex pointing away from the brake chamber.* See **Fig. 8**.
9. Secure the brake adjuster on the camshaft. Use at least one inner washer and enough outer washers to allow no more than 0.060 inch (1.52 mm) movement of the adjuster on the camshaft.

NOTICE

Do not pull the push rod out to meet the brake adjuster. Doing so could damage the push rod.

10. Rotate the 7/16 inch adjusting hexnut clockwise until the clevis hole lines up with the brake adjuster arm hole.

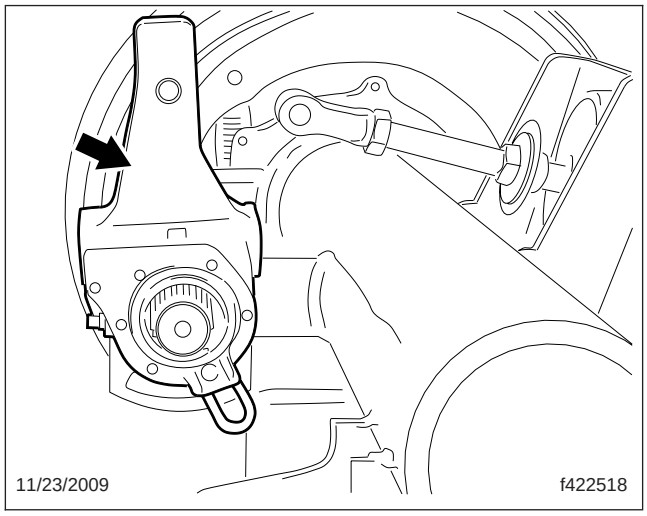


Fig. 8, Installing the Brake Adjuster

11. Apply antiseize to the clevis pin, then install and secure with the cotter pin.
12. The S-ABA control arm can be placed anywhere within the range of the bracket slot for automatic adjustment to take place. However, Haldex recommends rotating all control arms towards the axle until they come to a complete stop, as shown in **Fig. 9**, and then secure the arm in that position. This will create a 'common' position for all wheels.
13. The adjuster must now be manually adjusted.
    - 13.1 Rotate the adjusting hexnut clockwise until the lining lightly contacts the drum.
    - 13.2 Back-off the adjuster by turning the adjusting hexnut 1/2-turn counterclockwise. See **Fig. 10**.

NOTICE

Do not use an impact wrench or permanent internal damage will occur.

- 13.3 A minimum of 13 lbf·ft (18 N·m) is needed to overcome the internal clutch; a ratcheting sound will be present.

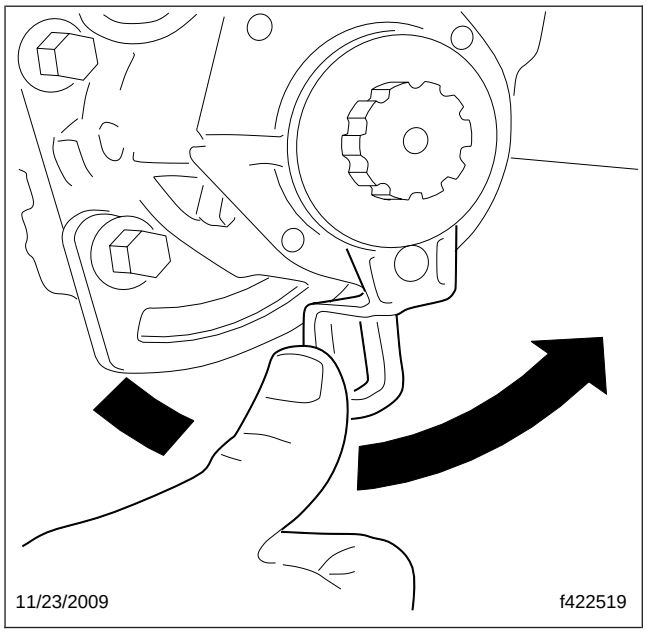


Fig. 9, Positioning the Control Arm

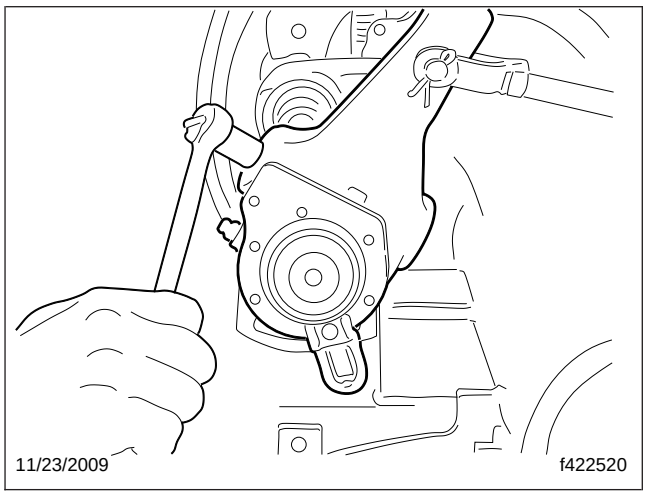


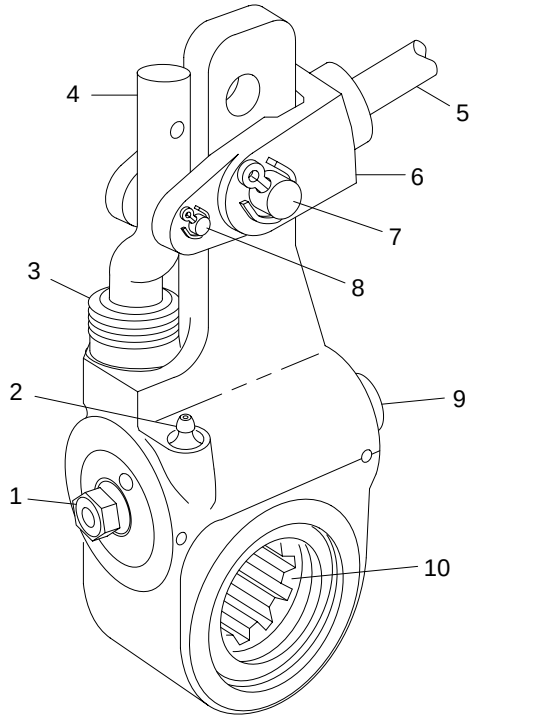
Fig. 10, Backing Off the Adjuster

Gunite Automatic Slack Adjuster

IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

1. Park the vehicle on a level surface, apply the parking brakes, and shut down the engine. Chock the tires on the axle that is not being repaired.
2. Raise the front or rear axle. Then, place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
3. Fully release the brakes (the air chamber pushrod must be fully retracted).
4. Measure how much torque is required to overcome the resistance of the internal clutch (internal clutch slippage).
   - 4.1 Using a 7/16-inch torque wrench, turn the adjusting nut counterclockwise. See **Fig. 11**. You will hear a ratcheting sound.
   - 4.2 If the clutch slips with a torque less than 15 lbf·ft (20 N·m), the slack adjuster must be replaced.
5. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment).
   - 5.1 Turn the adjusting nut clockwise until the brake linings contact the brake drum.
   - 5.2 Turn the adjusting nut counterclockwise 1/2 turn. There should be about 30 lbf·ft (41 N·m) resistance. You will hear a ratcheting sound.
6. Measure and adjust the free-stroke.
   - 6.1 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 12**. Record this measurement as dimension A.
   - 6.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.
   - 6.3 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 12**. Record this measurement as dimension B.
   - 6.4 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.
   - 6.5 The free-stroke should be 5/8 to 3/4 inch (16 to 19 mm). If it is not, turn the adjusting nut in the required direction. Then,

Brake Adjustment



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1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2-in
8. Clevis Pin, 1/4-in
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 11, Gunite Slack Adjuster

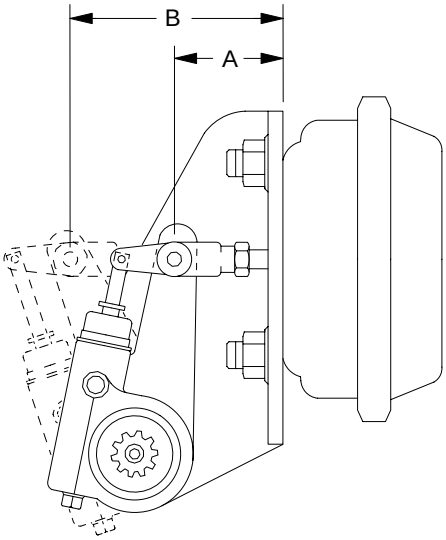
measure the free-stroke again and readjust it until it is correct.

7. Measure and adjust the applied chamber stroke (fine adjustment).

   7.1 Start the engine and build air pressure to 100 psi (690 kPa). Shut down the engine.

   7.2 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 12**, Ref. B. Record this measurement as dimension C.

   7.3 Subtract dimension A from dimension C. The difference between these measurements is the applied chamber stroke.



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A. Brakes Released B. Brakes Applied

Fig. 12, Measure the Stroke

   7.4 The applied chamber stroke must not exceed the maximum value specified in **Table 1**. If the stroke is not correct, turn the adjusting nut in the required direction. Then, measure the applied stroke again and readjust it until it is correct.

   7.5 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Subject 140**. If necessary, replace the slack adjuster.

8. Lower the vehicle, remove the safety stands, and remove the chocks from the tires.

⚠ WARNING

Do not operate the vehicle until the brakes have been checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

9. In a safe area, check for proper brake operation before you put the vehicle in service.

   9.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

9.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

9.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others shows a lack of braking effort on those wheels.

Brake Components Disassembly, Inspection, Cleaning, and Assembly

Disassembly and Inspection

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Three Q Plus brake assemblies are shown in the following figures:

- **Fig. 1**, Q Plus Brakes (other than MX500 Series)
- **Fig. 2**, MX500 Series with Cast Spider
- **Fig. 3**, MX500 Series with Stamped Spider

1. Remove the brake shoes. For instructions, see **Subject 110**.

IMPORTANT: Meritor recommends that the brake drum not be turned or rebored (resurfaced). Turning or reboring drums can decrease the strength and heat capacity of the drum.

2. Inspect the brake drum. See **Fig. 4**.
   - 2.1 Check the drum for cracks. Replace any cracked drum.
   - 2.2 Check the drum for severe heat-checking, heat-spotting, scoring, pitting, distortion, and out-of-round. Some drums that are glazed, grooved, or out-of-round can be repaired. For detailed instructions, see **Section 33.01** or **Section 35.01**.
   - 2.3 Using a drum caliper or other measuring device, measure the inside diameter of the drum in several locations. Replace the drum if it exceeds the maximum diameter stamped on it.
3. Disconnect the slack adjuster from the pushrod clevis. For detailed instructions, see **Section 42.10** for Meritor, **Section 42.11** for Haldex, or **Section 42.12** for Gunite automatic slack adjusters.
   - 3.1 Remove the cotter pin from the clevis pin; remove the clevis pin. See **Fig. 5**.

NOTICE

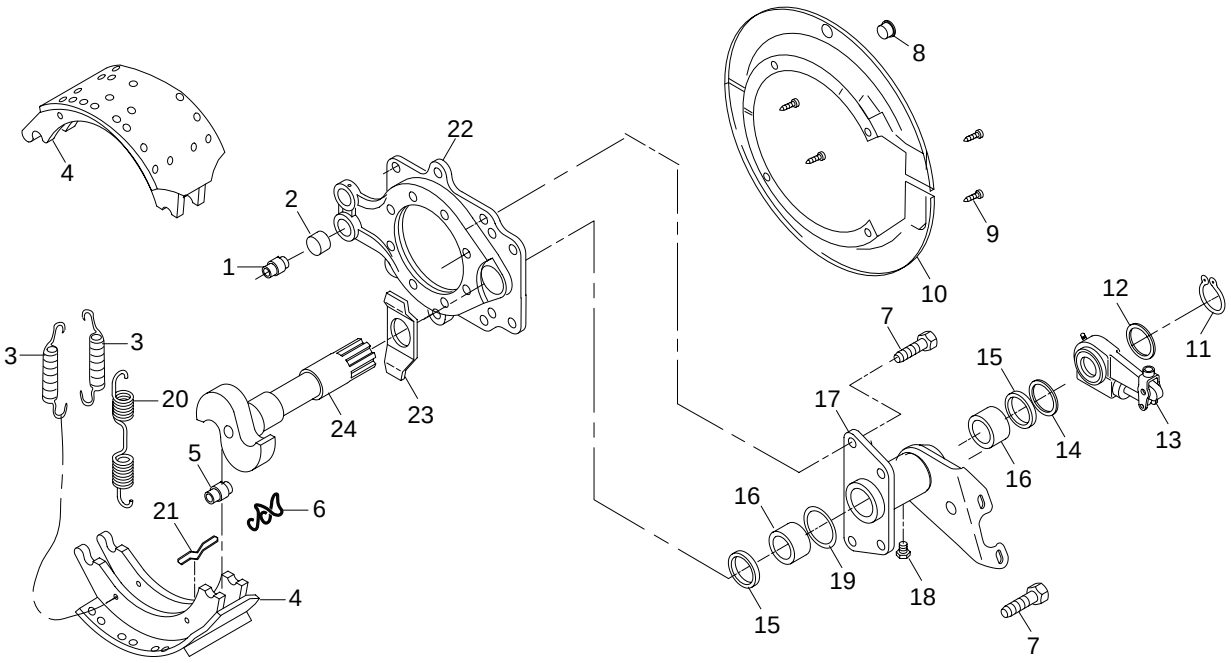
For a Meritor automatic slack adjuster, disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

   - 3.2 For a Meritor automatic slack adjuster, disengage the pull-pawl on the side of the adjuster. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm) and wedge the tool in place. See **Fig. 6**. Pull-pawls are spring loaded. When the tool is removed, the pull-pawl will engage the teeth automatically.

IMPORTANT: Never pull the slack adjuster out of the pushrod clevis. Always turn the adjusting nut for positioning.

   - 3.3 Using a wrench, turn the manual adjusting nut to back the slack adjuster out of the clevis.
     - On Meritor adjustors, turn the square adjusting nut clockwise (as if loosening a right-hand threaded fastener).
     - On Haldex or Gunite adjusters, turn the adjusting hexnut counterclockwise. You will hear a ratcheting sound.
4. Check the camshaft radial free play. See **Fig. 7**.
   - 4.1 Using a dial indicator, measure the up-and-down and side-to-side free play of the camshaft.
   - 4.2 Replace the camshaft bushings if there is more than 0.020 inch (0.5 mm) of free play.
5. Remove the slack adjuster.
   - 5.1 From the slack adjuster side of the camshaft-and-chamber bracket, remove the snap ring and any washers, spacers, and seals from the camshaft. See **Fig. 1**, **Fig. 2**, or **Fig. 3**.
   - 5.2 Remove the slack adjuster from the camshaft.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Plug
9. Capscrew, Dust Shield
10. Dust Shield
11. Camshaft Snap Ring
12. Washer (spacer)
13. Automatic Slack Adjuster
14. Washer (thick spacer)
15. Camshaft Grease Seal
16. Camshaft Bushing
17. Camshaft-and-Chamber Bracket
18. Grease Fitting
19. Chamber Bracket Seal
20. Return Spring
21. Return Spring Pin
22. Brake Spider
23. Camhead Thrustwasher
24. S-Head Camshaft

Fig. 1, Q Plus Brake (other than MX500 Series)

6. Inspect the slack adjuster for damage or binding.

   6.1 Check the slack adjuster clevis for cracks or bushing wear. Check the splines for chipped teeth and deformation. Replace as needed.

   NOTE: For a Haldex or a Gunite automatic slack adjuster, there is an internal clutch that resists the manual adjusting nut from being turned in the counterclockwise direction. When checking these slack adjusters for binding, only rotate the manual adjusting nut in the clockwise direction.

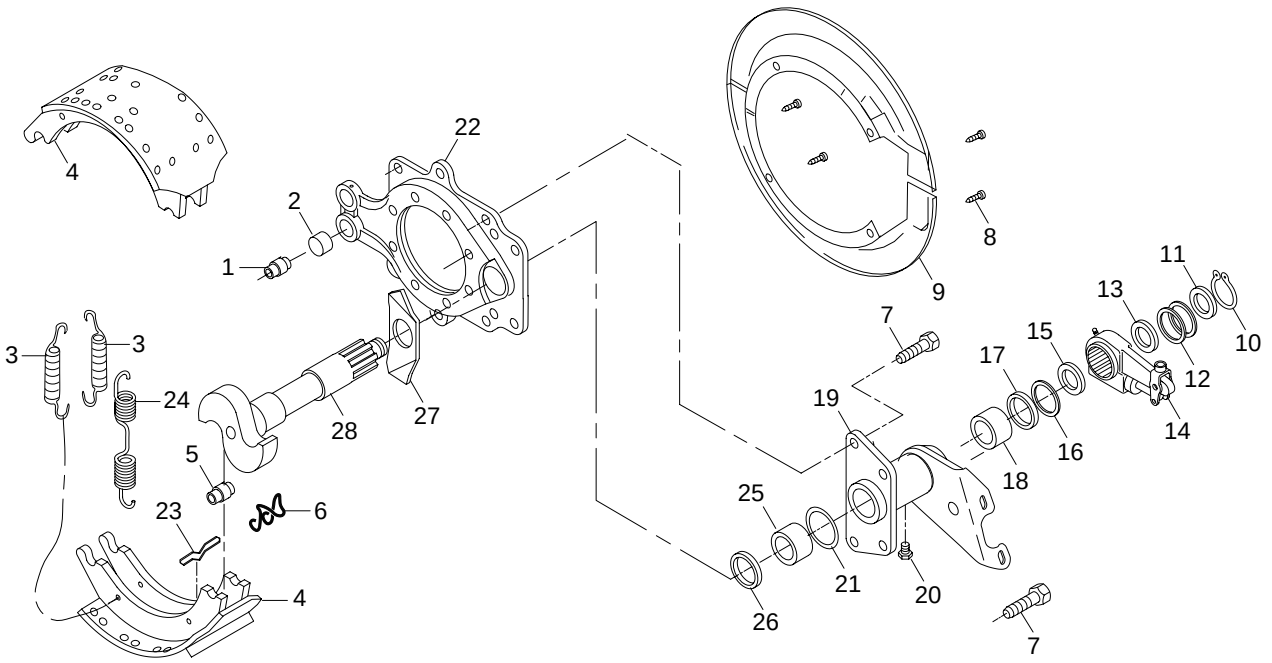
   6.2 Using a torque wrench that measures lbf·in (or N·cm), turn the manual adjusting nut clockwise so that the worm gear rotates a full 360 degrees (typically 22 turns of the wrench).

   If there is binding, or if more than 25 lbf·in (282 N·cm) is needed to turn the slack adjuster, replace it. For instructions, see the applicable slack adjuster section in this group.

IMPORTANT: If any slack adjuster problem is found, repair or replace the unit, depending on the manufacturer's recommendations.

7. Remove the camshaft by grasping its head and pulling the camshaft outboard from the brake spider and camshaft-and-chamber bracket. See **Fig. 8**. Then, remove the thrustwasher from the camshaft.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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NOTE: 16-1/2 inch Q Plus MX500 brake with cast spider shown.

1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Capscrew, Dust Shield
9. Dust Shield
10. Camshaft Snap Ring
11. Washer (spacer)
12. Washer (thin spacer)
13. Orange Seal, Automatic Slack Adjuster
14. Automatic Slack Adjuster
15. Seal, Automatic Slack Adjuster
16. Washer (thick spacer)
17. Camshaft Seal
18. Camshaft Bushing, 1-1/2 in. ID
19. Camshaft-and-Chamber Bracket
20. Pipe Plug
21. Chamber Bracket Seal
22. Brake Spider, Cast
23. Return Spring Pin
24. Return Spring
25. Camshaft Bushing, 1-5/8 in. ID
26. Orange Camshaft Seal
27. Camhead Thrustwasher
28. S-Head Camshaft

Fig. 2, Q Plus MX500 Brake (with cast spider)

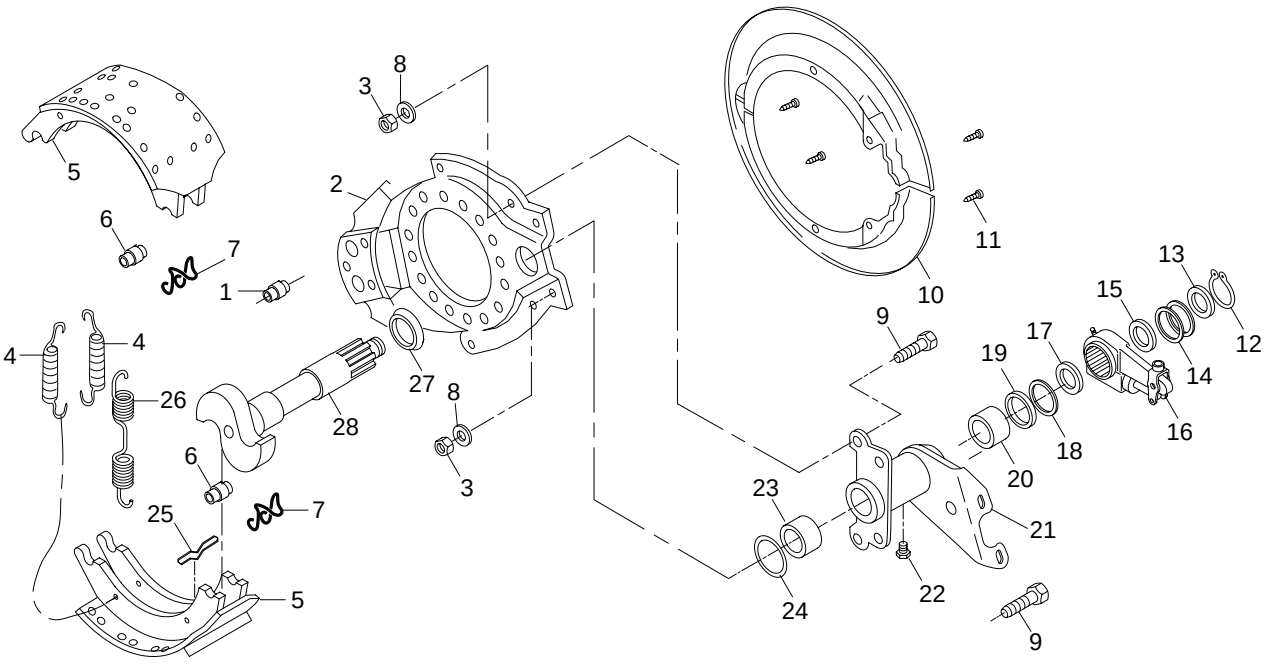
8. Check the camshaft spline end for cracks, corrosion, or worn or deformed splines. Replace the camshaft if it is damaged.
9. Check the camshaft bearing journals for wear or corrosion. Replace the camshaft if it is worn or if roughness is felt in the journal area.
10. Inspect the camshaft head for brinelling, cracking, or flat spots. Replace the camshaft if a ridge can be felt between the worn area and the cam head surface.
11. From the brake spider and slack adjuster ends of the camshaft-and-chamber bracket, remove and inspect the camshaft grease seals. If a grease seal lip is nicked, cut, or distorted, replace it.

⚠ WARNING

When removing bushings with a driver, wear eye protection. Do not hit steel parts with a steel hammer. To do so could cause steel pieces to break off, which could cause serious eye injury.

12. Using the correct size driver, remove the camshaft bushings from the camshaft-and-chamber bracket.
13. Check the camshaft bushings for wear. The inner surface must be smooth; if rough or abrasive, replace the bushings.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



NOTE: 16-1/2 inch drive axle Q Plus MX500 brake with stamped spider shown.

1. Anchor Pin
2. Brake Spider, Stamped
3. Hexnut (4 qty.)
4. Retaining Spring
5. Brake Shoe and Lining Assembly
6. Cam Roller
7. Retainer
8. Washer, Hardened (4 qty.)
9. Bolt (4 qty.)
10. Dust Shield
11. Capscrew, Dust Shield
12. Camshaft Snap Ring
13. Washer (spacer)
14. Washer (thin spacer)
15. Orange Seal, Automatic Slack Adjuster
16. Automatic Slack Adjuster
17. Seal, Automatic Slack Adjuster
18. Washer (thick spacer)
19. Camshaft Seal
20. Camshaft Bushing, 1-1/2 in. ID
21. Camshaft-and-Chamber Bracket
22. Pipe Plug
23. Camshaft Bushing, 1-5/8 in. ID
24. Orange Camshaft Seal
25. Return Spring Pin
26. Return Spring
27. Camhead Thrustwasher
28. S-Head Camshaft

Fig. 3, Q Plus MX500 Brake (with stamped spider)

14. Remove the brake chamber stud nuts and lockwashers that attach the brake chamber to the camshaft-and-chamber bracket.

    Check the chamber for a cracked housing, bent pushrod, loose clamp ring, loose air fitting, air leaks, or clogged vent holes. Repair or replace brake chamber parts as needed.

15. Remove and inspect the camshaft-and-chamber bracket. Remove and discard the gasket.

    Check the bracket for a bent, broken, or cracked arm and cracked welds. Replace the bracket if any of these conditions exist.

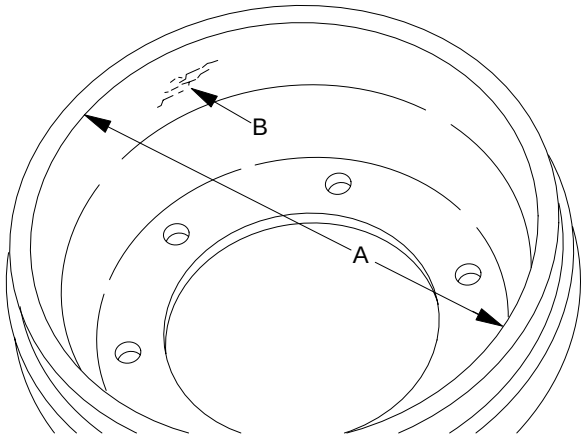
16. Remove the brake spider-to-axle attaching nuts, hardened washers, and bolts. Remove the brake spider from the axle flange.

17. If equipped, remove the four capscrews that attach the dust shield to the brake spider; remove the dust shield.

18. Inspect the brake spider and parts for damage; replace as needed.

    18.1 Check the bolt holes, cam area, and anchor pin area for cracks and check for expanded anchor pin holes. Replace if damaged.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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A. Check for diameter and out-of-round.
B. Check for cracks, heat checks, glazing, and grooves.

Fig. 4, Brake Drum Inspection

18.2 Check the anchor pins. If worn or loose, replace them.

18.3 Check the anchor pin bushings for wear. The inner surfaces must be smooth. If any surface is rough or abrasive, replace the part.

Cleaning

⚠ WARNING

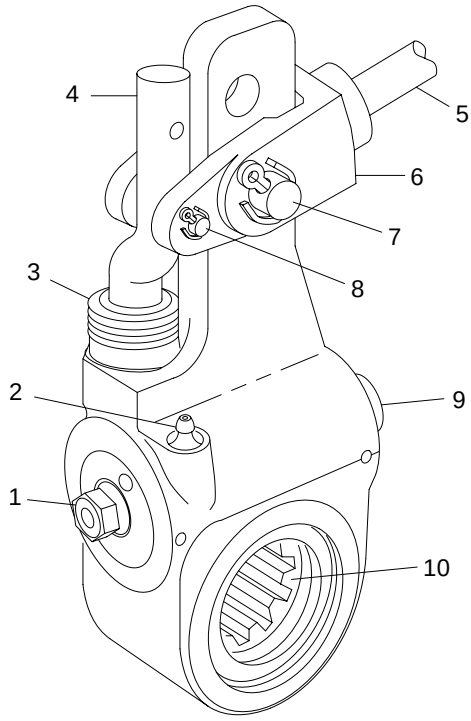
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTICE

Do not clean ground or polished metal parts in a hot solution tank or with water, steam, or alkaline solutions. These solutions will cause parts to corrode.

For corrosion protection, do not apply brake grease or corrosion-preventive materials to the brake linings or the brake drum.

After removing the brake parts being serviced, do the following:



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NOTE: Gunite automatic slack adjuster shown.

1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2-in
8. Clevis Pin, 1/4-in
9. Grease Relief Opening
10. Slack Adjuster Spline

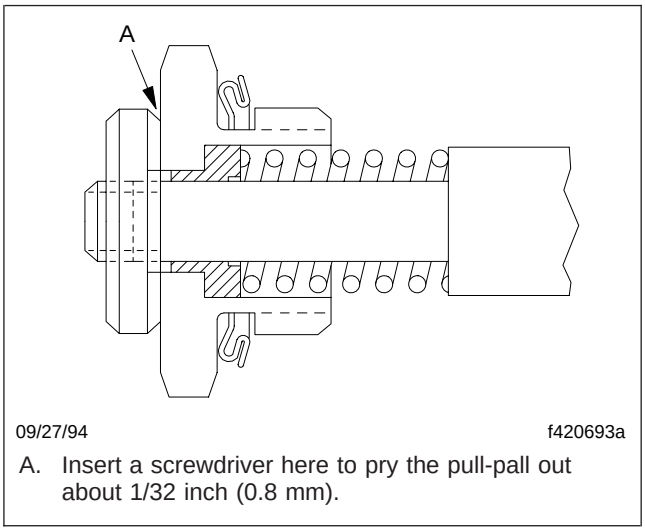
Fig. 5, Disconnect Slack Adjuster from Clevis

1. Clean the camshaft journals with an emery cloth.
2. Wire brush all parts exposed to mud, road dirt, and salt, including the exterior of the drum, brake spider, camshaft-and-chamber bracket, and dust shields (if equipped). If relining the shoes, thoroughly wire-brush the shoe tables, and paint them with a rust-inhibitive coating.

NOTICE

A thick layer of oxidation and dirt on the outside of a brake drum acts as an insulator and may hinder normal heat dissipation. Make sure oxidation and dirt are removed by wire brushing, or damage to brake components could occur.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



A. Insert a screwdriver here to pry the pull-pall out about 1/32 inch (0.8 mm).

Fig. 6, Disengage the Pull-Pall on Meritor Automatic Slack Adjusters

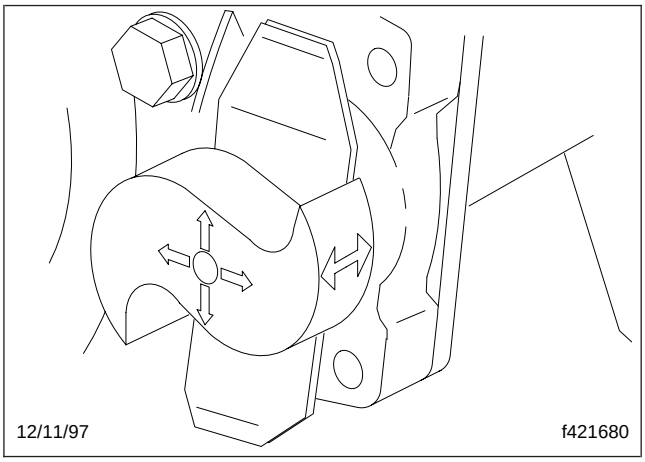


Fig. 7, Check Free Play

3. Using an industrial vacuum cleaner with a HEPA filter system, remove any dust accumulation from the brake parts.
4. Wipe the interior of the drums with a damp rag to remove lining dust.
5. Prepare the brake parts for assembly.

   5.1 Thoroughly clean all the brake parts.

   For ground or polished metal parts, use a cleaning solvent to clean the parts and surfaces that are ground or polished.

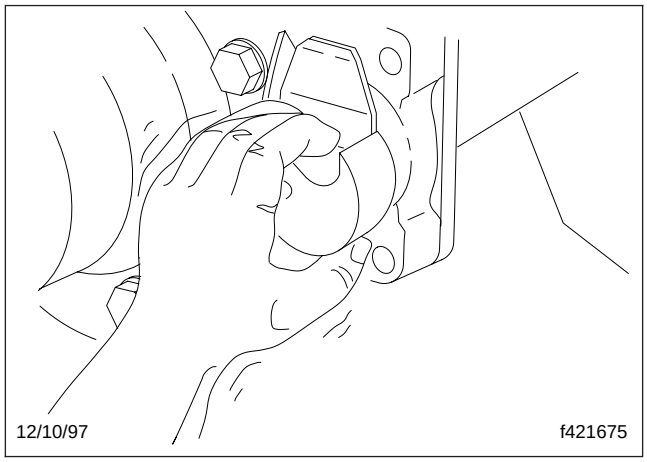


Fig. 8, Remove the Camshaft

For rough metal parts, use a cleaning solvent or a weak alkaline solution in a hot solution tank to clean the parts. If a hot solution tank is used, leave the rough parts in the hot solution tank until they are completely cleaned and heated. Remove the rough parts from the hot solution tank and wash them with water until the alkaline solution is removed.

5.2 Thoroughly dry all the brake parts with either compressed air or a clean soft cloth or paper towel.

⚠ WARNING

All worn or damaged brake parts must be replaced. If the brakes are assembled with worn or damaged parts, they may not perform to their capacity and a brake failure could occur, which could cause personal injury and property damage.

5.3 Thoroughly inspect all the brake parts for wear or damage. It is very important that all the parts be carefully inspected before they are assembled. Repair or replace any worn or damaged parts.

5.4 For parts that will be assembled, apply a thin layer of brake grease to the parts after they have been cleaned, dried, and inspected to protect them from corrosion.

If the parts will be stored, apply a special material that prevents corrosion and rust

on all surfaces. The parts should be stored in special paper (or other material) that prevents corrosion and rust.

Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Install the dust shield, if equipped. See **Fig. 1**, **Fig. 2**, or **Fig. 3**.

   Position the dust shield against the brake spider and install the capscrews. Tighten the capscrews to the specifications in **Table 1**.

2. Install the brake spider.

   Place the brake spider on the axle flange. Install the mounting fasteners with hardened washers under the bolt head and nut. Tighten the nuts to the specifications in **Table 1** in a cross pattern. See **Fig. 9**.

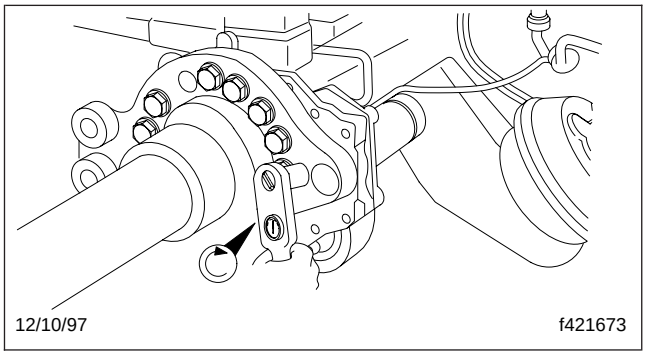


Fig. 9, Tighten the Brake Spider Fasteners

3. Install the camshaft-and-chamber bracket.

   Place the camshaft-and-chamber bracket and gasket against the brake spider and install the lockwashers and fasteners. Tighten the fasteners to the specifications in **Table 1**.

NOTE: If replacing a brake chamber, make sure that the new chamber is the same size and make as the brake chamber on the other side of the axle.

4. Install the brake chamber.

Dust Shield, Spider, and Bracket Torque Specifications

Fastener		Torque Specification	
Size	**Grade**	**lbf·ft**	**N·m**
Dust Shield Fasteners			
5/16–18	5	15 to 20	20 to 27
3/8–16	5	25 to 35	34 to 47
3/8–16	8	35 to 50	47 to 68
Brake Spider Fasteners			
7/16–20		60 to 75	81 to 102
1/2–20		85 to 115	115 to 156
9/16–18		135 to 165	183 to 224
5/8–18		180 to 230	244 to 312
Camshaft-and-Chamber Bracket Fasteners			
1/2–13 Capscrew (without nut)	5	65 to 85	88 to 115
1/2–13 Capscrew (without nut)	8	70 to 100	95 to 136
5/8–18 Bolt with Locknut		130 to 165	176 to 224

Brake Components Disassembly, Inspection, Cleaning, and Assembly

Dust Shield, Spider, and Bracket Torque Specifications			
Fastener		Torque Specification	
Size	Grade	lbf·ft	N·m
5/8–18 Bolt with Plain Hexnut		150 to 190	203 to 258

Table 1, Dust Shield, Spider, and Bracket Torque Specifications

4.1 Place the brake chamber on the mounting flange (camshaft-and-chamber bracket) with the chamber mounting studs through the flange holes.

4.2 Install the hardened flatwashers, lockwashers, and stud nuts.

4.3 Tighten the brake chamber fasteners to the specifications in **Table 2**.

Brake Chamber Torque Specifications: lbf·ft (N·m)	
Chamber Type	Haldex
16	100 (136)
20, 24, 30, 36	100 (136)
Spring Chamber	100 (136)

Table 2, Brake Chamber Torque Specifications: lbf·ft (N·m)

IMPORTANT: The grease seals are installed in both the brake spider and slack adjuster ends of the camshaft-and-chamber bracket. The grease seals must be installed with their lips toward the slack adjuster end of the camshaft-and-chamber bracket tube.

NOTE: To maximize lining life, Meritor recommends replacing the springs, rollers, anchor pins, and camshaft bushings when the linings are replaced. For Q Plus brakes with MX500 identification tags, if replacing the linings before the recommended service interval (3 years or 500,000 miles [800 000 km]), the camshaft bushings and the seals do not need to be replaced.

5. Using a seal driver, install the camshaft seals and the new camshaft bushings in the brake spider and slack adjuster ends of the camshaft-and-chamber bracket. See **Fig. 10**. Install the seals with their lips toward the slack adjuster. See **Fig. 11**.

6. Install the camshaft. See **Fig. 12**.

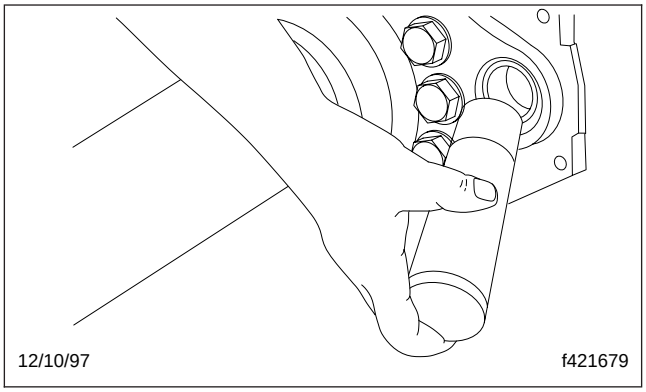
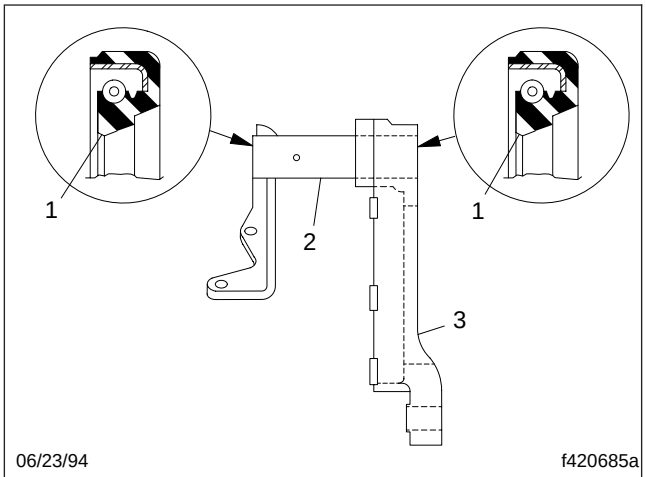


Fig. 10, Install the Seals and Bushings



NOTE: The seal faces the slack adjuster.
1. Seal Lip
2. Camshaft-and-Chamber Bracket
3. Brake Spider

Fig. 11, Positioning the Seals

6.1 Put the cam head thrustwasher on the camshaft with the bent flaps toward the brake spider.

6.2 Apply a thin film of grease on the inside of the camshaft bushings and journals. For

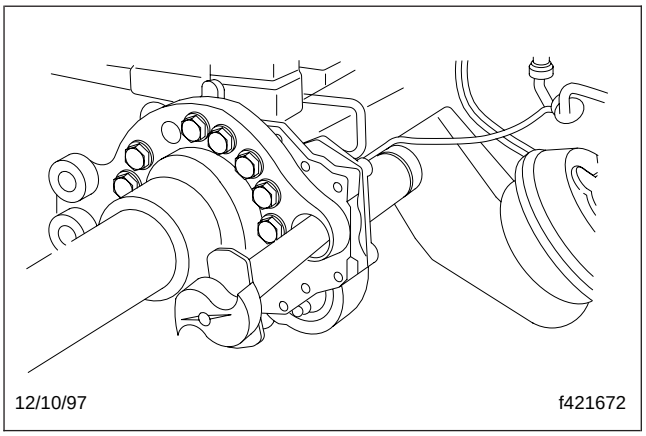


Fig. 12, Install the Camshaft

the recommended grease specification, see **Specifications, 400**. Do not grease the camshaft head area.

6.3 Apply a thin film of rust preventive grease on the camshaft splines. For the recommended grease specification, see **Specifications, 400**.

6.4 Carefully slip the camshaft in the brake spider and the camshaft-and-chamber bracket tube. The camshaft should turn freely by hand.

7. Install the slack adjuster. For instructions, see **Section 42.10** for Meritor, **Section 42.11** for Haldex, or **Section 42.12** for Gunite automatic slack adjusters.

⚠ WARNING

When lubricating the camshaft-and-chamber bracket, if grease leaks out under the cam head, the camshaft grease seal is worn or damaged. If the seal is not replaced, the brake linings could be contaminated by grease and the vehicle's stopping distance could be reduced, which could result in personal injury or property damage.

8. For all Cam-Master Q Plus brakes except MX500, pressure lube the camshaft-and-chamber bracket bushings.

   NOTE: Use meter-type fittings with a maximum 40 psi (276 kPa) pressure relief at the shutoff.

8.1 Pump multipurpose chassis grease (NLGI grade 1 or 2) into the camshaft-and-chamber bracket until it appears at the slack adjuster end of the bracket. Use care that no grease enters the drum cavity. For recommended grease specification, see **Specifications, 400**.

8.2 If grease leaks out under the cam head, the camshaft grease seal is worn, damaged, or installed backwards. See "Disassembly and Inspection" for grease seal replacement instructions.

NOTE: If the brake linings are being replaced on MX500 brakes before the service interval, the camshaft-and-chamber bracket and the slack adjuster do not need lubrication. The service interval is every 3 years or 500,000 miles (800 000 km), whichever comes first.

9. For MX500 brakes, when changing the brake linings at the service interval, lubricate the camshaft-and-chamber bracket and the automatic slack adjuster.

9.1 Remove the identification tag from the camshaft-and-chamber bracket housing.

9.2 Remove the grease plugs from both the camshaft-and-chamber bracket and the automatic slack adjuster.

9.3 Install grease fittings.

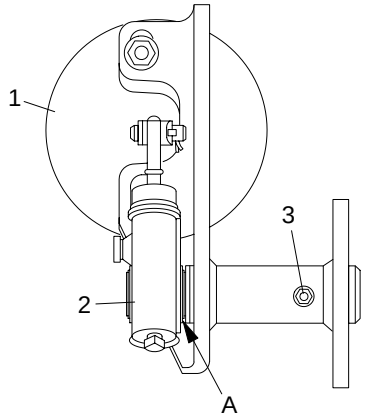
9.4 Using Meritor-approved NLGI grade 2 synthetic polyurea grease (EVO-LUBE TEK-615), lubricate the brake assembly through the grease fitting in the bracket until new grease flows from the inboard seal. See **Fig. 13**.

9.5 Using Meritor-approved NLGI grade 2 synthetic polyurea grease (EVO-LUBE TEK-615), lubricate the slack adjuster through the grease fitting until new grease flows out of the pull-pawl or camshaft seal. See **Fig. 14**.

9.6 Replace the grease fittings with new grease plugs and cover the bracket plug with a new identification tag.

10. Install the brake shoes. For instructions, see **Subject 110**.

Brake Components Disassembly, Inspection, Cleaning, and Assembly



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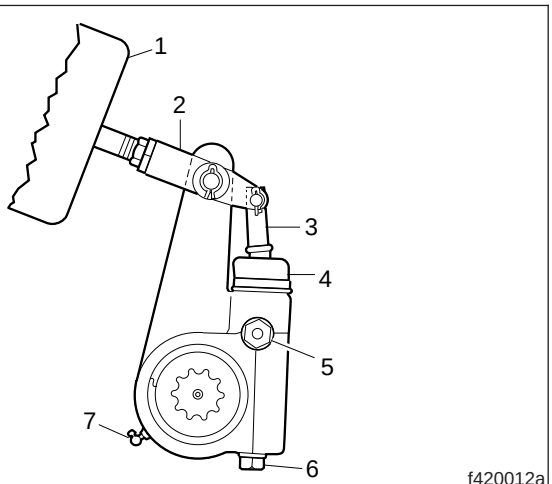
A. Grease Exit

1. Brake Chamber
2. Slack Adjuster
3. Grease Fitting (or lube plug)

Fig. 13, Camshaft-and-Chamber Bracket Lubrication



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1. Brake Chamber
2. Clevis
3. Actuator Rod
4. Boot
5. Pull-Pawl Seal
6. Adjusting Hexnut
7. Grease Fitting

Fig. 14, Slack Adjuster Lubrication

Troubleshooting Tables

Problem—No Adjustment or Adjusted Stroke is Too Long

Problem—No Adjustment or Adjusted Stroke is Too Long	
Possible Cause	**Remedy**
The wrong slack adjuster is installed.	Replace the slack adjuster with the correct one.
The clevis is not installed correctly.	Check the slack adjuster installation. For instructions, see the appropriate slack adjuster section in this group.
There is excessive wear between the clevis and collar.	Check the gap between the clevis and the collar. The maximum allowable gap is 0.060 inch (1.5 mm). Replace the threaded clevis as necessary.
The jam nut at the clevis is loose.	Tighten the jam nut to specifications.
The large clevis pin bushing in the slack adjuster arm is worn.	Measure the inside diameter of the large clevis pin bushing. The inside diameter must not be larger than 0.53 inch (13.5 mm). Replace the bushing as necessary.
The return spring in the air chamber is weak or broken.	Check the air spring force. At the first movement of the push rod, the spring force must beat least 32 lbf (142.3 N). Replace the return spring or air chamber as necessary.
The spring brake is not fully retracting.	Repair or replace the spring brake.
The pull-pawl or the actuator is worn (the teeth are stripped).	Replace the pull-pawl or the actuator in the slack adjuster.
The slack adjuster has internal damage.	Inspect the slack adjuster. Repair or replace the slack adjuster as necessary. For instructions, see the appropriate slack adjuster section in this group.
There is excessive play between the slack adjuster gear and the splines of the camshaft.	Replace the camshaft and/or the slack adjuster as necessary.
Foundation brake components are worn.	Replace the components.

Problem—Linings Dragging or Adjusted Stroke is Too Short

Problem—Linings Dragging or Adjusted Stroke is Too Short	
Possible Cause	**Remedy**
The incorrect brake linings are installed	Install the correct Meritor approved brake linings.
The wrong slack adjuster is installed.	Replace the slack adjuster with the correct one.
The clevis is not installed correctly.	Check the slack adjuster installation. For instructions, see the appropriate slack adjuster section in this group.
The jam nut at the clevis is loose.	Tighten the jam nut to specifications.
The spring brake is not fully retracting.	Repair or replace the spring brake.
The manual (free-stroke) adjustment is incorrect.	Adjust the free-stroke and applied chamber stroke. For instructions, see **Subject 130**.
Poor contact between the linings and the drum, or the drum is out-of-round.	Repair or replace the drum or the linings.
There is a brake temperature imbalance.	Correct the brake balance.

Q Plus Brake Torque Specifications			
Fastener Description and Size	**Grade**	**lbf·ft**	**N·m**
Brake Shoe Lining Nuts			
1/4 inch	5	80 to 100 lbf·in	904–1130 N·cm
3/8 inch	5	18–23	24–31
Dust Shield Fasteners			
5/16–18	5	15–20	20–27
3/8–16	5	25–35	34–47
3/8–16	8	35–50	47–68
Brake Spider Fasteners			
7/16–20	—	60–75	81–102
1/2–20	—	85–115	115–156
9/16–18	—	135–165	183–224
5/8–18	—	180–230	244–312
Camshaft-and-Chamber Bracket Fasteners			
1/2–13 Capscrew (without nut)	5	65–85	88–115
1/2–13 Capscrew (without nut)	8	70–100	95–136
5/8–18 Bolt with Locknut		130–165	176–224
5/8–18 Bolt with Plain Hexnut		150–190	203–258

Table 1, Q Plus Brake Torque Specifications

Brake Chamber Torque Specifications: lbf·ft (N·m)	
Chamber Type	**Haldex**
16	100 (136)
20, 24, 30, 36	100 (136)
Spring Chamber	100 (136)

Table 2, Brake Chamber Torque Specifications: lbf·ft (N·m)

Meritor Grease Specification			
Specification Number	**NLGI Grade**	**Grease Type**	**Outside Temperature: °F (°C)**
O-616-A	1	Clay Base	Down to –40 (–40)
O-617-A O-617-B	1 and 2	Lithium 12-Hydroxy Stearate or Lithium Complex	See Manufacturer's Specification
O-645	2	Synthetic Oil, Clay Base	Down to –65 (–54)
O-692	1 and 2	Lithium Base	Down to –40 (–40)
O-637	1 and 2	Calcium Base	See Manufacturer's Specification
O-641	—	Anti-Seize	See Manufacturer's Specification

Specifications

Meritor Grease Specification			
Specification Number	**NLGI Grade**	**Grease Type**	**Outside Temperature: °F (°C)**
O-695	2	Synthetic Polyurea	–40 (–40)

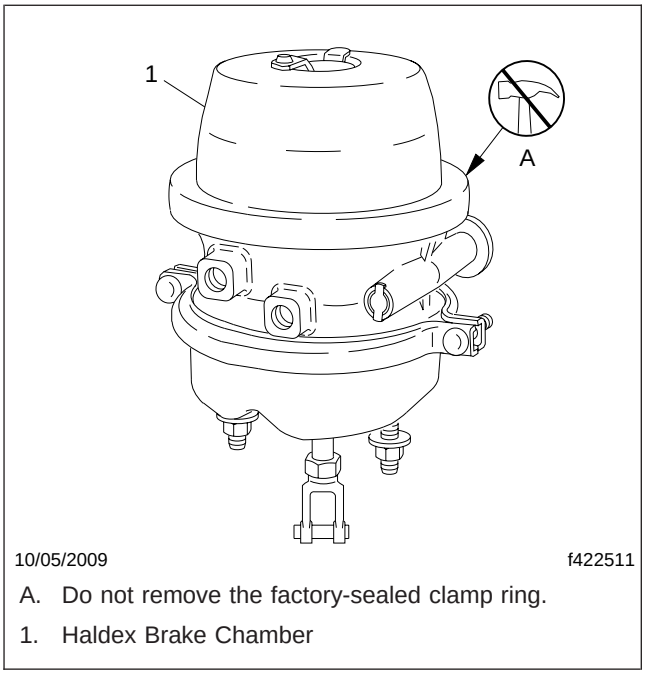
Table 3, Meritor Grease Specification

Component Lubrication						
Brake Type	**Meritor Grease Specification**					
	Clevis Pins	**Camshaft Splines**	**Anchor Pins**	**Brake Shoe Rollers**	**Camshaft Bushings**	**Slack Adjuster**
All Cam-Master Brakes Except Q Plus MX500	O-616-A O-637 O-641 O-645 O-692	O-616-A O-617-A O-617-B O-637 O-641 O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616-A O-617-A O-617-B O-645 O-692	O-616A O-645 O-692
Q Plus MX500 Brakes	O-695	O-695	O-617-A O-617-B O-645 O-692	O-617-A O-617-B	O-616-A O-617-A O-617-B O-645 O-692	O-695

Table 4, Component Lubrication

DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



A. Do not remove the factory-sealed clamp ring.
1. Haldex Brake Chamber

Fig. 1, Brake Chamber

IMPORTANT: On Haldex brake chambers, the parking/emergency brake section is factory-sealed (no clamp ring) and is a *non-serviceable* unit.

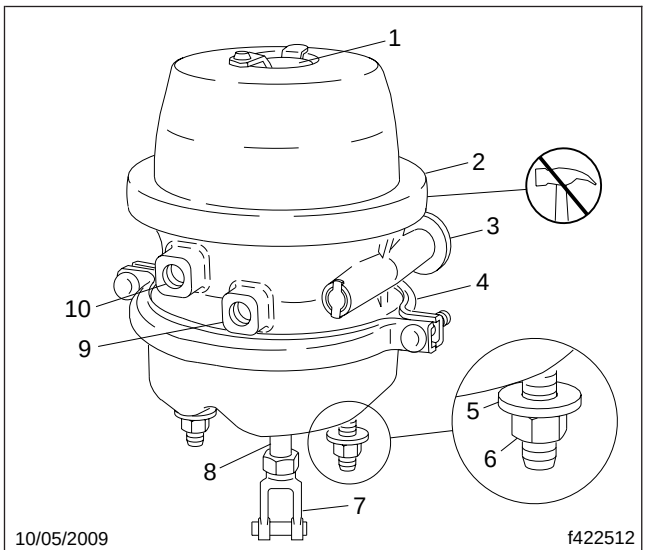
NOTE: All longstroke spring brake chambers have square bosses, not round, where the brake hoses connect. This was done to provide a quick differentiation between standard stroke and longstroke brake chambers.

NOTICE

Longstroke and standard stroke brake chambers should not be mixed on the vehicle. They have different force outputs for a given application pressure, which can cause adverse brake balance and wear.

General Description

The Haldex tandem cam brake chamber consists of a service brake section and a parking/emergency spring brake section. See **Fig. 2**. The service brake section is the smaller section near the clevis assembly.



Do not remove the factory-sealed clamp ring.
1. End-Cover Cap
2. Factory-Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Spring Brake Air Inlet
10. Parking Brake Air Inlet

Fig. 2, Haldex Longstroke Brake Chamber

In the service brake section, the flange case and non-pressure chamber contain a service return spring, piston rod assembly, and service brake diaphragm.

In the parking/emergency brake section, the flange case and the head contain a return spring, a push rod assembly, a parking (spring) brake diaphragm, a piston, a power spring, and a detachable release bolt.

General Information

All Haldex brake chambers are mounted to brackets on the axle using prevailing torque locknuts and hardened flatwashers.

Principles of Operation

Service Brakes

As the brake pedal is depressed, compressed air enters the service brake chamber through a port. Air pressure acts upon a diaphragm, which forces the piston rod toward the non-pressure chamber, applying a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

Then, when the brake pedal is released, air is exhausted from the service brake chamber, and the return spring allows the diaphragm, piston rod, and slack adjuster to return to their normal positions, releasing the brakes.

Parking/Emergency Brakes

During parking brake release, compressed air enters the parking brake chamber and acts upon the diaphragm and piston, fully compressing the power spring. When the power spring is compressed, the parking brakes are released; the service brakes can then be operated at the brake pedal.

During parking brake application, air is exhausted from the parking brake chamber. The power spring releases, forcing the piston and parking brake diaphragm toward the flange case. The resulting motion on the push rod forces the service brake diaphragm and piston rod outward, applying the brakes.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

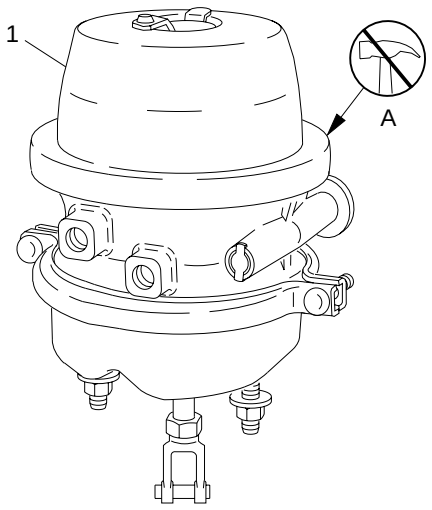
- Chock the tires and stop the engine before working under a vehicle. Keep hands away from brake chamber piston rods and slack adjusters; the brakes may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



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A. Do not remove the factory-sealed clamp ring.

1. Haldex Brake Chamber

Fig. 1, Brake Chamber

Manual Caging (Parking Brake Release)

1. Chock the tires.
2. Remove the end-cover cap from the center-hole in the head of the chamber. See **Fig. 2**.

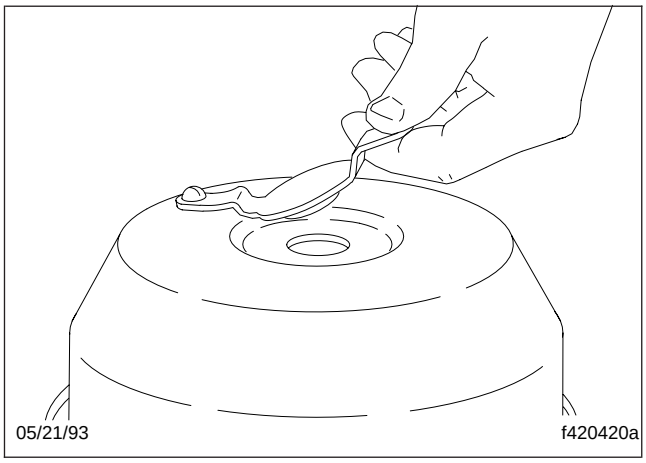

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Fig. 2, Removing the End-Cover Cap

⚠ DANGER

Do not attempt to cage the power spring if the parking brake chamber is damaged severely enough to lose its structural integrity. If the power spring were to break loose, it could result in death, severe personal injury, or property damage.

A DAMAGED PARKING BRAKE CHAMBER IS EXTREMELY DANGEROUS! Only qualified service personnel should attempt to remove and disarm a damaged chamber. Using a torch, burn off the piston rod in the space between the clevis and the base of the service chamber.

Remove the chamber carefully from its bracket, and disarm it inside a suitable container. For disarming procedures, consult the Haldex service manual.

3. Using a hand wrench (*don't use an impact wrench*), unscrew the release nut, and remove the nut, flatwasher, and release bolt from the storage pocket on the side of the chamber. See **Fig. 3**.

IMPORTANT: If these parts are not stored on the chamber, they must be otherwise obtained or purchased; the parking brake cannot be manually released without them.

4. Insert the release bolt in the center-hole into the chamber head. See **Fig. 4**. Insert the bolt until it bottoms out in the hole in the piston inside the chamber.

Caging and Resetting the Spring Brake

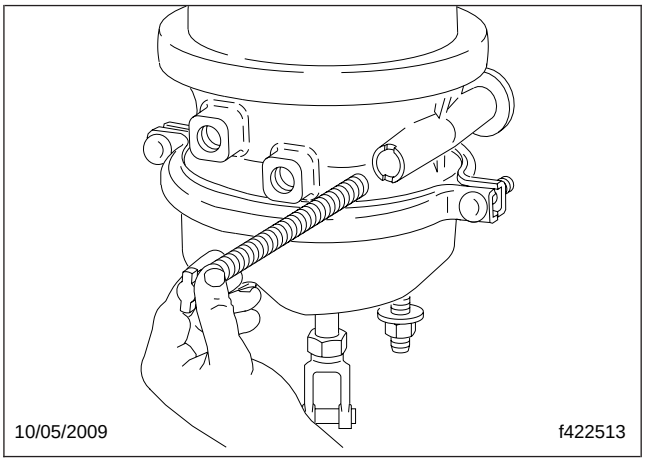


Fig. 3, Removing the Release Bolt

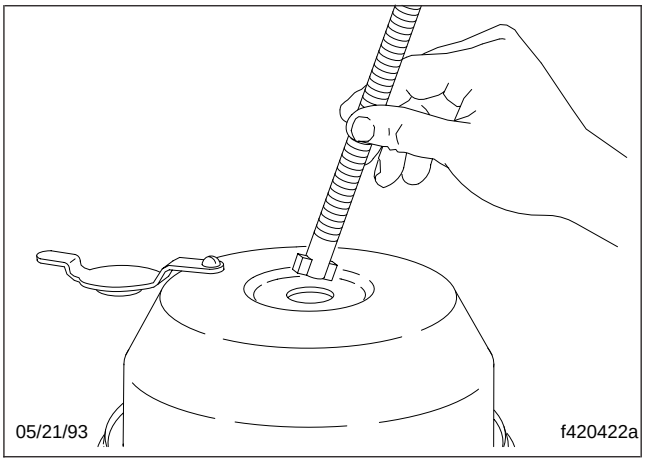


Fig. 4, Inserting the Release Bolt

IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged the piston correctly, repeat this step. Repeat it until you are absolutely sure.

5. Turn the release bolt one-quarter turn clockwise, and pull the bolt out to lock its formed end into the piston.

IMPORTANT: If the bolt doesn't lock into the piston in less than 1/2-inch (13-mm) outward movement, repeat these steps until you are sure it does lock.

IMPORTANT: Don't exceed the designated length for the type of chamber used.

6. Then, holding the bolt locked into the piston, install the flatwasher and release nut on the end of the release bolt, and turn down the nut against the flatwasher until it is finger-tight. See **Fig. 5**.

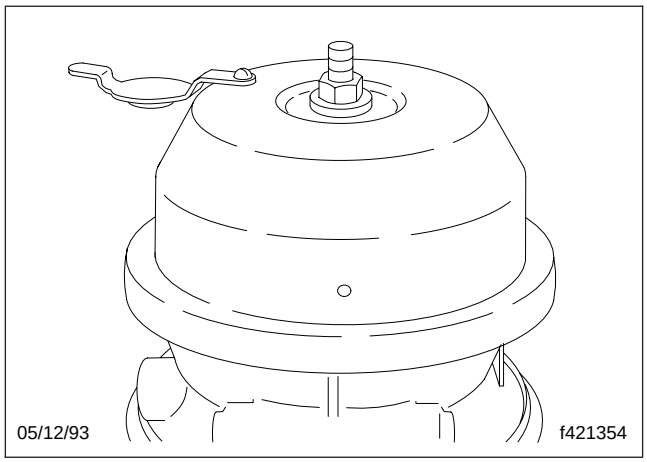


Fig. 5, Flatwasher and Release Nut Installed

NOTICE

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

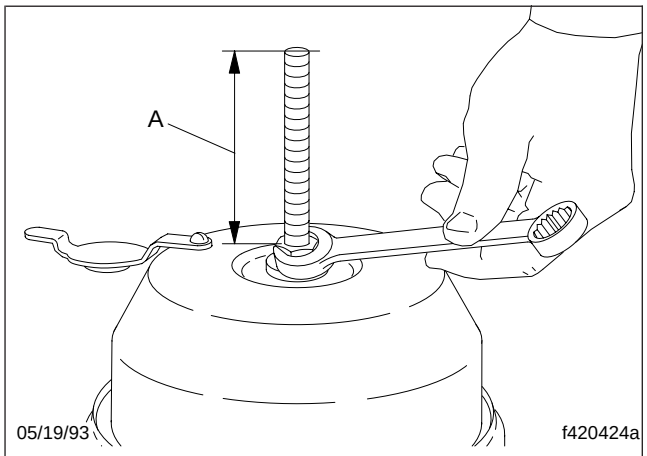
7. Using a hand wrench (*don't use an impact wrench*), turn the release nut clockwise until the bolt extends above the nut at least 2.915 inches (74 mm) on 24-inch chambers, or 2.875 inches (73 mm) on 30-inch chambers. See **Fig. 6**.

IMPORTANT: Do not exceed these bolt lengths. If the bolt lengths can not be obtained without exceeding the recommended maximum torque values, replace the tandem brake chamber.

8. Once the power spring has been caged, exhaust the compressed air from the parking brake.

Manual Reset (Parking Brake Reset)

1. Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set parking brake in the "release" position).



Don't exceed the designated length.
A. Measure this distance.

Fig. 6, Turning the Release Nut

NOTICE

Do not exceed 50 lbf·ft (68 N·m) torque on the release nut; and do not use an impact wrench on this nut. Too much torque could distort the head of the chamber and prevent manual release of the parking brake.

2. Use a hand wrench to turn the release nut *counterclockwise* until the bolt bottoms out in the unit.
3. Remove the nut and flatwasher.
4. Push the release bolt into the piston and turn the release bolt one-quarter turn counterclockwise to unlock its formed end from the piston. Remove the release bolt from the center-hole of the chamber.
5. Using a hand wrench (*don't use an impact wrench*), install the release bolt, flatwasher, and release nut in the storage pocket. Haldex recommends 10 lbf·ft (14 N·m) torque on the nut against the flatwasher. See **Fig. 7**.
6. Snap the end-cover cap in place over the center-hole in the chamber head. See **Fig. 8**.

NOTICE

If the end cover cap is missing or incorrectly installed, road dirt and debris can adversely affect the operation of the brake chamber. Once inside the chamber, dirt and debris cause the internal parts to deteriorate and shorten their lives. Operating the unit without the end cover cap in place voids the Haldex warranty.

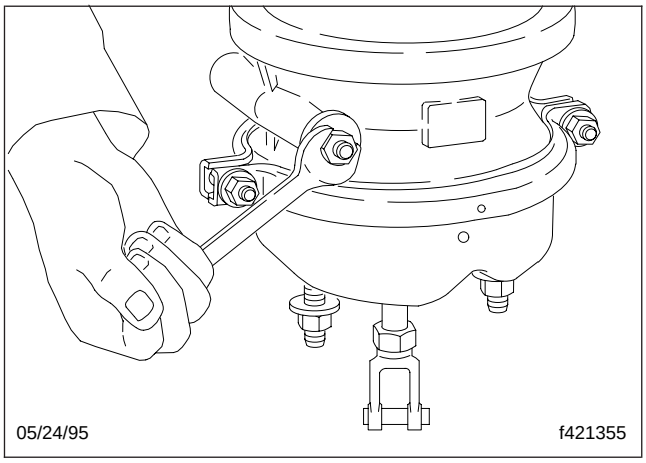


Fig. 7, Tightening the Release Nut

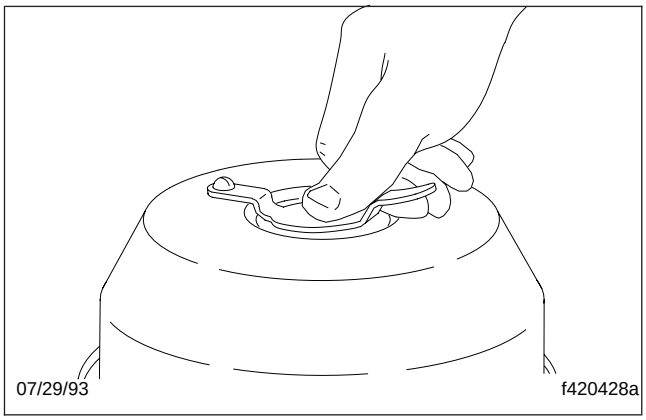


Fig. 8, Snapping the End-Cover Cap in Place

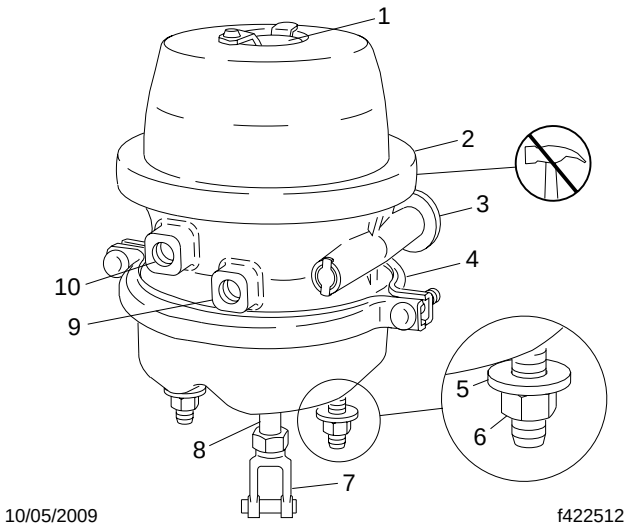
7. Check the plastic end-cover cap periodically, and replace it with a new one at once if damaged or missing.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



Do not remove the factory-sealed clamp ring.

1. End-Cover Cap
2. Factory-Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Spring Brake Air Inlet
10. Park Brake Air Inlet

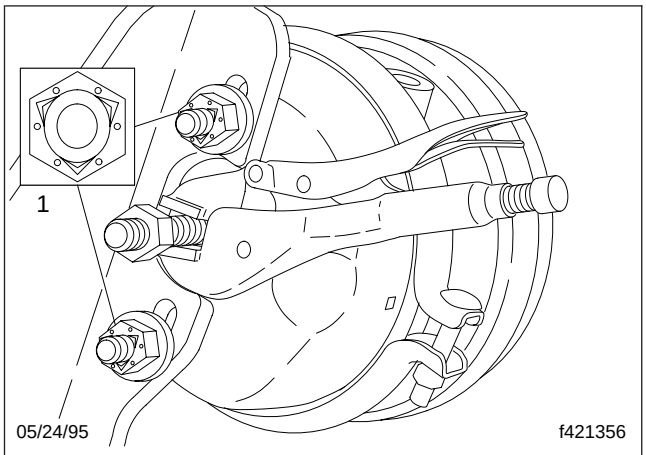
Fig. 1, Haldex Longstroke Brake Chamber

Replacement

1. To make removal and installation of the parking brake section easier (without removing the service brake chamber), lock off the service chamber piston rod, as follows.

   1.1 Apply the service brakes by actuating the driver's foot brake treadle valve.

   1.2 With the brakes applied, clamp a pair of locking-jaw pliers on the piston rod to lock the rod in place when the air pressure is released. See **Fig. 2**.



1. Prevailing Torque Locknut

Fig. 2, Locking the Piston Rod in Place

⚠ WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 110. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

2. Manually release the parking brake (cage the power spring). For instructions, see **Subject 110**.
3. Mark the air lines for later reference. Then carefully disconnect them from the brake chamber.

⚠ DANGER

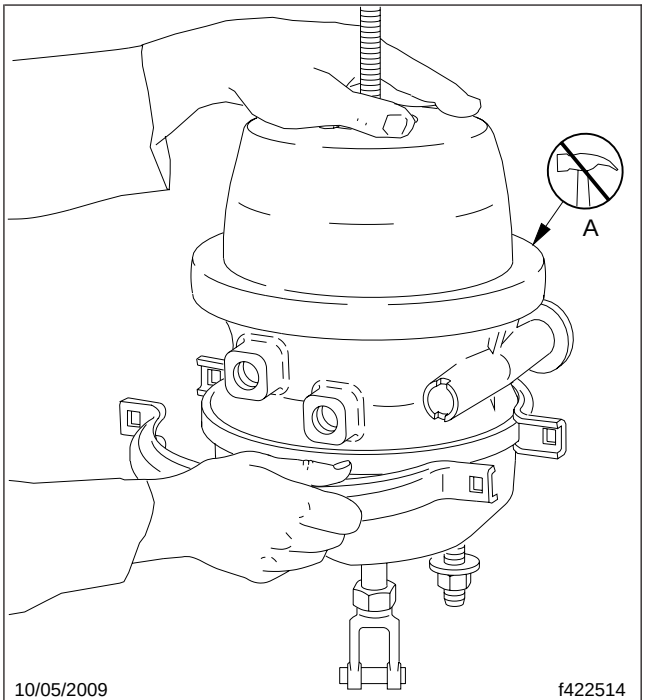
Do not attempt to remove the factory-sealed clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

Service Brake Diaphragm Replacement

4. Remove the parking brake section from the service brake section, as follows.

   4.1 Using a hand wrench (*don't use an impact wrench*), remove the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 While holding the parking brake section securely in place, remove the service clamp ring. Then remove the parking brake section from the service brake non-pressure chamber. See **Fig. 3**.



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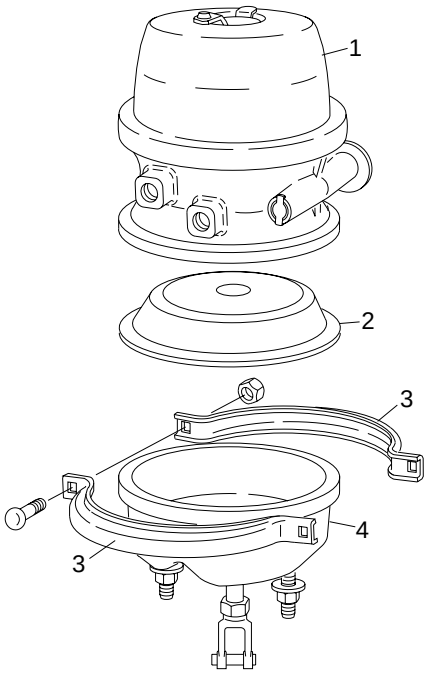
A. Do not remove the factory-sealed clamp ring.

Fig. 3, Removing the Service Clamp Ring

5. Remove the service brake diaphragm from the bottom of the parking brake section.
6. Inspect the parking/emergency brake section, and replace it if it shows signs of damage, corrosion, or rust.
7. Inspect all parts in the service (non-pressure) chamber. Replace any damaged or worn parts with genuine Haldex-engineered replacement parts.
8. Place the new service brake diaphragm in the bottom recess of the parking brake section. See **Fig. 4**.



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1. Parking/Emergency Brake Section
2. Service Brake Diaphragm
3. Service Brake Clamp Ring
4. Service Brake (Non-Pressure) Chamber

Fig. 4, Brake Chamber Parts

9. Install the (new, if needed) parking/emergency brake section, as follows.

   9.1 If installing a new parking brake section, be sure it is the same size and make as the old one.

   9.2 Check that the release bolt is fully extended outward. For instructions, see **Subject 110**.

   9.3 Install the parking brake section on the service chamber so that all mating parts are aligned straight and the air lines are positioned to mate with the vehicle air supply lines.

10. Install the service brake clamp ring, as follows.

10.1 With the service brake clamp ring in place, install the clamp bolts and nuts.

10.2 Using a hand wrench (*don't use an impact wrench*), alternately tighten each clamp nut in increments of 5 to 10 lbf·ft (7 to 14 N·m) while constantly rechecking the alignment of mating parts.

If realignment is needed, loosen the nuts again, and repeat this substep.

10.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

11. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).
12. Using the vehicle system air, charge the parking brake with full line pressure—at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).
13. With the parking brake still charged with full line pressure, apply and hold the foot brake treadle valve down to charge the service brake chamber. Remove the locking-jaw pliers from the service piston rod so that the piston returns to a normal position in the chamber.

⚠ DANGER

Do not attempt to remove the factory-sealed clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

14. Test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). Haldex recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.
15. With air pressure now exhausted from the service brake chamber, but held on the parking brake, uncage the power spring, and snap the end-cover cap in place. For instructions, see **Subject 110**.
16. Adjust the brakes at the slack adjuster. Refer to the appropriate section in this manual.

IMPORTANT: After replacing any brake chamber components, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

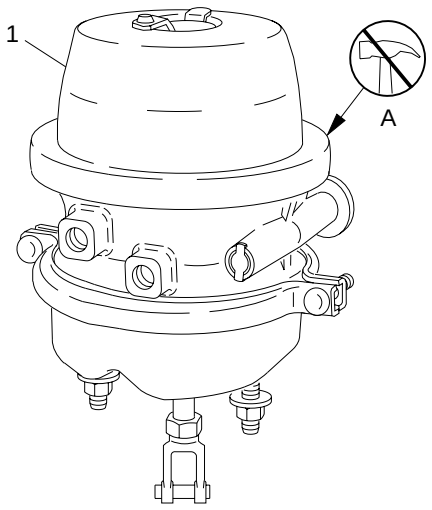
Combination Service and Parking Brake Chamber Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

DANGER

Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



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A. Do not remove the factory-sealed clamp ring.
1. Haldex Brake Chamber

Fig. 1, Brake Chamber

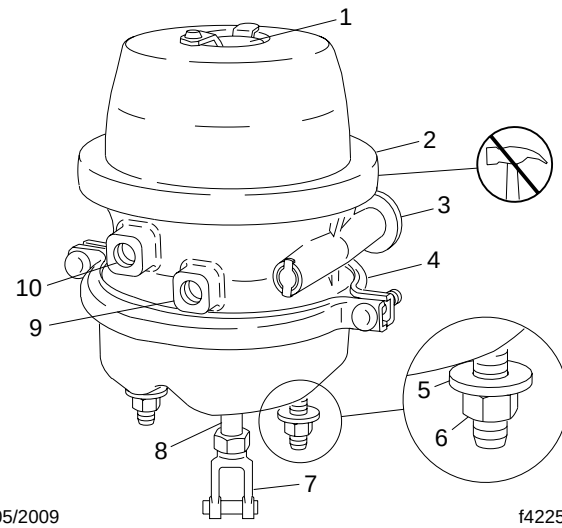
Removal

Refer to **Fig. 2** for brake chamber parts identification.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Manually release the parking brake (cage the power spring). For instructions, see **Subject 110**.



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Do not remove the factory-sealed clamp ring.
1. End-Cover Cap
2. Factory-Sealed Parking Brake Clamp Ring
3. Release Bolt Storage Pocket
4. Service Brake Clamp Ring
5. Hardened Flatwasher
6. Prevailing Torque Locknut
7. Clevis Assembly
8. Piston Rod
9. Spring Brake Air Inlet
10. Parking Brake Air Inlet

Fig. 2, Haldex Longstroke Brake Chamber

2. Mark the air lines for later reference. Then carefully disconnect them from the brake chambers.
3. Remove the cotter pins from the clevis pins, then remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster.
4. Make sure the parking brake has been released manually (the power spring has been caged). For instructions, see **Subject 110**. Also, make sure that the service brake piston is fully retracted (in the brakes "OFF" position). Then, record both of the following dimensions in either millimeters or inches, measuring outward from the base of the service brake chamber. See **Fig. 3**:

   X dimension: to end of threaded piston rod

   Y dimension: to centerline of (large) clevis pin

IMPORTANT: New chambers are attached to automatic slack adjusters. The X dimension is the most critical measurement. When installing

Combination Service and Parking Brake Chamber Removal and Installation

the new assembly, its service piston rod must be cut to exactly duplicate the "rod only" length *before* the clevis assembly is installed on the piston rod. See **Fig. 4**.

5. From each mounting stud, remove any installed nuts and washers. Then, cautiously remove the brake chamber from the mounting bracket.

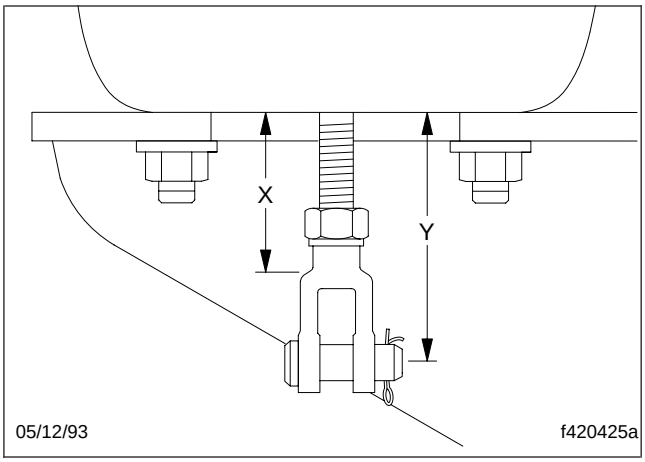


Fig. 3, Measuring X and Y

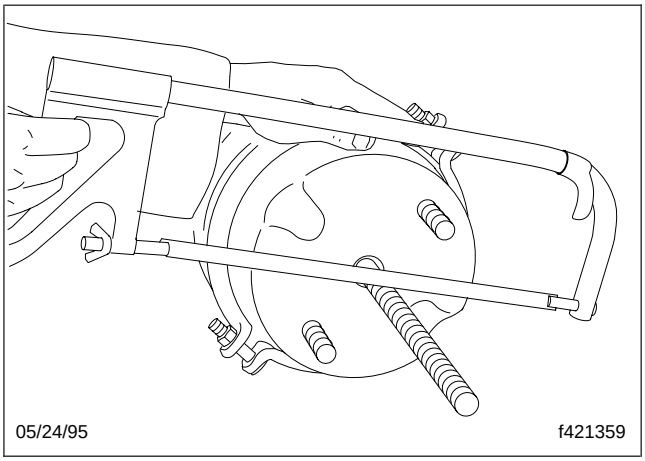


Fig. 4, Cutting the Service Piston Rod

Installation

Refer to **Fig. 2** for brake chamber parts identification.

1. If installing a new brake chamber unit, do the following:

   1.1 First, make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 110** and do the applicable steps.

   1.2 Make sure that the piston rod is the same length as the rod on the old unit (measure the rods when *both* chambers are caged).

   1.3 Be sure the new chamber is the same size and make as the brake chamber installed on the other side of the axle.

   1.4 Remove the prevailing torque locknut and hardened flatwasher from each of the mounting studs on the chamber.

2. Clean the face of the mounting bracket, and install the chamber on the bracket, paying close attention to positioning the chamber air inlet ports for correct alignment to the vehicle air lines.

⚠ WARNING

Tighten the mounting nuts with a hand wrench, not an impact wrench. An impact wrench could damage the mounting fasteners, reducing the force of the brakes. This could result in personal injury or property damage.

3. Install one hardened flatwasher and prevailing torque locknut on each mounting stud. Using a hand wrench (*don't use an impact wrench*), tighten the nuts 100 to 115 lbf·ft (136 to 156 N·m). Make sure the flatwasher is installed between the locknut and the mounting bracket.

4. Check mating and alignment with the vehicle air lines, as follows. If alignment is okay, skip this step.

⚠ DANGER

Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

   4.1 Using a hand wrench (*don't use an impact wrench*), loosen the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 Reposition the air inlet ports, as needed, to mate with vehicle air supply lines.

Alternately tighten each clamp nut in increments of 60 to 120 lbf·in (678 to 1356 N·cm) while constantly rechecking the alignment of mating parts.

If realignment is needed, loosen the nuts again, and repeat this substep.

4.3 Firmly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. Tighten the nuts to a final torque of 25 to 30 lbf·ft (34 to 41 N·m).

5. Install the slack adjuster. Refer to the applicable slack adjuster section in this group for installation instructions.
6. Inspect the piston rod to be sure it is working free, not binding, and is square with the chamber bottom within ±3 degrees in any direction from zero to full stroke. If there is misalignment, make corrections by loosening the locknuts and repositioning the chamber on the mounting bracket, or by shimming the slack adjuster to the right or left on the camshaft.
7. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).
8. Using the vehicle system air, charge the parking brake with full line pressure, at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 30 lbf·ft (41 N·m).

⚠ DANGER

Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose, at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

IMPORTANT: If the service brake clamp ring was loosened to reposition the air inlet ports, apply air to the parking brake, and then apply and hold the foot brake treadle valve down to charge the service brake chamber. Now test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). Haldex recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.

9. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the end-cover cap in place. For instructions, see **Subject 110**.
10. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

IMPORTANT: After replacing any brake chamber, check the piston rod stroke and actuating alignment to ensure correct installation and foundation brake adjustment. No foundation brake adjustments, parking brake or service brake, can be made at the chamber, and all "stroke" adjustments must be made at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

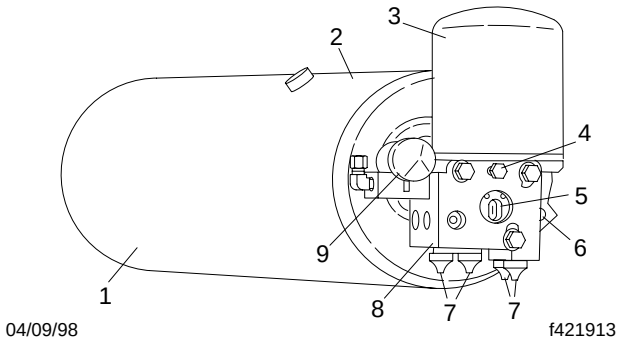
Specifications

Torque Values	
Description	**Torque: lbf·ft (N·m)**
Spring Brake Release Bolt Nut (in storage pocket)	10 (14)
Service Brake Clamp Ring Nut	25–30 (34–41)
Brake Chamber Mounting Stud Nut	100–115 (136–156)
Air Hose Fitting-to-Chamber	30 (41)

Table 1, Torque Values

General Information

The function of the dryer reservoir module (DRM) is to provide the vehicle with an integrated air dryer, secondary reservoir, purge reservoir, and governor. See **Fig. 1**.



1. Secondary Reservoir
2. Integrated Purge Reservoir
3. Desiccant Cartridge
4. Safety Valve
5. Heater/Thermostat Assembly
6. Auxiliary Delivery Port
7. Pressure Protection Valves
8. AD-IS Air Dryer
9. Governor

Fig. 1, Dryer Reservoir Module

The air dryer collects and removes air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system.

Charge Cycle

Figure 2 shows the charge cycle.

When the compressor is loaded, compressed air, oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer body.

As air travels through the air dryer assembly, its temperature falls, causing some of the contaminants to condense and drop to the bottom of the air dryer assembly, ready to be expelled at the next purge cycle.

The air then flows into the desiccant cartridge. Once in the desiccant cartridge, air flows through an oil separator which removes oil and solid contaminants.

Air then flows into the desiccant drying bed. Air flowing through the desiccant becomes progressively dryer as water vapor adheres to the desiccant material.

Dry air exits the bottom of the desiccant cartridge and flows through the center of the base assembly. The air then flows to the delivery check valve, to the safety valve and also through an orifice plug into the purge reservoir. Air traveling through the delivery check valve flows to the governor and two pressure protection valves.

As pressure builds during the initial charge, the purge reservoir fills. When the air pressure reaches 103 psi (710 kPa), the first pressure protection valve opens, filling the primary reservoir. When the primary reservoir pressure reaches 109 psi (752 kPa) the second pressure protection valve opens and air is supplied to the secondary reservoir and accessory pressure protection valves. When air pressure in the secondary reservoir reaches 55 and 85 psi (379 and 586 kPa) respectively, the two remaining pressure protection valves open and supply air to the accessories.

NOTE: There is no external air line from the air dryer to the secondary reservoir. Air is supplied by a line passing through the purge reservoir.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting of approximately 130 psi (896 kPa).

Purge Cycle

Figure 3 shows the purge cycle.

When air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor and the purge cycle begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the dryer control port. The purge piston moves in response to air pressure, causing the purge valve to open and the turbo cutoff valve to close. When the purge valve opens, water and contaminants are expelled. Air flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected in the oil separator are removed by air flowing from the purge reservoir, through the desiccant drying bed, and out through the open purge valve.

General Information

The purge cycle lasts only a few seconds and is detected by an audible burst of air at the air dryer exhaust.

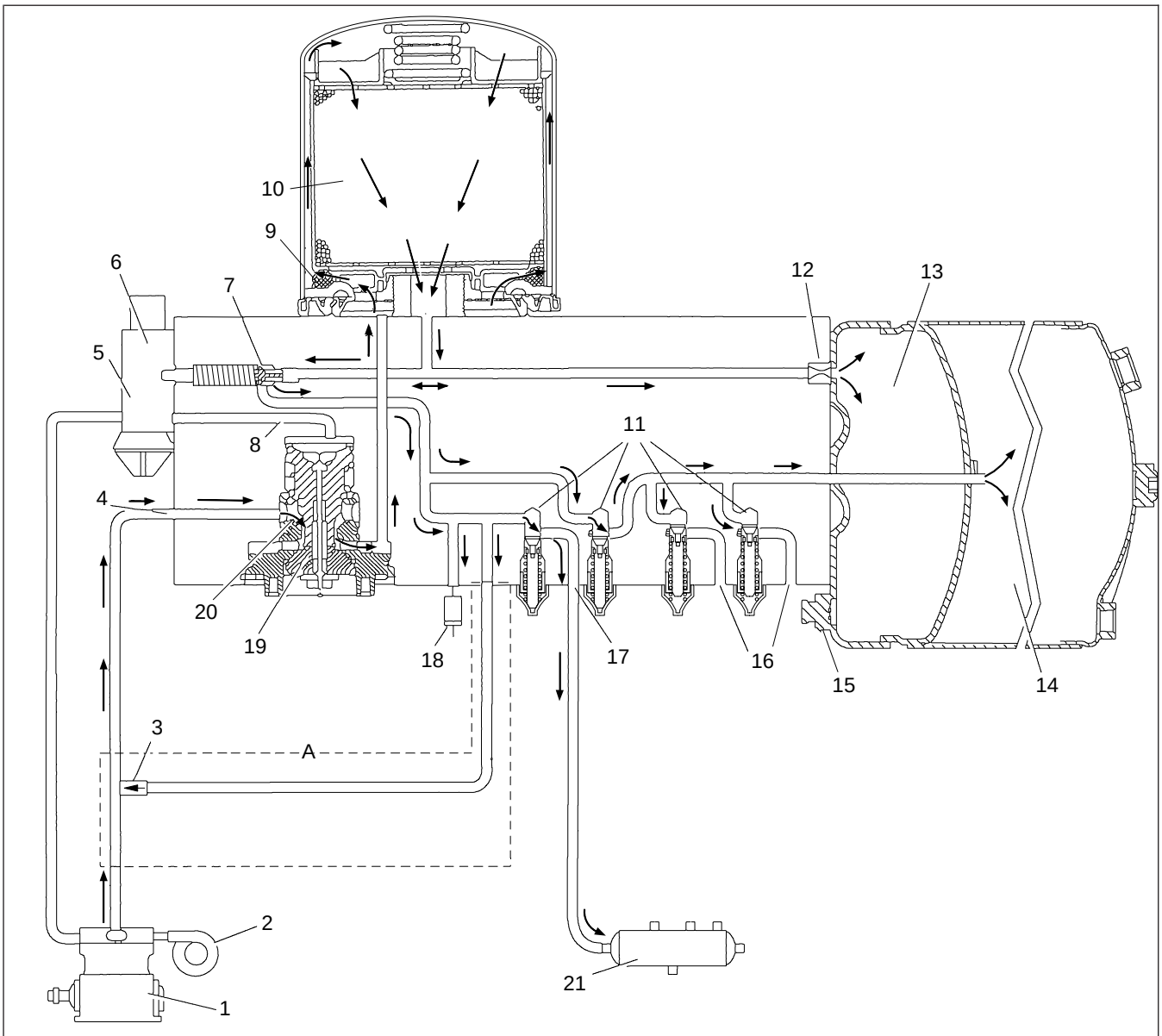
The reactivation of the desiccant drying bed begins as dry air flows from the purge reservoir, through the purge orifice, and into the desiccant bed. Pressurized air from the purge reservoir expands after passing through the purge orifice; its pressure is lowered and its volume is increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Approximately 30 seconds is required for the entire purge reservoir of a standard air dryer to flow through the desiccant dryer bed.

The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

Turbo Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of turbocharger air pressure through the air dryer in systems where the compressor intake is connected to the engine turbocharger.

During the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and air dryer inlet port cannot enter the air dryer. This maintains turbocharger boost pressure to the engine.

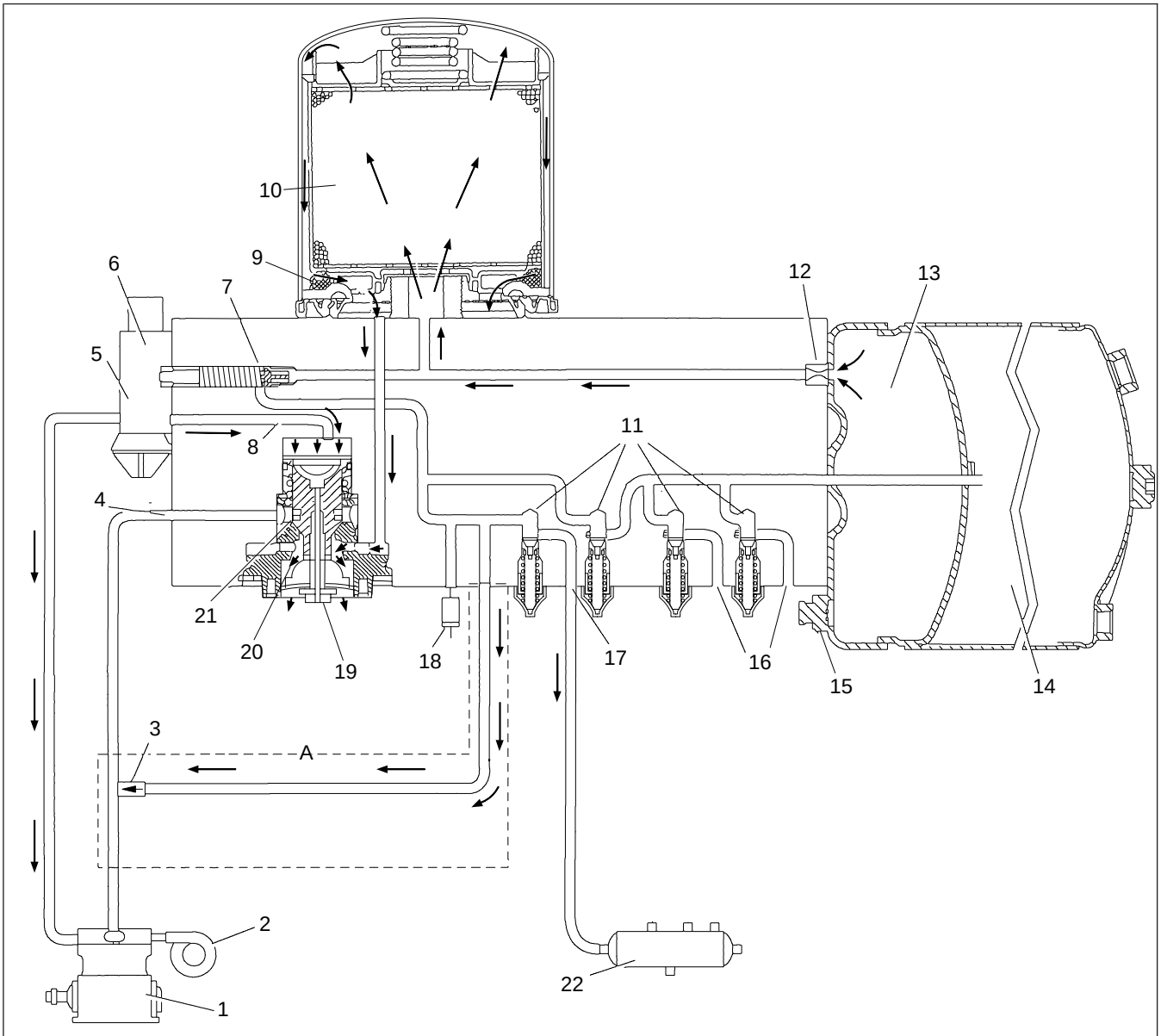


A. Feedback Line: Used only with Type E and QE Holset Compressors.

1. Compressor
2. Engine Turbo
3. Check Valve
4. Inlet Port
5. Unloader Port
6. Governor
7. Delivery Check Valve
8. Purge Control Line
9. Oil Separator
10. Desiccant Bed
11. Pressure Protection Valves
12. Purge Orifice
13. Purge Reservoir
14. Secondary Reservoir
15. Purge Reservoir Drain Cock
16. Auxiliary Ports
17. Primary Port
18. Safety Valve
19. Purge Valve (closed)
20. Turbo Cutoff Valve (open)
21. Primary Reservoir

Fig. 2, Air Dryer Charge Cycle

General Information



A. Feedback Line: Used only with Type E and QE Holset Compressors.

1. Compressor
2. Engine Turbo
3. Check Valve
4. Inlet Port
5. Unloader Port
6. Governor
7. Delivery Check Valve
8. Purge Control Line
9. Oil Separator
10. Desiccant Bed
11. Pressure Protection Valves
12. Purge Orifice
13. Purge Reservoir
14. Secondary Reservoir
15. Purge Reservoir Drain Cock
16. Auxiliary Ports
17. Primary Port
18. Safety Valve
19. Exhaust
20. Purge Valve (open)
21. Turbo Cutoff Valve (closed)
22. Primary Reservoir

Fig. 3, Air Dryer Purge Cycle

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

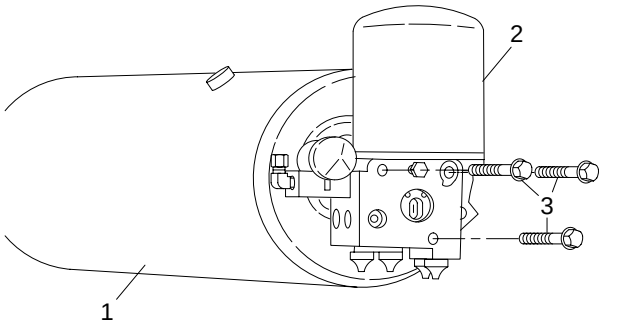
- Chock the tires and stop the engine before working under the vehicle. Releasing air from the system may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters; they will apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs and injury can result if not correctly disassembled. Use only correct tools and observe all precautions regarding use of those tools.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Mark and remove the air lines from the air reservoir.
4. Unplug the wiring harness from the heater/thermostat assembly.
5. Remove the three capscrews that fasten the air dryer to the air reservoir. See **Fig. 1**. Remove the air dryer.



1. Air Reservoir
2. Air Dryer
3. Capscrews

Fig. 1, DRM (air dryer capscrews shown)

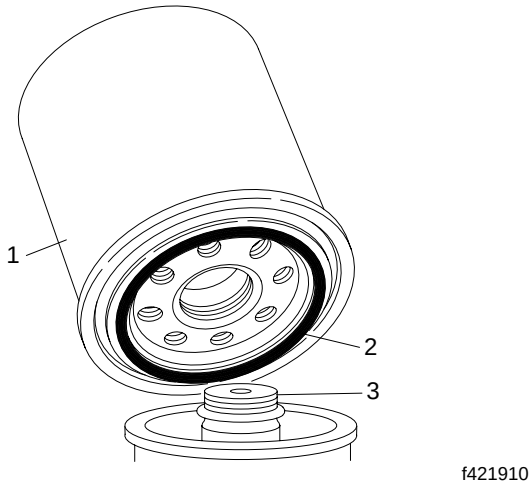
6. Remove the governor and delivery check valve from the air dryer. For instructions, see **Subject 130**.
7. Remove the desiccant cartridge. For instructions, see **Subject 120**.
8. Install the delivery check valve and governor onto the new air dryer. For instructions, see **Subject 130**.
9. If removed, install the desiccant cartridge. For instructions, see **Subject 120**.
10. Install the air dryer, making sure the two O-rings are installed between the air dryer and air reservoir. Use the three capscrews to fasten the air dryer to the reservoir. Tighten the capscrews 30 to 35 lbf·ft (41 to 47 N·m). See **Fig. 1**.
11. Connect the air lines and plug the wiring harness into the heater/thermostat assembly.
12. Perform the operational tests in **Subject 170**.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for desiccant cartridge replacement.



1. Desiccant Cartridge
2. Cartridge Sealing Ring
3. Threaded Base Post

Fig. 1, Desiccant Cartridge Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Using a strap wrench or equivalent, loosen the desiccant cartridge. Spin the cartridge off by hand and discard it.
4. On the new desiccant cartridge, lubricate the sealing rings with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

5. Screw the desiccant cartridge onto the body, by hand, until the seal makes contact with the body. Rotate the cartridge clockwise about one full turn. If necessary, use a strap wrench to tighten the cartridge.

Delivery Check Valve and Governor Replacement

⚠ WARNING

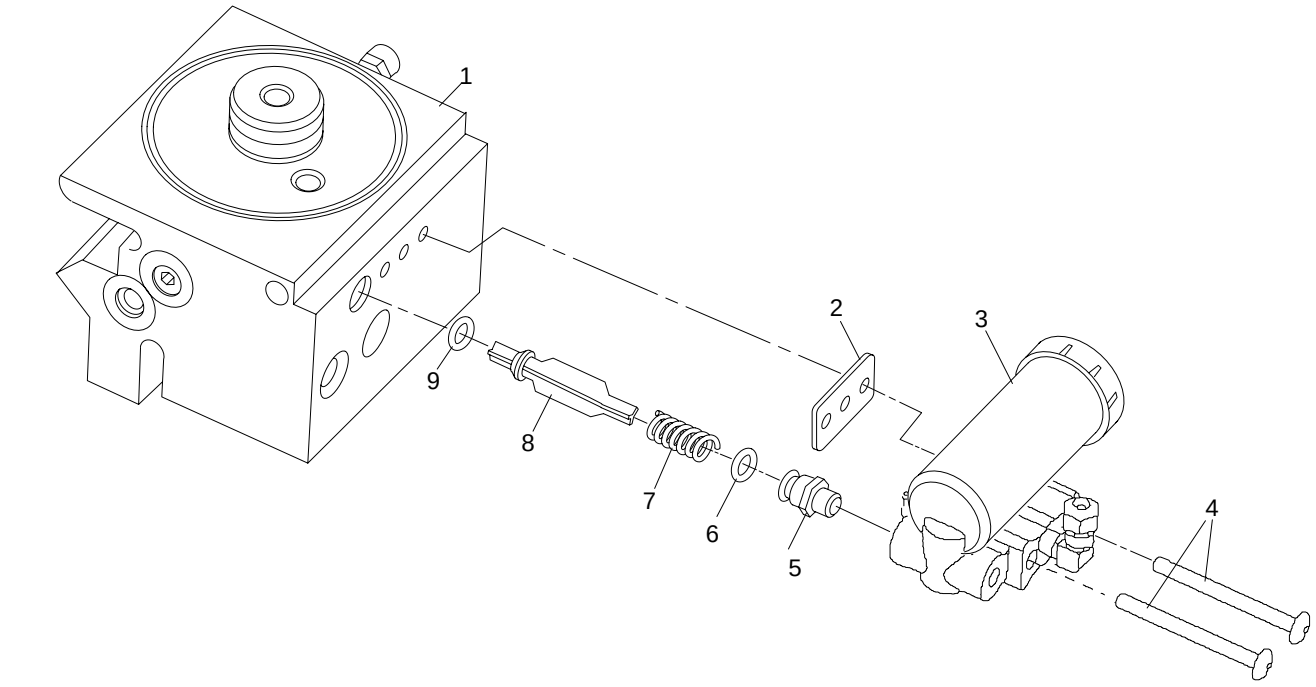
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Disconnect the air line from the governor and mark it for later reference. See **Fig. 1**. Remove the capscrews that attach the governor to the air dryer.
4. Remove the governor, adaptor fitting, and the adaptor O-ring. Remove the governor gasket and discard it.
5. Remove the spring and check valve.
6. Lubricate the new smaller O-ring and check valve body with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

7. Install the O-ring on the check valve body and push the O-ring down, over the longer set of three guide lands, until it is in the O-ring groove of the check valve body.
8. Install one end of the check valve spring over the check valve's shorter set of three guide lands. Turn the valve about 1/4 turn while holding the spring, if necessary, to secure the valve in place. Install the assembled check valve body, O-ring, and spring in the delivery port, so the O-ring rests on its seat and the free end of the spring is visible.



1. Air Dryer Base
2. Gasket
3. Governor
4. Capscrews
5. Adaptor
6. O-Ring
7. Spring
8. Check Valve Body
9. O-Ring

Fig. 1, Delivery Check Valve Replacement

Delivery Check Valve and Governor Replacement

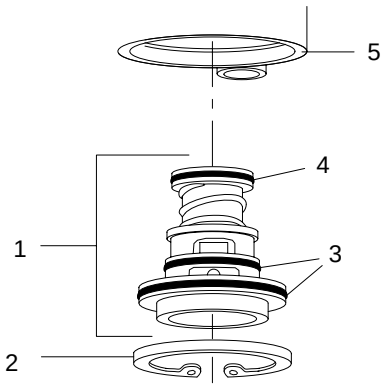
9. Install the adaptor fitting into the governor. Using the silicone grease, lubricate the remaining larger O-ring, and install it into the groove of the adaptor. Install the gasket supplied in the kit. Install the governor, and torque the capscrews 10 lbf·ft (14 N·m).
10. Perform the operational tests in **Subject 170**.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for purge valve replacement.



1. Purge Valve Assembly
2. Retaining Ring
3. O-Rings
4. Quad-Ring
5. Air Dryer

Fig. 1, Purge Valve Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the vehicle air reservoirs.
3. Remove and discard the snap ring that secures the purge valve assembly in the end cover.
4. Remove the purge valve assembly from the air dryer end cover.
5. Lubricate the new O-rings, and O-ring grooves of the new purge valve assembly.
6. Lubricate the end cover bore of the new purge valve assembly.

IMPORTANT: Use only the silicone grease supplied with the AlliedSignal replacement kit.

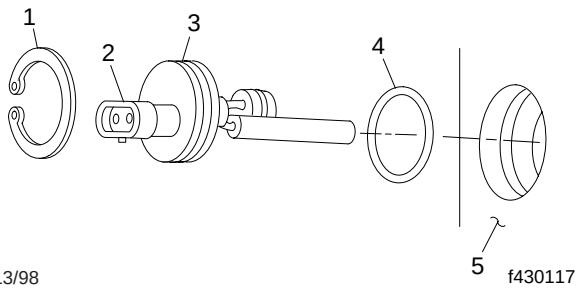
7. Install the two new O-rings on the purge valve housing cover, and the new quad-ring on the purge piston.
8. Install the new purge valve assembly in the end cover while making sure the purge valve housing is fully seated against the end cover.
9. Install the new retaining ring in its groove in the end cover.
10. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Lift the lock tab on the vehicle wiring harness connector and disconnect it from the air dryer base. See **Fig. 1**.



1. Retaining Ring
2. Heater/Thermostat Connector Plug
3. Heater/Thermostat Assembly
4. O-Ring
5. Air Dryer Body

Fig. 1, Heater and Thermostat Assembly

3. Remove and discard the retaining ring that secures the heater and thermostat assembly in the air dryer body.
4. Carefully pull the heater and thermostat assembly straight out of the air dryer body and discard it.
5. Using the silicone grease provided with the AlliedSignal replacement kit, lubricate the O-ring groove and O-ring of the new assembly.

IMPORTANT: Do not lubricate the heater stick or thermostat.

6. Install the O-ring on the heater/thermostat assembly. Then, slide the assembly into the air dryer body, making sure not to scrape insulation from the wires.
7. Install the retaining ring in the groove of the air dryer body, making certain that it is fully seated in the groove.
8. Remove the protective cover from the assembly.
9. Turn the ignition on without starting the engine. Make sure vehicle power is present at the contacts of the vehicle wire harness.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

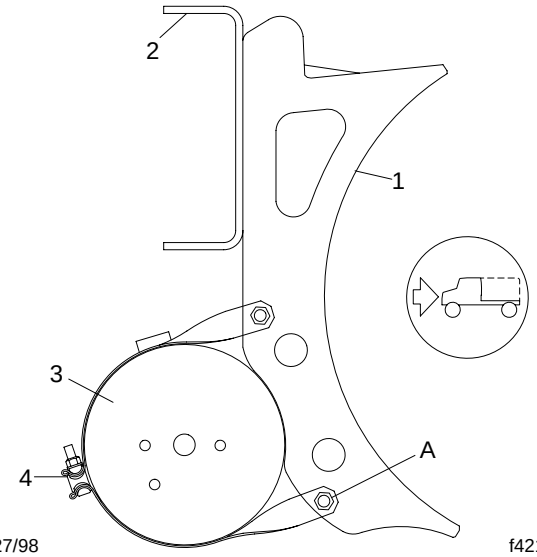
Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air system.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the air dryer. For instructions, see **Subject 110**.

NOTE: Loosen the bottom strap fastener first. See **Fig. 1**.

5. Remove the reservoir strap fasteners. Remove the reservoir.
6. If access is limited, do the next step first. If not, place a new reservoir in the mount, and install the strap fasteners. Tighten the fasteners 30 to 40 lbf·ft (41 to 54 N·m). Tighten the bottom strap fastener 136 lbf·ft (184 N·m).
7. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

   Install the air dryer. For instructions, see **Subject 110**.
8. Perform the operational test in **Subject 170**.



A. Loosen this bottom strap fastener.

1. Fuel Tank Bracket
2. Right Frame Rail
3. Air Reservoir
4. 3/8–16 Strap Fastener

Fig. 1, Air Reservoir, Fuel Tank Bracket Mounting

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operational Tests

1. Shut down the engine, and chock the tires.
2. Install a pressure gauge in one of the spare governor ports labeled "RES."
3. Close all drain cocks and start the engine. Build the air system to governor cutout, then shut down the engine.
4. Check all air lines and fittings leading to and from the air dryer for leakage. Note the pressure on the air gauge after the governor cutout pressure is reached, a rapid loss of pressure could indicate a leaking delivery port check valve or turbo cut-off valve.
5. To check for delivery check valve leakage, allow the system air pressure to charge and listen for the air dryer to purge. The purge should last about 30 seconds.
6. Gradually open the drain cock on the purge tank and exhaust any residual pressure.
7. Coat the drain cock with a soap solution. If leakage does not exceed a 1-inch (25-mm) bubble in 1 second, go to step 9.

   If leakage does exceed a 1-inch (25-mm) bubble in one second, proceed with the following step.
8. Apply the brakes a few times, bring the air pressure to a point below governor cut-in (about 95 psi [655 kPa]). The governor will then signal the end of the purge cycle, closing the turbo cut-off valve. Allow any delivery line air pressure to drain, then check again for leakage at the purge tank drain cock. If excessive leakage has stopped, the turbo cut-off valve should be checked.

NOTE: If after replacing the delivery check valve, rapid loss of system air pressure continues, the delivery check valve and turbo cut-off valve are still leaking. Check the valves.

9. Check the operation of the end cover heater and thermostat assembly during cold-weather operation as follows:

   9.1 Check the electric power to the air dryer. With the ignition or engine kill switch in the ON position, check for voltage to the heater and thermostat assembly using a voltmeter or test-light. Unplug the electrical connector at the air dryer and place the test leads on each of the connections of the female connector on the vehicle power lead. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check to see if a good ground path exists.

   9.2 Test the thermostat and heater operation. Turn off the ignition switch and cool the thermostat and heater assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the air dryer connector half. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly and 6 to 9 ohms for the 24-volt heater assembly.

   Warm the thermostat and heater assembly to about 90°F (32°C) and check the resistance again. The resistance should exceed 1000 ohms. If the resistance values obtained are within the stated limits, the thermostat and heater assembly is operating properly. If the resistance values obtained are outside the stated limits, replace the heater and thermostat assembly. For instructions, see **Subject 150**.
10. Check the pressure protection valves. Observe the pressure gauges of the vehicle as system pressure builds from zero. The primary gauge should rise until it reaches approximately 109 psi (752 kPa), then level off as the second pressure protection valve opens and allows the secondary volume to build. When the secondary pressure gauge passes through approximately 55 and 85 psi (379 and 586 kPa) there should be an associated leveling off of pressure as the third and fourth pressure protection valves open. Then, both the primary and secondary gauges should reach their full pressure of about 130 psi (896 kPa).

Troubleshooting Tables

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively

Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively	
Possible Cause	**Remedy**
There is excessive system leakage.	Using a soap and water solution, test for leakage at the air line fittings, drain cock (or valve), and the safety valve in the primary reservoir. Repair or replace as necessary. NOTE: A drop of 3 psi (21 kPa) in system air pressure per minute is normal.
The application air lines are leaking excessively.	Check the application air line, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
The delivery check valve is leaking excessively.	Replace the check valve. See **Subject 130**.
The compressor unloader O-rings are leaking excessively.	Troubleshoot the compressor. See **Group 13**.

Problem—There is Water in the Air Reservoirs

Problem—There is Water in the Air Reservoirs	
Possible Cause	**Remedy**
Maximum air dryer inlet temperature is exceeded due to improper discharge line length or improper line material.	Check the length of the air lines. The lines should not have excessive slack. If excessive slack exists in any air lines, replace the lines. For instructions, see **Section 42.07**.
The air dryer is not purging.	See **Problem—The Air System Will Not Charge**.
Purge time is insufficient due to excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively**.
The air by-passes the desiccant cartridge assembly.	If the vehicle uses a Holset compressor, inspect the feedback check valve for proper installation and operation.
The compressor is running loaded for long periods of time.	Check the vehicle air system for leakage.
The desiccant cartridge requires replacement.	Replace the desiccant cartridge. See **Subject 120**.

Problem—Safety Valve on the Air Dryer is Exhausting Air

Problem—Safety Valve on the Air Dryer is Exhausting Air	
Possible Cause	**Remedy**
There is a defective delivery check valve in the end cover of the air dryer.	Test to determine if air is passing through the check valve. Repair or replace the check valve. For replacement, see **Subject 130**.
The air system pressure is over 140 psi (965 kPa).	Replace the governor.
The safety valve setting is too low.	Replace the safety valve.

Troubleshooting

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve	
Possible Cause	**Remedy**
The air dryer purge valve is leaking excessively.	Test for leakage. With the compressor loaded, apply soap solution on the purge valve exhaust. If necessary, replace the purge valve. For instructions, see **Subject 140**.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or replace the governor. For replacement instructions, see **Section 13.01**.
The purge valve is frozen open.	Perform the heater operating test in **Subject 160**.
There is excessive system leakage.	See **Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively**.
The air dryer delivery check valve is defective.	See **Problem—Air Dryer is Constantly Purging (Cycling) or Purging Excessively**.
The turbo cutoff valve is leaking.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air System Will Not Charge

Problem—The Air System Will Not Charge	
Possible Cause	**Remedy**
The inlet and outlet air connections are reversed.	Connect the compressor discharge to the air dryer supply port. Reconnect the lines properly.
Kinked or blocked discharge line.	Check to determine if air passes through the discharge line. Check for kinks, bends, excessive carbon deposits, or ice blockage.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The turbo cutoff valve is stuck closed.	Repair or replace the turbo cutoff valve. For instructions, see **Subject 140**.
The purge valve is leaking excessively.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—The Air Dryer Does Not Purge or Exhaust Air

Problem—The Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The governor adaptor is plugged.	Test to determine if air flows through the purge control port when the compressor is unloaded. Check for adaptor obstruction. See **Problem—Constant Exhaust of Air at the Air Dryer Purge Valve**.
The air dryer purge valve is faulty.	If air is flowing through the purge valve in the "Remedy" above, repair or replace the purge valve. For replacement instructions, see **Subject 140**.
There are excessive bends in the discharge line (water collects and freezes).	The discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
The governor is defective.	Check the governor for proper "cut-in" and "cut-out" pressure, and excessive leakage in both positions. Repair or replace the governor. For replacement instructions, see **Section 13.01**.
The purge valve control piston is leaking.	Repair or replace the purge valve. For instructions, see **Subject 140**.

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust

Problem—Desiccant Material is Being Expelled from the Air Dryer Purge Valve Exhaust	
Possible Cause	**Remedy**
The air dryer is not securely mounted.	Replace the air dryer. For instructions, see **Subject 110**.
The desiccant cartridge is saturated or malfunctioning.	Replace the air dryer. For instructions, see **Subject 110**.
The compressor is passing excessive oil.	Troubleshoot the compressor. See **Group 13**. If necessary, replace the air dryer. For instructions, see **Subject 110**.

Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle

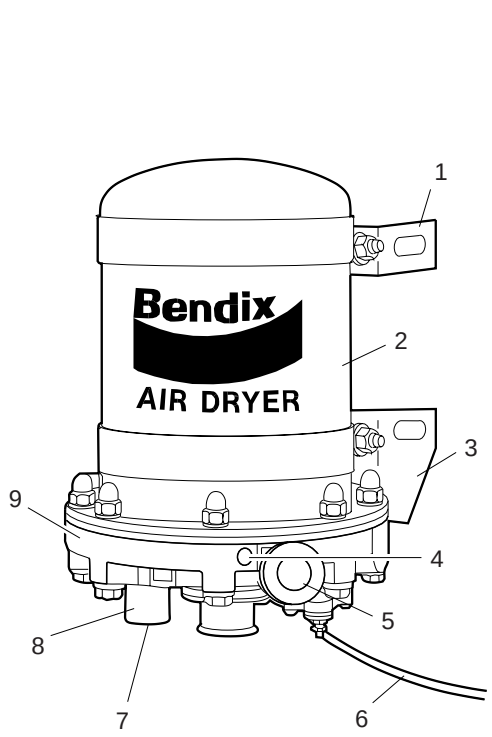
Problem—"Pinging" Noise is Excessive During Compressor Loading Cycle	
Possible Cause	**Remedy**
The compressor is a single cylinder with high pulse cycles.	A slight "pinging" sound may be heard during system build up when a single cylinder compressor is used. No remedy is needed.

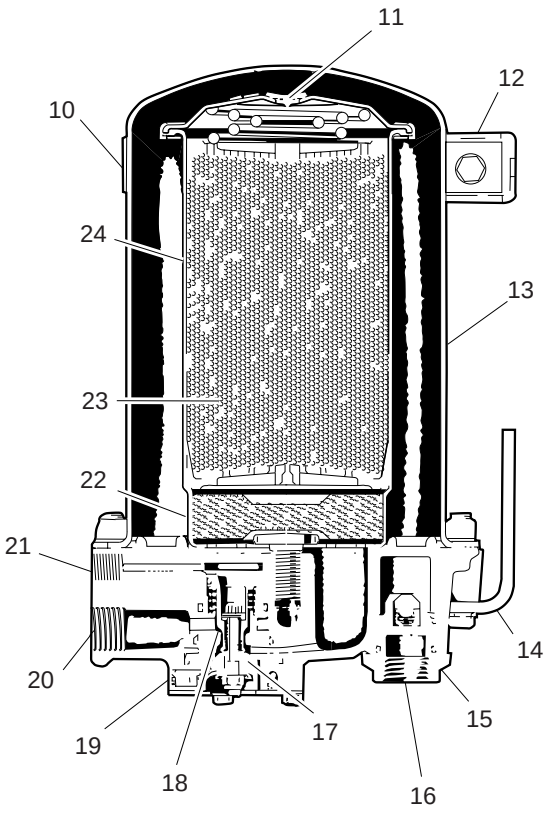
General Description

The function of the Bendix AD-9 air dryer is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. See **Fig. 1**.

purge valve housing assembly. The removable purge valve housing assembly features a purge valve mechanism and a turbocharger cutoff that are designed to prevent loss of engine turbocharger boost pressure during the purge cycle of the air dryer.

To ease servicing, the desiccant cartridge and dis-





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1. Upper Bracket
2. Outer Shell
3. Lower Bracket
4. Control Port
5. Supply Port
6. Wiring Harness
7. Delivery Port
8. Check Valve Assembly
9. End Cover
10. Upper Bracket Strap
11. Check Valve
12. Upper Bracket
13. Housing
14. Lower Bracket
15. Check Valve Assembly
16. Delivery Port
17. Purge Valve
18. Turbocharger Cutoff Piston
19. Purge Valve Housing Assembly
20. Supply Port
21. Control Port
22. Oil Separator
23. Desiccant Bed
24. Desiccant Cartridge

Fig. 1, Bendix AD-9 Air Dryer (cutaway view)

The AD-9 air dryer consists of the desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight bolts and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connections and the

charge check valve assembly are screw-in types. The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced without removing the air dryer from the vehicle. The

General Information

screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD-9 has three female pipe thread air connections; each is identified as follows in **Table 1**.

Air Dryer Port Identification	
Port I.D.	**Function/Connection**
4-CON	Control Port (purge valve control and turbocharger cutoff)
11-SUP	Supply Port (air in)
2-DEL	Delivery Port (air out)

Table 1, Air Dryer Port Identification

There are 2 versions of the AD-9 air dryer available:

- Standard Air Dryer; see **Fig. 2**:

  The standard air dryer uses a metal seat turbocharger cutoff valve. The function of the metal seat is to prevent turbocharger boost pressure loss through the air dryer during the purge (compressor unloaded) mode. Some low level turbocharger air leakage can occur in the unloaded mode.

- Drop-In Air Dryer; see **Fig. 3**:

  The drop-in style air dryer *can only be used* on vehicles equipped with Holset "E" and "QE" type air compressors. This air dryer eliminates any external plumbing requirements (such as the ECON valve, make-up line, and make-up line check valve). All of these components are an integral part of the air dryer.

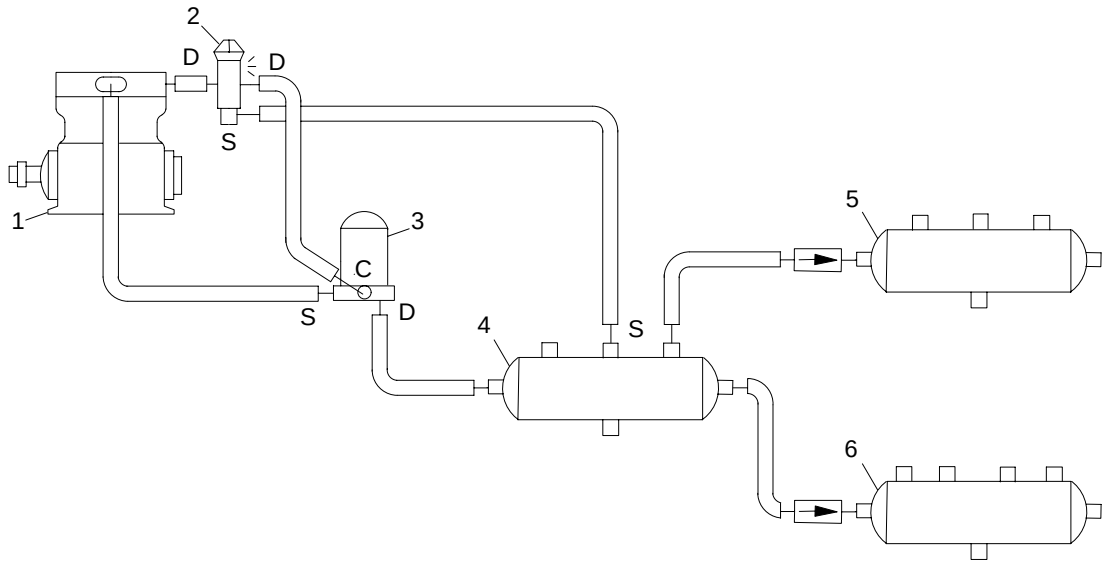
Principles of Operation

The AD-9 air dryer alternates between two operational modes or cycles during operation: the charge cycle and the purge cycle.

Charge Cycle

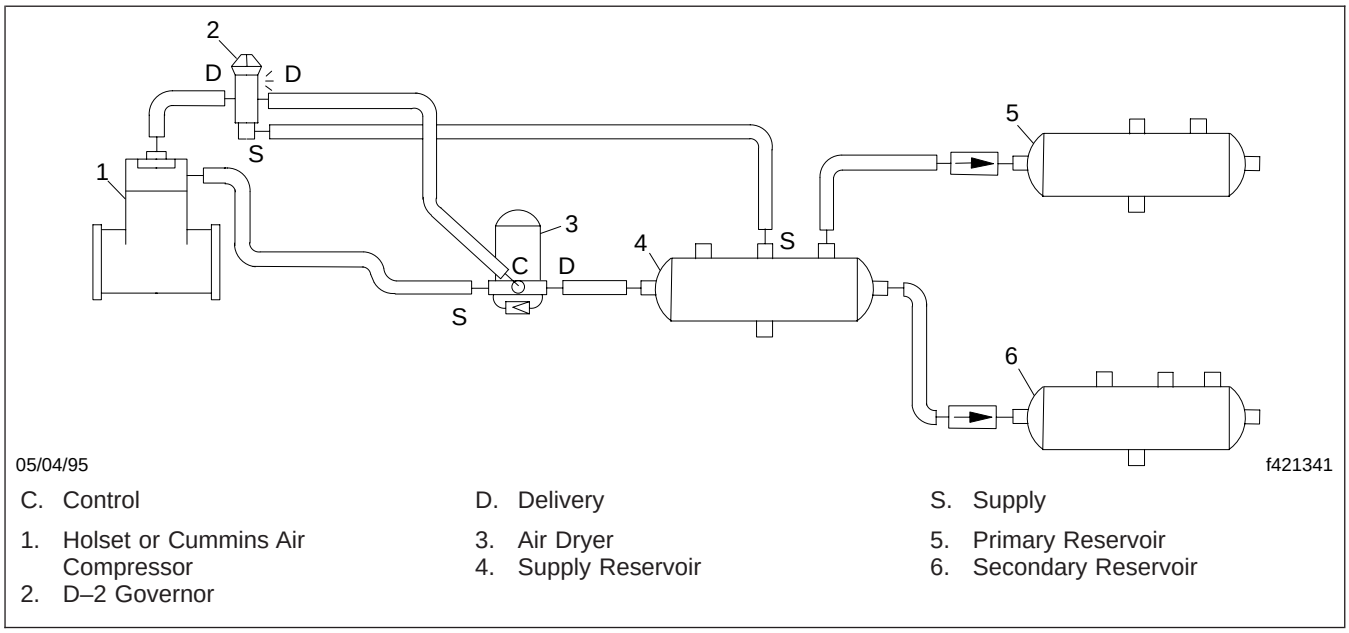
Figure 4 illustrates the AD-9 charge cycle.

When the compressor is loaded (compressing air), pressurized air, along with oil, oil vapor, water, and water vapor flow through the compressor discharge line to the supply port of the air dryer end cover. As air travels through the end-cover assembly, its direc-



C. Control
D. Delivery
S. Supply
1. Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply Reservoir
5. Primary Reservoir
6. Secondary Reservoir

Fig. 2, Standard Air Dryer Plumbing Diagram



C. Control
D. Delivery
S. Supply
1. Holset or Cummins Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply Reservoir
5. Primary Reservoir
6. Secondary Reservoir

Fig. 3, Drop-In Style Air Dryer Plumbing Diagram (with Holset or Cummins air compressor)

tion of flow changes several times, reducing the temperature, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, air flows into the desiccant cartridge. Once in the cartridge, air first flows through an oil separator, which removes water, oil, oil vapor, and solid contaminants.

Air exits the oil separator and enters the desiccant drying bed. Air flowing through the column of desiccant becomes progressively drier as water vapor sticks to the desiccant material in a process known as adsorption. The desiccant cartridge, using the adsorption process, typically removes 95 percent of the water vapor from the pressurized air.

Most of the dry air exits the desiccant cartridge through its integral single check valve to fill the purge volume between the desiccant cartridge and outer shell. Some air also exits the desiccant cartridge through the purge orifice adjacent to the check valve.

Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.

Purge Cycle

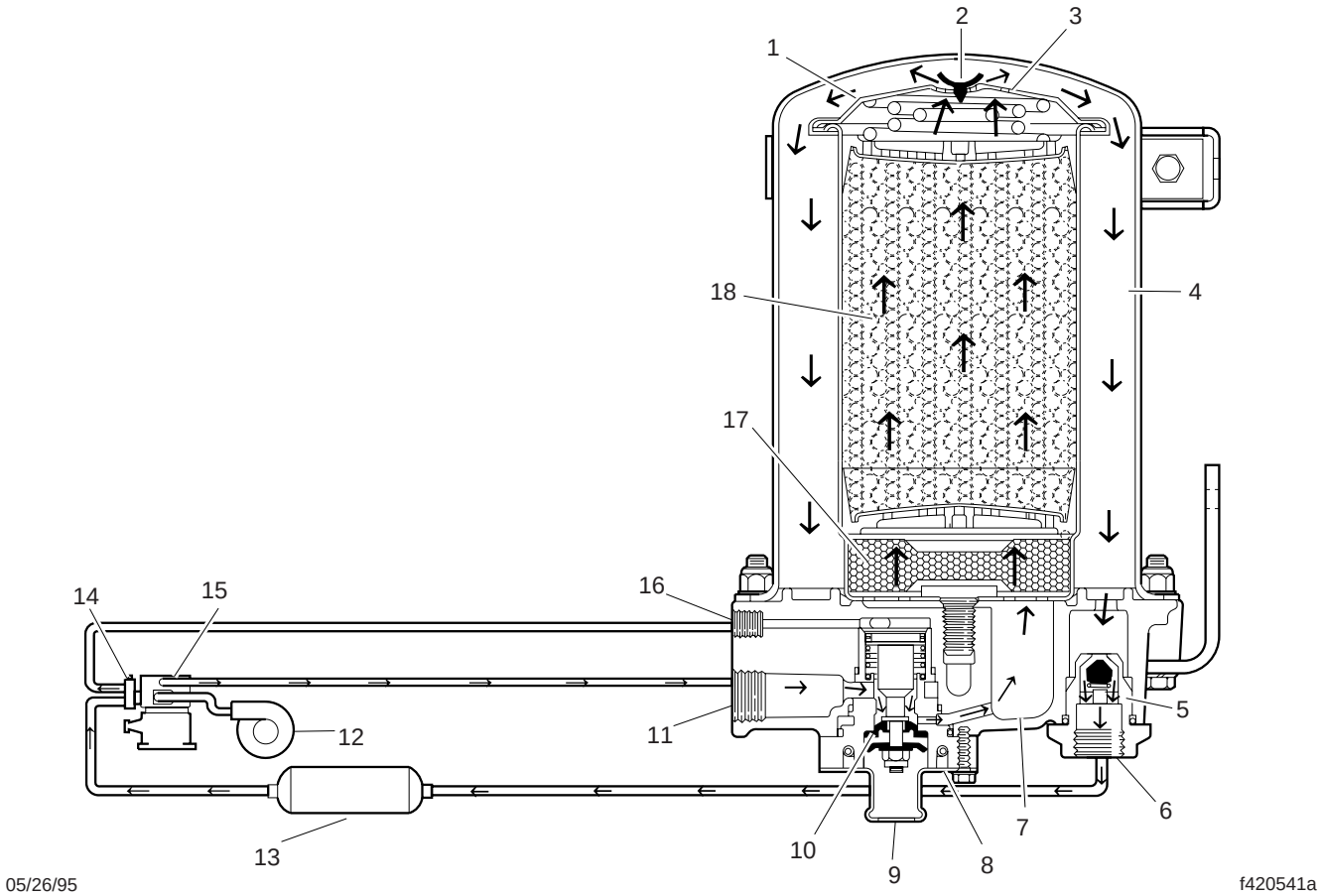
Figure 5 illustrates the AD-9 purge cycle.

When the brake system pressure reaches the governor cutout setting, the compressor unloads (air compression stopped), and the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the unloader mechanism and line connecting the governor unloader port to the AD-9 end cover control port. The purge piston moves in response to air pressure causing the purge valve to open to atmosphere and partially close off the supply of air from the compressor. This is further discussed under "Turbocharger Cutoff Feature."

Contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air that was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the desiccant drying bed to the open purge valve.

The initial purge and desiccant cartridge decompression last only a few seconds and are signaled by an audible burst of air at the AD-9 exhaust. The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the desic-

General Information



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Supply Port
12. Engine Turbocharger
13. Reservoir
14. Governor
15. Compressor
16. Control Port
17. Oil Separator
18. Desiccant Bed

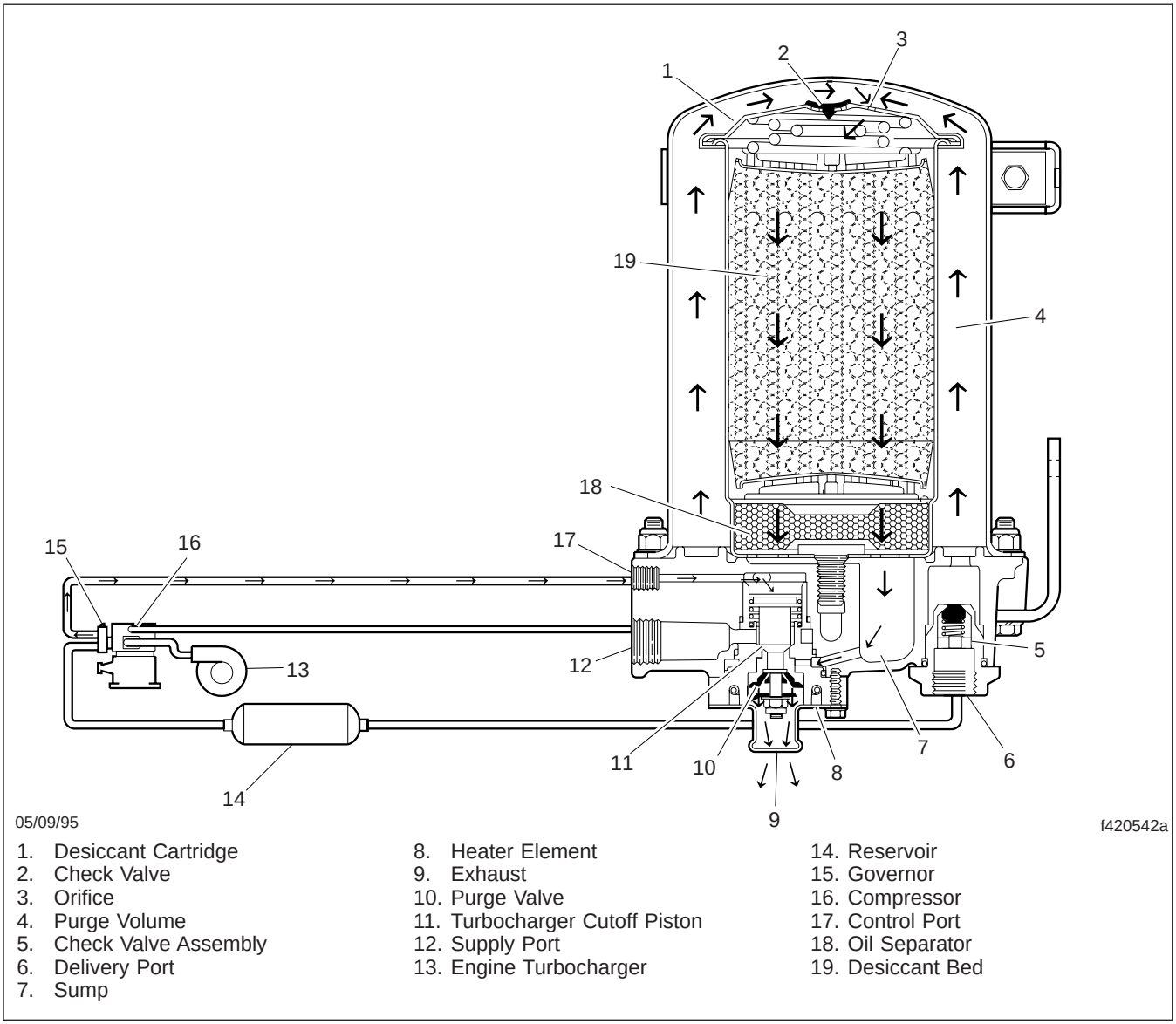
Fig. 4, AD-9 Charge Cycle

cant cartridge purge orifice and into the desiccant drying bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. Dry air flowing through the drying bed reactivates the desiccant material by removing the water vapor sticking to it. Generally, it takes 15 to 30 seconds for the entire purge volume of a standard AD-9 to flow through the desiccant drying bed.

The end cover single check valve assembly prevents compressed air in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

The purge valve will remain open after the purge cycle is complete, and will not close until air brake system pressure is reduced and the governor signals the compressor to charge.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the *108SD and 114SD Maintenance Manual* for intervals and procedures.



1. Desiccant Cartridge
2. Check Valve
3. Orifice
4. Purge Volume
5. Check Valve Assembly
6. Delivery Port
7. Sump
8. Heater Element
9. Exhaust
10. Purge Valve
11. Turbocharger Cutoff Piston
12. Supply Port
13. Engine Turbocharger
14. Reservoir
15. Governor
16. Compressor
17. Control Port
18. Oil Separator
19. Desiccant Bed

Fig. 5, AD-9 Purge Cycle

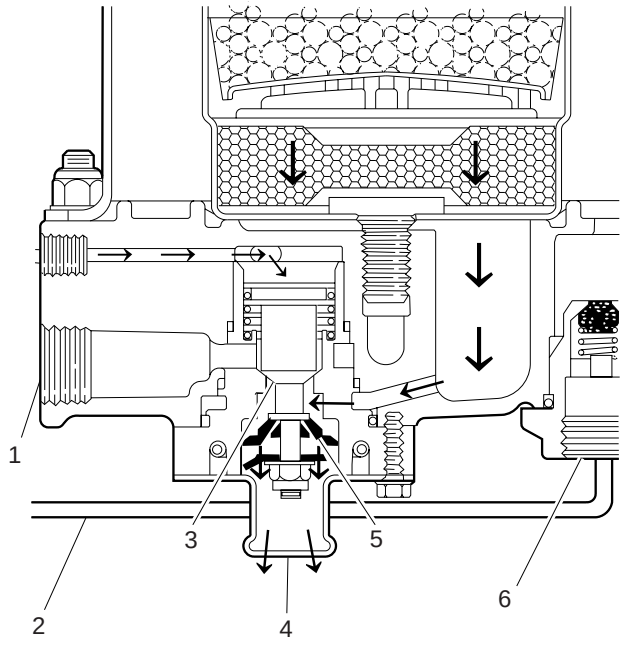
Turbocharger Cutoff Feature

Figure 6 shows the AD-9 turbocharger cutoff.

Primarily, the turbocharger cutoff valve prevents loss of engine turbocharger air pressure through the AD-9 in systems where the compressor intake is connected to the engine turbocharger. The turbocharger cutoff valve also reduces the puffing of air out the open exhaust when a naturally aspirated, single-cylinder compressor equipped with an inlet check valve is in use.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbocharger cutoff valve (tapered portion of the purge piston) contacts its mating metal seat in the purge valve housing. With the turbocharger cutoff valve seated (closed position), air in the discharge line and AD-9 supply port is restricted from entering the air dryer. While the turbocharger cutoff *effectively* pre-

General Information



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1. Supply Port
2. Discharge Line
3. Turbocharger Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 6, AD-9 Turbocharger Cutoff

vents loss of turbocharger boost pressure to the engine, some seepage of air may be detected under certain conditions of compressor, engine, and turbocharger operation. Even so, there will be low pressure trapped in the discharge line.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don't disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

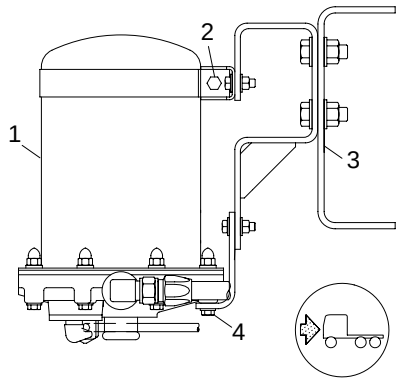
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and chock the tires.
2. Completely drain all of the reservoirs.
3. Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle. See **Fig. 1**.



1. Air Dryer
2. Upper Bracket Strap Bolt
3. Right Frame Rail
4. End Cover Fastener

Fig. 1, Air Dryer Mounting

4. Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the exhaust cover.
5. Loosen the bolt that secures the upper bracket strap.
6. Remove, save, and mark the two end cover bolts, locknuts, and four special washers that retain the lower mounting bracket to the end cover. Also mark the two holes of the end cover (these receive the two longest bolts.)
7. Remove the air dryer from its mounting brackets.

Installation

1. Position the air dryer up into the upper mounting bracket and strap. See **Fig. 1**. Align the two unused holes in the end cover with the bottom mounting bracket so that the bottom bracket supports the air dryer. The end cover should rest on the bracket.
2. Using the two longest bolts, four special washers, and two locknuts, secure the air dryer to the lower bracket. Tighten the two remaining bolts 23 to 32 lbf·ft (31 to 43 N·m).
3. Tighten the capscrew and nut on the upper mounting bracket strap 48 lbf·in (542 N·cm).
4. As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
5. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
6. Test the air dryer following the instructions in "Testing" below.

Testing

Check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it

Air Dryer Removal and Installation

doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

Figure 1 shows an exploded view of the AD-9 air dryer.

NOTICE

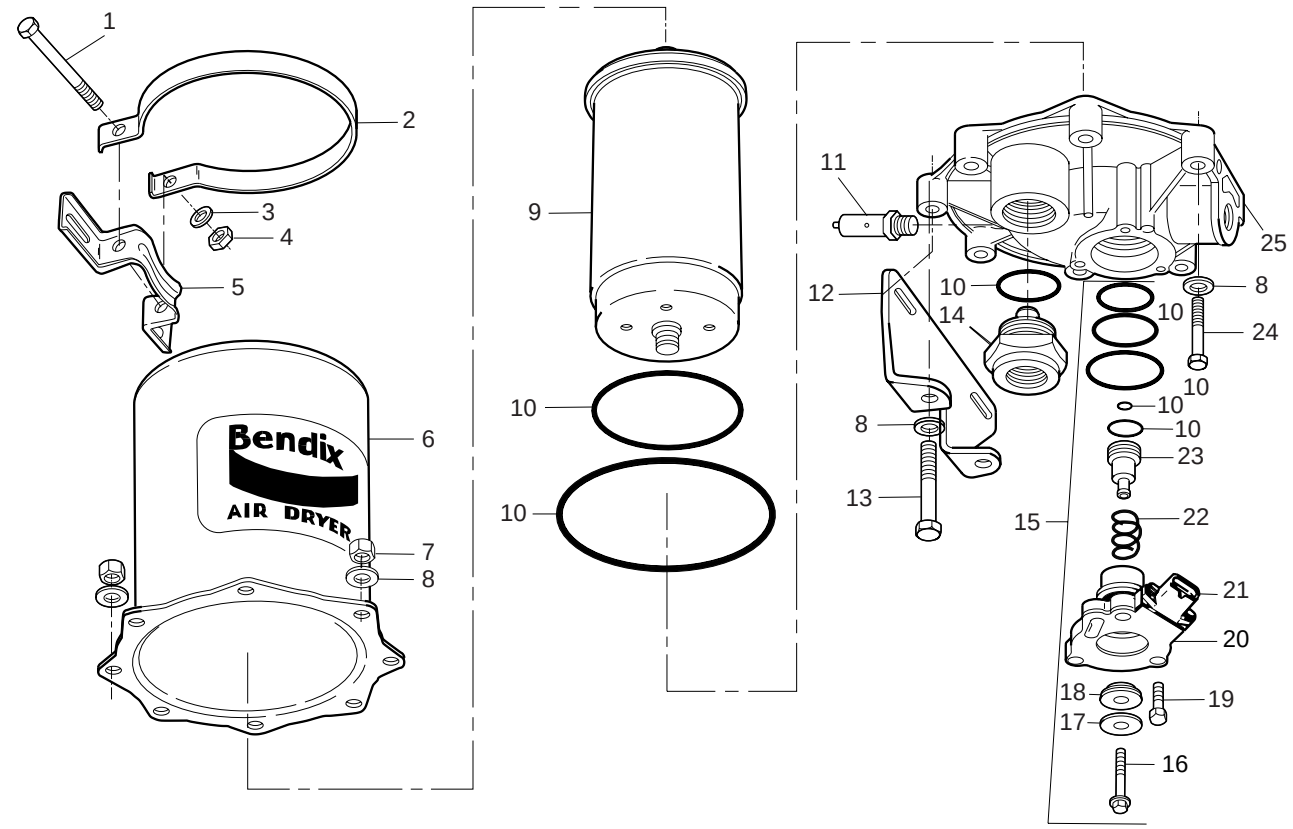
While servicing the air dryer, do not use a clamping device (vise, C-clamp, etc.) to hold any die-cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Remove the check valve assembly and O-ring. Remove the O-ring from the check valve assembly.
3. Remove the purge valve housing assembly, as follows.
   - 3.1 Remove the three self-tapping screws that secure the purge valve housing assembly to the end cover assembly.
   - 3.2 Pull the purge valve housing assembly out of the end cover assembly.
   - 3.3 Remove and discard the three O-rings from the exterior of the purge valve housing assembly.

   NOTE: These O-rings may lodge in and have to be removed from the end cover bores.
4. Remove the heater and thermostat assembly, as follows.
   - 4.1 Remove and discard the two screws that attach the heater and thermostat assembly to the purge valve housing.
   - 4.2 Gently rotate the electrical connector to the left until the thermostat clears the purge valve housing. Then, slide the heater element out, to the right and up. Discard the assembly.
5. Disassemble the purge valve housing assembly, as follows.
   - 5.1 If a flat non-extended exhaust cover is used, leave it intact while servicing the purge valve housing assembly.

     If an extended type exhaust cover is used for the attachment of an exhaust hose, *carefully* separate the exhaust cover from the purge valve housing. *Use a thin flat blade to pry the exhaust cover off, taking care not to damage the potting material (RTV sealant) under the cover.*
   - 5.2 Remove the capscrew from the bottom of the purge valve housing assembly. Remove the diaphragm and the purge valve from the purge valve housing.
   - 5.3 Remove the purge piston, the return spring, and two O-rings (one on the outside and the other in the inside of the purge piston).
6. Remove the remaining six bolts (Item 24), locknuts (Item 7), and twelve special washers (Item 8) that secure the end cover to the housing (Item 6). Separate the end cover and desiccant cartridge (Item 9) from the housing (Item 6).
7. Remove the end-cover-to-outer-housing O-ring.
8. Don't remove the safety valve (Item 11) from the end cover unless it is known to be inoperative. If replacement is needed, apply thread sealant or Teflon® tape on the threads of the replacement valve and tighten 120 to 400 lbf·in (1356 to 4519 N·cm). Make sure the drain hole (slot) is facing down.
9. Place a strap or chain wrench around the desiccant cartridge (Item 9) so that it is about 2 to 3 inches (5 to 8 cm) away from the end cover. Rotate the cartridge counterclockwise until it completely separates from the end cover.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



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1. 5/16-Inch x 4-1/2 Inch Upper Bracket Bolt
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Capscrew
17. Exhaust Diaphragm
18. Purge Valve
19. 1/4-Inch Tapping Screw
20. Purge Valve Housing
21. Heater and Thermostat Assembly
22. Return Spring
23. Purge Piston
24. 3/8-Inch Capscrew
25. End Cover

Fig. 1, AD-9 (exploded view)

NOTE: Torque of up to 50 lbf·ft (68 N·m) may be needed to do this disassembly.

10. Remove the desiccant cartridge O-ring from the end cover.

Cleaning and Inspection

1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.
2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.

5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
9. Replace all removed O-rings with new ones that are provided in the kits.

   Replace parts that show any of the conditions described in the previous steps.

Assembly

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.

IMPORTANT: When installing the heater and thermostat assembly, make sure that the seal ring under the electrical connector is not twisted.

2. Install the heater and thermostat assembly, as follows.
   - 2.1 Insert the heater element into the slot in the purge valve housing until the connector contacts the housing.
   - 2.2 Gently push the connector and the thermostat to the left until the thermostat clears the cavity in the housing. Then, turn the connector to the right while pushing the thermostat all the way down into the cavity.

     Make sure that the connector is seated evenly against the housing.
   - 2.3 Install the two mounting screws. Tighten the screws 10 to 20 lbf·in (113 to 226 N·cm).
3. Assemble the purge-valve housing, as follows.
   - 3.1 Install the O-ring on the purge piston. Place the return spring in the purge-valve housing. Place the O-ring in the bore of the purge piston. Insert the purge piston into the spring. Push the piston into the purge-valve housing until it bottoms.
   - 3.2 While holding the purge piston in, install the following parts: the purge valve with its rubber side first, followed by the diaphragm and the capscrew. Torque the purge valve capscrew 60 to 80 lbf·in (678 to 904 N·cm).
   - 3.3 Install the three O-rings in their correct locations on the purge-valve housing.
   - 3.4 If an extended type exhaust cover was removed, install it on the purge-valve housing assembly, making sure the "bubble" portion is positioned over the thermostat.
   - 3.5 Install the assembled purge-valve housing in the end cover; make sure you orient both parts so that the connector is about 10 degrees clockwise from the supply port. Also, make sure the purge-valve housing is fully seated against the end cover.
   - 3.6 Secure the purge-valve housing to the end cover using the three self-tapping screws. Start all three screws by hand, then torque them 85 to 125 lbf·in (960 to 1412 N·cm).
4. Install an O-ring on the check-valve assembly, then install the assembly in the end cover using a socket. Tighten it 200 to 250 lbf·in (2260 to 2825 N·cm).
5. Install the desiccant cartridge in the end cover, as follows.
   - 5.1 Install the smaller desiccant cartridge O-ring in its groove in the end cover. Using a light coat of barium grease, lubricate the bottom of the desiccant cartridge in the area that will contact the O-ring and end cover.
   - 5.2 Screw the desiccant cartridge into the end cover until the cartridge contacts the O-ring. Using a strap or chain wrench positioned 2 to 3 inches (5 to 8 cm) from the bottom of the cartridge, turn the desiccant cartridge clockwise 180 to 225 degrees beyond the position where initial contact was made with the O-ring. Torque should not exceed 50 lbf·ft (68 N·m).
6. Install the housing over the desiccant cartridge, as follows.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

6.1 Install the large O-ring on the shoulder in the end cover. Place the housing over the desiccant cartridge and align the holes.

6.2 Install the six bolts, locknuts, and the twelve special washers, making sure they are positioned as referenced earlier. The two longer bolts will be used to secure the air dryer to its mounting bracket.

6.3 Tighten the six bolts and nuts in a star pattern (depending on lower bracket location) 23 to 32 lbf·ft (31 to 43 N·m). See **Fig. 2**.

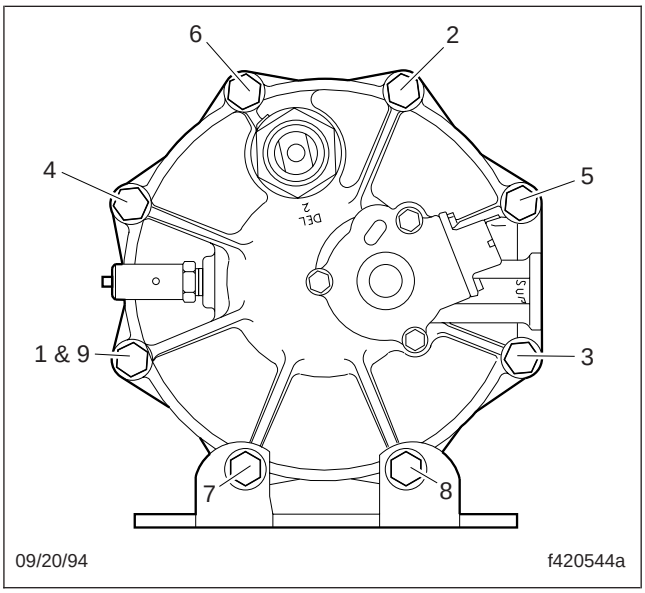


Fig. 2, End Cover to Housing Torque Pattern

NOTE: The two remaining bolt holes in the end cover and two 3/8-inch bolts must be the ones marked during removal to ensure correct orientation of the ports and adequate length of the bolts.

7. Connect the electrical connector to the heater and thermostat assembly.
8. Test the air dryer for proper operation. For instructions, see "Testing" below.

Testing

Check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
The check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at the opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (827 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Holset "E" type compressor.	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO-08-19 entitled "Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
The air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
The check valve in the air dryer end cover is inoperative.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
The air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
The air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat, following instructions in this manual.

Troubleshooting

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
Desiccant cartridge is not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

The following diagrams are for general reference. For vehicle-specific plumbing diagrams, refer to EZWiring.

For an air brake installation with two dash valves (Daimler Trucks diagrams D12-23500-000 and D12-24181-000) and a conventional air dryer, see **Fig. 1**, **Fig. 2**, **Fig. 3**, **Fig. 4**, **Fig. 5**, **Fig. 6**, and **Fig. 7**.

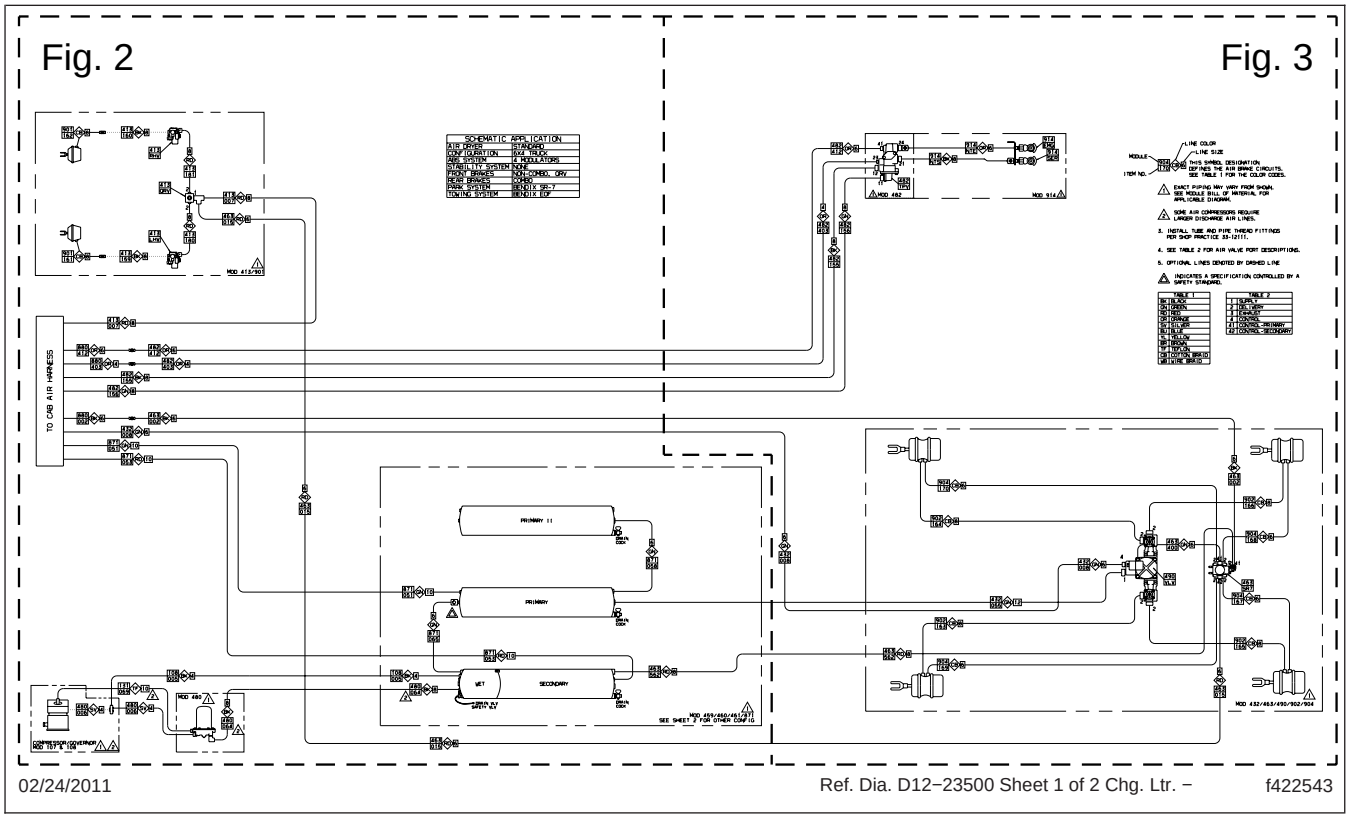


Fig. 1, Air Plumbing Diagram with Standard Air Dryer, (full view)

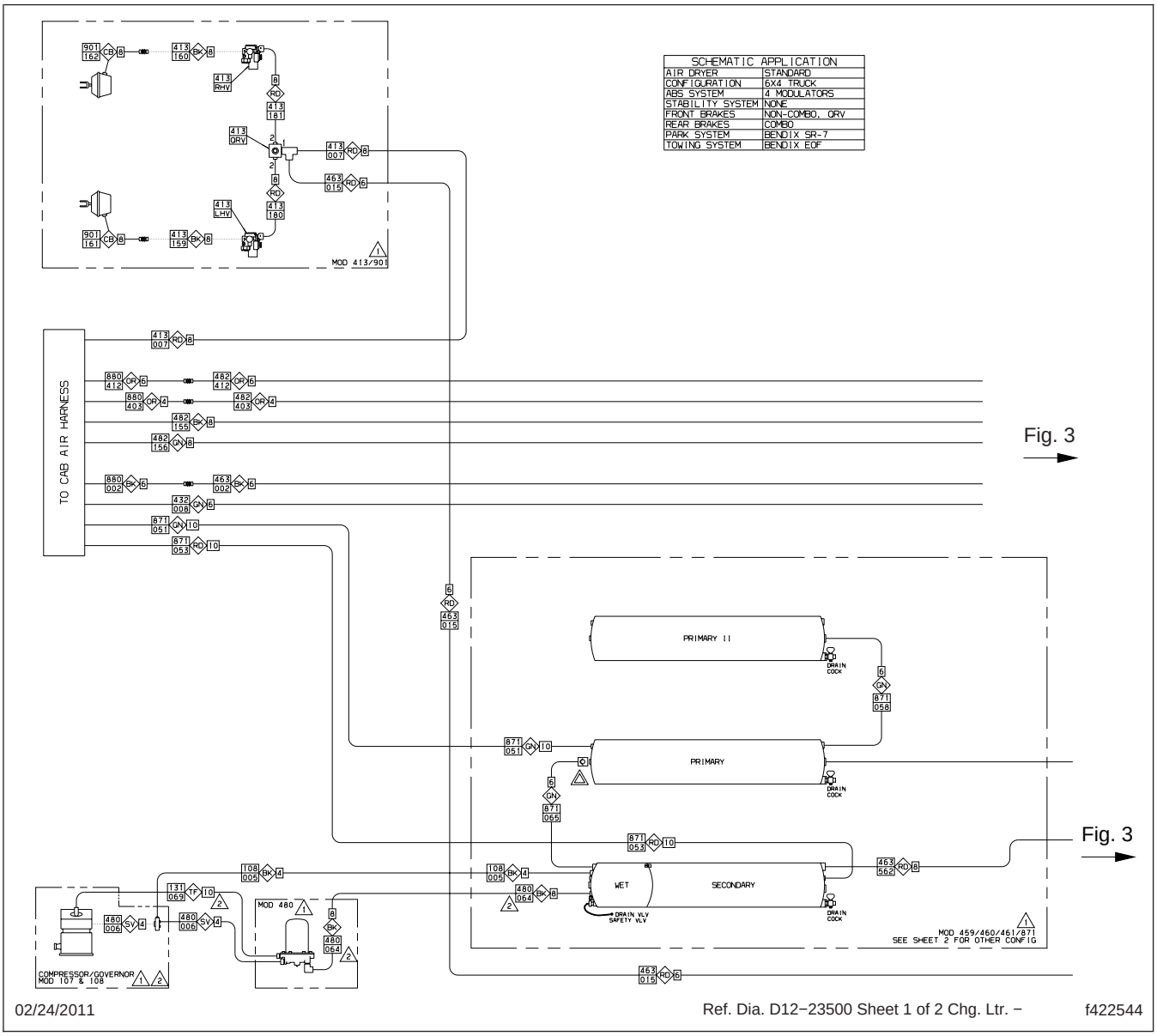


Fig. 2, Air Plumbing Diagram with Standard Air Dryer, (partial view)

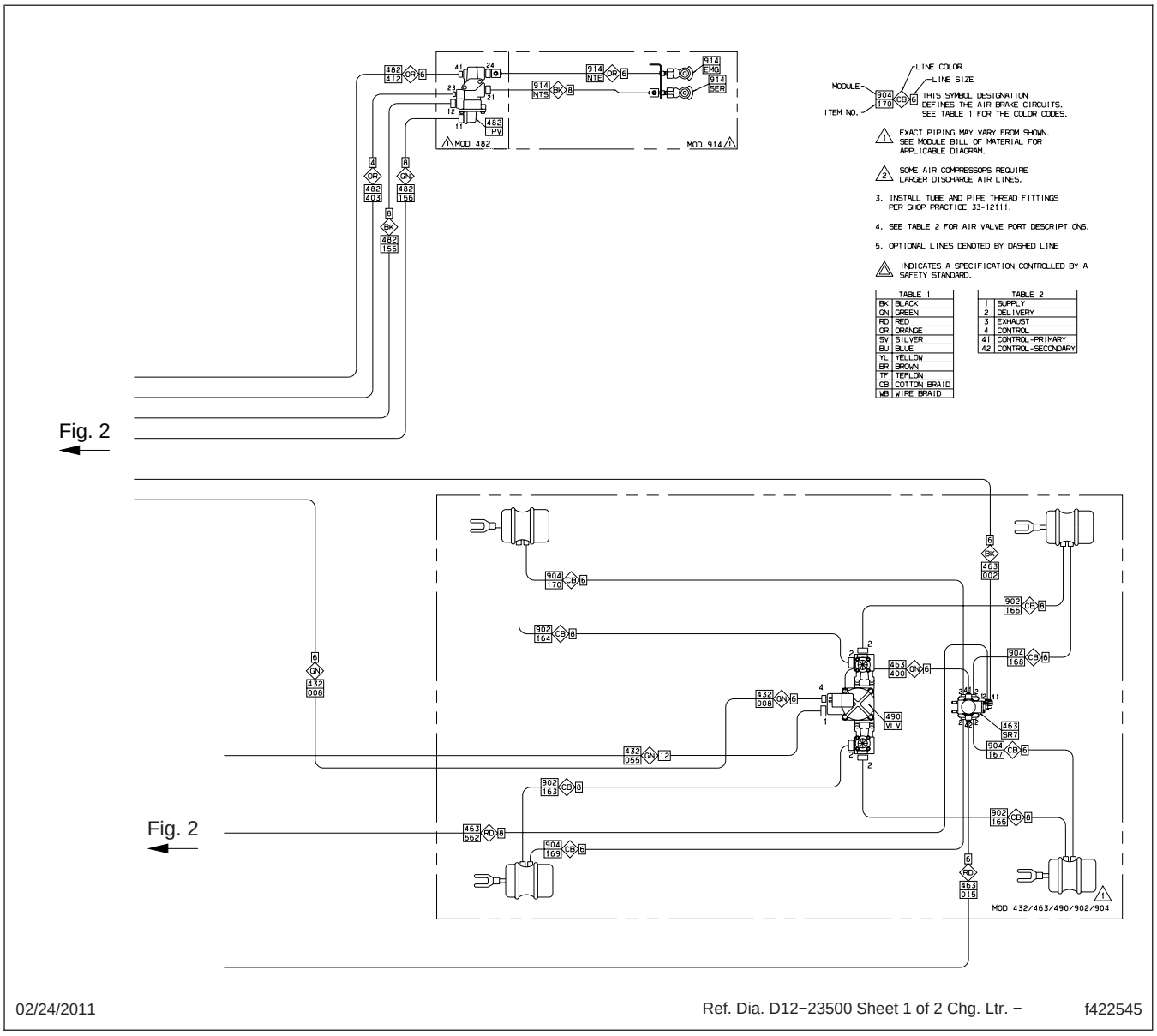


Fig. 3, Air Plumbing Diagram with Standard Air Dryer, (partial view)

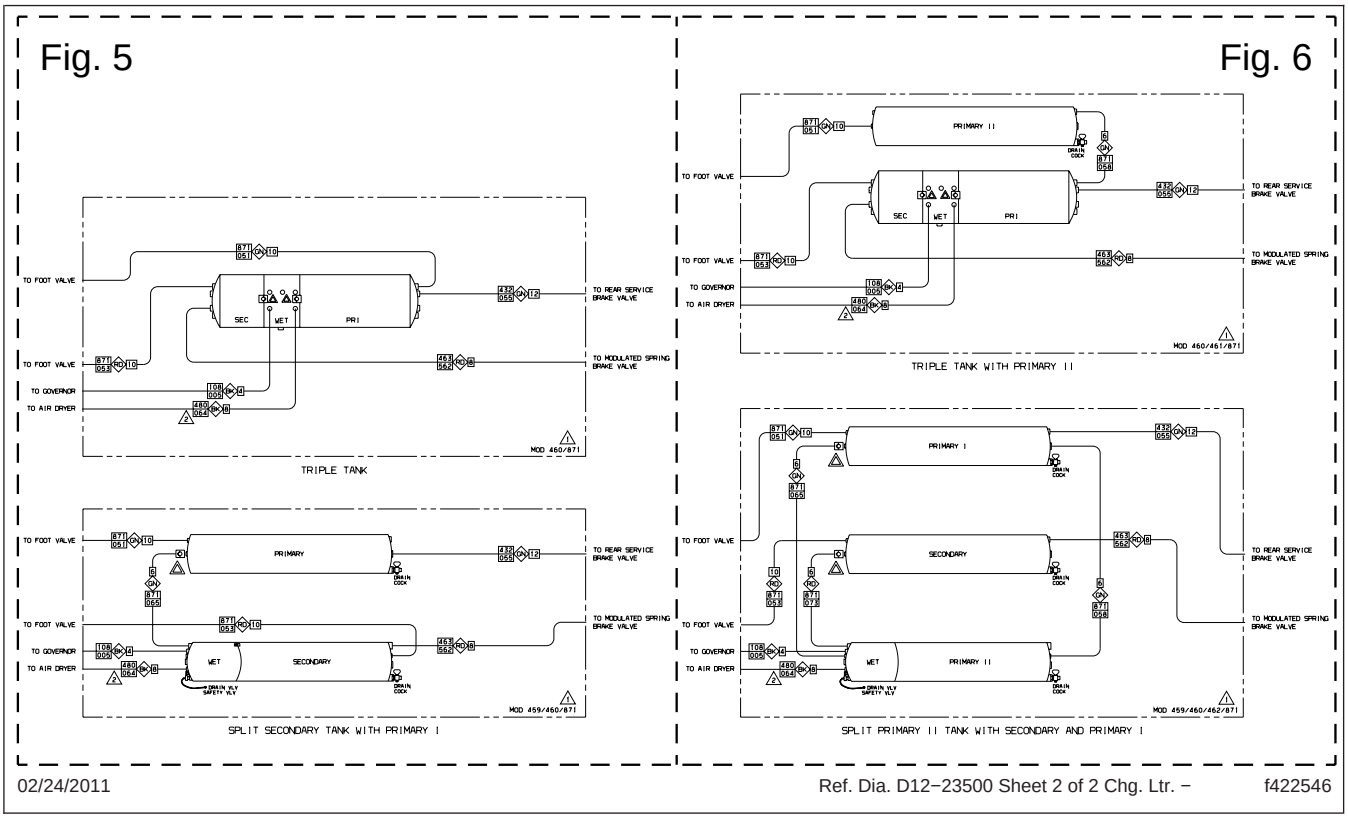


Fig. 4, Chassis Air Brake Plumbing with Standard Air Dryer, (full view)

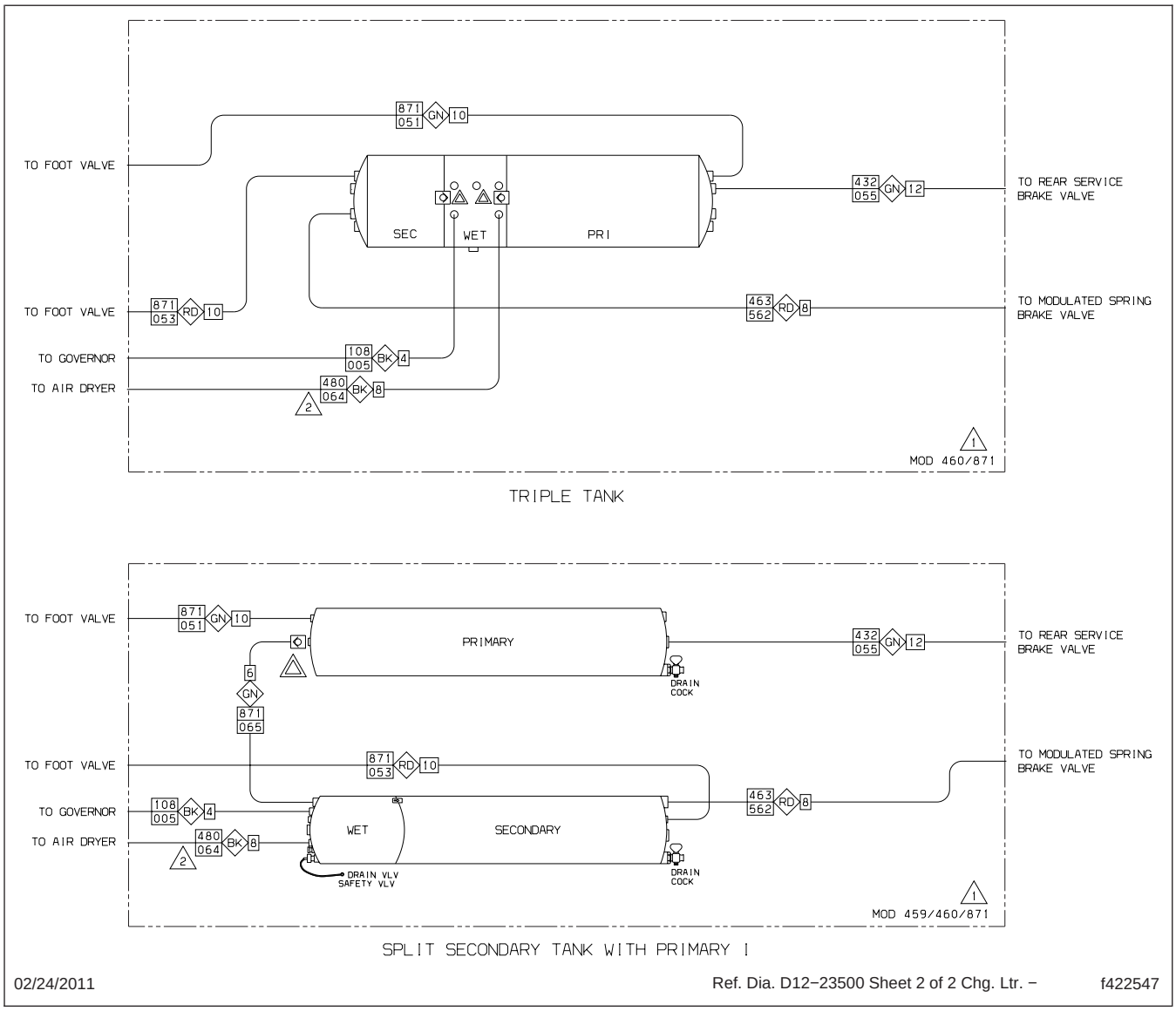


Fig. 5, Chassis Air Brake Plumbing with Standard Air Dryer, (partial view)

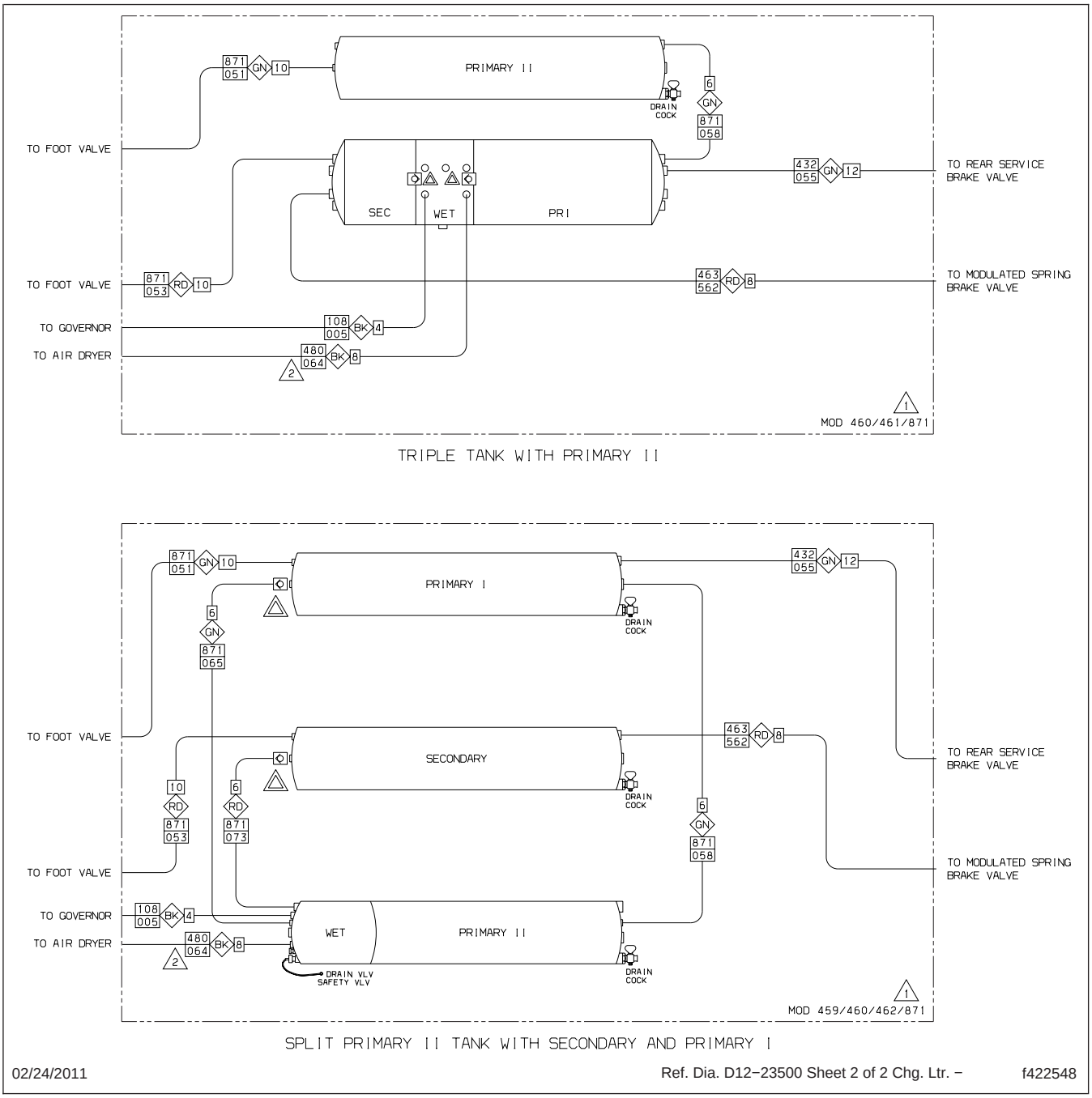


Fig. 6, Chassis Air Brake Plumbing with Standard Air Dryer, (partial view)

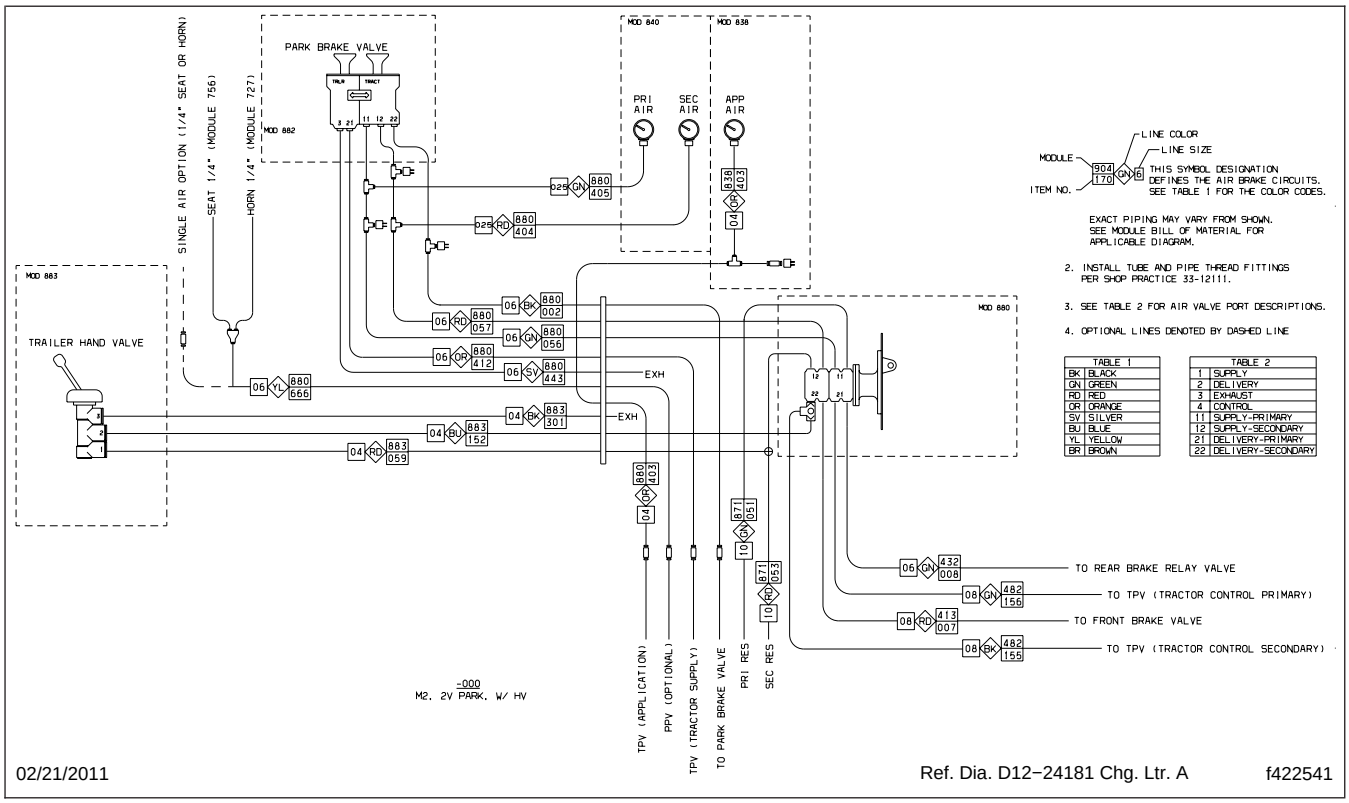


Fig. 7, Cab Air Brake Plumbing with Standard Air Dryer

General Information

NOTE: Vehicles with a Bendix Dryer Reservoir Module (DRM) have a separate primary reservoir. The secondary reservoir and purge reservoir are part of the DRM. See **Section 42.03** for more information on the DRM.

Air reservoirs serve two main purposes:

- They store compressed air used to apply the brakes and operate other air-powered devices, such as air seats, cab suspension, transmission shift, and rear suspension.
- They provide a place where air, heated during compression, can cool, and water vapor can condense into a liquid. Also, air reservoirs collect small amounts of oil passed by the compressor.

Each vehicle is equipped with three or more air reservoirs, depending on the number of rear axles. On all vehicles, each reservoir is identified as one of three types: supply, primary, or secondary.

A supply reservoir receives compressed air from an air dryer or directly from the compressor. Also referred to as the wet tank, its functions are to collect most of the water and oil condensate from the air, and to supply air to the other reservoirs. With a properly functioning air dryer, there should be little or no water or oil in any reservoir.

In the supply reservoir is a safety valve that protects the air system against excessive air pressure buildup. The supply reservoir is usually mounted on the left-hand frame rail.

Primary reservoirs are air sources for the brakes on the rear axles. One or more primary reservoirs are installed on a vehicle, depending on the number of rear axles and the air system configuration. The first primary reservoir, plumbed to the supply tank is equipped with an in-line check valve. Other primary tanks plumbed to this first primary tank will not have check valves. The main primary reservoir is usually mounted on the right-hand frame rail.

A secondary reservoir is the air source for the front axle brakes. It is usually mounted on the left-hand frame rail. The secondary reservoir is usually the aft compartment of the internally isolated air tank mounted on the left-hand frame rail. The forward compartment is the supply reservoir. There is an internal check valve that feeds the secondary reservoir from the supply reservoir.

The secondary reservoir supplies air to a pressure protection valve. This valve prevents complete loss of secondary air pressure if there is an air leak in any non-brake accessory.

All air reservoirs are equipped with drain valves to eject the water and oil emulsion from the tanks.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and stop the engine before working under the vehicle. Releasing air from the system may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters; they will apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- When working with compressed air, always wear safety glasses, and never exceed recommended air pressure.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if not correctly disassembled. Use only correct tools and observe all precautions regarding use of those tools.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement and Leak Elimination

NOTE: If the vehicle is equipped with an automatic moisture-ejection valve, see **Section 42.14** for replacement instructions.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Drain the air system.
3. Using two wrenches (hold the coupler in place with one of them), unscrew the drain valve from the coupler. Clean off the threads inside the coupler on the reservoir, removing all sludge and sealant buildup.

   Obtain a new drain valve if leaks occurred through the body of the valve.

   If leaks occurred at the joint of the drain valve and coupler, clean off the sludge and sealant from the threads of the valve. Check for damaged threads on the valve and inside the coupler. Replace damaged parts. If no damage exists, leakage was probably due to inadequate tightening of the drain valve in the coupler.
4. Apply Loctite®, or an equivalent sealant, to the end threads of the drain valve or coupler, as applicable, and install finger-tight. Tighten one and one-half additional turns (use two wrenches if installing the drain valve).
5. Perform a leak test after completing the installation. If leaks occur at the joint of the drain valve and coupler, tighten the valve up to one additional turn to stop the leaks.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

NOTE: For replacement of the Bendix Dryer Reservoir Module (DRM), see **Section 42.03**.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the rear tires.
2. Drain the air system.

NOTE: If access is limited, reverse the order of the next two steps and remove the air lines, couplers, and valves after removing the reservoir from its mount.

3. Mark or tag all reservoir air lines, couplers, and valves for later assembly, then disconnect the components. Cap the exposed ports tightly to keep out contaminants.
4. Remove the reservoir, as follows. See **Fig. 1** for a fuel tank bracket mounting and **Fig. 2** for a frame rail mounting.

   4.1 Loosen the reaction joint clamp bolts.

   NOTE: If the reservoir is mounted on the fuel tank bracket, loosen the bottom strap fastener first.

   4.2 Remove the reservoir strap fasteners.

   4.3 Remove the reservoir.

NOTE: If access is limited, connect the air lines, couplers, and valves before installing the new reservoir.

5. If there is sufficient work space, place a new reservoir in the mount and install the strap fasteners.
   - Tighten the strap fasteners 64 lbf·ft (87 N·m).
   - Tighten the reaction joint clamp bolts 26 lbf·ft (35 N·m).
6. Connect all air lines, couplers, and valves to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed in **Section 42.07, Subject 100**.

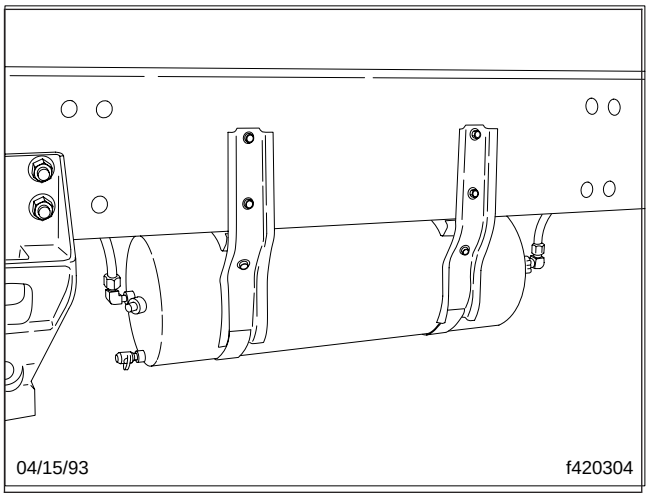


Fig. 1, Air Reservoir, One-Piece Strap (Under Frame Rail) Mounting

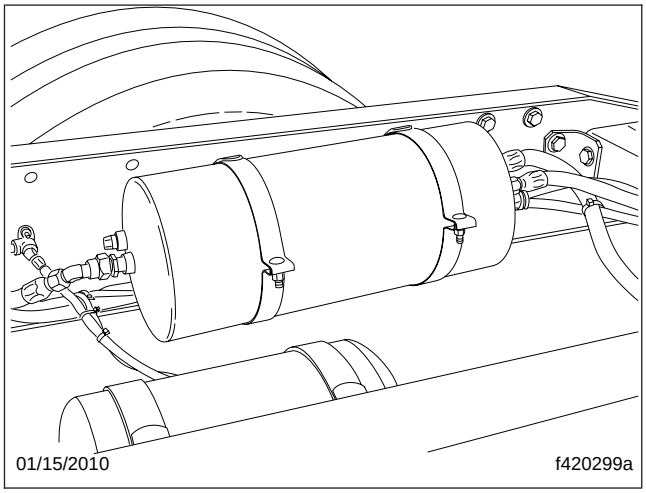


Fig. 2, Air Reservoir, Frame Rail Mounting

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Internal Check Valve Replacement, Two-Chamber Air Reservoir

General Information

Contamination in two-chamber, wet/secondary, reservoirs may cause the inline check valve to become clogged or stuck closed. This can result in insufficient air buildup. If insufficient air buildup is noted, replace the check valve. If the check valve can not be removed (due to corrosion), it is acceptable to install a bypass line.

There are two styles of check valves that may have been installed in the tank. An internal check valve is threaded into the internal wall that separates the wet side and secondary side of the reservoir. Or an external check valve is mounted in a port on the top surface of the reservoir.

Internal Check Valve Replacement (located in the separator wall of the reservoir)

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. Disconnect the air lines, then remove the reservoir from the vehicle.
4. On the supply (wet) side of the reservoir, disconnect the pressure-protection valve, and the 90-degree elbow located on the end of the reservoir.
5. The check valve is located on the interior wall that separates the sides of the reservoir. To reach it, use a 1/4-inch drive, 1/2-inch deep-well socket with a 1/4- to 3/8-inch drive adapter, and necessary 3/8-inch extensions to reach the valve. Tape the socket and extensions, to ensure the valve will stay in the socket, and that the wrench assembly will stay together inside the tank. Insert the socket assembly through the end port of the reservoir, and remove the valve. See **Fig. 1** and **Fig. 2**.

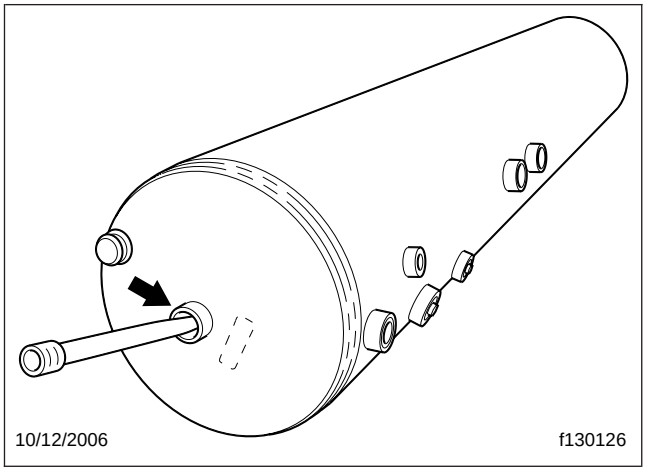
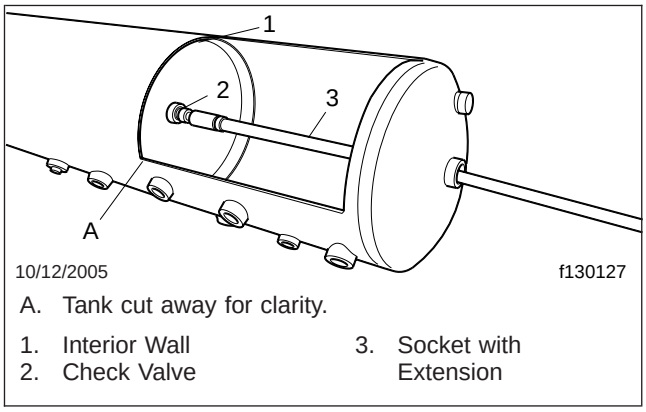


Fig. 1, Accessing the Internal Check Valve



A. Tank cut away for clarity.

1. Interior Wall
2. Check Valve
3. Socket with Extension

Fig. 2, Cutaway View of Split Air Reservoir

NOTICE

Take care not to drop the check valve into the reservoir when removing or installing it. The reservoir can not be used if the check valve is lost in it. A loose check valve could scratch the teflon coating of the interior of the reservoir, causing it to corrode. If the check valve is not recoverable, replace the reservoir.

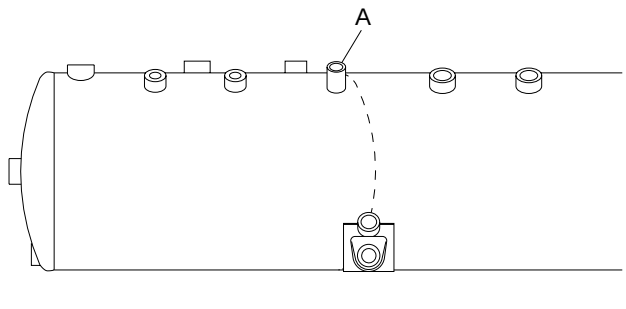
6. Install a new check valve.
7. Attach the pressure-protection valve and the 90-degree elbow.

Internal Check Valve Replacement

8. Install the reservoir on the vehicle and attach the air lines.
9. Charge the air system and inspect for leaks.
10. Remove the chocks from the tires.

Internal Check Valve Replacement (located in the side port of the reservoir)

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. Remove the check valve assembly from the top port on the reservoir. See **Fig. 3** and **Fig. 4**.



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A. Check valve is located in this port.

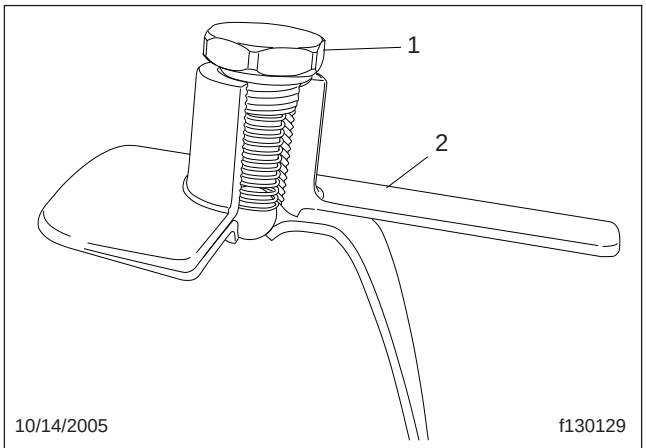
Fig. 3, Check Valve Location

4. Install a new check valve.
5. Charge the air system and inspect for leaks.
6. Remove the chocks from the tires.

Bypass Line Installation

Check with the PDC for the appropriate bypass line kit for your vehicle.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain the air reservoir.
3. On the top port on both sides of the reservoir, disconnect the existing plumbing from the tank. Install a T-fitting, and connect the existing plumbing to the top port of the T-fitting. See **Fig. 5**.



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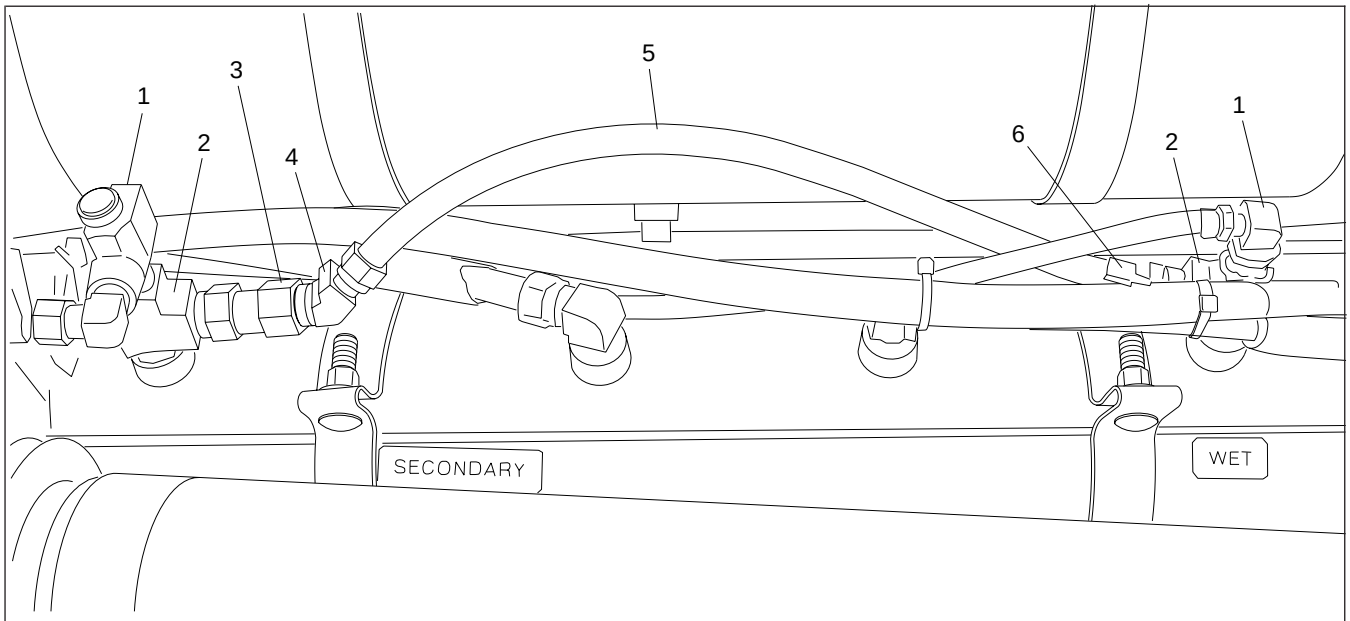
1. Check Valve
2. Tank Shell (cut away)

Fig. 4, Cutaway View of the Check Valve Installation

4. On the secondary (dry) side of the reservoir, on the side port of the T-fitting, install a check valve, then a 45-degree elbow.
5. On the supply (wet) side of the reservoir, on the side port of the T-fitting, install the straight brass fitting.
6. Install a 1/2-inch air line between the 45-degree elbow on the secondary (dry) side, and the brass fitting on the supply (wet) side.
7. Charge the air system and inspect for leaks.



1. Existing Plumbing
2. T-Fitting
3. Check Valve
4. 45-Degree Elbow
5. 1/2-Inch Air Line
6. Brass Fitting

Fig. 5, Check Valve Bypass

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don't disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

WARNING

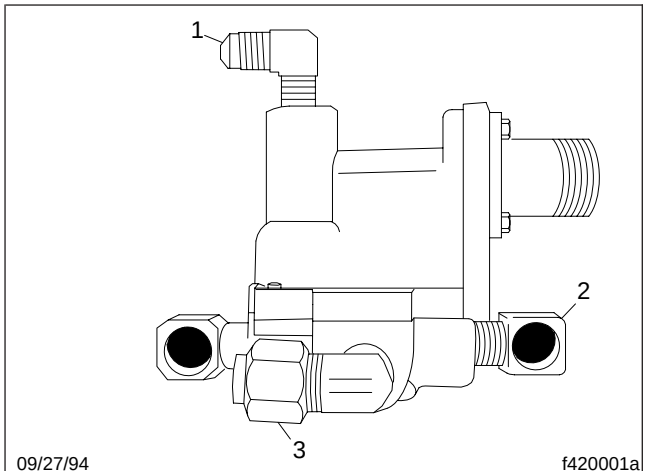
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Installing Air Lines

Nylon Tubes

When installing a nylon tube, be careful not to bend it past its minimum bend radius. For minimum bend radius values, refer to the appropriate table in **Specifications 400**.

Figure 1 and **Fig. 2** show tubing and compression fittings used in the air system.



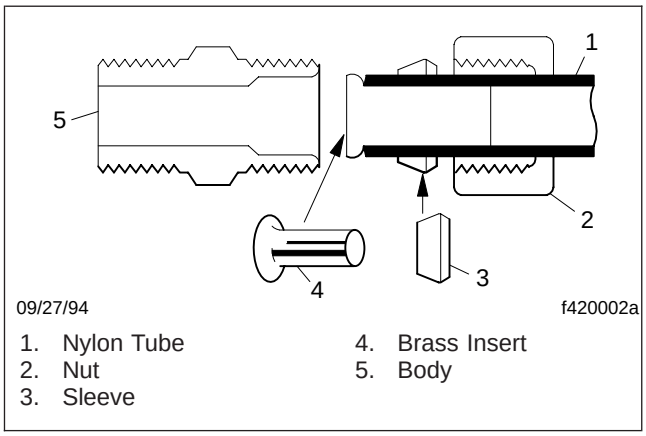
1. Wire Braid Hose Fitting
2. Pipe Fitting
3. Nylon Tube Fitting

Fig. 1, Tube and Hose Fittings (for reference only)

NOTICE

If the tubing is bent to a radius smaller than the specified minimum bend radius, it may kink, and shut off normal airflow to the component.

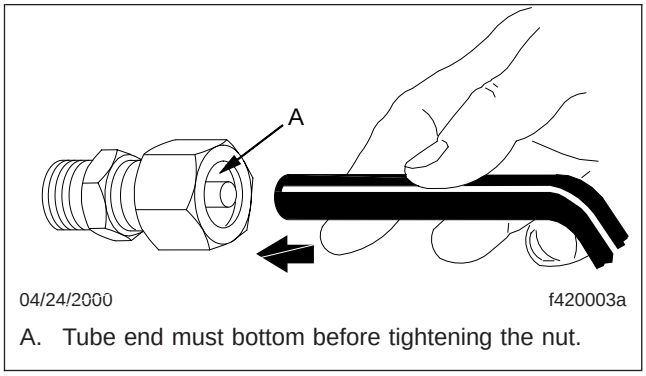
1. Cut the end of the tubing smooth and square.
2. Make sure the nylon tubing ends and fittings are free of grease and debris. If the tubing is crimped or otherwise damaged, replace it with new tubing.



1. Nylon Tube
2. Nut
3. Sleeve
4. Brass Insert
5. Body

Fig. 2, Nylon Tube Fitting

3. Slide the nut onto the tubing.
4. Install a new sleeve in the nut, and a new brass insert in the end of the tubing.
5. Insert the squared end of the tubing in the fitting, until it bottoms in the body of the fitting. See **Fig. 3**.



A. Tube end must bottom before tightening the nut.

Fig. 3, Installing Nylon Tubing

6. Tighten the nut finger-tight. Then, using two wrenches to prevent twisting of the tube, tighten the nut a minimum of two turns (refer to the appropriate table in **Specifications 400**) or until one thread shows on the fitting body.

Wire Braid Hoses

When installing a wire braid hose, as shown in **Fig. 1**, be careful not to bend it past its minimum bend radius. For minimum bend radius values, refer to the appropriate tables in **Specifications 400**.

Installing Air Lines and Fittings

IMPORTANT: If the hose is bent to a radius smaller than the specified minimum bend radius, it may kink, and shut off normal airflow to the component.

Make sure the wire braid hose assembly is free of grease and dirt. Replace the assembly if the hose or fitting is crimped or otherwise damaged.

Install the hose and tighten the nut finger-tight. Then, using two wrenches to prevent twisting of the hose, tighten the nut until it seats solidly. Tighten the nut one-sixth turn more.

Installing Fittings

Brass and Steel Pipe Fittings

For brass pipe fittings, as shown in **Fig. 1**, both male and female parts, tighten as follows:

1. Make sure the fittings are free of grease, dirt, and old sealant. Apply liquid Loctite® Hydraulic Sealant (brown), or an equivalent, to the threads, then tighten securely, finger-tight.

NOTE: Always apply the sealant to the external thread, so that any excess will be scraped off externally rather than internally to the joint.

2. For fittings that must be positioned, tighten one additional turn from finger-tight using a wrench. Then, continue tightening until the fitting is correctly positioned.

   For fittings that do not require positioning, tighten 1-1/2 additional turns from finger-tight.

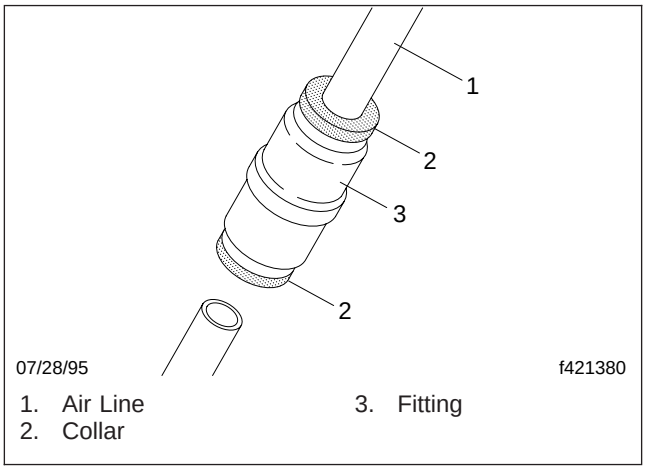
Copper Tube Fittings

For copper tube fittings, tighten the nut finger-tight. Then, using two wrenches to prevent twisting of the tube, tighten the nut the number of turns shown in the table in **Specifications 400**.

Quick-Connect Fittings

NOTE: If damaged, quick-connect fittings must be replaced as an assembly.

1. Push in on the fitting collar to release the air line and pull on the line while holding the fitting collar. See **Fig. 4**.
2. Push the air line all the way into the fitting. Pull the collar away from the fitting to secure the air line. Check and make sure that the air line is seated in the fitting.



1. Air Line
2. Collar
3. Fitting

Fig. 4, Quick-Connect Fitting

Tube and Pipe Fittings on Plastic Components

For tightening specifications, refer to the table in **Specifications 400**.

Nylon Tube			
Number	Inside Diameter: inch	Outside Diameter: inch	Minimum Bend Radius: inch (mm)
4	0.170	1/4	1.00 (25)
6	0.251	3/8	1.50 (38)
8	0.376	1/2	2.00 (51)
10	0.439	5/8	2.50 (64)
12	0.566	3/4	3.00 (76)

Table 1, Nylon Tube

Additional Turns from Hand-Tight (Nylon Tube)	
Tube Size: inch	Additional Turns from Hand-Tight
1/4	3
3/8 or 1/2	4
5/8 or 3/4	3-1/2

Table 2, Additional Turns from Hand-Tight (Nylon Tube)

211 Wire Braid (Medium Pressure) Hose (211 hose is identified by dash number and size; for example, hose numbers 211-4, 211-5, and so on)			
Dash Number	Inside Diameter: inch	Outside Diameter: inch	Minimum Bend Radius: inch (mm)
4	3/16	0.52	3.00 (76)
5	1/4	0.58	3.38 (86)
6	5/16	0.67	4.00 (102)
8	13/32	0.77	4.63 (118)
10	1/2	0.92	5.50 (140)
12	5/8	1.08	6.50 (165)
16	7/8	1.23	7.38 (187)
20	1-1/8	1.50	9.00 (229)

Table 3, 211 Wire Braid (Medium Pressure) Hose (211 hose is identified by dash number and size; for example, hose numbers 211-4, 211-5, and so on)

213 Wire Braid (Diesel) Hose (213 hose is identified by two green stripes 180 degrees apart, dash numbers, and size; for example, hose 213-4, 213-5, and so on)			
Dash Number	Inside Diameter: inch	Outside Diameter: inch	Minimum Bend Radius: inch (mm)
4	3/16	0.49	0.75 (19)
5	1/4	0.55	1.00 (25)
6	5/16	0.62	1.25 (32)
8	13/32	0.74	1.75 (44)
10	1/2	0.83	2.25 (57)
12	5/8	0.96	2.75 (70)
16	7/8	1.21	3.50 (89)
20	1-1/8	1.49	4.50 (114)

Table 4, 213 213 Wire Braid (Diesel) Hose (213 hose is identified by two green stripes 180 degrees apart, dash numbers, and size; for example, hose 213-4, 213-5, and so on)

214 High Temperature Wire Braid (Diesel) Hose (214 hose is identified by two blue stripes 180 degrees apart, dash numbers, and size; for example, hose 214-10 and 214-16)			
Dash Number	Inside Diameter: inch	Outside Diameter: inch	Minimum Bend Radius: inch (mm)
10	1/2	0.83	2.25 (57)
16	7/8	1.21	3.50 (89)

Table 5, 214 High Temperature Wire Braid (Diesel) Hose (214 hose is identified by two blue stripes 180 degrees apart, dash numbers, and size; for example, hose 214-10 and 214-16)

Specifications

Copper Tube Fittings			
Number	Outside Diameter: inch	Additional Turns from Hand-Tight	
		Compression	Threaded Sleeve
2	1/8	1-1/4	1-1/2
3	3/16		
4	1/4		
5	5/16	1-3/4	
6	3/8	2-1/4	
8	1/2		
10	5/8		
12	3/4		
16	1		
20	1-1/4		

Table 6, Copper Tube Fittings

Tube and Pipe Fittings on Plastic Components			
Description	Port Size: inch	Torque	
		lbf·in (N·cm)	lbf·ft (N·m)
Midland Quick Release Valve	3/8	60–90 (678–1017) *	—
	1/2	—	13–17 (18–23) *
Bendix MV-2/MV-3 Valve	1/4	—	10 (14)
Pass Through Manifold with Metal Thread Inserts	1/8 NPT	50–60 (565–678)	—

* Tighten to the lower torque value. Then, if needed, turn the fittings to allow for the proper routing of the air lines.

Table 7, Tube and Pipe Fittings on Plastic Components

Air System Nylon Tube Color Code			
System	Color	Size: I.D.	Where Used
Primary Air	Green	3/4 inch	Air tank to rear service supply (6x4 vehicles only)
		5/8 inch	Primary air tank to foot valve
		1/2 inch	Air tank to rear service supply (4x2 vehicles only)
		3/8 inch	Foot valve to rear service control
			Wet tank to primary air tank
Secondary Air	Red	5/8 inch	Secondary air tank to foot valve
		1/2 inch	Foot valve to front service brake

Specifications

Air System Nylon Tube Color Code			
System	**Color**	**Size: I.D.**	**Where Used**
Tractor Protection	Green	1/2 inch	Foot valve primary delivery to tractor protection valve
	Black	5/8 inch	Tractor protection valve to service anchor coupling
		1/2 inch	Foot valve secondary delivery to tractor protection valve
	Orange	3/8 inch	Dash park valve to tractor protection valve
			Tractor protection valve to emergency anchor coupling
		1/4 inch	Tractor protection valve to stop light switch
Park Brake	Black	3/8 inch	Dash valve to park quick release valve
			Rear relay to park quick release valve
Air Supply	Black	1/2 inch	Air dryer to wet tank
		1/4 inch	Wet tank to air governor
	Silver	1/4 inch	Air governor to air dryer purge valve
	Yellow	3/8 inch	Pressure protection constant air
Non-Brake Applications	Blue	3/8 inch	Chassis air suspension
		1/4 inch	Air suspension dump control
	Brown	1/4 inch	Air suspension pressure gauge
	White	1/4 inch	Interaxle lock control
	Red	1/4 inch	Driver-controlled differential lock
	Green	1/4 inch	Sliding fifth-wheel control
	Yellow	1/4 inch	Fan air solenoid

Table 8, Air System Nylon Tube Color Code

General Information

See **Fig. 1** for a sectional view of the Bendix E-6 Dual Circuit Foot Valve.

The dual circuit brake valve (foot valve) controls the air supply and delivery of the dual circuit brake system. The brake valve is mounted on the firewall.

Applying

The primary circuit of the brake valve is controlled by the brake pedal and a plunger. When the brake pedal is depressed, the plunger applies pressure on the spring seat, rubber spring, and the primary (upper) piston. The downward movement of the primary piston closes the upper exhaust valve, and then opens the upper inlet valve, allowing high-pressure air from port 11 to flow to low-pressure port 21.

The secondary circuit is pneumatically operated by the pressure from the primary circuit. Primary circuit pressure on top of the relay piston first closes the lower exhaust valve, and then opens the lower inlet valve, allowing high-pressure from port 12 to flow to low-pressure port 22.

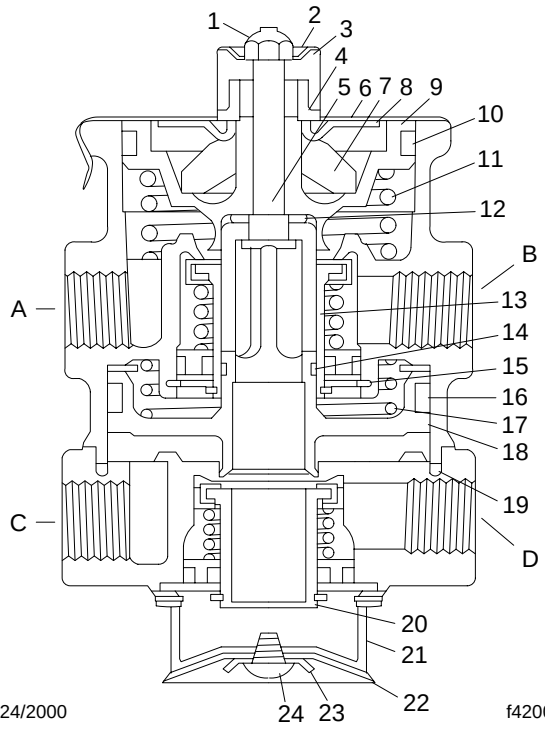
Holding

As air pressure builds in the primary circuit, the pressure under the primary piston will match the pressure of the rubber spring. This allows the piston to move up enough to close the upper inlet valve, and prevent the flow of air from the primary air tank into the brake valve. The exhaust port remains closed.

Releasing

When the pedal is released, the pushrod releases pressure from the spring seat, rubber spring, and the primary (upper) piston. Air pressure builds to push the piston up, opening the upper exhaust valve and allowing air from the primary circuit to escape through the exhaust port.

In the secondary circuit, the release of primary air pressure allows air under the relay piston, pushing the piston up and opening the lower exhaust valve. All remaining air pressure is vented through the exhaust port.



A. Port 21: to primary air circuit.
B. Port 11: from primary air tank.
C. Port 22: to secondary air circuit.
D. Port 12: from the secondary air tank.

1. Locknut
2. Spring Seat
3. Stem Spring
4. Spring Seat Nut
5. Primary Piston Stem
6. Primary Piston Retainer
7. Rubber Spring
8. Spring Seat
9. Primary Piston
10. Primary Piston O-Ring
11. Primary Piston Return Spring
12. Small Washer
13. Upper Inlet and Exhaust Valve Assembly
14. Small O-Ring
15. Retaining Ring
16. Large O-Ring
17. Relay Piston Spring (if equipped)
18. Relay Piston
19. Rubber Seal Ring
20. Lower Inlet and Exhaust Valve Assembly
21. Exhaust Cover
22. Exhaust Diaphragm
23. Washer
24. Phillips Screw

Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don't disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

Bendix E-6 Brake Valve Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

Figure 1 shows the E-6 brake valve mounting.

1. Park the vehicle on a level surface, shut down the engine, and chock the tires. Tilt the hood.

⚠ WARNING

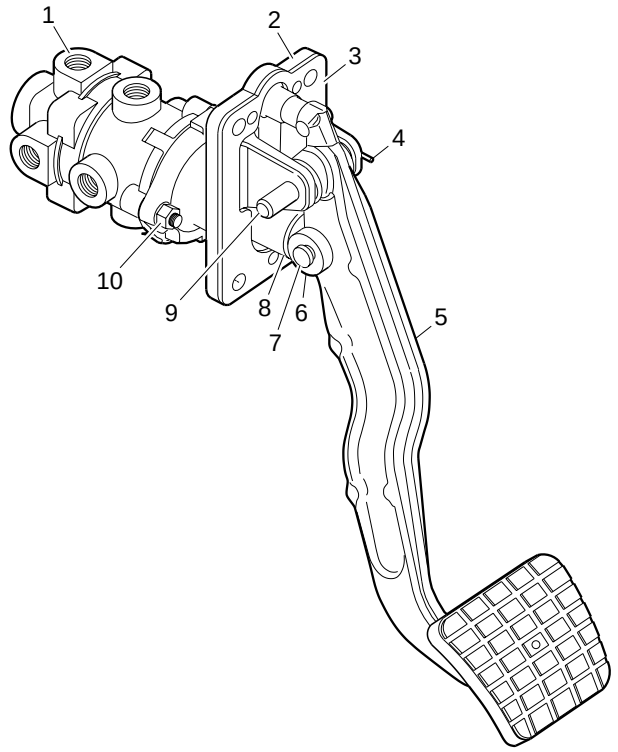
When draining the air system, do not look into the air lines/ports or direct them toward another person, because dirt or sludge particles may be in the airstream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can result in personal injury.

2. Drain all of the air reservoirs.
3. Mark the brake valve air supply and delivery lines for assembly reference. Disconnect the air lines from the brake valve, and plug them to keep out contaminants.
4. Remove the locknuts and washers that attach the brake valve to the mounting adaptor.
5. Remove the plunger from the mounting adaptor. Wipe off the old grease from the plunger and adaptor.
6. Note the locations and positions of the double check valve (if equipped), then remove them from the brake valve. Clean off the dirt and old sealant from the threads of the valve and elbows.

Installation

⚠ WARNING

When applying sealant, make sure that excess sealant does not get inside either the male or the female fittings. Loose foreign material inside the air plumbing may clog a valve, causing a loss of brake control, which could result in personal injury.



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1. Brake Valve
2. Mounting Plate Adaptor
3. Gasket
4. Roll Pin
5. Brake Pedal Assembly
6. Roller
7. Roller Pivot Pin
8. Plunger
9. Shaft Pivot Pin
10. Locknut and Washer

Fig. 1, Brake Valve Mounting

1. If equipped with a hand brake valve, apply a small quantity of Loctite® Pipe Sealant (with Teflon® 59241), or an equivalent sealant, to the male threads of each of the double check valves and the elbows.

   Install the double check valves and elbows in the ports of the brake valve. Tighten each valve finger-tight, then tighten them one additional turn with a wrench. As needed, further tighten them until they are properly positioned.
2. Lubricate the sliding surface of the brake plunger with barium grease, part number BW 246671 or Pennzoil Adhezoplex EP 2. Install the plunger in the mounting adaptor.

Bendix E-6 Brake Valve Removal and Installation

3. Using the locknuts and washers, attach the mounting adaptor to the brake valve. Tighten the capscrews 10 to 13 lbf·ft (14 to 18 N·m).
4. Connect the air lines, as previously marked. Tighten the nuts finger-tight. Using a wrench, further tighten the nuts until there is resistance, then tighten one-sixth additional turn.
5. Return the hood to the operating position.
6. Perform the operating and leakage checks, as instructed in **Subject 130**.
7. Remove the chocks from the tires.
8. Test drive the vehicle in a safe area at low speed. Make several brake applications to be sure the vehicle comes to a safe stop.

Bendix E-6 Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

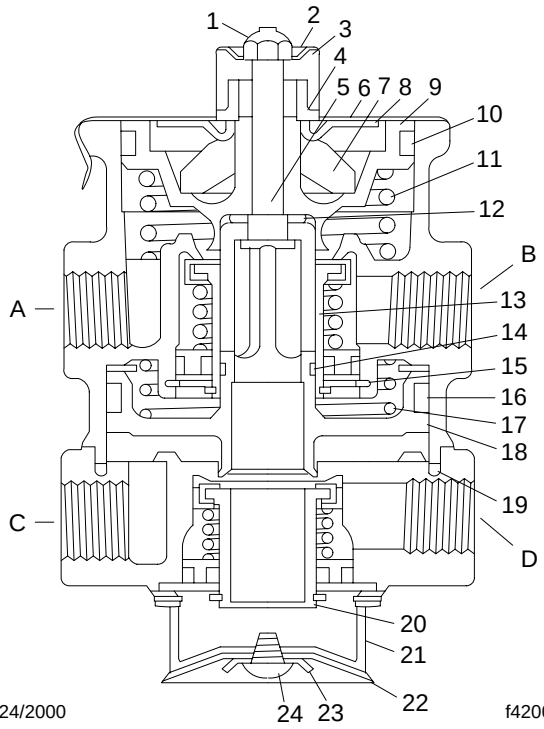
See **Fig. 1** for an exploded view of the Bendix E-6 valve.

1. Remove the valve from the vehicle. For instructions, see **Subject 110**.
2. Remove the screw that attaches the exhaust diaphragm and washer to the exhaust cover.
3. Remove the four screws that attach the exhaust cover to the lower valve body.
4. Remove the lower inlet and exhaust valve assembly.
5. Remove the four hexhead capscrews and washers that attach the lower and upper valve bodies. Separate the valve bodies.
6. Remove the rubber seal ring from the lower valve body.
7. Apply thumb pressure to the primary piston, then lift out and up on the three locktabs of the primary piston retainer.

⚠ WARNING

The locknut and spring seat are used to restrain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is about 50 lbf (222 N). When removing these springs, use care to prevent them from flying out and possibly causing personal injury. Manually or mechanically hold down these springs when removing the locknut.

8. Using a 3/8-inch wrench, hold the locknut on the threaded end of the primary piston stem. Insert a screwdriver in the exhaust passage through the center of the valve, and engage the slotted head of the stem.
9. Using the screwdriver to keep the stem from turning, remove the locknut, spring seat, and the stem spring.



A. Port 21: to primary air circuit
B. Port 11: from primary air tank
C. Port 22: to secondary air circuit
D. Port 12: from the secondary air tank

1. Locknut
2. Spring Seat
3. Stem Spring
4. Spring Seat Nut
5. Primary Piston Stem
6. Primary Piston Retainer
7. Rubber Spring
8. Spring Seat
9. Primary Piston
10. Primary Piston O-Ring
11. Primary Piston Return Spring
12. Small Washer
13. Upper Inlet and Exhaust Valve Assembly
14. Small O-Ring
15. Retaining Ring
16. Large O-Ring
17. Relay Piston Spring (if equipped)
18. Relay Piston
19. Rubber Seal Ring
20. Lower Inlet and Exhaust Valve Assembly
21. Exhaust Cover
22. Exhaust Diaphragm
23. Washer
24. Phillips-Head Screw

Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

Bendix E-6 Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

10. Being careful to avoid damaging the valve seats, remove the relay piston, relay piston spring, and the primary piston and primary piston return spring.
11. Turn the spring seat nut counterclockwise, and separate the spring seat nut, spring seat, and the rubber spring. Remove the primary piston O-ring.
12. Remove the small and large O-rings from the relay piston.
13. Remove the retaining ring. Remove the upper inlet and exhaust valve assembly.

Cleaning and Inspecting

Wash all metal parts in mineral spirits and dry them thoroughly with compressed air. Inspect the valve seat surfaces of the pistons and the valve housings for conditions that could cause leakage. Inspect air line fittings for corrosion, and replace corroded fittings.

Assembly

NOTE: Keep the work area, tools, and brake valve parts clean during assembly.

1. Using Bendix BW 291126, or Dow Corning 55-M, or an equivalent pneumatic grease, lightly grease all the new O-rings, O-ring grooves, piston bores, and all sliding surfaces.
2. Place the upper inlet and exhaust assembly in the upper body, and secure the assembly with the retaining ring. Make sure that the retaining ring is seated in its groove.
3. Install the large and small O-rings on the relay piston.
4. Install the primary piston O-ring in the piston O-ring groove.
5. Install the rubber spring, concave side down, in the primary piston. Place the spring seat, flat side up, over the rubber spring.
6. Install the spring seat nut and turn the nut clockwise until the top surface of the spring seat is even with the top surface of the piston. Set this assembly aside.
7. Place the relay piston spring, if equipped, in the concave portion of the relay piston. Install the relay piston through the upper inlet and exhaust assembly, and into the underside of the upper valve body.
8. Place a screwdriver (blade up) in a vise. Place the primary piston stem in the relay piston. Position the upper valve body over the screwdriver blade, with the blade engaged in the slotted head of the piston stem.
9. Place the small washer over the stem.
10. Install the primary piston return spring in the upper valve body piston bore.
11. Install the primary piston and rubber spring assembly (assembled previously) over the stem, and into the upper valve body piston bore.

⚠ WARNING

The locknut and spring seat are used to restrain the primary piston return spring, stem spring, and the relay piston spring. The combined force of these springs is about 50 lbf (222 N). When installing these springs, use care to prevent them from flying out and possibly causing personal injury. Manually or mechanically hold down these springs when installing the locknut.

12. Push down and hold the primary and relay pistons in the upper valve body.
13. Place the stem spring over the spring seat nut (Item 4). Place the spring seat over the stem.
14. Install the locknut on the stem. Tighten the locknut 20 to 30 lbf·in (220 to 340 N·cm).
15. Install the primary piston retainer over the piston. Make sure that all three locktabs have engaged the outer lip of the valve body.
16. Install the rubber seal ring in the lower valve body.
17. Attach the lower and upper valve bodies. Install the four hexhead capscrews and washers. Tighten the capscrews 11 lbf·ft (15 N·m).
18. Install the lower inlet and exhaust valve assembly (Item 20).
19. Install the four screws that attach the exhaust cover to the lower valve body.
20. Install the screw that attaches the exhaust diaphragm and washer to the exhaust cover.

Bendix E-6 Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

21. Install the brake valve. For instructions, see **Subject 110**.

Bendix E-6 Brake Valve Operating and Leakage Checks

⚠ WARNING

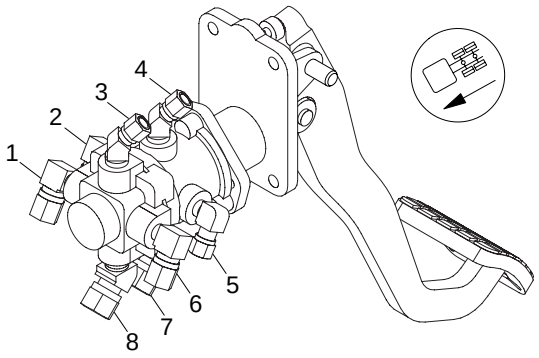
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operating Checks

IMPORTANT: If there is a change in the way a vehicle brakes, or if low pressure warnings occur, check the operation of the air system. Although the brake system may continue to work, do not operate the vehicle until the braking circuits, including the pneumatic and mechanical devices, have been repaired and are operating normally. Always check the brake system for proper operation after doing brake work, and before returning the vehicle to service.

Check for proper brake valve operation as follows:

1. Apply the parking brakes, and chock the tires.
2. Connect test gauges to the primary and secondary delivery ports (ports 21 and 22) on the brake valve. See **Fig. 1** and **Fig. 2**.



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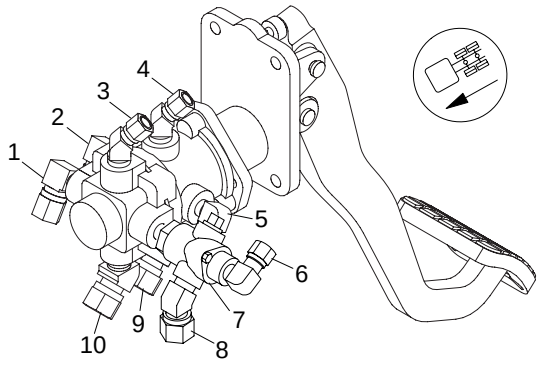
1. Secondary Delivery Circuit to Front Brake Valve
2. Delivery Circuit to Rear Brake Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Primary Delivery Circuit to Tractor Protection Valve
6. Secondary Delivery Circuit to Tractor Protection Valve (if not equipped with a hand valve)
7. Primary Supply Circuit to Primary Supply Reservoir
8. Secondary Supply Circuit to Secondary Supply Reservoir

Fig. 1, Brake Valve Plumbing Circuits



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1. Secondary Delivery Circuit to Front Brake Valve
2. Primary Delivery Circuit to Rear Brake Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Primary Delivery Circuit to Tractor Protection Valve
6. Delivery Circuit to Trailer Hand Valve
7. Double Check Valve
8. Secondary Delivery Circuit to Tractor Protection Valve
9. Primary Supply Circuit to Primary Supply Reservoir
10. Secondary Supply Circuit to Secondary Supply Reservoir

Fig. 2, Brake Valve Plumbing Circuits (with double-check valve)

NOTE: When checking the delivery pressure of the primary and secondary circuits, use test gauges that are accurate.

3. Start the engine and build air pressure to 120 psi (827 kPa).
4. Depress the pedal to several different positions; check the pressure on the test gauges to ensure that it varies equally and proportionately with the movement of the brake pedal.
5. Fully depress the brake pedal, then release it. After a full application is released, the reading on the test gauges should promptly fall to zero.

NOTE: Pressure in the primary delivery circuit will be about 2 psi (14 kPa) greater than pressure in the secondary delivery circuit (if both supply reservoirs are at the same pressure). This is normal for this valve.

6. Go to "Leakage Check."

Bendix E-6 Brake Valve Operating and Leakage Checks

Leakage Check

1. Make and hold a pressure application of 80 psi (552 kPa).
2. Check the air line fittings for leaks: tighten or replace fittings as needed.
3. Coat the exhaust port and body of the valve with a soap solution, and check for leakage. The leakage permitted is a 1-inch (25-mm) bubble in 3 seconds.

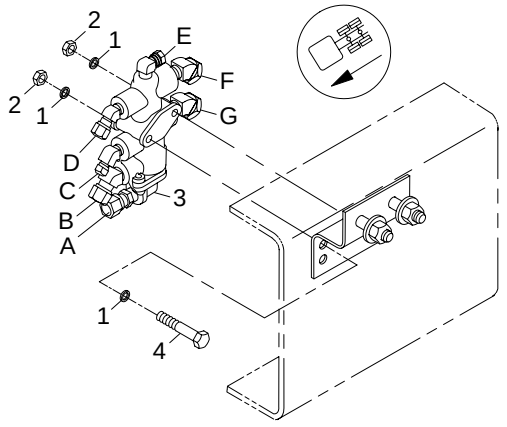
   If the brake valve does not function as described above, or if leakage is excessive, replace it with a new or remanufactured unit. Repeat the leakage test before placing the brake valve in service.

General Description

The Bendix TP–3DC is a tractor protection valve that includes an integral double check valve. The TP–3DC serves two purposes. First, as required by Federal law, the valve protects the tractor brakes in the event of trailer breakaway or a severe air system leak. Second, when used with a dash-mounted trailer supply control valve, the TP–3DC valve can be used to shut off the trailer control line before the trailer is disconnected.

The TP–3DC also includes an integral single check valve that prevents air from getting trapped in the trailer control line. Trapped air in this line could cause service/spring brake compounding and, if the trailer is parked with air applied, a trailer roll-away situation.

There are several different mounting locations for the TP–3DC tractor protection valve. A common mounting location is in the frame rail channel. See **Fig. 1**.



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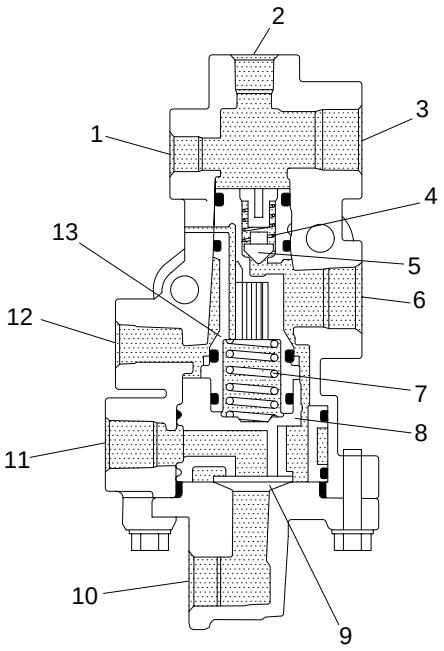
A. From service brake foot valve, primary circuit.
B. From service brake foot valve, secondary circuit.
C. To air manifold (stop lamp switch).
D. From trailer supply valve.
E. To proportioning relay (if installed).
F. To trailer emergency port.
G. To trailer service port.

1. 1/4" Flatwasher
2. 1/4–20 Locknut
3. TP–3DC Tractor Protection Valve
4. 1/4–20 Capscrew

Fig. 1, TP-3DC Mounting Location and Connections

TP–3DC valve port designations and internal components are shown in **Fig. 2**.



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1. Tractor Supply Port
2. Auxiliary Supply Port
3. Trailer Supply Port
4. Check Valve Spring
5. Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Tractor Control Port (Secondary)
12. Stop Lamp Switch Port
13. Plunger

Fig. 2, TP-3DC, Sectional View

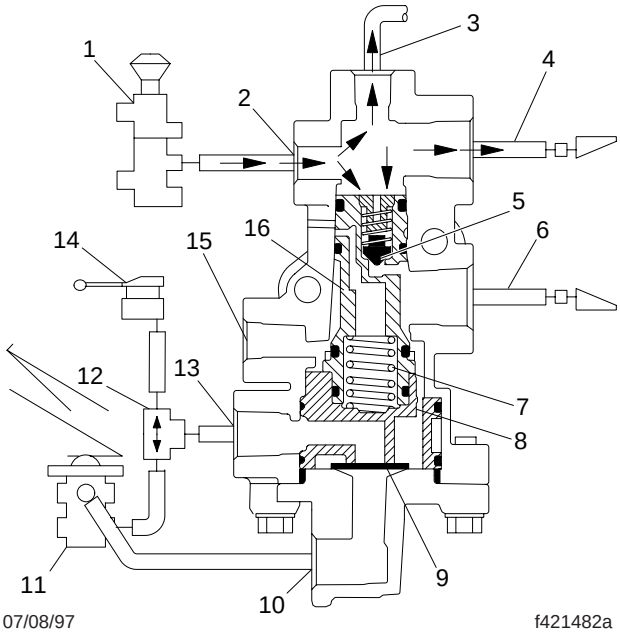
Principles of Operation

Initial Charge

Pushing in the red trailer air supply knob on the instrument panel causes air to flow into the TP–3DC valve at the tractor supply port. See **Fig. 3**. Air flows through the valve housing, exiting via the auxiliary supply port (if used) and the trailer supply port, to pressurize the trailer brake system and release the trailer parking brakes.

As air pressure builds in the trailer supply circuit, the single check valve seats, and the valve plunger be-

General Information



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

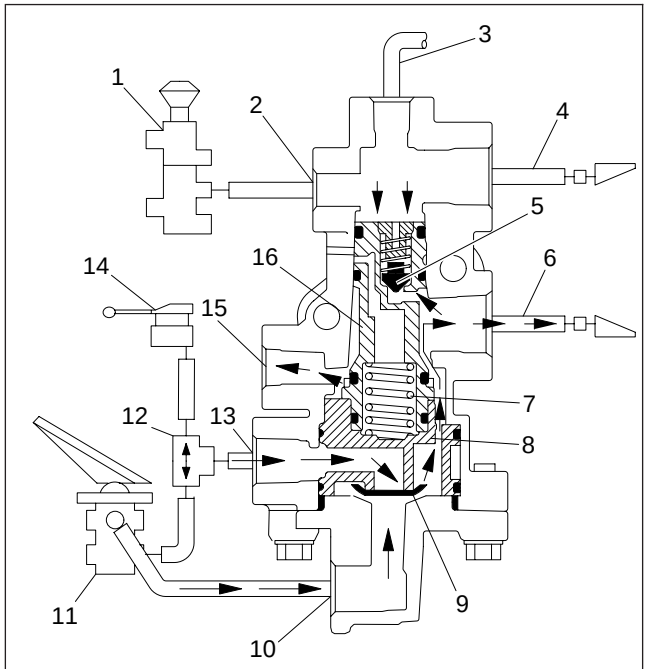
Fig. 3, Initial Charge

gins to move (against spring pressure) toward the guide. When pressure reaches about 45 psi (310 kPa), the inlet valve opens.

The TP–3DC valve is in the "run" mode, and ready to receive and deliver a service brake application from either the foot valve or the hand valve.

Service Brake Application

When the foot pedal is pressed, air flows to the TP–3DC valve tractor control primary and secondary ports. See **Fig. 4**. If the trailer control valve is also used, the external double check delivers the higher pressure (trailer control or foot valve secondary) to the TP–3DC Tractor Control secondary port.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

Fig. 4, Service Brake Application

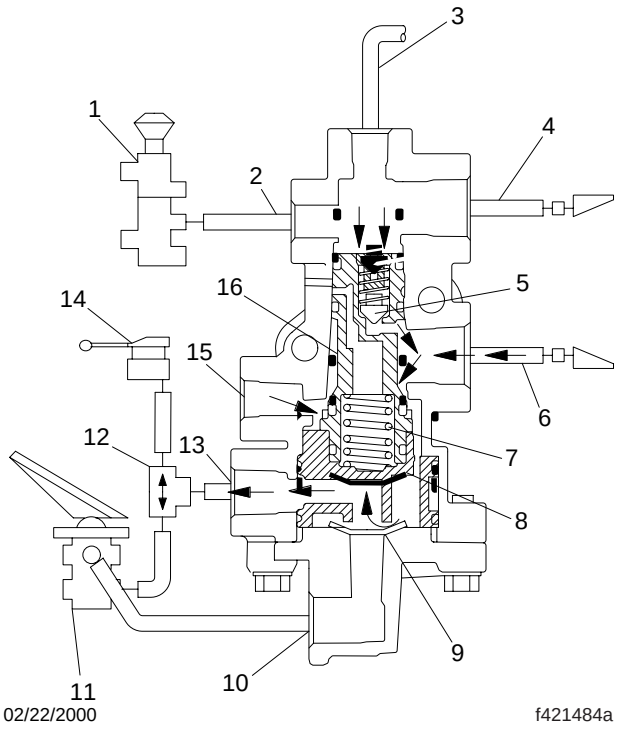
Inside the TP–3DC valve, the higher pressure (primary or secondary) moves the diaphragm to seal off the port at the lower pressure.

With the plunger bottomed against the guide and the inlet valve open (as described earlier), the higher pressure air flows through the valve to the trailer control port and the stop lamp switch, applying the brakes and activating the stop lamps.

NOTE: While air pressure also reaches the TP–3DC single check valve, the valve stays closed because supply pressure is acting on the other side.

Service Brake Release

When the foot pedal is released, air stops flowing into the TP–3DC valve at the tractor control primary or secondary port. See **Fig. 5**. At the same time, air in the trailer control line returns to the valve, flowing back through the open inlet valve.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

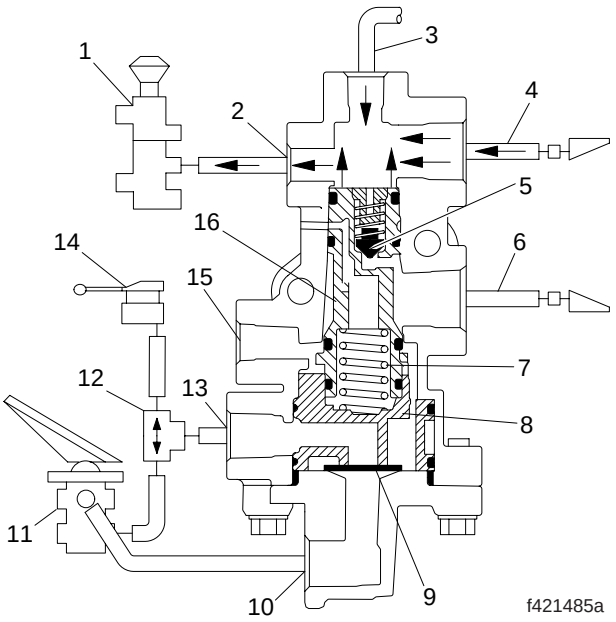
Fig. 5, Service Brake Release

Once the exhausting air has reached a sufficient flow level, a quick release valve located in-line between the trailer control line and the TP3-DC service brake port allows rapid exhausting.

The air forces the diaphragm to seat, sealing off the tractor control primary port. The air then exits the valve at the tractor control (secondary) port and flows to the foot valve or hand valve where it is exhausted.

Tractor Protection

If the red trailer air supply knob on the instrument panel is pulled out (or if a large leak develops in the trailer supply circuit), pressure in the trailer supply circuit (and the auxiliary supply circuit, if used) is vented. See **Fig. 6**. When pressure drops to about 20 to 30 psi (138 to 207 kPa), the pressure can no longer overcome the spring force inside the TP–3DC valve and the inlet valve closes.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Valve Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

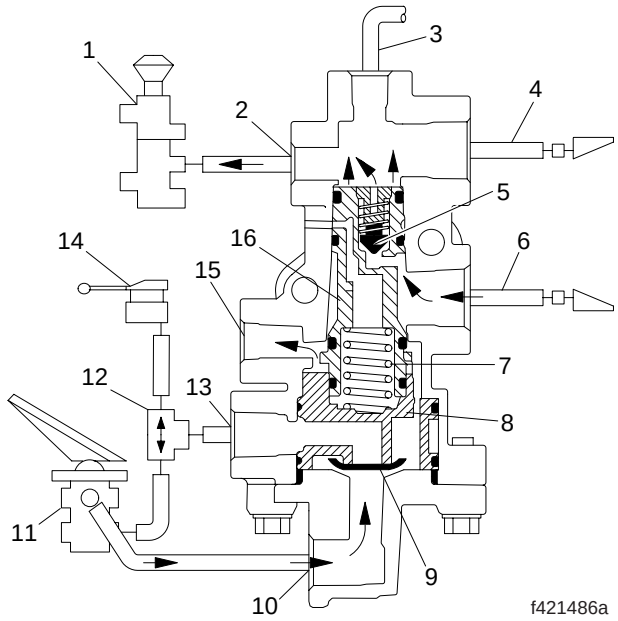
Fig. 6, Tractor Protection

General Information

With the inlet valve closed, air pressure from the brake foot or hand control valves will not reach the trailer control circuit when the brakes are applied.

Anti-Compounding

If the red trailer air supply knob on the instrument panel is pulled out while the service brakes are applied, the single check valve in the TP–3DC prevents simultaneous spring and service brake application. See **Fig. 7**. As pressure in the trailer supply circuit drops, the spring in the TP–3DC valve forces the inlet valve closed (as described above in "Tractor Protection".) Any pressure in the trailer control circuit is relieved by passing first through the single check valve and then exhausting at the trailer supply valve.



1. Trailer Air Supply Valve
2. Tractor Supply Port
3. Auxiliary Supply Port
4. Trailer Supply Port
5. Single Check Valve
6. Trailer Control Port
7. Spring
8. Guide
9. Diaphragm (Double Check Valve)
10. Tractor Control Port (Primary)
11. Foot Valve
12. Double Check Valve
13. Tractor Control Port (Secondary)
14. Hand Valve
15. Stop Lamp Switch Port
16. Plunger

Fig. 7, Anti-Compounding

If the service brakes (hand or foot) are released and applied again, the closed inlet valve prevents air pressure from reaching the trailer control circuit.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under the vehicle. Releasing air from the system may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they will apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if not correctly disassembled. Use only correct tools and observe all precautions regarding use of those tools.

Removal

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Chock the tires, and open the air reservoir drain cocks to bleed the air from the system.
2. Remove the trailer hose assemblies from the TP–3DC valve. Disconnect the tractor service and supply lines. Mark the lines for later assembly reference. Cap the air lines tightly to keep out contaminants.
3. Remove the fasteners that attach the TP–3DC valve to the vehicle, and remove the valve.

Installation

1. Place the TP–3DC valve on the vehicle, and attach it with bolts, washers, and nuts. Tighten the nuts 11 to 15 lbf·ft (15 to 20 N·m).

NOTE: The delivery line from the trailer air supply valve is connected to the tractor emergency port of the TP–3DC valve. See Fig. 1. The delivery line from the brake valve (double check valve) is connected to the tractor service port of the TP–3DC valve. Trailer hose assemblies are installed in the trailer emergency and trailer service ports of the TP–3DC valve.

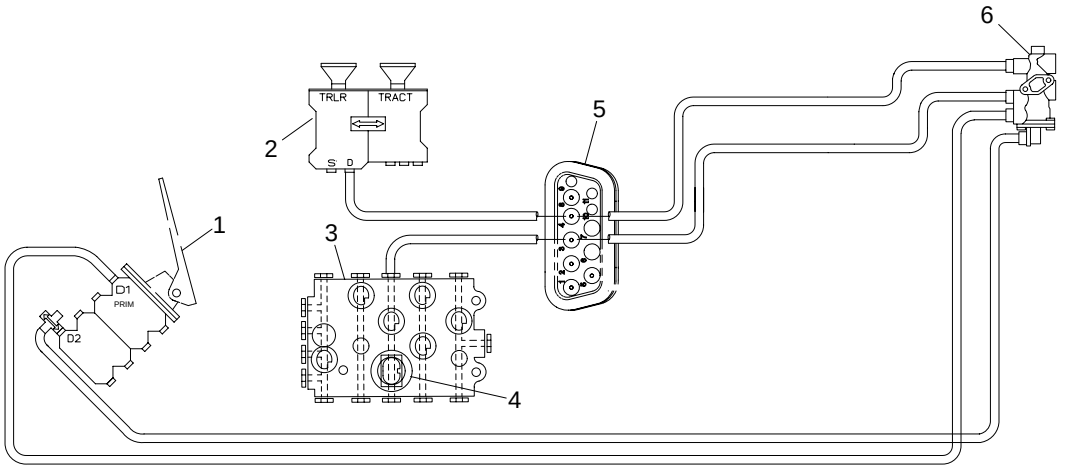
2. Remove the caps from the air lines, and, depending on the type of air hose, use the following instructions to connect the air hoses to the TP–3DC valve:

   If equipped with nylon tube air hoses, connect the hose fittings to the valve ports, and tighten the nuts finger-tight. Then, using a wrench, tighten the nuts at least two turns, or until no threads show on the fitting.

   If equipped with wire braid hoses, connect the hose fittings to the valve ports, and hand-tighten the nuts. Using a wrench, tighten the nuts until there is resistance. Tighten one-sixth turn more. Do not overtighten.

3. Close the drain cocks to the air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the TP–3DC valve following the instructions in Subject 130.

Valve Removal and Installation



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1. Foot Valve
2. Dash Valves
3. Air Manifold and Pressure Switch
4. Stop Lamp Switch
5. Pass-Thru Grommet
6. TP–3DC Valve

Fig. 1, TP-3DC Plumbing Diagram

Valve Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

See **Fig. 1** for an exploded view of the TP-3DC valve.

1. Remove the valve from the vehicle, retaining the mounting hardware. For instructions, see **Subject 110**.
2. Scribe a line across the valve cover and valve body to ensure proper alignment during assembly.
3. Remove the two 1/4-inch screws that secure the valve cover to the valve body, and allow the valve spring to expand until the valve cover can be removed.
4. Remove the cover O-ring and discard it.
5. Remove the diaphragm, from the valve body, and discard it.
6. Remove the guide from the valve body.
7. Remove the O-rings from the guide and discard them.
8. Remove the valve spring from the plunger, then the plunger from the valve body.
9. Remove the O-rings from the plunger and discard them.
10. Remove the collar and the O-ring from the plunger. Discard the O-ring, but keep the collar.

Cleaning and Inspection

WARNING

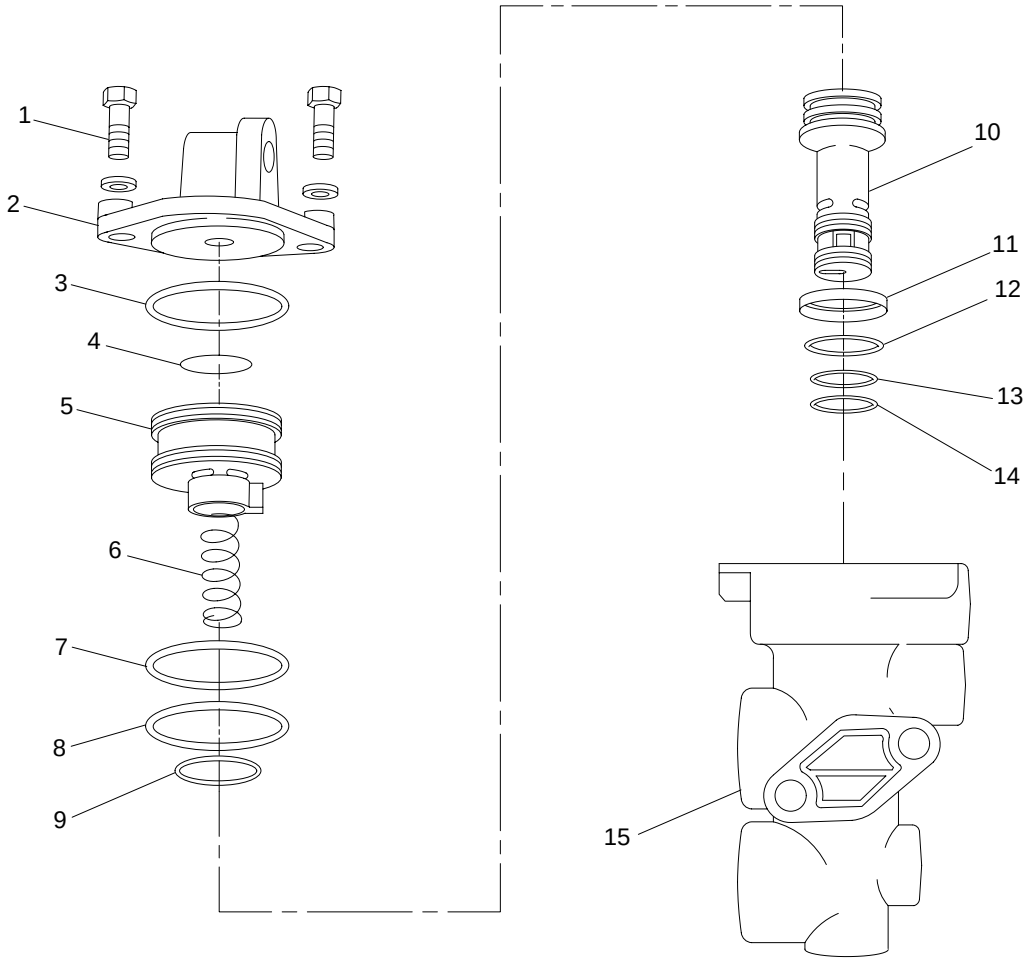
Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the TP–3DC valve in cleaning solvent, then dry them using compressed air.
2. Examine the cover, body, guide, and plunger for corrosion, excessive wear, cracks, or other damage. If any of these conditions are found on a part, replace the part with a new one.
3. Check the spring for distortion and corrosion. If the spring is distorted or corroded, replace it.
4. Check the valve body bores for deep scratches or gouging.

Assembly

1. Lubricate the O-rings, O-ring grooves, body bores, and all sliding parts with the lubricant provided in the overhaul kit (Bendix silicone lubricant #291126 or equivalent).
2. Install the O-rings on the plunger.
3. Install the O-ring on the plunger and then the collar over the O-ring. Make sure that the collar is fully seated and firmly in place over the O-ring.
4. Install the plunger into the valve body and the spring into the plunger.
5. Install the O-rings in their grooves on the guide.
6. Align the indexing tab on the guide with the notch in the valve body and install the guide in the valve body.
7. Place the diaphragm in its recess on the guide.
8. Place the O-ring on the cover.
9. Place the cover on the guide and press them down, against spring pressure, until the cover is seated against the valve body.
10. Install the two 1/4-inch screws and tighten them 30 to 60 lbf·in (338 to 678 N·cm).
11. Install the TP–3DC valve on the vehicle following the instructions in **Subject 110**.

Valve Disassembly, Cleaning and Inspection, and Assembly



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1. 1/4" Hex/Torx Screw
2. Valve Cover
3. O-Ring
4. Diaphragm
5. Guide
6. Valve Spring
7. O-Ring
8. O-Ring
9. O-Ring
10. Plunger
11. Collar
12. O-Ring
13. O-Ring
14. O-Ring
15. Valve Body

Fig. 1, Exploded View of TP-3DC Valve

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operation and Leakage Test

1. Chock the tires, start the engine, and run it until the air system is fully charged.
2. Shut down the engine and place the trailer air supply valve in the emergency position (red knob pulled out).
3. Disconnect the trailer control line hose coupling. Then make a service application with either the foot valve or trailer control valve and check for leakage at the hose coupling with a soap-and-water solution. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
4. Release the service brake application and place the trailer supply valve in the "run" position (red knob pushed in). Connect the trailer control valve to a test gauge.
5. Make a service brake application and note that service air pressure is present at the trailer control line hose coupling.
6. With the ignition on, make and hold a service brake application and note that the stop lights function.
7. Disconnect the air line at the TP–3DC tractor control port (primary) and plug the line. Using a soap-and-water solution, make a service brake application and check for leakage at the open tractor control port. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.
8. Reconnect the air line to the tractor control port (primary) and disconnect the air line at the tractor control port (secondary). Then, plug the disconnected line. Make a service brake application, and check for leakage at the open tractor control port using a soap-and-water solution. Leakage should not exceed a 1-inch (2.5-cm) bubble in 5 seconds.

IMPORTANT: If the valve does not function as described, or if leakage is excessive, repair or replace the valve.

General Information

The Meritor automatic slack adjuster has two main functions:

- As a lever, it converts the straight-line force of the brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the brake drum.
- As an automatic adjuster, it maintains the brake chamber pushrod stroke, which controls the lining-to-drum clearance during operation.

The Meritor automatic slack adjuster automatically adjusts the clearance between the brake lining and the brake drum when needed. As long as the pushrod stroke does not exceed the desired length, no adjustment takes place.

When linings wear, the clearance increases, causing the pushrod to move a greater distance to apply the brakes. If the chamber stroke exceeds the design limit, the automatic slack adjuster adjusts the pushrod's return stroke to control the clearance and resets the stroke to the correct length.

As the brake is applied, the brake chamber pushrod and clevis move outward, forcing the slack adjuster arm to rotate around the camshaft centerline. The clevis outward movement also pulls the actuator rod and piston upward. See **Fig. 1**.

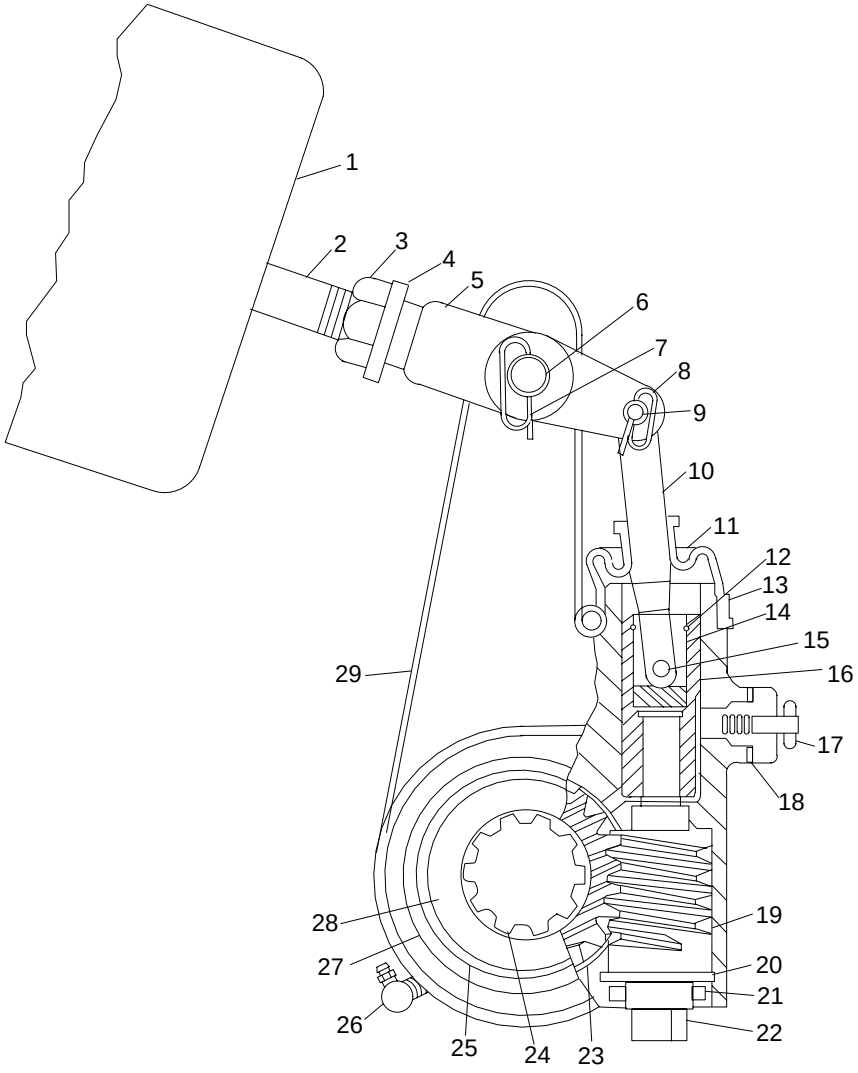
Inside the slack adjuster, the piston, actuator (adjusting sleeve), and pull-pawl work together to adjust the length of the pushrod stroke as the brake linings wear. The actuator has internal splines and angled serrations on the outside.

- The internal splines on the actuator mesh with the splined end of the worm so that any rotation of the actuator turns the worm.
- Angled serrations on the exterior surface of the actuator correspond to those on the spring-held pawl and provide a ratcheting effect. The pawl serrations allow free upward movement of the actuator but lock on the actuator serrations on downward movements.

When lining wear becomes excessive, the brake chamber pushrod stroke goes beyond the desired length. The piston then travels higher and contacts the retaining ring near the top of the actuator, pulling the actuator up. As the actuator moves upward and reaches a preset distance, it slides over one serration on the pawl.

When the pushrod moves back toward the brake chamber, the actuator is forced downward. Because the curved serrations in the pawl and actuator are locked together on the downward stroke, the actuator turns slightly. This action causes the worm to turn, advancing the gear and the camshaft to automatically adjust the brake.

General Information



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1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Retainer Clip (large)
8. Retainer Clip (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retaining Ring
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Housing

Fig. 1, Meritor Slack Adjuster

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Slack Adjuster Removal, Installation, and Brake Adjustment

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the tires.

WARNING

Manually cage each parking brake chamber power spring in the release (no application) position before continuing. Loss of brake chamber air pressure will cause sudden application of the parking brakes, which could result in personal injury.

2. If the rear slack adjusters will be removed, release the parking brakes, then cage the power spring of the parking brake chamber.
3. Remove the retainer clips from the large and small clevis pins. Remove the clevis pins. See Fig. 1.

NOTICE

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

4. Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See Fig. 2.

   Wedge the tool in place. Pull-pawls are spring-loaded; when the tool is removed, the pull-pawl will engage the teeth automatically.
5. Using a wrench, manually turn the square adjusting nut clockwise to move the slack adjuster away from the clevis. See Fig. 3.
6. Remove the snap ring, washer(s), and seal (if equipped) that secure the slack adjuster in place on the brake camshaft; save them for later installation.
7. Remove the slack adjuster from the camshaft.
8. Note the location and number of any remaining spacing washers on the camshaft. Remove the spacers and seal (LX500 and MX500 series only), and save them for later installation.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

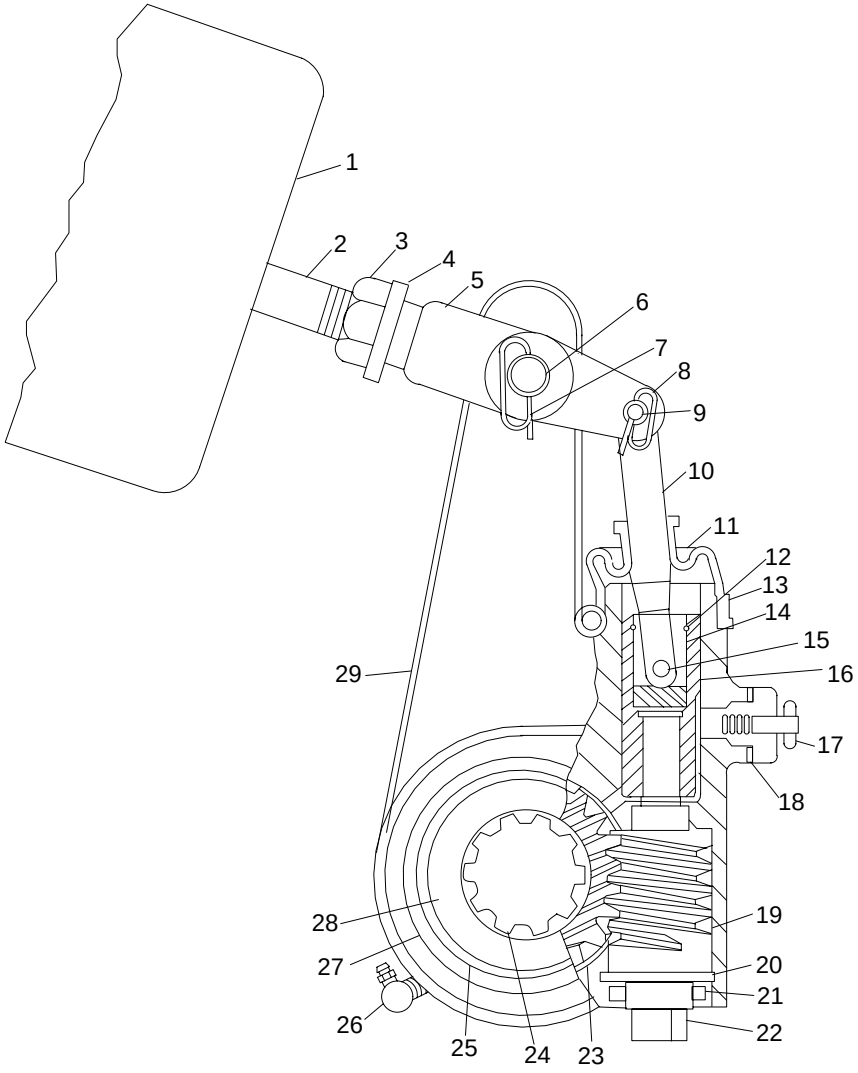
1. Inspect the parts and prepare the slack adjuster for installation.
2. Check the brake camshaft splines for wear or corrosion.

IMPORTANT: The following lubricants provide corrosion protection. Do not mix them with other types of lubricants.

3. Coat the camshaft splines and the splines of the slack adjuster gear with Meritor 0-637, Meritor 0-695 (LX500 and MX500 only), Southwest SA 8249496, or an equivalent.
4. Apply the service brake several times. Make sure the return spring retracts the pushrod quickly and completely. Replace the return spring or brake chamber, if needed.
5. Slide the spacing washer(s) on the camshaft.

   On LX500 and MX500, install the slack adjuster seal with the lip facing the brake spider.
6. If reinstalling the same slack adjuster:
   - 6.1 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.
   - 6.2 On LX500 and MX500, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.
   - 6.3 Install the outer washer(s) and snap ring on the camshaft.

Slack Adjuster Removal, Installation, and Brake Adjustment



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1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Retainer Clip (large)
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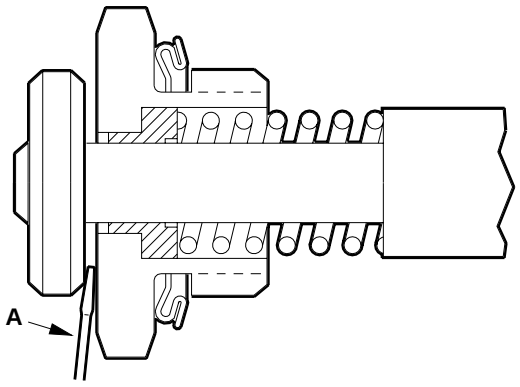
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Sleeve)
17. Pull-Pawl Assembly (shown 90 degrees out of position)
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retaining Ring
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Housing

Fig. 1, Meritor Automatic Slack Adjuster

Slack Adjuster Removal, Installation, and Brake Adjustment



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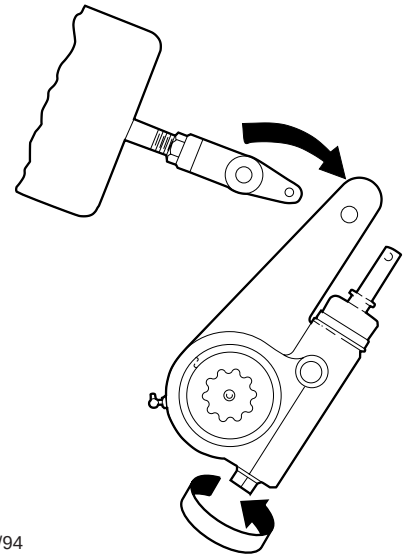
A. Insert screwdriver here.

Fig. 2, Disengaging the Pull-Pawl



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Turn the manual adjusting nut clockwise.

Fig. 3, Slack Adjuster Removal

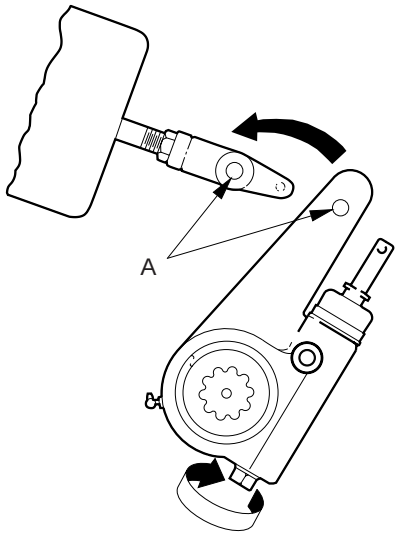
NOTICE

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

6.4 Using a screwdriver or an equivalent tool, pry the pawl button out at least 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

6.5 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.



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A. Turning the adjusting nut counterclockwise, align the large holes in the slack adjuster and clevis.

Fig. 4, Slack Adjuster Installation

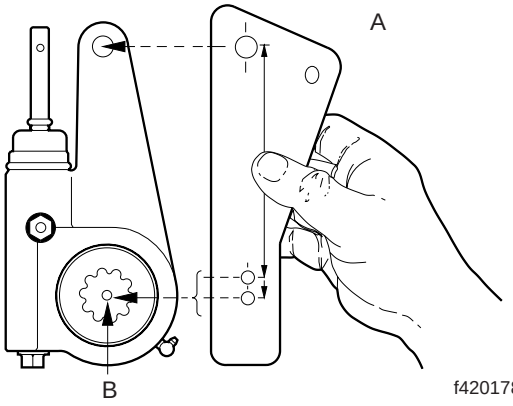
7. If installing a new slack adjuster:

7.1 Using an installation template, measure the old and new slack adjusters. Measure from the center of the large clevis-pin hole to the center of the camshaft opening. See **Fig. 5**.

Make sure the old and new slack adjusters are the same length.

7.2 Slide the slack adjuster on the camshaft, with the actuator rod on the side opposite the brake chamber.

Slack Adjuster Removal, Installation, and Brake Adjustment



A. Using a template, measure the slack adjuster arm length.
B. Camshaft Center

Fig. 5, Slack Adjuster Measurement

7.3 On LX500 and MX500 series, install the orange slack adjuster seal on the camshaft. The lip on the seal must face the snap ring.

7.4 Install the outer washer(s) and snap ring on the camshaft.

7.5 Using a dial indicator, measure the in-and-out (axial) end play of the camshaft. If necessary, add the appropriate number of spacing washers to achieve the correct axial end play.

- For all Cam-Master brakes, except LX500 and MX500 series, there should be no more than 0.060 inch (1.52 mm) movement.
- For LX500 and MX500, the axial end play should be no more than 0.020 inch (0.51 mm).

NOTICE

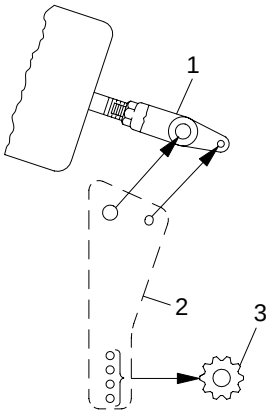
Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

7.6 Using a screwdriver or an equivalent tool, pry the pawl button out about 1/32 inch (0.8 mm). See **Fig. 2**. Wedge the tool in place.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting nut for positioning.

7.7 Using a wrench, turn the manual adjusting nut counterclockwise to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig. 4**.

7.8 With the brakes fully released, place the installation template over the clevis and camshaft end. See **Fig. 6**.



Place the template over the clevis and camshaft end.
1. Clevis
2. Template
3. Camshaft End

Fig. 6, Template Placement

7.9 Temporarily insert the large clevis pin through the large holes in the template and the clevis.

7.10 Select the hole in the lower part of the template that matches the length of the slack adjuster. Hold the template in place on the center of the camshaft with a pencil.

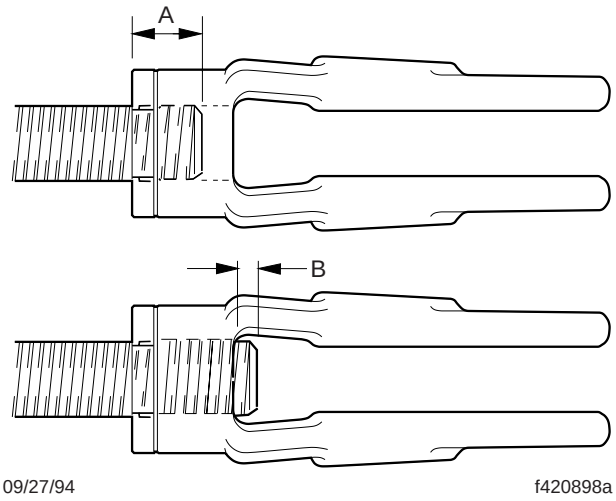
7.11 Make sure the small hole in the clevis is completely visible through the 1/8 inch hole at the top of the template.

If it is not, loosen the clevis jam nut, and turn the clevis adjusting nut to adjust the position of the clevis on the pushrod until the small clevis hole is completely visible.

IMPORTANT: The pushrod must be installed in the clevis at least 1/2 inch (13 mm) and not extend beyond it more than 1/8 inch (3 mm).

7.12 Make sure there is at least 1/2 inch (13 mm) of thread engagement between the clevis and the pushrod. Also, check that the pushrod does not extend through the clevis more than 1/8 inch (3 mm). See **Fig. 7**.

If necessary, cut the pushrod, install a new pushrod, or install a new brake chamber.



A. Minimum 1/2 inch (13 mm).
B. Maximum 1/8 inch (3 mm).

Fig. 7, Check Pushrod Engagement

7.13 Temporarily insert the small clevis pin through the template, clevis, and actuator rod to make sure the alignment is correct. Repeat the adjustment, if necessary. When the alignment is correct, remove both clevis pins and the template.

8. Apply antiseize compound to the two clevis pins.
9. Insert both clevis pins with their pinheads on the inboard side of the slack adjuster. Be sure the small clevis pin is inserted through the hole in the actuator rod. Install new retaining clips to secure the clevis pins.
10. If it was loosened, tighten the clevis jam nut to the following values.
    - For 1/2–20 threads, tighten the clevis jam nut 20 to 30 lbf·ft (27 to 41 N·m).
    - For 5/8–18 threads, tighten the jam nut 25 to 50 lbf·ft (34 to 68 N·m).
11. Lube the slack adjuster through the grease fitting until the lubricant is forced out through the pawl slot or through the gear splines around the inboard snap ring.
12. Adjust the brakes. See "Brake Adjustment" below.

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

1. If a rear axle slack adjuster was installed, manually uncage the parking brake.
2. Fully release the brakes (the air chamber pushrod must be fully retracted).

NOTICE

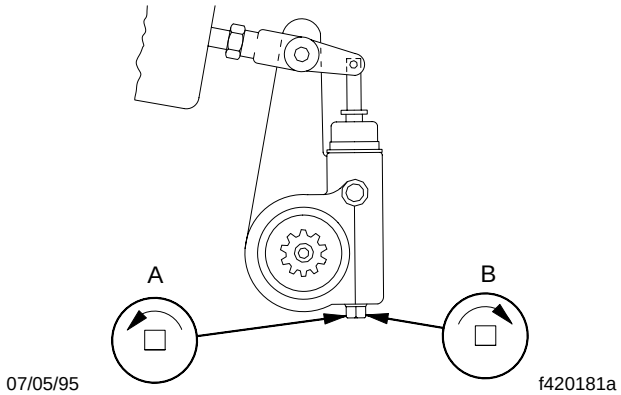
Before turning the manual adjusting nut on the slack adjuster, disengage the pull-pawl. Failure to do so could damage the pull-pawl teeth. A damaged pull-pawl will not allow the slack adjuster to automatically adjust the brake clearance.

3. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 2**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

Slack Adjuster Removal, Installation, and Brake Adjustment

4. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows. See **Fig. 8**.



A. Shorten stroke. B. Lengthen stroke.

Fig. 8, Adjusting the Stroke

4.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.

4.2 Then, turn the adjusting nut clockwise 1/2 turn.

5. Measure and adjust the free-stroke, as follows.

5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

5.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension B. See **Fig. 9**.

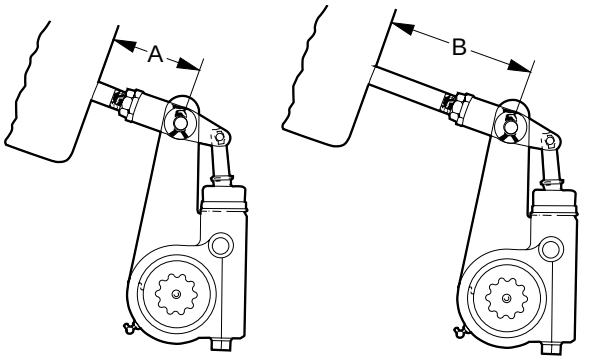
5.3 Subtract dimension A from dimension B. The difference between these measurements is the free-stroke.

5.4 The free-stroke for a new brake installation should be 5/8 to 3/4 inch (16 to 19 mm). For a brake that is in service, the free-stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not, turn the adjusting nut 1/8 turn, as shown in **Fig. 8**. Then, measure the free-stroke again; readjust it until it is correct.

6. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

6.1 If system pressure is not already at 100 psi (690 kPa), start the engine and build air pressure, then shut down the engine.

6.2 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.



NOTE: For either free-stroke or applied chamber stroke, subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied by manual lever (free-stroke) or pressurized brake application (applied chamber stroke).

Fig. 9, Measuring the Stroke

6.3 Fully apply the brakes. Then, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 9**, Ref. B. Record this measurement as dimension B.

6.4 Subtract dimension A from dimension B. The difference between these measurements is the true applied chamber stroke.

Slack Adjuster Removal, Installation, and Brake Adjustment

NOTICE

The adjusted applied chamber stroke should be as short as possible but not so short that the free-stroke is too short and the linings drag. If the linings drag, the brakes could be damaged.

6.5 The applied chamber stroke must not exceed the maximum value specified in **Table 1**.

If the applied chamber stroke is incorrect, turn the adjusting nut 1/8-turn counterclockwise to shorten the stroke, or 1/8-turn clockwise to lengthen it. See **Fig. 8**. Measure the applied stroke again and readjust it until it is correct.

6.6 If the slack adjuster is not maintaining the correct applied chamber stroke, check the condition of the foundation brakes. See **Section 42.01**.

7. Remove the screwdriver from the pull-pawl assembly. This will engage the pull-pawl with the actuator.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation before you put the vehicle in service, as follows.

8.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.

8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.

8.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than others show a lack of braking effort on those wheels.

Brake Chamber Stroke Specifications			
Chamber Type (Size)	Maximum Applied Stroke*: inch (mm)	Free-Stroke: inch (mm)	
		New Brake Installation	In-Service Brake
Long Stroke†			
16 and 20	2-1/2 (64)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (552–621 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

Specifications

Slack Adjuster Arm Length		
Chamber Size	Length	
	inch	mm
9, 12, 16, 20, 24, 30	5	127
9, 12, 16, 20, 24, 30, 36	5-1/2	140
24, 30, 36	6	152
30, 36	6-1/2	165

Table 1, Slack Adjuster Arm Length

Lubricant Specifications	
Lubricant	Ambient Temperature
Meritor 0-616-A Texaco Thermotex EP No. 1 Shell Darina No. 1 Texaco Hytherm EP No. 1 Aralub 3837 Tribolube 12, Grade 1 Meritor 0-692 Amoco Super Permalube No. 2 Citco Premium Lithium EP No. 2 Exxon Ronex MP No. 2 Kendall L-427 Super Blu No. 2 Mobilith AW No. 1 Sohio Factran EP No. 2	Above –40°F (–40°C)
Meritor 0-645 Mobil 28 Meritor 0-695	Below –40°F (–40°C)

Table 2, Lubricant Specifications

Maximum Adjusted Brake Chamber Stroke		
Chamber Size	Maximum Chamber Stroke: in (mm)	
	Standard Stroke	Long Stroke
9, 12	1-3/8 (35)	—
16, 20	1-3/4 (44)	2 (51)
24	1-3/4 (44)	2 (51) — *2-1/2 inch rated stroke*
		2-1/4 (57) — *3-inch rated stroke*
30	2 (51)	2-1/2 (64)

Specifications

Maximum Adjusted Brake Chamber Stroke		
Chamber Size	Maximum Chamber Stroke: in (mm)	
	Standard Stroke	Long Stroke
36	2-1/4 (57)	—

Table 3, Maximum Adjusted Brake Chamber Stroke

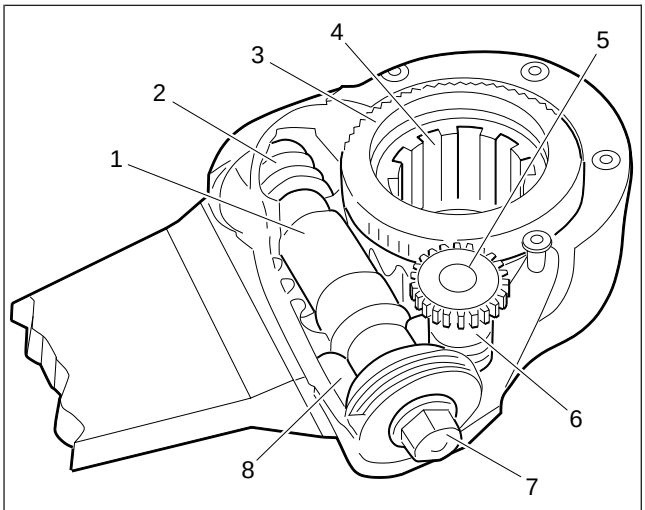
General Description

The Haldex (SAB) automatic slack adjuster, shown in **Fig. 1**, serves two main functions:

- As a lever, it converts the straight-line force of the air brake chamber pushrod to torque on the brake camshaft. Rotation of the camshaft spreads the brake shoes out against the brake drum, applying the brakes.
- As an adjuster, it maintains cam brake chamber pushrod stroke and lining-to-drum clearance automatically during normal use.

Principles of Operation

When the brakes are applied, the slack adjuster rotates and moves the shoes into contact with the drum. The indicator notch corresponds to the normal lining-to-drum clearance. As the brake application continues, the rack moves upward and rotates the one-way clutch, which slips in this direction.



1. Wormshaft
2. Coil Spring
3. Control Disc
4. Worm Wheel
5. Regulator Gear
6. One-Way Clutch
7. Adjustment Hex
8. Clutch Wheel

Fig. 1, Haldex Slack Adjuster

As the brake torque increases, the coil-spring load is overcome and the wormshaft is displaced axially, releasing the cone clutch.

When the brake begins its return stroke, the coil spring load returns to normal and the cone clutch is again engaged. The rack is pulled back to its original position in the notch. Any additional travel brought about by brake lining wear causes the rack to turn the locked one-way clutch and rotates the wormshaft through the locked cone clutch. The wormshaft then rotates the worm wheel and camshaft, adjusting the brakes.

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

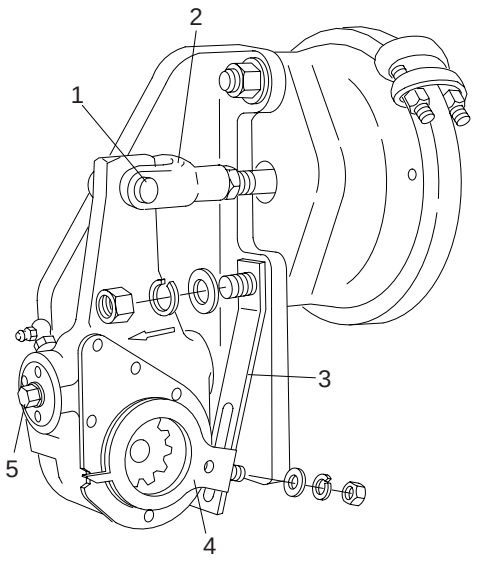
Slack Adjuster Removal, Installation, and Brake Adjustment

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface, set the parking brakes, and shut down the engine. Chock the front and rear tires.
2. If a rear-axle slack adjuster will be removed, release the parking brakes and cage the power spring of the parking brake chamber. For instructions, refer to the applicable brake chamber section in this group.
3. Remove the anchor bracket fasteners and the anchor bracket. See **Fig. 1**.



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1. Clevis Pin
2. Clevis
3. Anchor Bracket
4. Control Arm
5. Adjusting Hexnut

Fig. 1, Anchor Bracket Removal/Installation

4. Remove the cotter pin from the clevis pin. Remove the clevis pin.
5. Remove the snap ring that secures the slack adjuster on the camshaft.

NOTICE

Do not use an impact wrench on the adjusting hexnut. To do so may damage the slack adjuster or camshaft.

6. Using a 7/16-inch box wrench, turn the adjusting hexnut counterclockwise to move the adjuster arm out of the clevis. A minimum of 13 lbf·ft (18 N·m) is required to overcome the internal clutch. You will hear a ratcheting sound.
7. Remove the slack adjuster from the camshaft.

Installation

NOTE: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing a new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2 inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

1. Check that the brake-chamber pushrod is fully retracted.
2. Apply antiseize compound to the camshaft splines.

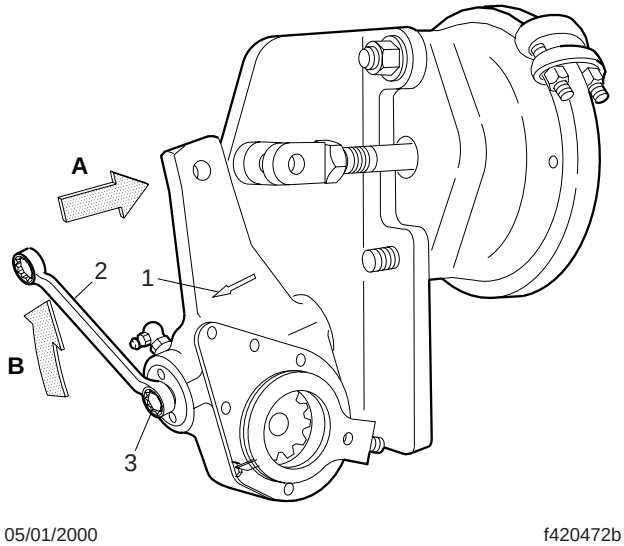
IMPORTANT: When correctly installed, the brake-chamber pushrod pushes in the direction of the arrow on the slack adjuster housing.

3. Install the slack adjuster on the camshaft, with the adjusting hexnut pointing away from the brake chamber. See **Fig. 2**.
4. Using a snap ring, secure the slack adjuster on the camshaft. Use at least one inner washer and enough outer washers to allow no more than 0.060-inch (1.52-mm) movement on the shaft.

IMPORTANT: Never pull the pushrod out to meet the slack adjuster or push the slack adjuster into position. Always turn the adjusting hexnut for positioning.

5. Using a 7/16-inch box wrench, turn the adjusting hexnut clockwise until the slack adjuster hole is aligned with the pushrod clevis hole. See **Fig. 2**.

Slack Adjuster Removal, Installation, and Brake Adjustment



A. Use only the adjusting hexnut to align the slack adjuster with the pushrod clevis.
B. Turn the adjusting hexnut clockwise.

1. Direction of Applied Stroke
2. Box Wrench, 7/16 in
3. Adjusting Hexnut

Fig. 2, Slack Adjuster Installation

6. Apply antiseize compound to the clevis pin, and insert the pin in the clevis hole. Do not install the cotter pin at this time.

NOTICE

Never hammer the control arm. Hammering may damage the slack adjuster or camshaft splines.

7. The S-ABA control arm can be placed anywhere within the range of the bracket slot for automatic adjustment to take place. However, Haldex recommends rotating all control arms towards the axle until they come to a complete stop, as shown in **Fig. 3**, and then secure the arm in that position. This will create a 'common' position for all wheels.

NOTE: The anchor bracket and slack adjuster housing design will vary, depending on the axle. The anchor bracket mounting location is determined by the length of the control arm.

8. Install the control-arm anchor bracket, as follows. See **Fig. 1**.

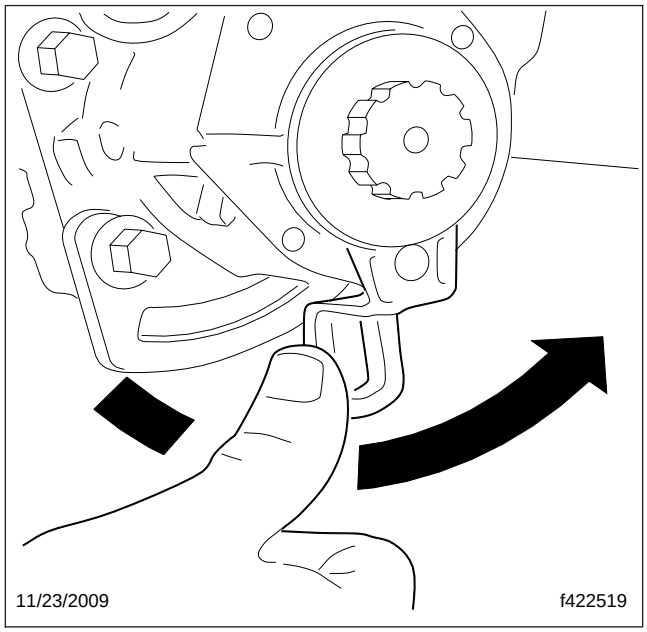


Fig. 3, Positioning the Control Arm

8.1 Tighten the anchor bracket fastener at the control arm 10 to 15 lbf·ft (14 to 20 N·m), making sure the control arm does not move from its position.

8.2 Tighten the fastener at the brake chamber mounting stud according to the brake chamber manufacturer's specifications.

9. Adjust the brakes. See "Brake Adjustment".

Brake Adjustment

NOTE: A properly working self-adjusting slack adjuster does not require manual adjustment while in service.

⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

Slack Adjuster Removal, Installation, and Brake Adjustment

1. Adjust the brake lining clearance by manually turning the adjusting hexnut clockwise until the brake lining contacts the brake drum, then back off the hexnut counterclockwise 1/2 turn. You will hear a ratcheting sound.

IMPORTANT: Incorrect installation can cause dragging brakes.

2. Make sure the brakes are still fully released, then check the position of the installation indicator on the control arm. It must be within the indicator notch on the slack adjuster.

   If the indicator is out of position, loosen the control arm fasteners and repeat the control-arm adjustment procedure. Then, tighten the bracket fasteners.

⚠ WARNING

Install and lock a new cotter pin in the clevis pin. Failure to do so could allow the pushrod to disengage from the slack adjuster, causing a loss of braking ability that could result in personal injury and property damage.

3. Install and lock a new cotter pin in the clevis pin.

IMPORTANT: Ensure that the air system has at least 100 psi prior to uncaging the brake chamber. This will aid in the uncaging of the parking brake since the parking brake should be fully released.

4. If a rear-axle slack adjuster was installed, manually uncage the parking brake. For instructions, refer to the applicable brake chamber section in this group.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

IMPORTANT: To check the brake adjustment, measure both the applied and free strokes.

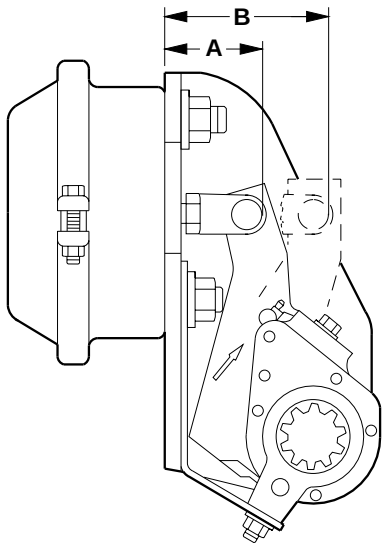
NOTE: The location of the measurements is the same for both strokes but the applied stroke is measured with the brakes applied, while a lever is used to manually move the slack adjuster to measure the free stroke.

5. Measure the free stroke, as follows. The free stroke is the distance the slack adjuster has to travel to move the brake shoes against the drum.
   - 5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement A.
   - 5.2 Using a lever, move the slack adjuster until the brake shoes contact the drum. Measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement B.
   - 5.3 Subtract measurement A from measurement B to determine the free stroke. For new brake installations, the free stroke should be 5/8 to 3/4 inch (16 to 19 mm). For in-service brakes, the free stroke should be 1/2 to 5/8 inch (13 to 16 mm).
6. Measure the applied stroke, as follows.
   - 6.1 With the brakes released (pushrod fully retracted), measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. See **Fig. 4**. Record the exact distance as measurement A.
   - 6.2 Apply and hold an 80 psi (552 kPa) brake application. Measure the distance from the bottom of the brake chamber to the far side of the clevis-pin hole. Record the exact distance as measurement B.
   - 6.3 Subtract measurement A from measurement B to determine the applied stroke. Compare this value to the value in **Table 1**.
7. Apply the parking brakes.
8. Remove the chocks from the tires.
9. In a safe area, check for proper brake operation, as follows.
   - 9.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.

Slack Adjuster Removal, Installation, and Brake Adjustment

9.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.

9.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.



NOTE: Measurements are from the bottom of the brake chamber to the far side of the clevis-pin hole.

A. Measurement with brakes released.
B. Measurement with brakes applied at 80 psi (551 kPa).

Fig. 4, Brake Applied Stroke Check

Brake Chamber Stroke Specifications			
Chamber Size	Maximum Applied Stroke: inch (mm)	Free Stroke: inch (mm)	
		New Brake Installation	In-Service Brake Installation
16	1-3/4 (44)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
20			
24	1-7/8 (48)		
30	2 (51)		

Table 1, Brake Chamber Stroke Specifications

Problem—Tight or Dragging Brakes

Problem—Tight or Dragging Brakes	
Possible Cause	**Remedy**
The control arm anchor bracket is not positioned properly.	See instructions in **Subject 110**.
System air pressure is too low to fully release the spring brake.	Check that the air governor cuts out at the recommended setting.
A spring brake diaphragm is ruptured or a piston seal is leaking.	Replace the diaphragm or spring brake piston seal.
A return spring in the brake chamber is broken.	Replace the spring brake return spring.
The pushrod binds on the chamber housing.	Check for correct alignment and correct chamber mounting bracket. Adjust or replace parts as needed.
The air supply does not exhaust completely.	Test the air system valves for leakage and correct operation.
The brake drums are out-of-round.	Turn the brake drums, if possible. If the maximum allowable diameter of any brake drum has been exceeded, replace the drum. Also, turn or replace the other drum on the axle. For turning the drums, refer to the brake manufacturer's service manual.
Extreme differences exist in lining-to-drum clearances between shoes on the same wheel.	Check for proper operation of the brake mechanism. Lubricate or overhaul as needed.
The wheel bearings are out of adjustment.	Adjust the wheel bearings, or replace them if damaged. For instructions see **Group 33** or **Group 35** in this manual.
The brake shoe return spring is broken.	Replace the brake shoe return spring.

Problem—Brake Chamber Pushrod Travel Is Excessive

Problem—Brake Chamber Pushrod Travel Is Excessive	
Possible Cause	**Remedy**
The control arm anchor bracket is loose, broken, or bent.	Tighten or replace the anchor bracket as required.
There is excessive wear between the anchor bracket bolt and the control arm slot.	Replace the worn parts.
The control arm assembly is damaged or worn, resulting in lateral movement between the control arm and the cover plate.	Replace the slack adjuster.
The camshaft bushings are worn.	Replace the worn camshaft bushings.
The camshaft binds.	Lubricate the camshaft or overhaul the brake mechanism as needed.
The brake chamber mounting is loose.	Tighten the brake chamber mounting fasteners.
The slack adjuster is bound against the camshaft housing. There is no end play.	Check that the correct camshaft and camshaft tube have been used and that they are assembled correctly. Overhaul the brake mechanism as needed.
The slack adjuster clutch assembly is worn.	Replace the slack adjuster.

Specifications

Approved Lubricants	
Lubricants Type	**Lubricant Type**
Low Lube	Mobilgear SHC 460 Synthetic
Standard	Standard Chassis Grease

Table 1, Approved Lubricants

Brake Chamber Stroke Specifications			
Chamber Size	**Maximum Applied Stroke: inch (mm)**	**Free Stroke: inch (mm)**	
		New Brake Installation	**In-Service Brake Installation**
16	1-3/4 (44)	5/8–3/4 (16–19)	1/2–5/8 (13–16)
20			
24	1-7/8 (48)		
30	2 (51)		

Table 2, Brake Chamber Stroke Specifications

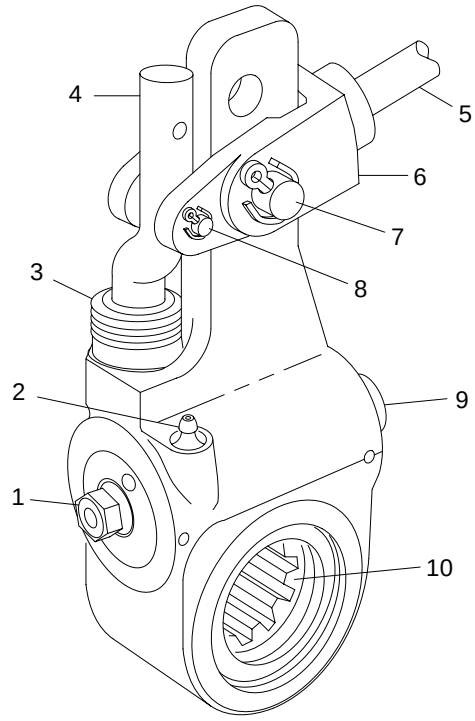
General Information

The Gunite automatic slack adjuster has two main functions:

- As a lever it converts the straight-line force of the brake chamber push rod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the drum.
- As an automatic slack adjuster, it maintains the lining-to-drum clearance needed for proper brake chamber push rod stroke.

The slack adjuster is installed between the brake chamber push rod and the brake camshaft. A clevis connects the brake chamber push rod to the top of the slack adjuster. See **Fig. 1**. The bottom of the slack adjuster is splined to the brake camshaft. The splines hold the slack adjuster internal gear to the camshaft, so the camshaft turns when the slack adjuster moves. When the brakes are applied, the brake chamber push rod moves outward forcing the slack adjuster and camshaft to rotate. This movement forces the brake shoes against the drum.

The brakes are adjusted when the slack adjuster senses an increase in the lining-to-drum clearance. The slack adjuster's internal worm shaft and ratchet shorten excessive lining-to-drum clearance. This provides maximum leverage for the brake chamber push rod. The automatic slack adjuster adjusts the brakes at the beginning of the brake application.



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1. 7/16-Inch Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Push Rod
6. Clevis
7. 1/2-Inch Clevis Pin
8. 1/4-Inch Clevis Pin
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 1, Gunite Slack Adjuster

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

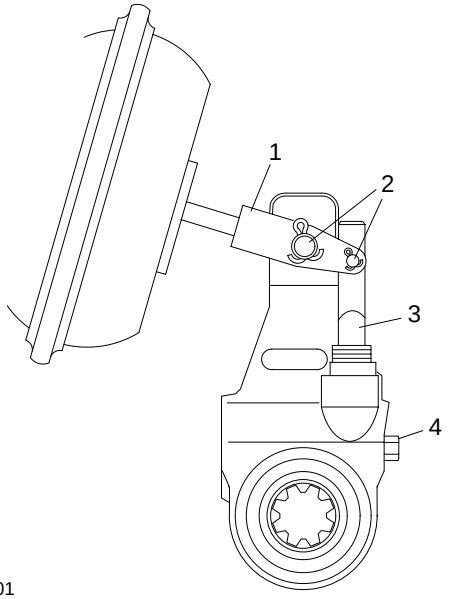
Slack Adjuster Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: This automatic slack adjuster cannot be rebuilt. If it is damaged or inoperative, replace the unit.

The factory installed brake chambers have welded clevises on the pushrod. See **Fig. 1**. On replacement brake chambers, the clevis is threaded onto the pushrod, and has a jam nut installed. See **Fig. 2**.



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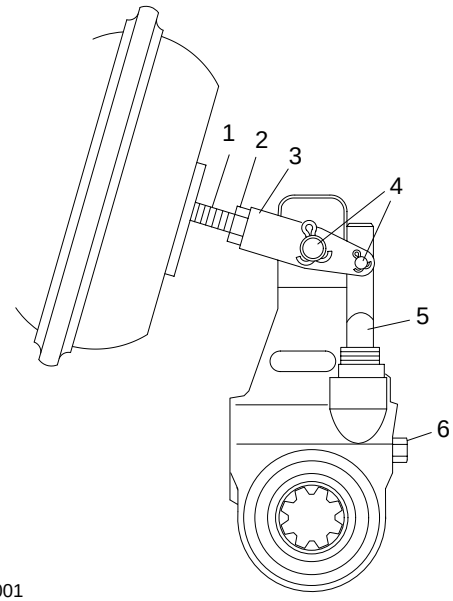
1. Brake Chamber Pushrod and Clevis Assembly
2. Cotter Pins and Clevis Pins
3. Link
4. Adjusting Hexnut

Fig. 1, Slack Adjuster (attached to welded clevis)

Removal

1. Park the vehicle on a level surface, and chock the tires. If a rear slack adjuster is being removed, cage the parking brake power spring. For instructions, refer to the applicable brake chamber section in this group.
2. Remove the cotter pins and clevis pins.



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1. Brake Chamber Pushrod (threaded)
2. Jam Nut
3. Threaded Clevis
4. Cotter Pins and Clevis Pins
5. Link
6. Adjusting Hexnut

Fig. 2, Slack Adjuster (attached to threaded clevis)

3. Rotate the adjusting hexnut counterclockwise until the slack adjuster clears the clevis.
4. Remove the snap ring from the brake camshaft, then slide the slack adjuster off the camshaft.

Installation

IMPORTANT: For brake chambers that have pushrods with threaded clevises, measure the pushrod length before installing the new slack adjuster. With the brakes fully released, and no air pressure to the chamber, check the dimension between the chamber face and the centerline of the 1/2-inch clevis pin hole. It should be 2.25 inches (57 mm) for long stroke chambers, and 2.75 inches (70 mm) for standard stroke chambers.

There is a difference between the clevis pin spacing for Gunite slack adjusters used with standard stroke chambers and long stroke

Slack Adjuster Removal and Installation

chambers. These two slack adjusters are **not** interchangeable.

- The pin-to-pin dimension on standard stroke slack adjusters is 1.0 inch (2.54 cm).
- The pin-to-pin dimension on long stroke chambers is 1.3 inches (3.3 cm).

1. Coat the camshaft splines, and the splines of the slack adjuster gear with an anticorrosive grease.
2. Using the old snap ring, install the automatic slack adjuster on the brake camshaft.
3. Turn the adjusting hexnut clockwise to rotate the slack adjuster toward the brake chamber until the holes line up.
4. Install the clevis pins and cotter pins.

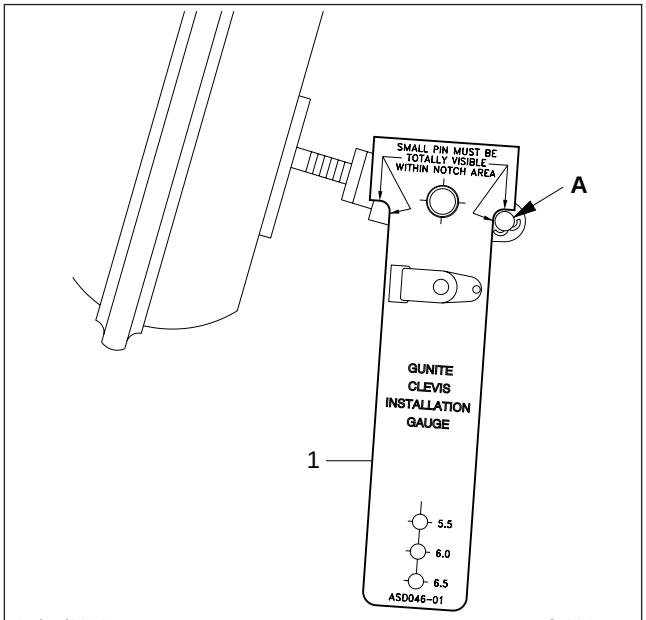
⚠ WARNING

Manually adjusting an automatic slack adjuster to bring the pushrod stroke within legal limits is likely masking a mechanical problem. Adjustment is not repairing. Before adjusting an automatic slack adjuster, troubleshoot the foundation brake system and inspect it for worn or damaged components. Improperly maintaining the vehicle braking system may lead to brake failure, resulting in property damage, personal injury, or death.

5. If the pushrod has a threaded clevis, use the gauge supplied with the new slack adjuster to check the adjustment of the clevis. See **Fig. 3**.
   - 5.1 Position the 1/2-inch hole in the gauge over the end of the 1/2-inch clevis pin.
   - 5.2 Align the applicable 1/4-inch hole in the bottom of the gauge over the center of the camshaft.
   - 5.3 Check that the 1/4-inch pin is visible in the notched area of the gauge. If the pin is not in the right location, back off the slack adjuster and readjust the pushrod length, then repeat this step.

NOTE: Make sure there is clearance between the slack adjuster and other vehicle components when the brakes are applied and the pushrod travels its maximum stroke.

6. Set the initial free-stroke.



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A. Adjust the clevis in or out to position the 1/4-inch clevis pin within the notched area of the gauge.

1. Installation Gauge

Fig. 3, Checking the Clevis Adjustment

   - 6.1 Turn the adjusting hexnut clockwise until the brake linings contact the drum.
   - 6.2 Turn the adjusting hexnut counterclockwise one-half turn. There should be about 30 lbf·ft (41 N·m) resistance, and a ratcheting sound will be heard.

7. Measure the brake chamber applied stroke.
   - 7.1 With the brakes fully released, use a ruler to measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**.
   - 7.2 Build air pressure to at least 85 psi (586 kPa). Apply the brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 4**. The difference between the measurements is the brake chamber stroke.
   - 7.3 The brake chamber stroke must be within the range shown in **Table 1**. If it is not, check the foundation brakes for problems such as worn cams, bushings, pins and

rollers, or broken springs. Repair or replace as needed. For instructions, refer to the applicable brake section in this group. Then, repeat the two previous steps.

8. If a rear axle slack adjuster was installed, manually uncage the parking brake. Refer to the applicable brake chamber section in this group for instructions.
9. Apply the parking brakes.
10. Remove the chocks from the tires.
11. In a safe area, check for proper brake operation, as follows.
    - 11.1 Apply and release the brakes several times to check for correct operation of the slack adjusters.
    - 11.2 Perform six low-speed stops to ensure correct parts replacement and full vehicle control.
    - 11.3 Immediately after doing the above stops, check the drum temperatures. Any drums that are significantly cooler than the others show a lack of braking effort on those wheels.

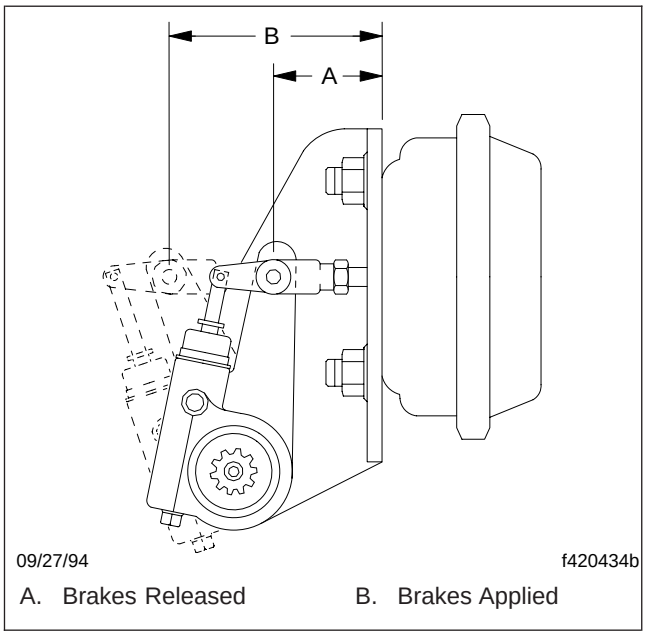


Fig. 4, Make these Measurements

Brake Chamber Stroke Specifications			
Chamber Type (Size)	**Maximum Applied Stroke*: inch (mm)**	**Free-Stroke: inch (mm)**	
		New Brake Installation	**In Service Brake**
Long Stroke†			
16 and 20	2-1/2 (64)	5/8 to 3/4 (16 to 19)	1/2 to 5/8 (13 to 16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (552–621 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 1, Brake Chamber Stroke Specifications

Specifications

Approved Lubricants	
Lubricant Type	**Temperature**
Lubriplate Aero	Above –40°F (–40°C)
Texaco Multifak EP–2 Mobil Grease 77	Above –20°F (–29°C)

Table 1, Approved Lubricants

Brake Chamber Stroke Specifications			
Chamber Type (Size)	**Maximum Applied Stroke*: inch (mm)**	**Free-Stroke: inch (mm)**	
		New Brake Installation	**In Service Brake**
Long Stroke†			
16 and 20	2-1/2 (64)	5/8 to 3/4 (16 to 19)	1/2 to 5/8 (13 to 16)
24 and 30	3 (76)		

* Specifications are relative to a brake application with 80–90 psi (552–621 kPa) air pressure in the brake chambers.

† Long stroke design is indicated by a tag, or embossing, on the brake chamber.

Table 2, Brake Chamber Stroke Specifications

General Description

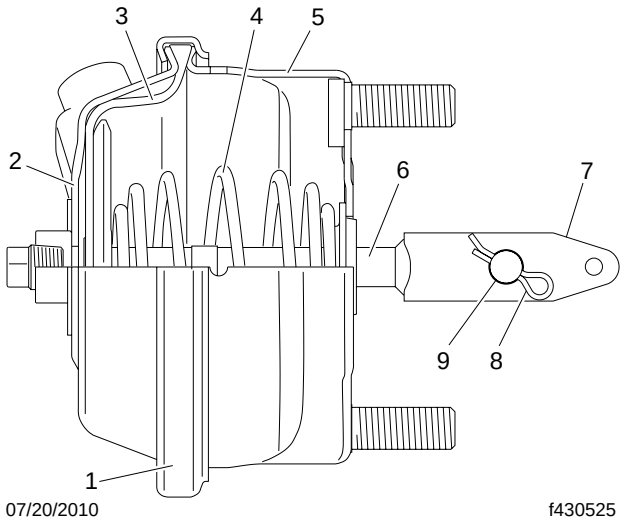
DANGER

Do not attempt to remove the sealed rolled-ring assembly on the brake chamber for any purpose at any time. The brake chamber is not intended to be serviced. Serious injury or death may result from the sudden release of the piston rod spring.

IMPORTANT: The Haldex brake chamber has a factory sealed rolled-ring assembly and is a *non-serviceable* unit.

Brake chambers convert the energy of compressed air into the mechanical force and motion needed to apply the brakes. Two chambers operate the brakes, one on each side of the axle.

Each brake chamber consists of two dished metal sections: the cover assembly and the body assembly, which are separated by a nylon reinforced rubber diaphragm. A metal rolled-ring assembly holds the sections together. See **Fig. 1**.



1. Rolled Ring Assembly (sealed)
2. Cover Assembly
3. Diaphragm
4. Piston Rod Spring
5. Body Assembly
6. Piston Rod Assembly
7. Welded Clevis Pushrod
8. Cotter Pin
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

In front of the diaphragm are the body, piston rod assembly, and a piston rod spring. The threaded piston rod assembly extends through the bottom of the body and connects to the clevis. See **Fig. 1**.

Different sized brake chambers are identified by numbers, which specify the effective area of the diaphragm. For example, a type 16 brake chamber has 16 square inches of effective area.

Principles of Operation

The greater the air pressure admitted to the brake chamber, the greater the force applied by the piston rod. Piston rod force is determined by multiplying the delivered air pressure by the effective diaphragm area. For example, if 60 psi (414 kPa) is admitted to a type 16 brake chamber, the force on the end of the piston rod is about 960 lb (436 kg).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber cover to move the diaphragm and piston rod assembly forward. This compresses the spring, and applies a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

When the brake pedal is released, compressed air behind the diaphragm exhausts through the quick release valve. The spring then allows the piston rod assembly and diaphragm to return to their previous positions.

Safety Precautions

When working on or around a vehicle, observe the following precautions.

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber Piston rods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if they not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses, that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Brake Chamber Removal and Installation

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Chock the tires.

⚠ WARNING

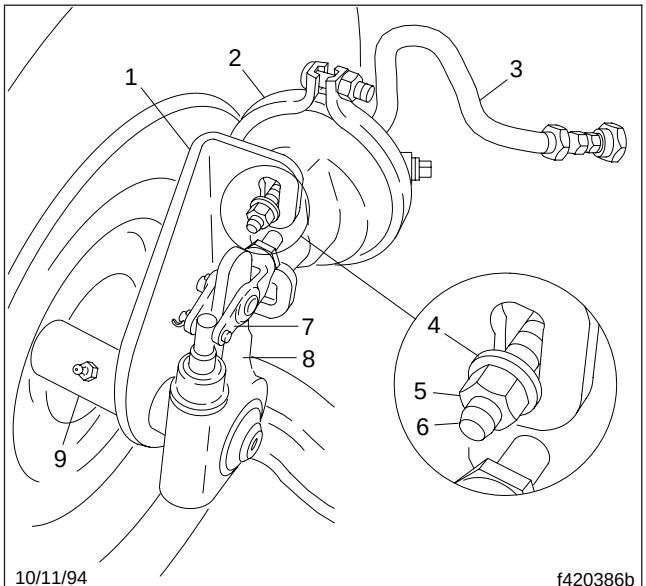
Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Do not direct the airstreams at other people. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in severe personal injury.

Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Carefully disconnect the air line from the brake chamber. See **Fig. 1**.
4. Remove the cotter pins from the clevis pins.
5. Remove the clevis pins from the slack adjuster.
6. From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation

1. Before installing a new chamber, be sure the new chamber is the same size and make as the brake chamber on the other side of the axle.
2. Attach the brake chamber to the mounting bracket, using a hardened flatwasher and prevailing torque locknut. See **Fig. 1**.
3. Tighten the locknuts. See **Specifications 400** for the correct torque value.
4. Connect the clevis pins to the slack adjuster.
5. Install and lock new cotter pin(s) to secure the clevis pin(s).



1. Chamber Mounting Bracket
2. Brake Chamber
3. Air Line
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Chamber Mounting Stud
7. Clevis Assembly
8. Slack Adjuster
9. Camshaft Tube

Fig. 1, Brake Chamber Mounting

6. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this group.
7. Make sure the air line fittings are clean and free of debris.
8. Connect the air line to the brake chamber and tighten the nut finger-tight. Then, using a wrench, further tighten the nut until there is resistance, then tighten one-sixth turn more.

   Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
9. Do both of the tests in **Subject 120**.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: For both of these tests, the air system must be pressurized to at least 80 psi (552 kPa).

Operating Test

1. Chock the tires.
2. Apply the brakes. Check that each piston rod moves out promptly, without binding.
3. Release the brakes. Check that each piston rod returns to the released position promptly, without binding.
4. Check the brake chamber stroke. It should be as short as possible without causing the brakes to drag. If needed, adjust the travel of the piston rod at the slack adjuster. For instructions, refer to the foundation brake section in this group.

Leakage Test

1. Apply the brakes and hold them on full line pressure of at least 80 psi (552 kPa).
2. Using a soap solution, coat the sealed clamp ring. Leakage is excessive if it produces a 1-inch (25-mm) bubble within five seconds.

   If leakage exceeds allowed amount, replace the brake chamber.

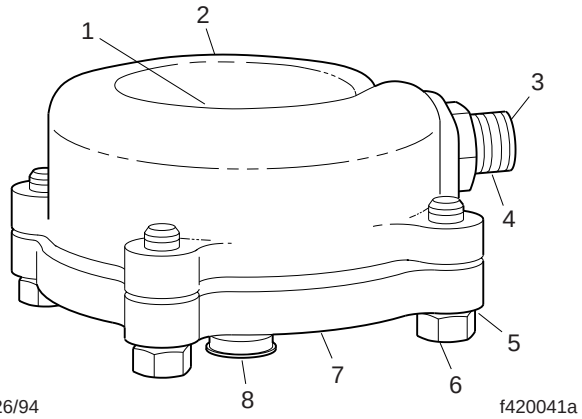
Specifications

Torque Values		
Description	**Chamber Size (all 5/8-inch Studs)**	**Torque: lbf·ft (N·m)**
Brake Chamber Mounting-Stud Locknuts	16	130–150 (176–203)
	20	
	24	
	30	

Table 1, Torque Values

General Description

The DV-2 automatic reservoir drain valve, shown in **Fig. 1**, automatically removes contaminants and water from the wet-air tank each time the brakes are applied. The drain valve is screwed into the port at the lowest end of the tank, located on the bottom of either end of the wet-air tank. Since the brake application valve is protected by a check valve between the wet- and dry-air tanks, any leak or failure will not reduce the supply of air that is in the dry part of the system. If the leak is severe, it could prevent the continued resupply of air as it is used up when applying the brakes. A failed drain valve will allow moisture to build up in the wet tank, which in turn could reach the dry tank, and then travel into the air brake system where it could cause brake failure. A leaking drain valve allows wet tank leakdown, which in turn can cause premature wear on the air compressor during vehicle operation as the air compressor continues to run to maintain wet tank air pressure.



1. Top Reservoir Port
2. Valve Body
3. Hexhead Nipple
4. Side Reservoir Port
5. Lockwasher (4 qty.)
6. Capscrew (4 qty.)
7. Valve Cover
8. Exhaust Port

Fig. 1, DV-2 Valve

Principles of Operation

With no pressure in the system, the drain valve's inlet and exhaust valves are closed. See **Fig. 2**. Upon charging the system, a slight pressure opens the inlet valve, which permits air and contaminants to collect in the sump. See **Fig. 3**. The inlet valve remains open when pressure is rising in the system until the air compressor cuts off, allowing the spring action of the valve guide in the sump cavity to close the inlet valve. The inlet valve and the exhaust valve are now both closed. See **Fig. 4**. When the wet tank pressure drops approximately 2 psi (14 kPa), the air pressure in the sump cavity opens the exhaust valve and allows moisture and contaminants to be ejected from the sump cavity until pressure in the sump cavity drops sufficiently to close the exhaust valve. See **Fig. 5**.

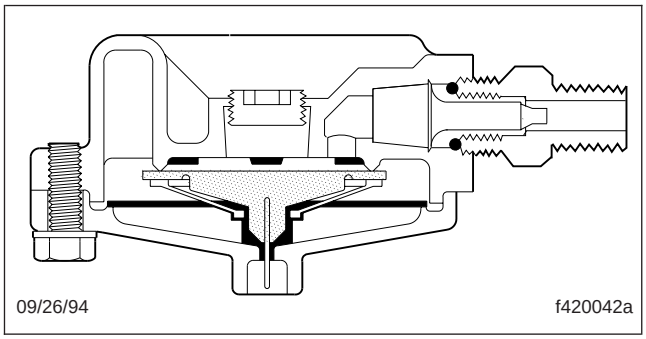


Fig. 2, No System Pressure

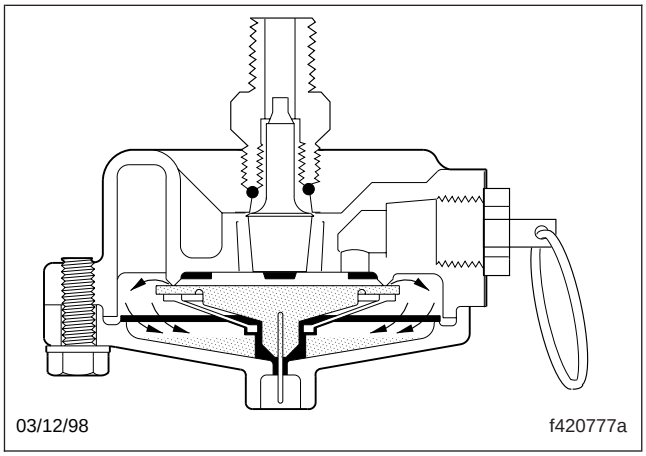


Fig. 3, Start of System Pressure Charging

The length of time the exhaust valve remains open and the amount of moisture and contaminants ejected depends upon the sump pressure and the wet tank pressure drop that occurs each time air is used from the system.

General Information

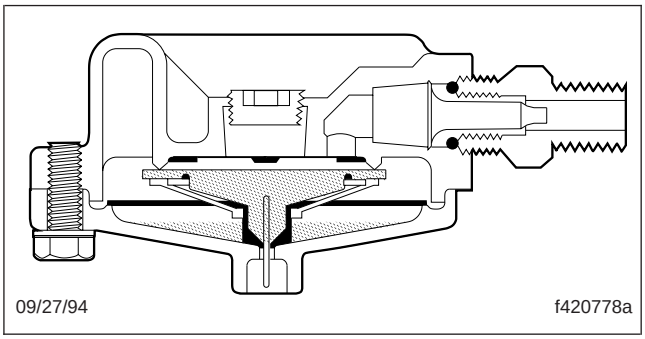


Fig. 4, System Pressure Rising

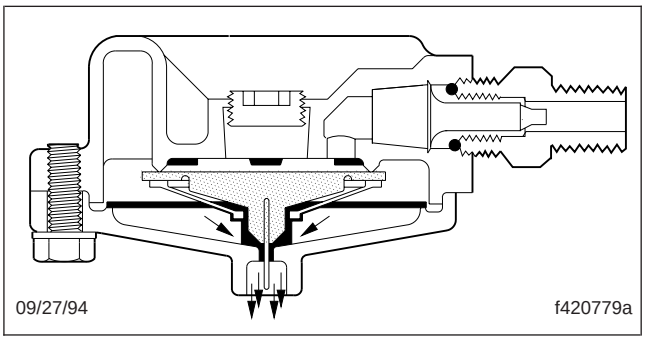


Fig. 5, Exhaust Cycle

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Always chock the vehicle's wheels and shut down the engine when working under a vehicle. Depleting vehicle air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing air pressure. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been depleted.
- Never exceed recommended air pressure, and always wear safety glasses when working with air pressure. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood the recommended procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Chock the tires, and drain the air system.
2. Remove the drain valve assembly from the end of the wet tank air reservoir.

Installation

1. Using a cleaning solvent, thoroughly flush and clean the wet tank reservoir to avoid early fouling at the drain valve. Aerate the wet tank thoroughly.
2. Install the drain valve assembly on the wet tank by tightening the hexagonal nipple until the drain valve is positioned so that the valve body is parallel to the bottom of the wet tank with the exhaust port facing straight down. Make sure that the exhaust port is clear of any air, electric, or fuel lines. Make sure the drain valve is attached tight enough to prevent leakage.
3. Close the drain cocks to the wet and dry air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the drain valve following the instructions in **Subject 130**.

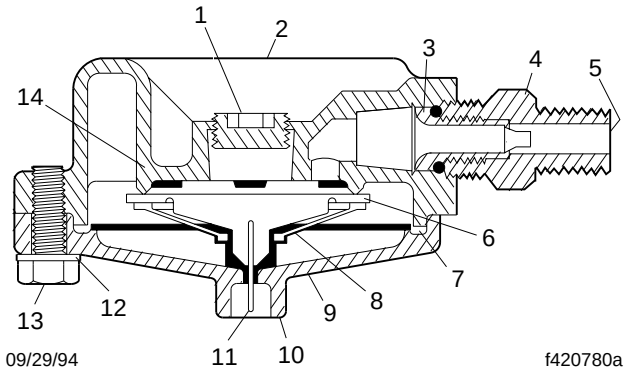
Drain Valve Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

Refer to **Fig. 1** during drain valve disassembly and assembly.



1. Top Reservoir Port
2. Valve Body
3. Filter Retainer
4. Hexhead Nipple
5. Side Reservoir Port
6. Inlet and Exhaust Valve
7. Valve Sealing Ring
8. Valve Guide
9. Valve Cover
10. Exhaust Port
11. Wire Stem
12. Lockwasher (4 qty.)
13. Capscrew (4 qty.)
14. Inlet Valve Seat

Fig. 1, DV-2 Valve (cutaway view)

1. Remove the drain valve, following the instructions in **Subject 110**.
2. Remove the four capscrews that hold the valve cover to the valve body.
3. Remove the valve cover and sealing ring.
4. Remove the valve guide, and the inlet and exhaust valve from the valve body.
5. Remove the hexhead nipple from the valve body.

Cleaning and Inspection

WARNING

Use eye protection when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the drain valve in an approved cleaning solvent. Dry the metal parts of the disassembled moisture ejection valve with compressed air.
2. Wipe all rubber parts clean with a clean cloth. Examine all rubber parts for wear, cracks, tears, or other deterioration. If any rubber parts are worn, cracked, torn, or otherwise deteriorated, replace them with new parts.
3. Examine all metal parts for wear, cracks, or other damage. If any metal parts are worn, cracked, or otherwise damaged, replace them with new parts.
4. Clean and examine the filter. If it will not clean completely, or is torn or damaged, replace it with a new filter.

NOTICE

Do not reassemble the drain valve with a dirty filter; to do so could result in failure of the drain valve in service.

Assembly

Before assembling the drain valve, apply a light film of grease on the inlet valve seat.

IMPORTANT: Do not apply oil to the inlet and exhaust valve.

1. Install the valve sealing ring into its groove in the valve cover.
2. Install the valve guide over the inlet and exhaust valve.
3. Install the valve guide, and the inlet and exhaust valve as an assembly into the valve cover. The wire stem will project through the exhaust port.
4. Install the valve body on the valve cover, and install the lockwashers and capscrews. Tighten the capscrews 95 to 130 lbf·in (1073 to 1469 N·cm).

Drain Valve Disassembly, Cleaning and Inspection, and Assembly

5. Install the hexhead nipple onto the valve body, and tighten it 65 to 95 lbf·in (734 to 1073 N·cm).
6. Install the drain valve on the wet tank, following the instructions in **Subject 110**.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operating Test

Perform the following test after repairing or replacing the DV-2 valve, to ensure that the valve is functioning properly.

With the system charged, apply the brakes several times. Each time the brakes are applied, an exhaust of air should occur from the exhaust port of the drain valve. If no air comes out, push the wire stem located inside the exhaust port. If no air comes out after pushing the wire stem, there may be a plugged filter in the adapter which should be replaced.

If the drain valve does not function properly, repair or replace it following the instructions in **Subject 110**.

Leakage Test

Perform the following test after repairing or replacing the DV-2 valve, to ensure that the valve is functioning properly.

With the system charged and pressure stabilized in the system, there should be no leaks at the drain valve exhaust port. A constant slight exhaust of air at the drain valve exhaust port could be caused by excessive leakage in the air brake system.

If the drain valve is leaking excessively, repair or replace it following instructions in this section.

Specifications

Torque Values	
Description	**Torque: lbf·in (N·cm)**
Valve Cover Capscrews	95–130 (1073–1469)
Hexhead Nipple (to valve body)	65–95 (734–1073)

Table 1, Torque Values

General Information

This troubleshooting guide is designed to help locate causes of problems originating in the air brake system. The corrective measures given are not intended to replace the detailed service information found in other sections of this manual or in the component manufacturer's service manuals. If the vehicle is equipped with ABS (antilock brake system), refer to the applicable section in this group for troubleshooting the ABS system.

Before attempting to isolate the causes of an air brake system problem, do the following:

1. Check the operation of the air compressor. Refer to the engine manufacturer's service manual.

   Check the pressure levels of the air reservoirs. See the pretrip inspection and daily maintenance chapter of the *108SD and 114SD Driver's Manual*.

2. Be sure that all relay valves are operating. See **Group 42** of the *108SD and 114SD Maintenance Manual*.
3. Check the operation of the brake chambers as instructed in **Group 42** of the *108SD and 114SD Maintenance Manual*.
4. Examine all tubing for kinks, dents, and other damage. Replace damaged tubing.
5. Examine all hoses for cracks, drying out, overheating, and other damage. Replace damaged hoses.
6. Examine all air line fittings. Tighten loose connections; replace fittings that are damaged. For instructions, refer elsewhere in this group.
7. Examine leaking pipe connections for cracks or thread damage; replace as needed. If there is no damage, retighten the fitting. For instructions, refer elsewhere in this group.

Safety Precautions

⚠ WARNING

Follow the manufacturer's procedures while working on any air device. Some parts are subject to mechanical (spring) or pneumatic propulsion and may cause personal injury or property damage when released. Failure to take all necessary precautions during servicing of the air brake system can result in personal injury or property damage.

Compression and storage of air in the air brake system is comparable to the energy in a coiled spring: when released, it may present a hazard. Because of this, certain precautions are required.

- Chock the tires. This will prevent accidental rolling of the vehicle when air is released from the brake system.
- Don't disconnect pressurized hoses because they will whip as air escapes from the line. Drain the air system before disconnecting the air hoses.
- When draining the air system, do not look into the air jets or direct them toward another person: dirt particles or sludge may be carried in the air stream.
- As air pressure is drained and the parking/emergency brakes apply, keep your hands away from the brake chamber push rods and parking brake chambers, which will activate automatically with the loss of pressure.

Troubleshooting Tables

Problem—Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied

Problem—Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied	
Possible Cause	**Remedy**
The vehicle is overloaded.	Observe the recommended maximum load limits.
There is low air pressure in the brake system, about 60 psi (414 kPa) or lower.	The drain cock on the air reservoir was left open; close the drain cock.
	Check the compressor output pressure; correct as necessary.
	Check the setting of the air governor with an accurate test gauge. Adjust the air governor to the recommended specification.
The application air lines are leaking excessively.	Check the application air lines, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
Brake valve delivery pressure is below normal.	Lubricate the brake valve parts; overhaul the unit, if necessary.
Wear or glazing of the brake linings is present.	Install new brake linings on the brake shoes on both sides of the axle.
Adjustment or lubrication of the brakes is needed.	Adjust or lubricate the brakes.
The automatic slack adjusters are not operating.	Lubricate the automatic slack adjusters and check for binding, damaged, or inoperative slack adjuster parts. Replace damaged or inoperative parts, or eliminate the cause of the binding.
The cam has flipped over.	Replace the linings and the cam on each end of the axle.
One or more of the brake drums is broken or cracked.	Replace the brake drum(s).
The wrong size brake linings were installed.	Replace the brake linings with the recommended size.
The wrong size brake chambers were installed.	Replace the brake chambers with the recommended size.
A camshaft bracket or chamber mounting bracket is bent or broken.	Replace the camshaft bracket or chamber mounting bracket.
The brake chamber mounting stud nuts or brake chamber mounting bracket is loose.	Tighten the brake chamber to its mounting bracket or the mounting bracket to the foundation brake housing.
There is a ruptured diaphragm in the service brake.	Replace the diaphragm.

Problem—Service Brakes Release Too Slowly

Problem—Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The brake shoe anchor pins are frozen.	Inspect the anchor pins. If damaged, replace them; if not damaged, lubricate them.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake foot valve is not returning to the fully released position.	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.

Troubleshooting

Problem—Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The exhaust port of the brake foot valve or quick-release valve is plugged.	Clear the exhaust port of obstructions.
The brake foot valve or quick-release valve is inoperative.	Overhaul or replace the inoperative valve, as needed.
The camshaft and bushings are binding.	Clean and lubricate the camshaft bushings.
The brake shoe return spring is weak or broken.	Replace the spring.

Problem—Service Brakes Do Not Apply or Apply Too Slowly

Problem—Service Brakes Do Not Apply or Apply Too Slowly	
Possible Cause	**Remedy**
Lubrication of the foundation brake assembly is needed.	Lubricate those components requiring periodic lubrication.
There is insufficient air pressure in the brake system.	Check all parts of the air pressure system for leaks or inoperative components.
The brake foot valve or relay valve is inoperative.	Repair or replace the brake foot valve or relay valve.
The camshaft bushings are binding.	Clean and lubricate the camshaft bushings.

Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure

Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure	
Possible Cause	**Remedy**
The air delivery lines to the brake chamber have been reversed.	Reverse the connections of the brake chamber air lines.

Problem—Service Brakes Do Not Release

Problem—Service Brakes Do Not Release	
Possible Cause	**Remedy**
The brake shoes are incorrectly adjusted.	Adjust the brakes. Also, make sure the slack adjuster is operating correctly. If not, overhaul or replace the slack adjuster.
The brake foot valve may not be in the fully released position.	Lubricate the brake foot valve if needed.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve.
There is restriction in the tubing, hose, or exhaust port of the brake foot valve or quick-release valve.	Check for bends or obstructions on the exhaust side of the service brakes. Remove any obstructions; plumb the air lines so that bends are minimal.
A broken power spring may be blocking the parking brake piston movement.	Replace the power spring or replace the parking brake assembly, whichever is recommended by the parking brake manufacturer.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
There is not enough weight on the vehicle (underloaded).	Add weight to the vehicle, reducing brake sensitivity.
Adjustment of the brakes on one axle is uneven.	Adjust the brakes.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake mechanism is binding.	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened.
The clevis pin or camshaft is binding at one or more wheels.	Clean and lubricate the camshaft bushings.
A brake spider is loose.	Tighten the mounting bolts or replace the brake spider.
A slack adjuster is damaged.	Replace the damaged component.
The air chamber push rods or slack adjusters are a different length.	Replace the components with the correct size and material.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve, as needed.
If equipped with cam brakes, there is a flat or dent on the S-head camshaft or on the cam roller(s).	Replace the damaged component(s).
Grease has saturated the brake linings or the linings are glazed.	Install a matched set of linings on both sets of brake shoes on that axle. Clean, turn, or replace both brake drums. For instructions on turning drums, refer to the brake manufacturer's service manual.
The brake linings are loose or broken.	Install a matched set of linings on both sets of brake shoes on that axle.
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new, matched set of brake linings. Clean, turn, or replace both brake drums on that axle. For instructions on turning drums, refer to the brake manufacturer's service manual.
A brake shoe is distorted or broken.	Replace the brake shoe. Install a new, matched set of linings on both sets of brake shoes on that axle.
The pilot pads are damaged, allowing the brake drum to be installed out-of-round.	Replace the wheel hub.
A brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
One or more brake drums is scored or broken.	Replace both of the drums on that axle.

Problem—Uneven Service Brakes

Problem—Uneven Service Brakes	
Possible Cause	**Remedy**
The wrong brake linings were installed, or the linings were not replaced in pairs.	Replace the brake linings with the recommended size. Install new linings on both sets of axle brake shoes.

Troubleshooting

Problem—Uneven Service Brakes	
Possible Cause	**Remedy**
Grease has saturated the brake linings or the linings are glazed.	Install new linings on both axle brake shoes. Clean the brake drums.
The return spring for the brake shoe release or the service brake has broken.	Replace all broken springs.
The brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
A service brake chamber diaphragm is leaking.	Tighten the clamp ring. If leaks persist, replace the service brake diaphragm.
The wheel bearings are out of adjustment.	Adjust the wheel bearings, or replace them if damaged. For instructions, see **Group 33** or **Group 35** of this manual.
A brake spider is damaged.	Replace the brake spider.
The brake shoes are bent or stretched.	Replace the axle brake shoes on each wheel.
Grease, oil, or dirt is on the linings.	Replace the linings on each set of axle brake shoes. Clean the brake drums.

Problem—Dragging Service Brake

Problem—Dragging Service Brake	
Possible Cause	**Remedy**
The service brake return spring is broken.	Replace the service brake return spring.
The service-application air is not exhausting or not exhausting fast enough, due to blockage in the control valve, the quick-release valve, or the limiting and quick-release valve.	Test the air system valves for leakage and operation.
A brake shoe retracting spring is broken.	Replace the brake shoe retracting spring.
Binding is occurring in the camshaft linkage.	Lubricate the camshaft linkage. Replace bent or broken parts.

Problem—Insufficient Parking Brake Application When Dash Control Valve Is Activated

Problem—Insufficient Parking Brake Application When Dash Control Valve Is Activated	
Possible Cause	**Remedy**
The brakes are improperly adjusted.	Adjust the brakes.
A power spring is broken.	Replace the parking/emergency brake section.
A power spring in a parking brake is manually caged.	Release the power spring by screwing in the release bolt.

Problem—Dragging Brakes Due to the Parking Brake Mechanism

Problem—Dragging Brakes Due to the Parking Brake Mechanism	
Possible Cause	**Remedy**
The system air pressure is insufficient to fully release the parking brake.	Be sure that all air lines are clear. Check that the air governor cutout settings meet recommended specifications.
A parking brake diaphragm is ruptured or a piston seal is ineffective.	Replace the diaphragm or parking brake piston seal.

Problem—Air Pressure Will Not Rise to Normal

Problem—Air Pressure Will Not Rise to Normal	
Possible Cause	**Remedy**
The air pressure gauge(s) on the dash is (are) registering inaccurately.	Check the dash gauge(s) with an accurate test gauge. Replace the dash gauge(s) as needed.
There is excessive leakage (not including the air compressor).	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
The compressor is inoperative (including excessive leakage of the compressor).	Rebuild or replace the compressor.
The air reservoir drain cock has been left open.	Close the drain cock.
The air governor cutout setting is not adjusted correctly.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
There is inadequate clearance at the compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
If so equipped, the compressor drive belt is slipping.	Adjust or replace the compressor drive belt.
Carbon is building up in the compressor cylinder head or discharge line.	Remove the carbon. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with either a new or factory-rebuilt unit.
The driveshaft coupling is broken	Replace the coupling.

Problem—Air Pressure Rises Above Normal

Problem—Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
The air reservoir pressure dash gauge is inaccurate.	Check the dash gauge with an accurate test gauge. Replace the dash gauge as needed.
The compressor air governor is out of adjustment.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
The air governor is not operating.	Repair or replace the air governor.

Troubleshooting

Problem—Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
There is too much clearance at the air compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
The air compressor unloading valve is stuck closed.	
The air compressor unloading valve cavities or the unloading valve passage is blocked with carbon.	

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released	
Possible Cause	**Remedy**
The brake foot valve is leaking.	Repair or replace the brake foot valve.
The air compressor discharge valve is leaking.	Repair or replace the discharge valve. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with either a new or factory-rebuilt unit.
The air governor is leaking.	Repair or replace the air governor.

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied	
Possible Cause	**Remedy**
A service or parking brake chamber is leaking.	Tighten the clamp ring(s). If leaks persist, replace the diaphragm(s) or assembly.
The brake foot valve or relay valve is leaking.	Repair or replace the component(s) or assembly.

Problem—Compressor Knocks (Continuously or Intermittently)

Problem—Compressor Knocks (Continuously or Intermittently)	
Possible Cause	**Remedy**
There is a loose drive pulley, belt, coupling, or gear (as indicated).	Tighten or replace the component. If applicable, inspect the pulley shaft for damage. Replace the shaft, if damaged.
Backlash is in the compressor drive gears on the drive coupling.	Repair or replace the compressor drive gears or drive coupling.
The air compressor bearings are damaged or worn.	Replace the bearings.
There are carbon deposits in the compressor cylinder head.	Remove the carbon deposits or replace the compressor.

Problem—Pressure Relief Valve Activates

Problem—Pressure Relief Valve Activates	
Possible Cause	**Remedy**
The pressure relief valve is out of adjustment.	Adjust the pressure relief valve, or install a new one.
There is excessive air pressure in the brake system.	Refer to the problem "Air Pressure Rises Above Normal".

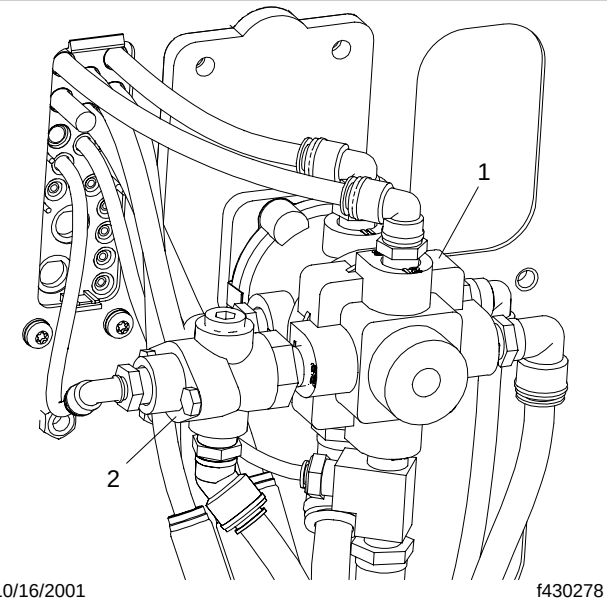
Problem—Oil or Water in the Brake System

Problem—Oil or Water in the Brake System	
Possible Cause	**Remedy**
Excessive oil is passing through the air compressor.	Rebuild or replace the compressor.
If so equipped, the air compressor air strainer is dirty.	Clean the strainer or install a new one.
Draining of the air reservoirs needs to be performed more often.	Drain the air reservoirs daily.
If so equipped, the air dryer desiccant cartridge is oil saturated.	Install a new desiccant cartridge.

General Information

The Bendix DC-4 shuttle-type double check valve, shown in **Fig. 1**, is normally used only when the vehicle is equipped with a trailer hand control valve. Double check valves are used in the air brake system to direct a flow of air into a common line from either of two sources, whichever is at the higher pressure. A shuttle-type valve has a movable shuttle to seal off the lower pressure source and allow the air from the higher pressure source to flow.

In this case, the valve allows air to be supplied to the trailer brakes from either the hand control valve or the foot valve, whichever supplies the higher pressure. This allows the trailer brakes to be applied with either the hand valve or the foot valve. If both the foot and hand valves are applied simultaneously, the DC–4 valve will supply air to the trailer brakes from whichever valve is applying higher pressure.



1. Foot Brake Valve
2. Double Check Valve

Fig. 1, Brake Valve and Double Check Valve Plumbing

Principles of Operation

As pressurized air enters either end of the double check valve inlet port, the moving shuttle responds to the greater pressure source and seals the opposite port. The air flow continues out the delivery port of the valve. The position of the shuttle will reverse if the pressure levels are reversed. Double check valves are designed so the shuttle cannot interfere with the backflow of air in the exhaust mode.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

- Chock the tires and shut down the engine before working under a vehicle. Dropping air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters; they will apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets, or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if they are not correctly disassembled. Use only the correct tools, and observe all precautions regarding use of those tools.

Double Check Valve Removal and Installation

WARNING

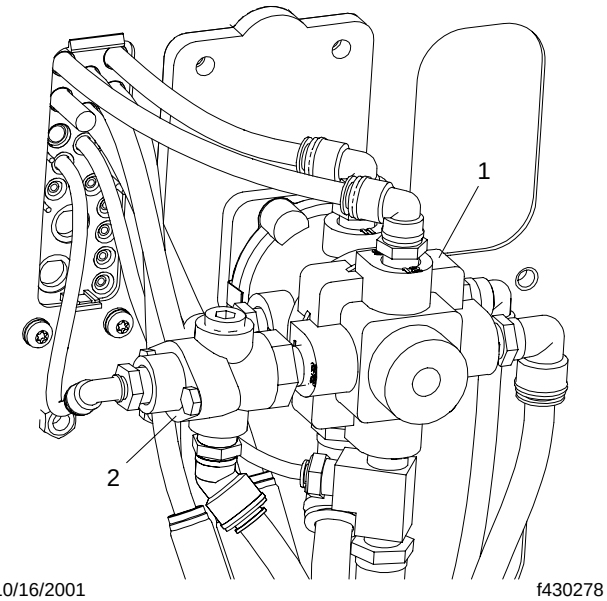
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

WARNING

Wear safety goggles when draining the air system or disconnecting an air line because dirt or sludge particles could fly out at high speeds. Do not direct the air streams at other people. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

1. Drain the air from the air reservoirs.
2. Mark the positions of the air lines on the valve, then disconnect them from the double check valve. See **Fig. 1**.



1. Foot Brake Valve 2. Double Check Valve

Fig. 1, Brake Valve and Double Check Valve Plumbing

3. Unscrew the double check valve from the foot brake valve.

Installation

1. Screw the double check valve into the foot brake valve. Tighten the valve firmly.
2. Connect the air lines to the double check valve as marked. Push the air lines firmly into the quick-connect fittings.

Double Check Valve Disassembly, Cleaning and Inspection, and Assembly

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Disassembly

See **Fig. 1** for a cross-sectional view of the check valve.

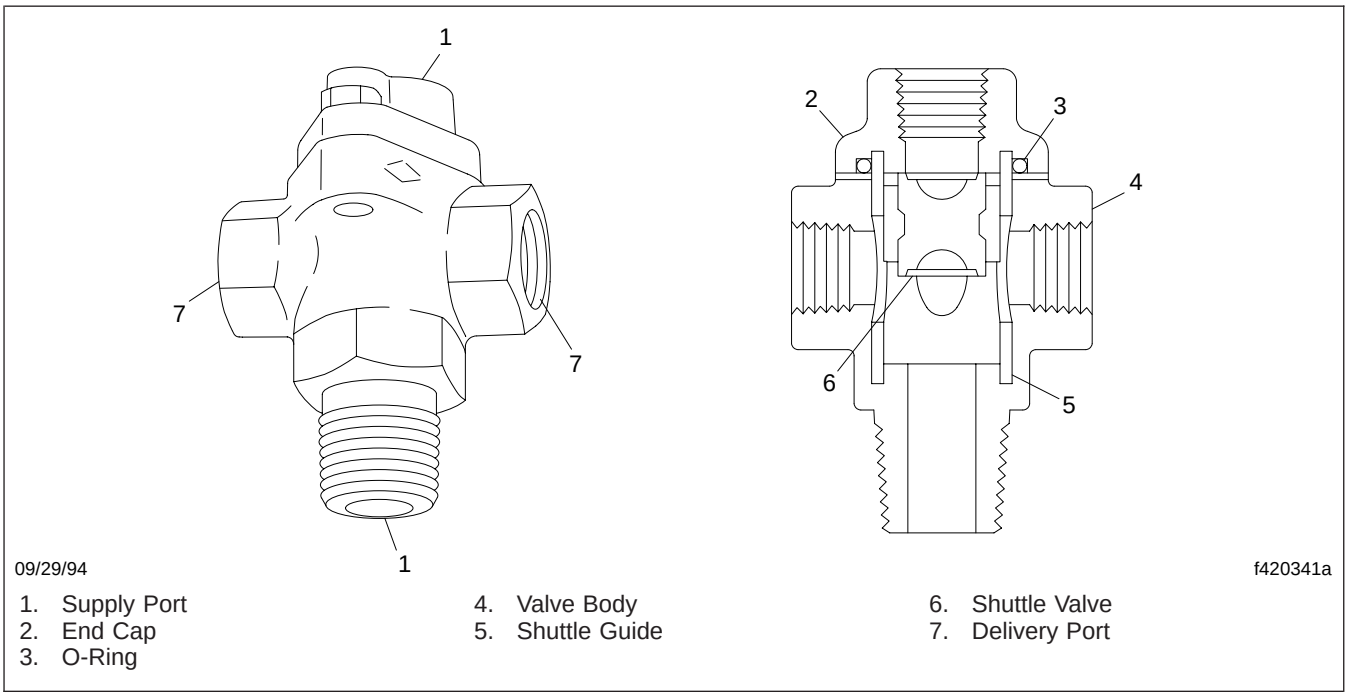
1. Remove the valve from the vehicle. For instructions, see **Subject 110**.
2. Remove the end cap from the valve.
3. Remove the O-ring.
4. Remove the shuttle valve and shuttle guide.

Cleaning and Inspection

1. Clean all metal parts in a cleaning solvent.
2. Inspect all metal parts for signs of cracks, wear, or deterioration. Replace all parts not considered serviceable.
3. Replace all rubber parts.

Assembly

1. Install the shuttle valve and shuttle guide in the valve body.
2. Coat a new O-ring with BW 650M silicone lubricant (BW 291126). It is not necessary to lubricate the shuttle valve.
3. Install the O-ring.
4. Install the end cap on the valve body.
5. Install the valve on the vehicle. For instructions, see **Subject 110**.
6. Test the valve. For instructions, see **Subject 130**.



1. Supply Port
2. End Cap
3. O-Ring
4. Valve Body
5. Shuttle Guide
6. Shuttle Valve
7. Delivery Port

Fig. 1, Double Check Valve

Double Check Valve Operating and Leakage Test

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operating and Leakage Test

On-Vehicle Testing

1. Push in and release the foot brake pedal while checking that the brakes apply and release on both the tractor and trailer.
2. Apply and release the trailer control valve while checking that only the trailer brakes apply and release.
3. Apply the trailer control valve and check the exhaust port of the foot brake valve for leakage, using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable. Release the valve.
4. Disconnect the air line from the trailer control valve exhaust port. Push the foot brake pedal until it stops, and hold it in place. Check the trailer control valve exhaust port for leakage, using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable.
5. If the double check valve does not function as described, or if the leakage is excessive, replace it. See **Subject 110** for instructions.

   If the valve cannot be replaced, repair it using Bendix parts. See **Subject 120** for instructions.
6. Connect the air line to the trailer control valve exhaust port.

Bench Testing

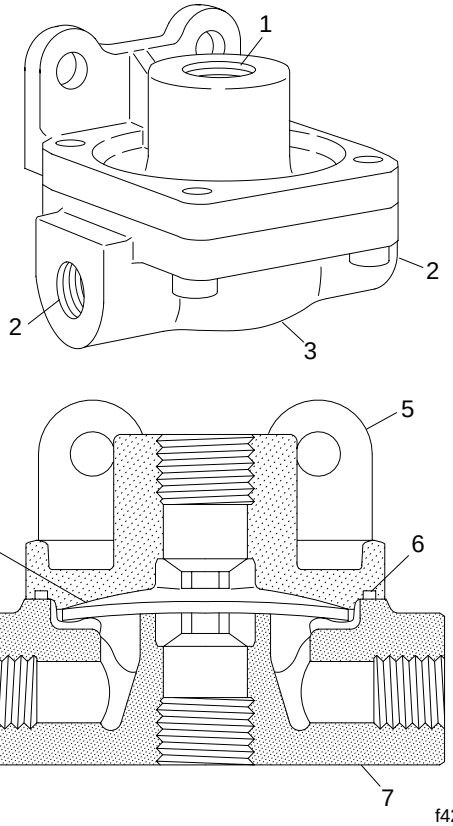
1. Connect two separately controlled air supplies to the inlet ports.
2. Apply and release air to one inlet port (foot brake pedal) while checking that the test gauge registers the application and release.
3. Apply and release air to the other inlet port (trailer control valve) while checking that the gauge registers the application and release.
4. Disconnect the line from one of the double check valve inlet ports. Apply air to the opposite inlet port while checking the first port for leakage, using a soap solution. A 1-inch (2.5-cm) bubble or less in 5 seconds is allowable. Connect the line to the inlet port. Repeat this step, checking the opposite inlet port for leaks.
5. If the double check valve does not function as described, or if the leakage is excessive, replace it. See **Subject 110** for instructions.

   If the valve cannot be replaced, repair it using Bendix parts. See **Subject 120** for instructions.

General Information

QR-1 Valve

The function of the QR-1 quick release valve, shown in **Fig. 1**, is to speed up the release of air pressure from the front service brake chambers. When the front brake chambers are equipped with a QR-1 valve, and a foot brake application is released, the exhaust port of the quick release valve opens and the air from the front brake chambers is exhausted through the quick release valve. This accelerates the release of the front brakes.



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1. Supply Port
2. Delivery Port
3. Exhaust Port
4. Diaphragm
5. Valve Cover
6. O-Ring
7. Valve Body

Fig. 1, QR-1 Valve and Cross-Section

When the front brake chambers are equipped with a QR-1 valve, it is located on the forward face of the crossmember just aft of the transmission. A delivery line from the foot valve is connected to the port on top of the QR-1 quick release valve; the two side ports are for brake chamber connections, and the exhaust port is located at the bottom of the valve.

QR-1C Valve

The QR-1C quick release valve is a dual function valve. See **Fig. 2**. Its primary function is to speed up the release of air pressure from the service brake chambers. Additionally, the valve works as an anti-compound device. The double check valve feature prevents a service and parking brake application from occurring at the same time.

The QR-1C valve is generally mounted on a rear suspension crossmember and can serve either two or four spring brake actuators. A balance line from the relay valve delivery port is connected to the balance port on top of the QR-1C quick release valve. The two side ports are for brake chamber connections. The supply port is connected to the delivery port of the parking brake control valve, and the exhaust port is located at the bottom of the valve. The air connections to the QR-1C are as follows:

1. The QR-1C delivery port is connected to the emergency port of the spring brake chamber.
2. The QR-1C balance port is connected to the delivery of the relay valve.

NOTE: The QR-1C valve should be connected to the delivery side (not to the service or signal side) of the relay valve.

3. The QR-1C supply port is connected to the delivery of the park control valve.

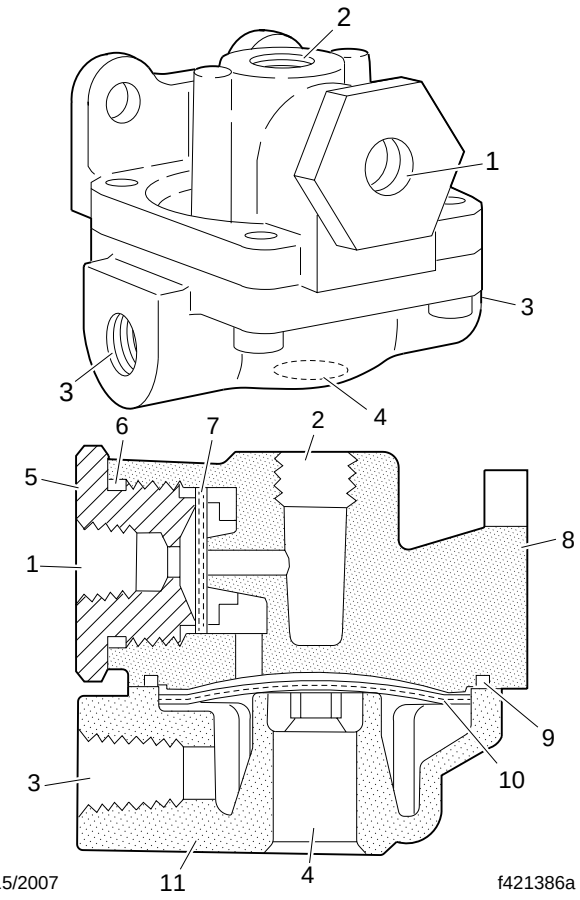
Principles of Operation

QR-1 Valve

When the foot brake control is applied, delivery air enters the brake valve port on the QR-1 quick release valve; the diaphragm moves down, sealing the exhaust port. At the same time, air pressure forces the edges of the diaphragm down, allowing air to flow out the brake chamber ports, filling the chambers and applying the front axle brakes.

When the brake chamber air pressure (beneath the diaphragm) equals the air pressure being delivered by the foot valve (above the diaphragm), the outer edge of the diaphragm will seal against the valve

General Information



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Capnut
6. Sealing Ring
7. Double Check Diaphragm
8. Valve Body
9. O-Ring
10. Quick Release Diaphragm
11. Valve Cover

Fig. 2, QR-1C Valve and Cross-Section

body seat. The exhaust port is still sealed by the center portion of the diaphragm. When the foot brake is released, the air above the diaphragm is released back through the foot brake valve exhaust, while the air beneath the diaphragm forces the diaphragm to rise, opening the exhaust port, and allowing air in the brake chambers to exhaust.

QR-1C Valve

Parking Brakes Released

When the parking brakes are released, air from the parking brake control valve flows through the QR-1C valve. This forces the double check diaphragm and the quick release diaphragm to flex and seal the balance and exhaust ports. Air flows into the inlet ports of the parking brake chambers from the QR-1C valve delivery ports.

Parking Brakes Applied

When the parking brakes are applied, supply line air pressure to the QR-1C valve is exhausted through the parking brake control valve. As air pressure is exhausted from one side of the double check diaphragm and the quick release diaphragm, both diaphragms flex in the opposite direction to open the balance and exhaust ports. Parking brake pressure is released at the exhaust port of the QR-1C valve while a small amount of air trapped between the two diaphragms is released through a relay valve or the foot valve exhaust port.

Anti-Compounding

When a service brake application is made with the parking brakes applied, service air enters the balance port and flows through the QR-1C valve into the inlet ports of the parking brake chambers. This prevents application of the service and parking brakes at the same time. Service air passing through the QR-1C valve flexes the double check and quick release diaphragms, sealing the supply and exhaust ports. When the service brake application is released, air is exhausted from the balance port allowing the supply port to seal the balance and exhaust ports and keep the spring brakes released.

Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses, that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

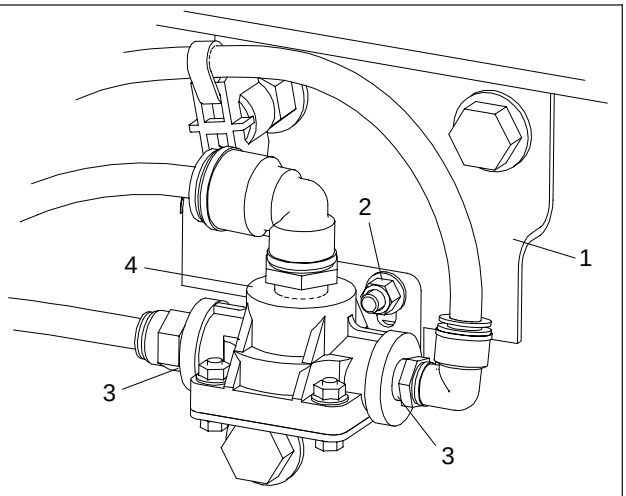
QR-1/QR-1C Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface and shut down the engine. Chock the tires or hold the vehicle by means other than air brakes.
2. Drain the air brake system.
3. Mark and disconnect the air lines from the quick release valve.
4. Remove the mounting bolts and the valve. See **Fig. 1**.



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1. Mounting Bracket
2. Mounting Nut and Bolt
3. Delivery Port
4. Supply Port

Fig. 1, Quick Release Valve Mounting (QR-1 valve shown)

Installation

1. Install the quick release valve with the exhaust port facing down. Securely tighten the mounting bolts.
2. Install the air lines to the quick release valve in the locations previously marked.
3. Perform the operating and leakage tests in **Subject 130**.

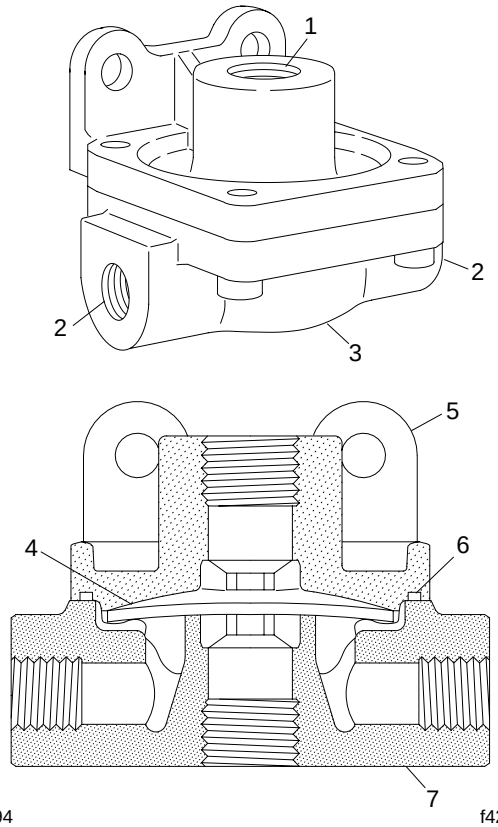
QR-1/QR-1C Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to the following figures during these procedures:

- QR-1 Valve — **Fig. 1**.
- QR-1C Valve — **Fig. 2**.



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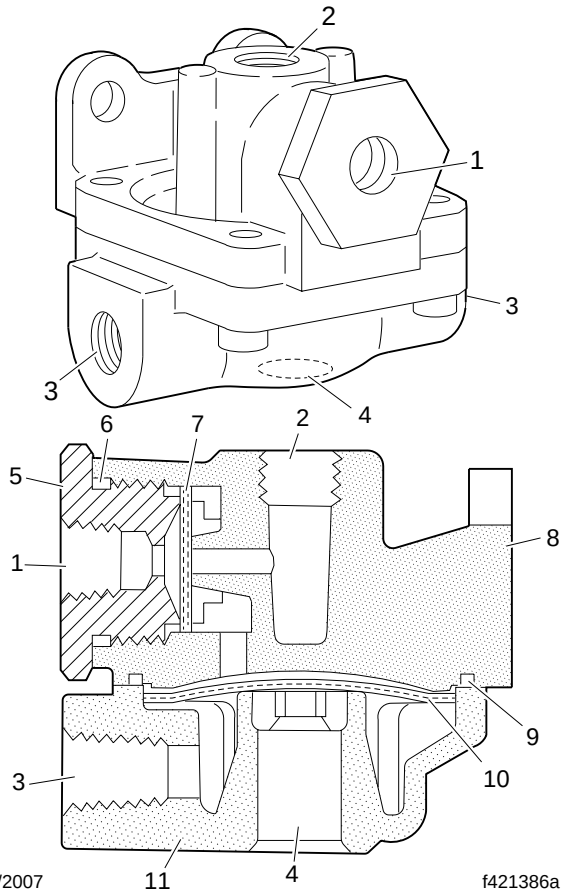
1. Supply Port
2. Delivery Port
3. Exhaust Port
4. Diaphragm
5. Valve Cover
6. O-Ring
7. Valve Body

Fig. 1, QR-1 Valve and Cross-Section



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1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Capnut
6. Sealing Ring
7. Double Check Diaphragm
8. Valve Body
9. O-Ring
10. Quick Release Diaphragm
11. Valve Cover

Fig. 2, QR-1C Valve and Cross-Section

Disassembly

1. Remove the quick release valve from the vehicle, following the instructions in **Subject 110**.
2. Mark the valve body and valve cover for ease of installation.
3. For a QR-1C valve, remove the capnut at the supply port, then remove the sealing ring from the capnut.
4. For a QR-1C valve, remove the double check diaphragm.
5. Remove the four screws that hold the valve cover on the valve body.

QR-1/QR-1C Disassembly, Cleaning and Inspection, and Assembly

6. Separate the cover from the valve body, then remove the O-ring and the quick release diaphragm.

Cleaning and Inspection

1. Clean all metal parts in mineral spirits. Wipe all rubber parts clean.
2. It is recommended that all rubber parts and any other part showing signs of wear or deterioration be replaced with genuine Bendix parts.

Assembly

1. For a QR-1C valve, install the sealing ring on the cap nut.
2. For a QR-1C valve, install the double check diaphragm in the valve body.
3. For a QR-1C valve, install the cap nut, and tighten it 13 to 33 lbf·ft (18 to 45 N·m).
4. Install the quick release diaphragm in the cover.
5. Install the O-ring and the valve cover on the body. Tighten the screws 30 to 60 lbf·in (339 to 678 N·cm) evenly and securely.
6. Install the quick release valve, following the instructions in **Subject 110**.
7. Do the operating and leakage test as instructed in **Subject 130**.

Operating and Leakage Tests

WARNING

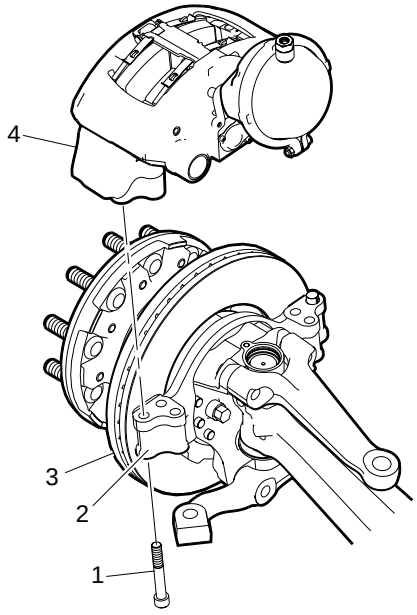
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

The following tests should be performed after repairing or replacing the quick release valve to ensure that it is functioning properly.

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine and chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. On QR-1C valves, remove the air line from the valve balance port. Build system air pressure to 120 psi (827 kPa). Coat the exhaust and balance ports with a soap solution; leakage of no greater than a 1-inch (2.5-cm) bubble in 5 seconds at either port is allowable. Install the air line at the balance port.
5. Apply the parking brakes. Step on the foot brake; the valve should exhaust air at the exhaust port when the foot brake is released.
6. Drain the air system.
7. Remove the air line from the valve supply port. Build system air pressure to 120 psi (827 kPa). With the foot valve depressed, coat the supply port and the seam between the body and cover with a soap solution; leakage of no greater than a 1-inch (2.5-cm) bubble in 5 seconds at the supply port is allowable. No leakage between the body and cover is permitted. Install the air line at the supply port.
8. If the valve does not function properly, or if leakage is excessive, repair or replace it following the instructions in this section.

Description

Bendix air disc brakes use a floating caliper design to provide foundation braking on all axles. They are fitted with a standard brake chamber or a combination spring brake chamber, depending on the vehicle specification, and the position on the vehicle. The caliper-carrier and anchor plate are a proprietary design available only on Daimler vehicles. This design allows for easy removal and installation of the caliper/carrier assembly on all axles, without removing other major components. See **Fig. 1**.



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1. Capscrew
2. Anchor Plate
3. Rotor
4. Caliper/Carrier

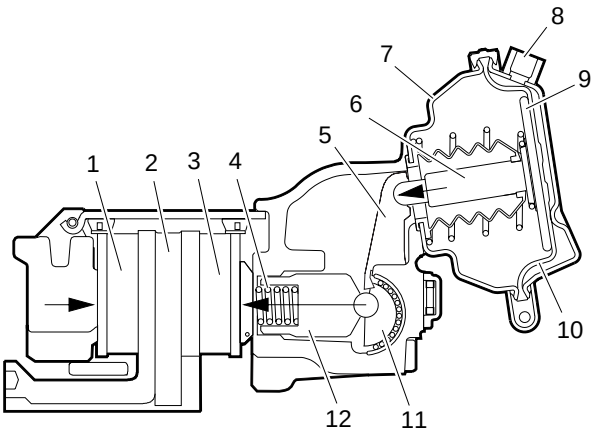
Fig. 1, Caliper/Carrier Installation

Operation

Bendix air disc brakes convert air pressure into braking force. See **Fig. 2**.

Brake Application

When the vehicle brakes are applied, air enters the service brake chamber through the supply port, applying pressure within the diaphragm. The pressure expands the diaphragm, applying force to the pressure plate and pushrod, and moving them forward.



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1. Outer Brake Pad
2. Rotor
3. Inner Brake Pad
4. Return Spring
5. Lever
6. Pushrod
7. Brake Chamber
8. Supply Port
9. Pressure Plate
10. Diaphragm
11. Eccentric Bearing
12. Bridge

Fig. 2, Brake Operation

The pushrod presses against a cup in the internal lever, which pivots on an eccentric bearing, moving the bridge. Moving against a return spring, the bridge transfers the motion to two threaded tubes and tappets, which move the inner brake pad. The inner brake pad (from its normal position of having a running clearance between it and the rotor) moves into contact with the brake rotor. Further movement of the bridge forces the caliper, sliding on two stationary guide pins, away from the rotor, which pulls the outer brake pad into the rotor. The clamping action of the brake pads on the rotor applies braking force to the wheel.

Brake Release and Adjustment

When the vehicle brakes are released, the air pressure in the service brake chamber is exhausted, and the return springs in the chamber and the bridge return the caliper to a neutral, non-braked position. To maintain the running clearance gap between the rotor and the brake pads over time, the non-braked position is mechanically adjusted by a mechanism in the caliper. The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or

General Information

rotor maintenance, the technician manually sets the system's initial non-braked position. The total running clearance (sum of clearances on both sides of the rotor) should be between 0.024 to 0.043 in. (0.6 and 1.1 mm).

General Safety Precautions

⚠ WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface and apply the parking brakes. Shut down the engine and chock the tires.
- If the vehicle is equipped with air brakes, make certain to drain the air pressure from all reservoirs before beginning any work on the vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake calipers, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, the brake assembly must be cleaned in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with a HEPA filter system, remove dust from the brake drums, brake backing plates, and brake parts. After vacuuming, any remaining dust should be removed using a rag soaked in water and wrung until nearly dry. Do not use compressed air or dry brushing to clean the brake assembly.

If grinding or other machining of the brake linings is necessary, other precautions must be taken because exposure to asbestos dust is highest during such operations. In addition to the use of an approved respirator, there must be local exhaust ventilation such that worker exposure is kept as low as possible.

Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should be used when emptying vacuum cleaners and handling asbestos waste products.

Workers should wash before eating, drinking, or smoking, should shower after work, and should not wear work clothes home. Work clothes should be vacuumed after use and then laundered, without shaking, to prevent the release of asbestos fibers into the air.

Brake Pad Removal, Inspection, and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

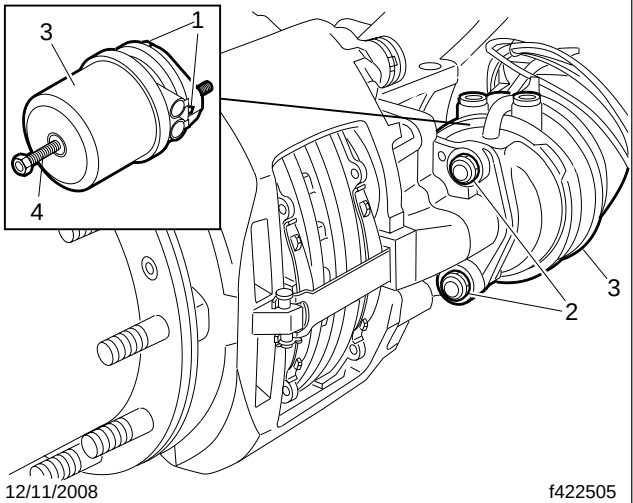
Removal

1. Shut down the engine. Chock the tires on the axle that is not being serviced.
2. If working on the drive axle, carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft (35 N·m) to release spring force on the pushrod. See **Fig. 1**.
3. Drain the air from the air system.
4. Raise the front or rear axle and place safety stands under the frame or axle. Be sure the stands will support the weight of the vehicle.
5. Remove the wheel(s). See **Group 40**.

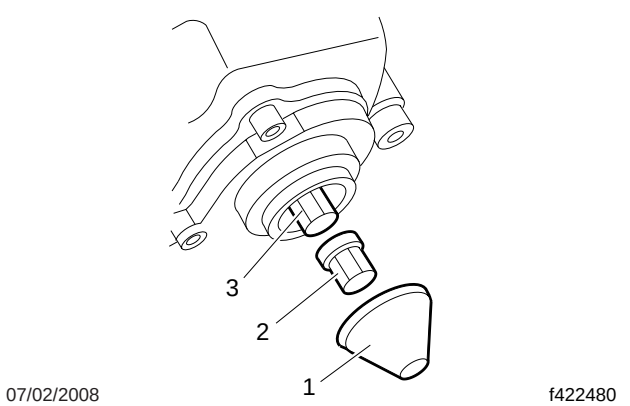
IMPORTANT: Before removing the brake pads, check the adjuster mechanism for proper operation.

6. Using the tab, pull off the adjuster cap, being sure to keep the shear adaptor in position on the adjuster. See **Fig. 2**.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 1, Spring Brake Chamber Installation



1. Adjuster Cap
2. Shear adaptor
3. Adjuster

Fig. 2, Shear adaptor

NOTICE

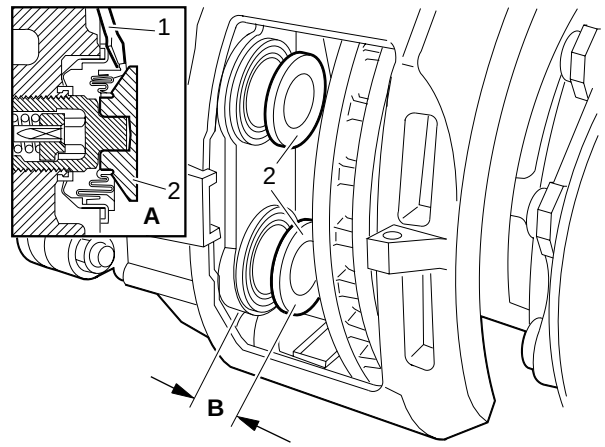
Do not use an open-ended wrench, as this may damage the adaptor.

IMPORTANT: Never turn the adjuster without the shear adaptor installed. The shear adaptor is a safety feature and is designed to prevent an excess of torque being applied to the adjuster. The shear adaptor will come loose if too much

Brake Pad Removal, Inspection, and Installation

torque is applied. If the shear adaptor fails, try again with a new adaptor. A second failure confirms that either the brake is applied or the adjustment mechanism is seized and the caliper/carrier assembly must be replaced.

7. Using a box-end wrench or socket, fully retract the tappet and boot assemblies by rotating the shear adaptor counterclockwise. See **Fig. 3**.



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A. Boot Location Ring
B. Extend less than 1.18 in (30 mm)

1. Boot Location Ring
2. Tappet and Boot Assembly

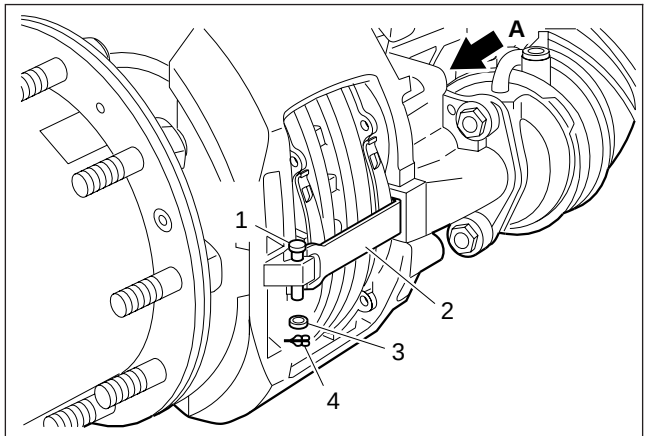
Fig. 3, Tappet and Boot Assembly

8. Remove the pad retainer clip and washer. See **Fig. 4**. Depress the pad retainer and remove the pad retainer pin. Discard all components that have been removed.
9. Slide the caliper to the outboard position. Remove the outer pad. See **Fig. 5**.
10. Slide the caliper to the inboard position. Remove the inner pad.

Inspection

Brake Pads

1. Measure the thickness of the friction material on the brake pad.



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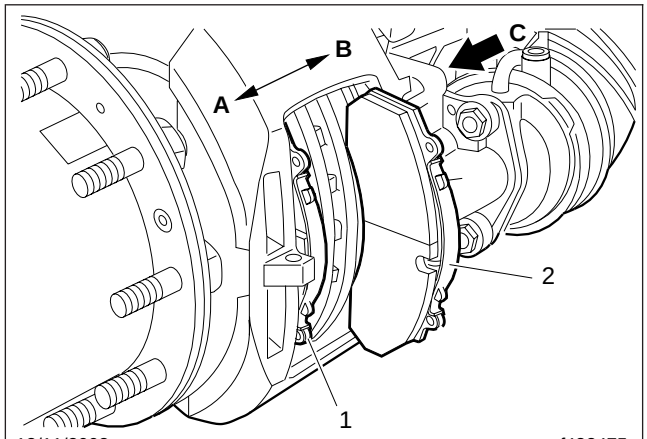
A. Shear Adjuster Location

1. Pad Retainer Pin
2. Pad Retainer
3. Washer
4. Clip

Fig. 4, Caliper Assembly



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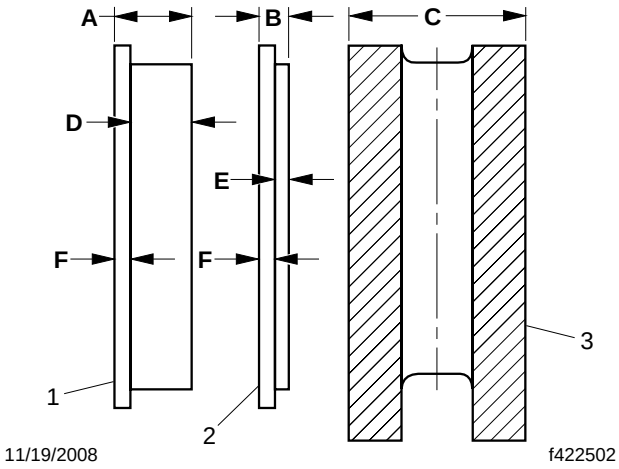
A. Outboard
B. Inboard
C. Area of Shear Adaptor

1. Outboard Brake Pad
2. Inboard Brake Pad

Fig. 5, Brake Pad Removal

If the thickness of the friction material is less than 0.079 in (2 mm) the pads must be replaced. See **Fig. 6**, Ref. E.

Most Bendix air disc brakes use 0.35 in (9 mm) backing plates. On a used brake pad, the combined pad and backing plate thickness should be no less than 0.43 in (11 mm).



1. New Pad
2. Used Pad
3. Rotor

A. New Pad Thickness 1.18 inch (30 mm)
B. Used Pad Thickness 0.43 inch (11 mm)
C. Rotor Thickness 1.77 to 1.46 inches (45 to 37 mm)
D. New Pad Friction Material Thickness
E. Used Pad Friction Material Thickness 0.079 inch (2 mm) minimum
F. Backing Plate Thickness 0.35 to 0.43 inch (9 mm to 11 mm)

Fig. 6, Brake Pad Inspection

2. If the pad thickness is within the acceptable range, inspect the pad surface.

   Minor damage (small amount of brake material chipped) at the edges is permitted, but replace the pads if major damage (section damaged or missing) is found on the surface.

Rotors

1. Examine the rotor and measure the thickness at the thinnest point. Avoid measuring near the edge of the rotor as minor burrs may be present. Replace the rotors when the minimum thickness is 1.46 in (37 mm), or when **one side** is greater than 0.15 inch (4 mm).

NOTE: It is recommended to replace the rotor with the same type that was originally installed on the vehicle and to replace the brake pads at the same time.

2. Inspect the rotor for grooves and cracks.

   Conventional rotors may be turned when changing pads, but is not normally necessary. In the case of severe grooving of the entire friction surface, then turning could be useful and may increase the load-bearing surface of the pads. To meet Bendix recommendations, the minimum rotor thickness after turning must be greater than 1.53 in (39 mm).

IMPORTANT: Always maintain air disc brake pads and rotors within specifications. Excessive pad or rotor wear will degrade optimum performance. When replacing rotors, be sure to adhere to Daimler Trucks North America (DTNA) recommended bolt tightening torques and sequence. See **Subject 130** for rotor replacement.

Installation

NOTE: When replacing brake pads, replace them as an axle set. Only use pads that have the same backing plate thickness as originally specified.

1. Install the outboard brake pad by sliding the caliper to the outboard position (be sure the brake lining material is facing the rotor).
2. Install the inboard pad by sliding the caliper to the inboard position.
3. Using a box-end wrench or socket, turn the shear adaptor clockwise until the pads come into contact with the rotor. Then turn the shear adaptor counterclockwise two clicks to set the initial running clearance.
4. Install the new pad retainer into the groove of the caliper. Depress the pad retainer, and install the new pad retainer pin so that it is pointing downward.
5. Install the new washer and spring clip to secure the pad retainer pin. See **Fig. 1**.

NOTE: The adjustment mechanism operates automatically whenever the brakes are activated, to compensate for rotor and brake pad wear and to keep the running clearance constant. During pad or rotor maintenance the technician is to manually set the systems' initial non-braked position.

Brake Pad Removal, Inspection, and Installation

6. Set the total running clearance (sum of clearances on both sides of the rotor), between 0.024 to 0.043 in (0.6 to 1.1 mm). See **Fig. 7**.

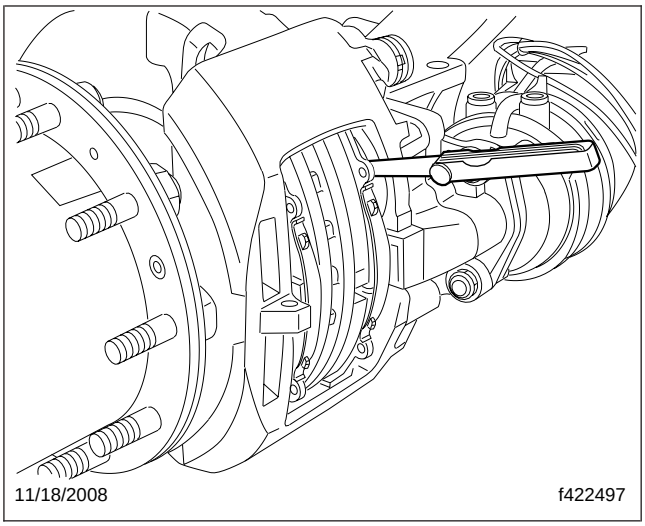


Fig. 7, Checking Brake Pad Running Clearance

7. Uncage the spring brake.
8. Apply and release the brake, then check that the hub turns easily by hand.
9. Using white lithium-based grease, lightly grease and install the adjuster cap.
10. Install the wheel(s). See **Group 40**.
11. Remove the safety stands and lower the vehicle.

Brake Caliper/Carrier Assembly Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: Replacement bolts are not supplied with the caliper, use only bolts of a grade and type specified by Daimler Trucks North America (DTNA).

Replacement caliper/carrier assemblies may be delivered with a plastic cap, adhesive tape, or a breakthrough diaphragm in the area where the actuator is mounted. Remove the cap or tape only after installing the replacement caliper. If the replacement caliper has the breakthrough diaphragm, it should be left in place. Refer to **Fig. 1** for front caliper/carrier removal and installation.

Front Caliper/Carrier Assembly Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheel. See **Group 40**.
5. Cut the zip ties holding the ABS harness to the brake hose as needed.

NOTE: If you are not replacing the caliper, it is not necessary to disconnect the air hose, if it can be safely supported out of the way while doing other work.

6. If replacing the caliper, disconnect the brake hose at the swivel connection at the frame rail, then remove the brake chamber from the caliper. See **Subject 150**.
7. With the caliper/carrier assembly securely supported, remove and discard the six bolts attaching the carrier to the anchor plate. Remove the caliper/carrier assembly.
8. Clean and inspect the anchor plate contact area. If damage is found, replace the anchor plate. See **Subject 140**.

Front Caliper/Carrier Assembly Installation

1. Position the carrier/caliper assembly, and attach it to the anchor plate with new bolts. Tighten 170 to 200 lbf·ft (230 to 271 N·m).
2. Install the brake pads, and brake pad shield, if equipped. See **Subject 110**.
3. Using new nuts, attach the brake chamber to the caliper/carrier assembly. Tighten 127 to 137 lbf·ft (172 to 186 N·m). See **Subject 150**.
4. Connect the brake hose.
5. Position the ABS harness, and install new zip ties to hold the harness to the brake hose. Leave room for movement.
6. Install the wheel. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

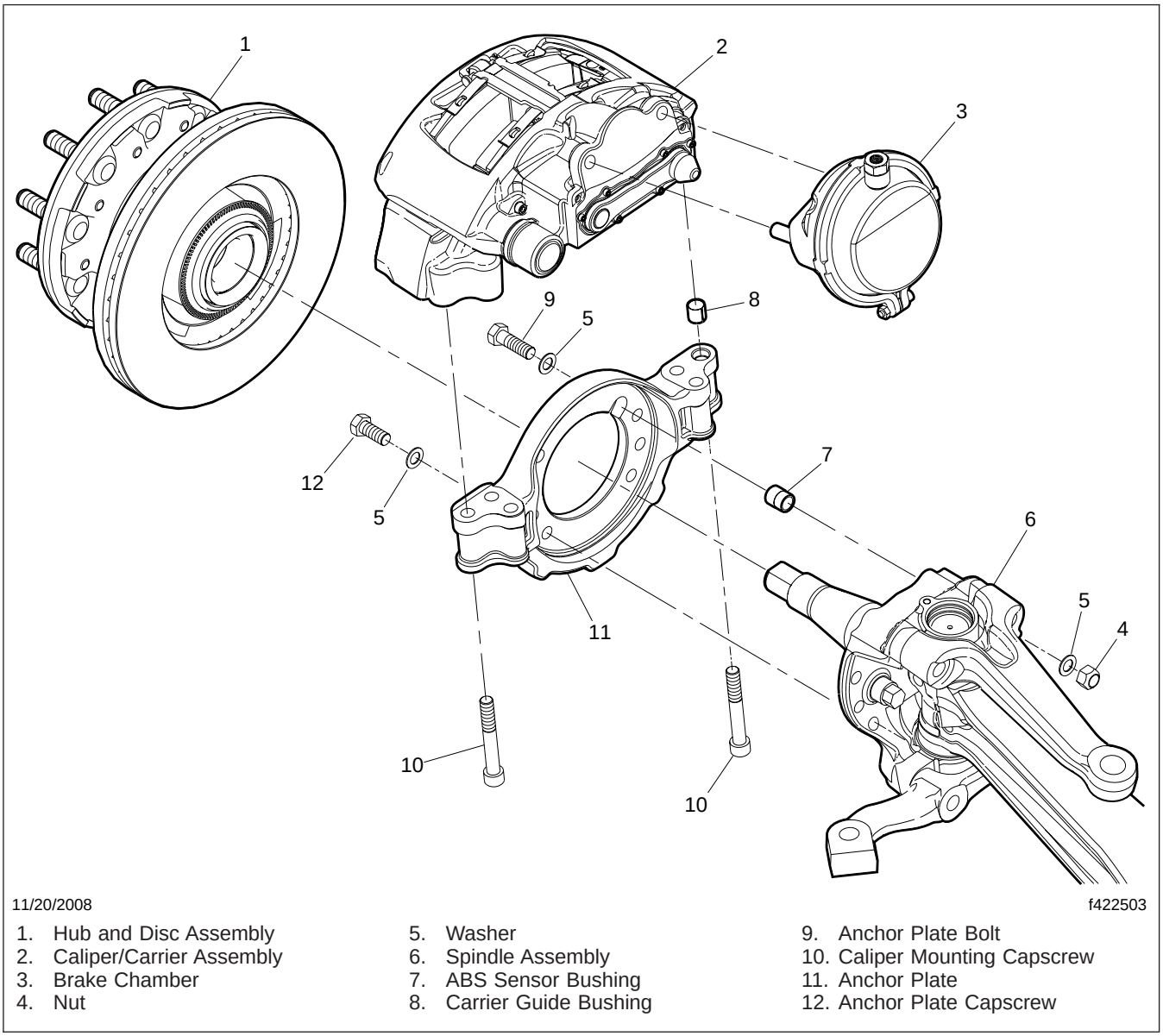
8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Rear Caliper/Carrier Assembly Removal

Refer to **Fig. 2** for rear caliper/carrier removal and installation.

1. Apply the brakes and chock the tires.

Brake Caliper/Carrier Assembly Removal and Installation



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1. Hub and Disc Assembly
2. Caliper/Carrier Assembly
3. Brake Chamber
4. Nut
5. Washer
6. Spindle Assembly
7. ABS Sensor Bushing
8. Carrier Guide Bushing
9. Anchor Plate Bolt
10. Caliper Mounting Capscrew
11. Anchor Plate
12. Anchor Plate Capscrew

Fig. 1, Front Caliper and Carrier Assembly Installation

2. Raise the axle being serviced, and support it with an appropriate jackstand.
3. Remove the wheels. See **Group 40**.

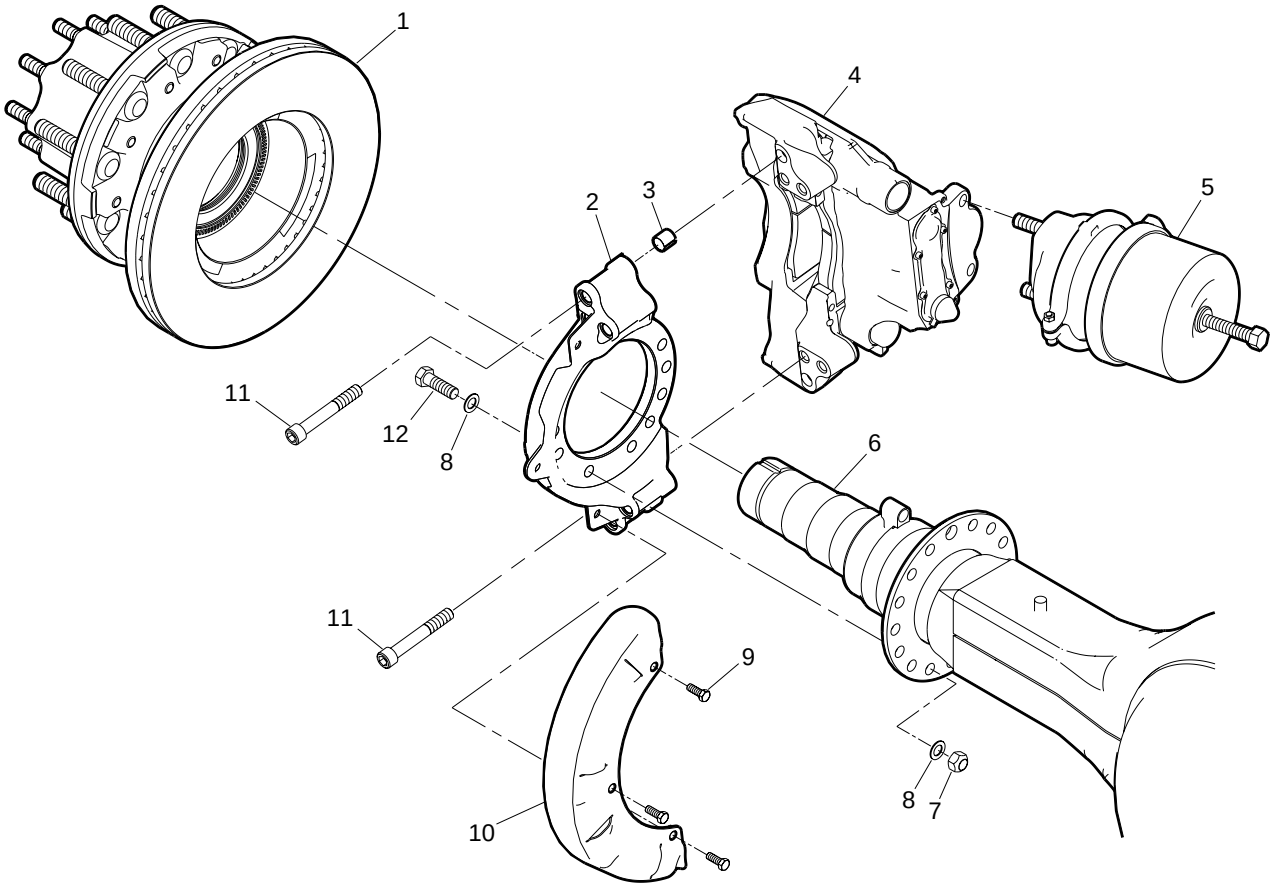
⚠ WARNING

When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury or death.

4. Carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft. (35 N·m) to release spring force on the pushrod. See **Fig. 3**.
5. Drain the air from the air system.

Brake Caliper/Carrier Assembly Removal and Installation



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1. Hub and Rotor Assembly
2. Anchor Plate
3. Carrier Guide Bushing
4. Caliper/Carrier Assembly
5. Spring Brake Chamber
6. Axle End
7. Nut
8. Washer
9. Rotor Shield Capscrew
10. Rotor Shield
11. Caliper Mounting Capscrew
12. Bolt

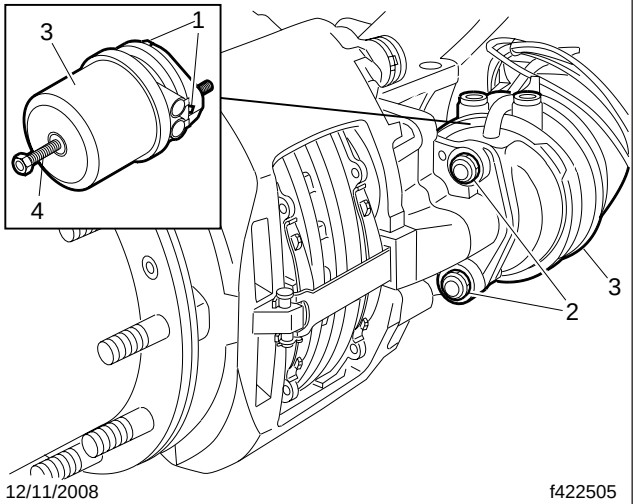
Fig. 2, Rear Caliper and Carrier Assembly Installation

6. Cut the zip ties holding the ABS harness to the brake hose as needed.
7. Remove the brake chamber from the caliper. See **Subject 150**.
8. Remove the rotor shield, if equipped.
9. With the caliper/carrier assembly securely supported, remove and discard the six bolts attaching the carrier to the anchor plate. Remove the caliper/carrier assembly.
10. Clean and inspect the anchor plate contact area. If damage is found, replace the anchor plate. See **Subject 140**.

Rear Caliper/Carrier Assembly Installation

1. Position the new carrier/caliper assembly, and attach it to the anchor plate with new bolts. Tighten 170 to 200 lbf·ft (230 to 271 N·m).

Brake Caliper/Carrier Assembly Removal and Installation



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 3, Spring Brake Chamber Installation

2. Install the brake pads, and brake pad shield, if equipped. See **Subject 110**.
3. Using new nuts, attach the brake chamber to the caliper/carrier assembly. Tighten 127 to 137 lbf·ft (172 to 186 N·m). See **Subject 150**.
4. Install the rotor shield, if equipped.
5. Uncage the spring brake chamber.
6. Install the wheels. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

WARNING

When replacing brake pads, shoes, rotors, or drums, always replace components as an axle set.

- Always reline both sets of brakes on an axle at the same time.
- Always replace both rotors/drums on an axle at the same time.
- Always install the same type of linings/pads or drums/rotors on both axle ends of a single axle, and all four axle ends of a tandem axle, at the same time. Do not mix component types.

Failure to do so could cause uneven braking and loss of vehicle control, resulting in property damage, personal injury, or death.

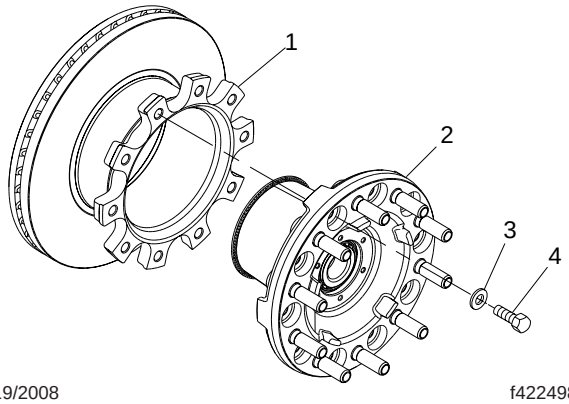
Brake Rotor Removal

1. Chock the wheels on an axle that is not being serviced.
2. Raise the axle end to be serviced, and secure it on a jackstand.
3. Remove the wheel(s). See **Group 40**.
4. Remove the brake caliper/carrier assembly. See **Subject 120**.
5. Remove the hub and rotor assembly. See **Group 33** for the front axle, or **Group 35** for the rear axle.

   If replacing the rotor, remove the capscrews from the hub, and remove the brake rotor. See **Fig. 1** for front axles, or **Fig. 2** for rear axles.

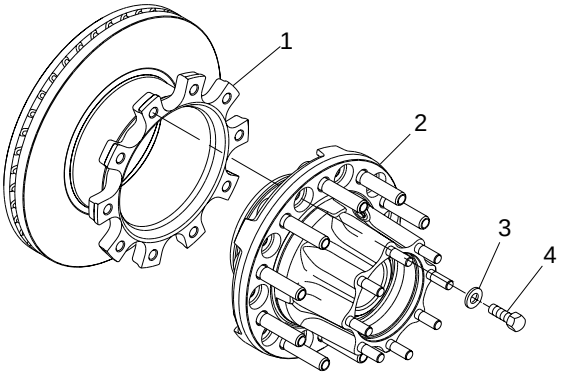
Brake Rotor Installation

1. If the rotor was removed from the hub, clean the mating surface of the hub and brake rotor as needed.



1. Rotor
2. Hub
3. Washer
4. Capscrew

Fig. 1, Front Rotor Installation



1. Rotor
2. Hub
3. Washer
4. Capscrew

Fig. 2, Rear Rotor Installation

NOTE: It may be necessary to install the hub prior to tightening the hub-to-rotor capscrews to their final torque setting.

2. If replacing the rotor, position the new rotor on the hub, and install the capscrews. See **Fig. 1** for front axles, or **Fig. 2** for rear axles. Tighten 190 to 210 lbf·ft (258 to 285 N·m) using the sequence shown in **Fig. 3**.
3. Install the hub and rotor assembly. See **Group 33** for the front axle, or **Group 35** for the rear axle.

Brake Rotor Removal and Installation

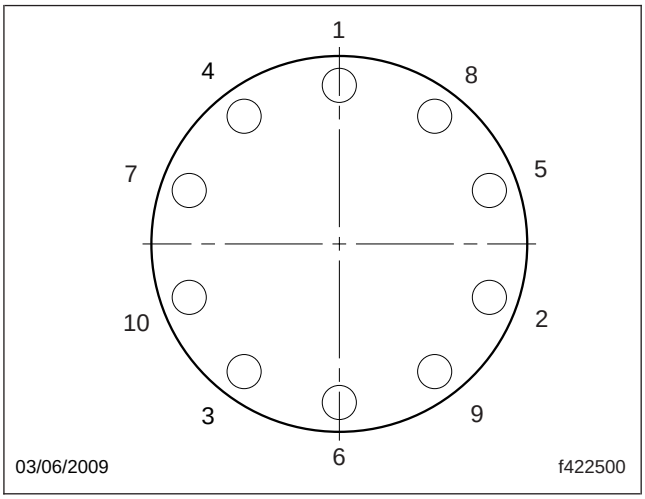


Fig. 3, Tightening Sequence

4. Install the brake caliper/carrier assembly. See **Subject 120**.
5. Install the wheel(s). See **Group 40**.
6. Remove the jackstand, and lower the vehicle.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

7. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 7.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 7.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 7.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Front Anchor Plate Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheel. See **Group 40**.
5. Remove the caliper/carrier assembly. See **Subject 120**.
6. Remove the hub and disc assembly. See **Subject 130**.
7. Pull the ABS sensor from its hole in the axle flange, and secure it in a safe place.
8. Remove the fasteners and remove the anchor plate. See **Fig. 1**.

Rear Anchor Plate Removal

1. Apply the brakes and chock the tires.
2. Drain the air from the air system.
3. Raise the axle being serviced, and support it on a jackstand.
4. Remove the wheels. See **Group 40**.
5. Remove the rotor shield, if equipped. See **Fig. 2**.
6. Remove the caliper/carrier assembly. See **Subject 120**.
7. Remove the hub and disc assembly. See **Subject 130**.
8. Cut the zip ties holding the ABS sensor harness in place.
9. Disconnect the ABS sensor harness at its connection to the chassis harness, then feed it through the hole in the anchor plate and secure it in a safe manner.
10. Remove the fasteners and remove the anchor plate.

Anchor Plate Cleaning and Inspection

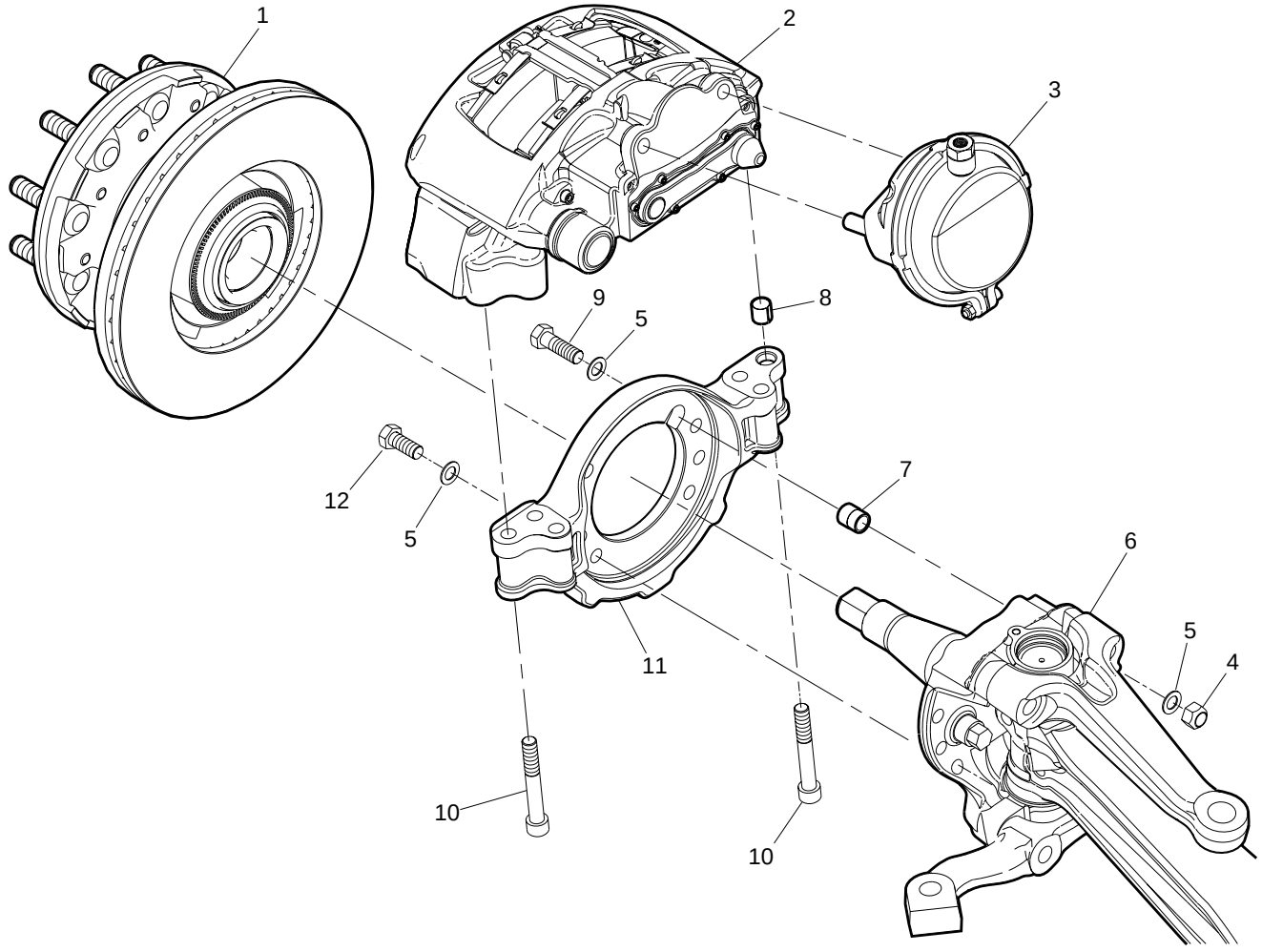
If replacing the anchor plate, it is not necessary to clean and inspect it. If the anchor plate will be reused, clean and inspect it as follows.

1. Clean the anchor plate with a brush and solvent.
2. Inspect the anchor plate for cracks or other damage. If damage is found, replace the anchor plate.
3. Inspect the carrier and axle flange mounting surface of the anchor plate. All surfaces must be clean and free of any rust or corrosion. Use a hand-held wire brush to clean these surfaces, if needed.
4. Check that the carrier bolt hole threads are clean and free of foreign matter, and that the carrier guide bushing is secure and properly seated.

Front Anchor Plate Installation

1. Position the anchor plate on the spindle flange with the caliper mounting bosses facing up, and the ABS sensor hole (larger) aligned with the uppermost forward hole on the axle flange.
2. Install the capscrews, washers, and nuts, as shown in **Fig. 1**.
   - 2.1 Install the 2-inch capscrew, washers, and nut, in the hole next to the ABS sensor hole.
   - 2.2 Then install the 1-1/2-inch capscrews that thread into the steering knuckle.
   - 2.3 Tighten the 2-inch capscrew 144 to 164 lbf·ft (195 to 222 N·m), and the 1-1/2-inch capscrews 168 to 188 lbf·ft (228 to 255 N·m) using the sequence shown in **Fig. 3**.
3. Install the hub and disc assembly. See **Subject 130**.
4. Install the ABS sensor. Push it in by hand, as far as it will go.
5. Install the caliper/carrier assembly. See **Subject 120**.
6. Install the wheel. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly



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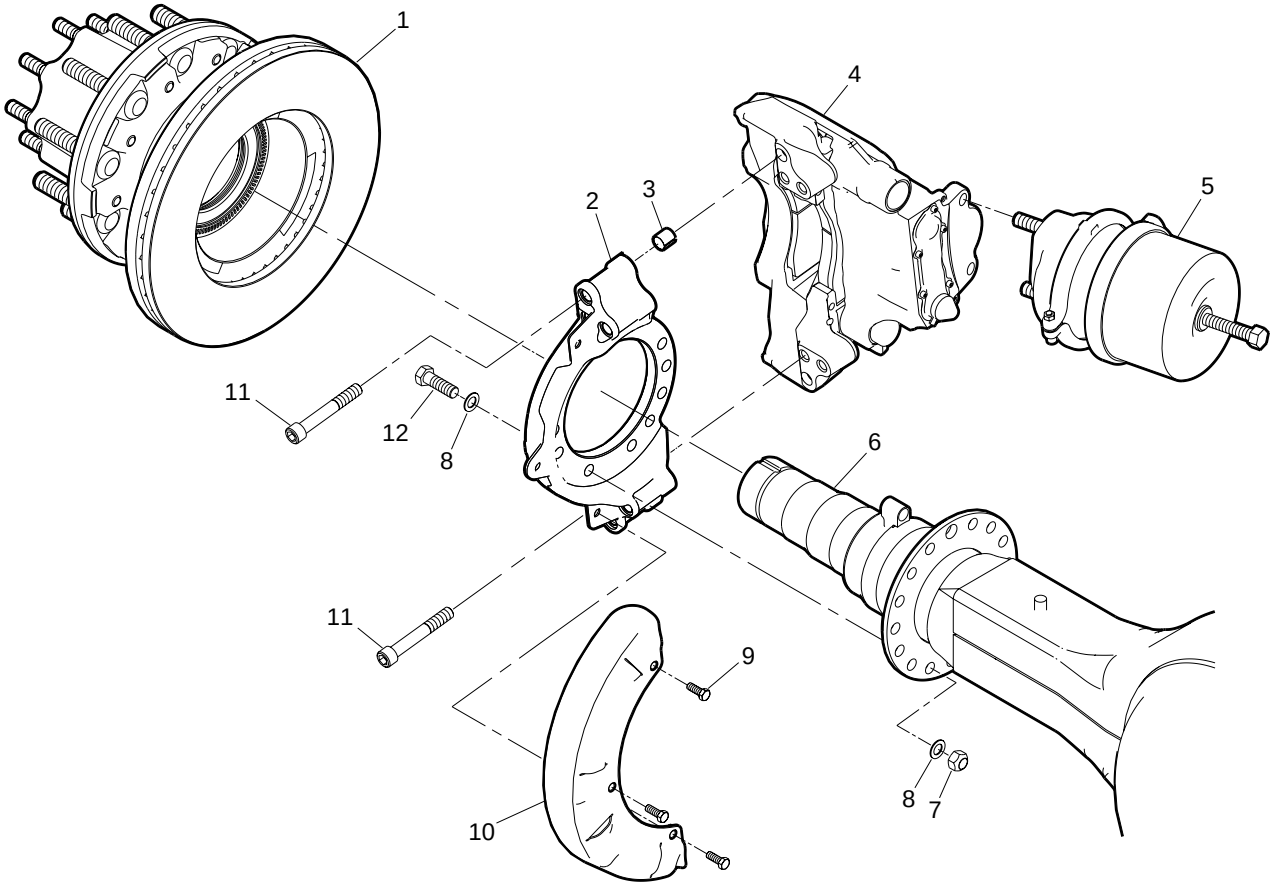
1. Hub and Disc Assembly
2. Caliper/Carrier Assembly
3. Brake Chamber
4. Nut
5. Washer
6. Spindle Assembly
7. ABS Sensor Bushing
8. Carrier Guide Bushing
9. Anchor Plate Bolt
10. Caliper Mounting Capscrew
11. Anchor Plate
12. Anchor Plate Capscrew

Fig. 1, Front Axle Anchor Plate Installation

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.



1. Hub and Rotor Assembly
2. Anchor Plate
3. Carrier Guide Bushing
4. Caliper/Carrier Assembly
5. Spring Brake Chamber
6. Axle End
7. Nut
8. Washer
9. Rotor Shield Capscrew
10. Rotor Shield
11. Caliper Mounting Capscrew
12. Bolt

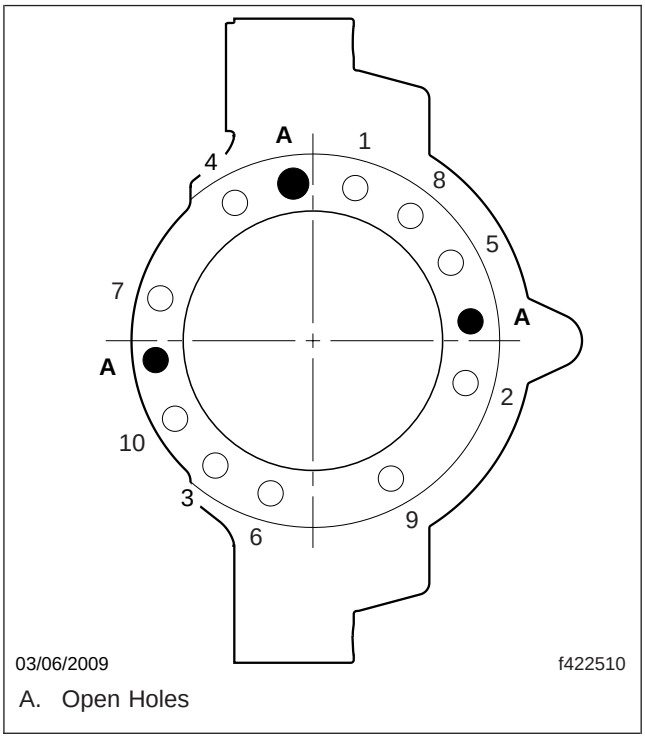
Fig. 2, Rear Axle Anchor Plate Installation

8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Rear Anchor Plate Installation

1. Position the anchor plate on the axle flange with the ABS sensor hole at the 12 o'clock position on the axle flange. Install the ten capscrews, washers, and nuts, leaving the holes at 12, 3, and 9 o'clock positions empty. Tighten 144 to 164 lbf·ft (195 to 222 N·m), using the sequence shown in **Fig. 3**.
2. Feed the ABS sensor harness through the hole in the anchor plate, and connect it at the chassis harness. Secure it with zip ties as needed.
3. Install the hub and disc assembly. See **Subject 130**.
4. Install the caliper/carrier assembly. See **Subject 120**.
5. Install the rotor shield, if equipped.

Anchor Plate Disassembly, Inspection, Cleaning, and Assembly



A. Open Holes

Fig. 3, Tightening Sequence

6. Install the wheels. See **Group 40**.
7. Remove the jackstand, and lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 8.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

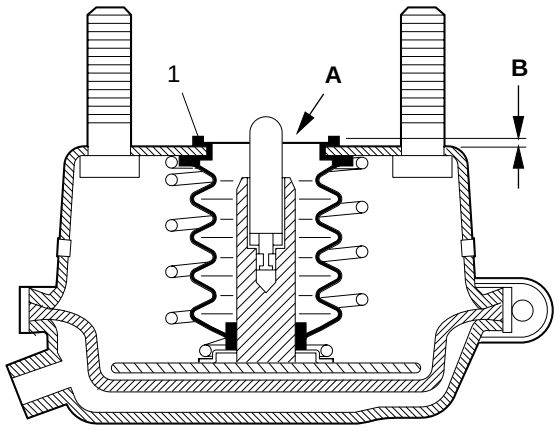
Brake Chamber, or Spring Brake Chamber, Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: Replace the brake chamber, or spring-brake chamber, only with units that are the same as originally installed on the vehicle. Replacement with alternate equipment could compromise brake performance and the vehicle warranty. Do not use brake chambers with seals with a thickness less than 0.12 inch (3 mm). See Fig. 1. Use only brake chambers which are recommended by Daimler Trucks North America (DTNA).

NOTE: New brake chambers have drain hole plugs installed in all positions. After installation, remove whichever plug is at the lowest position. Be sure that all other drain holes remain plugged.



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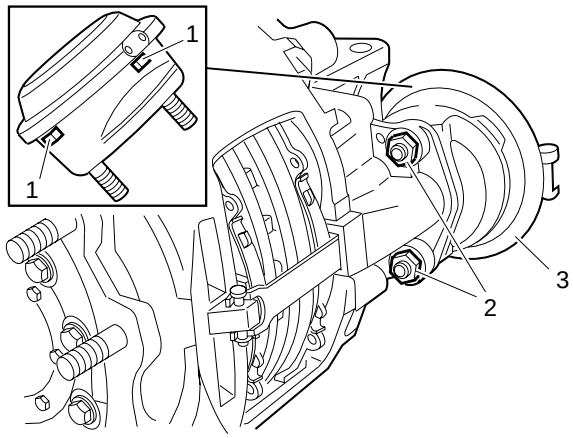
A. Pushrod Area
B. Do Not Use if Thickness is Less than 0.12 in (3 mm)

1. Seal

Fig. 1, Pushrod Area

Front Brake Chamber Removal

1. Apply the brakes and chock the tires.
2. Remove the wheels.
3. Drain the air from the air system.
4. Cut the zip ties holding the ABS wire to the air hose.
5. Disconnect the air hose at the frame rail connection.
6. Remove and discard the brake chamber mounting nuts. See Fig. 2.



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1. Drain Plugs
2. Brake Chamber Mounting Nuts
3. Brake Chamber

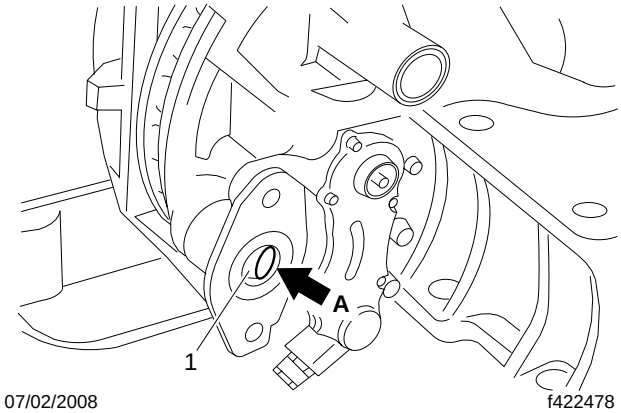
Fig. 2, Brake Chamber Installation

7. Remove the brake chamber.
8. If replacing the brake chamber, remove the air hose to use on the new one.

Front Brake Chamber Installation

1. If replacing the brake chamber, install the air hose from the old chamber.
2. Before installing the new brake chamber, clean and inspect the brake chamber flange for damage. See Fig. 3. The seal, as well as the pushrod area must be clean and dry. See Fig. 1.
3. Lubricate the spherical cup in the lever with white grease. Do not use grease containing molybdenum disulfate.

Brake Chamber, or Spring Brake Chamber, Removal and Installation



A. Actuator Flange
1. Spherical Cup in Lever

Fig. 3, Actuator Flange

4. Install the brake chamber using new self-locking nuts. Alternately tighten both nuts in increments to a final torque of 126 to 140 lbf·ft (170 to 190 N·m).
5. Connect the air hose. Be sure that the hose is not twisted, or in contact with moving vehicle components. The air hose routing must allow for full caliper travel.
6. Secure the ABS wire to the brake hose. Be sure to leave flex room.
7. Install the wheels.
8. Lower the vehicle.

WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

9. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 9.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 9.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 9.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Spring Brake Chamber Removal

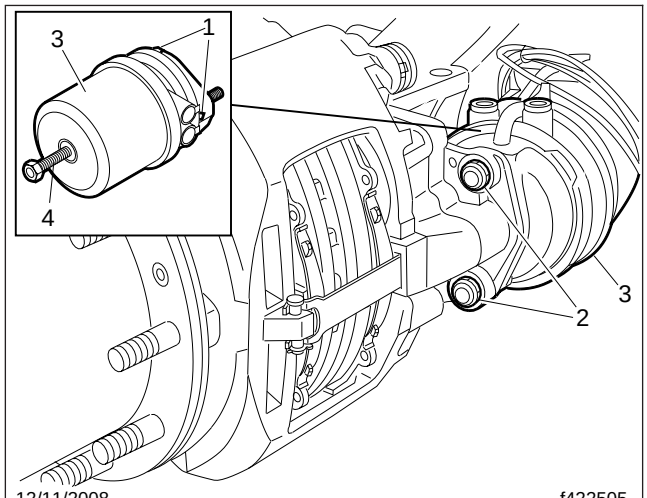
1. Set the brakes and chock the tires.
2. Remove the wheels.

WARNING

When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury or death.

3. Carefully cage and lock the spring brakes so that the springs cannot actuate during disassembly.

   Back out the release bolt using a maximum torque of 26 lbf·ft. (35 N·m) to release spring force on the pushrod. See **Fig. 4**.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 4, Spring Brake Chamber Installation

4. Drain all the air pressure from the air brake system.

5. Cut the zip ties holding the ABS wire to the air hose.
6. Disconnect the air hose at the frame rail connection.
7. While supporting the spring brake chamber in position, remove and discard brake chamber mounting nuts. Remove the brake chamber.
8. If replacing the brake chamber, remove the air hose to use on the new one.

Spring Brake Chamber Installation

IMPORTANT: Replace the brake chamber, or spring-brake chamber, only with units that are the same as originally installed on the vehicle. Replacement with alternate equipment could compromise brake performance and the vehicle warranty. Do not use brake chambers with seals with a thickness less than 0.12 in. (3 mm). See **Fig. 1**. Use only brake chambers which are recommended by DTNA.

NOTE: New brake chambers have drain hole plugs installed in all positions. After installation, remove whichever plug is at the lowest position. Be sure that all other drain holes remain plugged.

1. If replacing the brake chamber, install the air hose from the old chamber.
2. Before installing the new brake chamber, clean and inspect the brake chamber flange for damage. The seal, as well as the pushrod area must be clean and dry. See **Fig. 3**.
3. Lubricate the spherical cup in the lever with white grease. Do not use grease containing molybdenum disulfate. See **Fig. 3**.
4. Install the brake chamber using new self-locking nuts. Alternately tighten both nuts in increments to a final torque of 126 to 140 lbf·ft (170 to 190 N·m).
5. Connect the air hose. Be sure that the hose is not twisted, or in contact with moving vehicle components. The air hose routing must allow for full caliper travel.
6. Secure the ABS wire to the brake hose. Be sure to leave flex room.
7. Uncage the spring brake.
8. Install the wheels.
9. Lower the vehicle.

⚠ WARNING

Do not operate the vehicle until the brakes have been adjusted and checked for proper operation. To do so could result in inadequate or no braking ability, which could cause personal injury or death, and property damage.

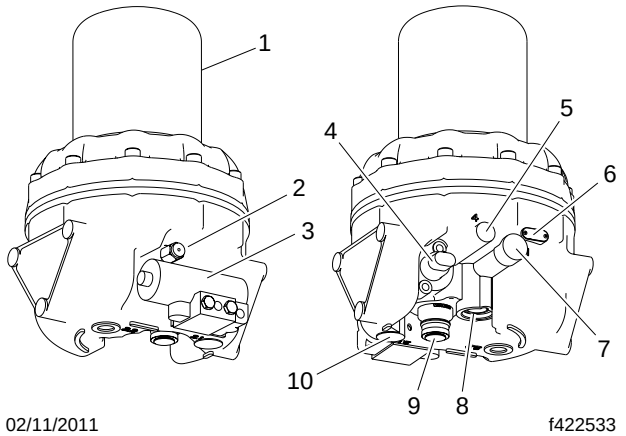
10. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
    - 10.1 Apply and release the brakes several times to check for air leaks and proper operation.
    - 10.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
    - 10.3 Immediately after doing the above stops, check the rotor temperatures. Any rotors that are significantly cooler than others show a lack of braking effort on those wheels.

Bendix Air Disc Brake Fastener Torque Specifications	
Installation	**Torque: lbf·ft (N·m)**
Hub to Rotor	190–210 (258–285)
Anchor Plate to Axle Flange: 2-inch (front)	144–164 (195–222)
Anchor Plate to Axle Flange: 1.5-inch (front)	168–188 (228–255)
Anchor Plate to Axle Flange (rear)	144–164 (195–222)
Caliper to Anchor Plate	170–200 (230–271)
Brake Chamber to Caliper	126–140 (170–190)
Rotor Shield to Anchor Plate	25–35 (34–47)

Table 1, Bendix Air Disc Brake Fastener Torque Specifications

General Information

The System Saver 1200 Plus air dryer, shown in **Fig. 1**, is a desiccant air dryer, mounted vertically between the air compressor and the supply reservoir. The air dryer receives hot compressed air, which it cools and filters before sending it to the supply reservoir, reducing the buildup of dirt and moisture in the vehicle air system.



1. Desiccant Canister
2. Pressure Relief Valve
3. Governor
4. Heater/Thermostat Assembly
5. Control Port (to the air compressor unloader port)
6. Date Code Information (for the air dryer)
7. Air Dryer Inlet (from the air compressor discharge)
8. Turbocharger Cutoff Valve
9. Exhaust Port (Purge Valve Assembly)
10. Delivery/Outlet Port (to the air supply reservoir)

Fig. 1, WABCO System Saver 1200 Plus

The air dryer consists of a light weight aluminum and steel body. The desiccant cartridge is contained in a spinoff canister at the top of the air dryer.

The bottom half of the air dryer houses the following components.

- Pressure Relief Valve—this valve protects the air dryer from over pressurization. The valve is attached directly to the air dryer.
- Desiccant Canister—a cylindrical steel housing that contains the filter elements and the desiccant needed to filter and dry the air that passes through it.
- Heater/Thermostat Assembly—located in the air dryer base, this assembly is designed to prevent the collected moisture from freezing.
- Outlet Check Valve—this valve prevents air in the system from flowing back through the air dryer and escaping out the purge valve during the compressor unload cycle.
- Purge Valve—this valve allows the collected moisture and contaminants to be expelled from the air dryer during the purge cycle.
- Silencer (Muffler)—an optional component that is attached to the purge valve and used to eliminate most of the noise during the air dryer purge cycle.
- Turbocharger Cutoff Valve—this optional valve closes the path between the air compressor and the air dryer purge valve to help maintain boost pressure for maximum engine horsepower during the compressor unload cycle. A turbocharger cutoff valve is required with air compressors that use a turbocharged air intake.

NOTE: If the air compressor is naturally aspirated, the air passes from the vehicle air filter directly to the air compressor intake and **does not** require a turbocharger cutoff valve.

Principles of Operation

Hot, compressed air enters the air dryer through the inlet port. As the hot air is forced into the desiccant cartridge, the temperature of the compressed air falls to nearly ambient. Oil and water vapor condense and initially settle into the base of the dryer. The moisture-laden air also passes through the desiccant bed, where any remaining moisture is retained by the desiccant. The clean air then passes through the air dryer outlet port to the supply reservoir.

When the compressor reaches 125 psi (862 kPa), the purge valve opens, allowing the initial decompression of the dryer, and expelling the water and contaminants collected in the base of the dryer.

Safety Precautions

⚠ WARNING

When draining the air system, do not look into the air jets or direct them toward another person, as dirt or sludge particles may be in the air-stream. Do not disconnect pressurized hoses because they may whip as air escapes from the line. Failure to take all necessary precautions during service operations of the air brake system can cause personal injury.

When working on or around air brake systems and components, observe the following precautions.

- Apply the parking brake, chock the tires, and stop the engine when working under the vehicle. Draining the air system may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air system pressure drops.
- Wear safety goggles.
- Never connect or disconnect a hose or line containing air under pressure; it may whip as air escapes. Never remove a component or pipe plug unless you are sure all system pressure has been depleted.
- Do not disassemble a component before reading and understanding recommended procedures. Use only the correct tools and follow basic tool safety.
- Replacement hardware, tubing, hose, fittings, etc., should be the same size, type, length, and strength as the original equipment. When replacing tubing or hose, be sure that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace any components that have stripped threads or damaged parts. Do not attempt to repair parts by machining.
- Never exceed recommended air pressure.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

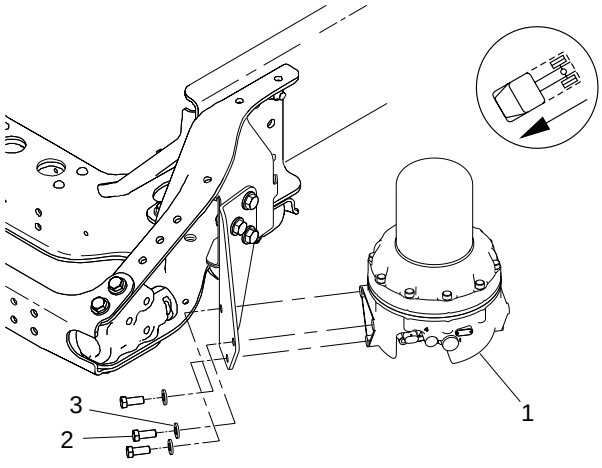
Refer to **Fig. 1** for removal and installation of the air dryer.

Removal

1. Drain the air system.
2. Disconnect the wiring harness from the air dryer.
3. Mark the air lines for later reference; then, disconnect them from the air dryer.
4. Remove the mounting screws and washers that attach the air dryer to the mounting bracket.
5. Remove the air dryer.

Installation

1. Position the air dryer on the mounting bracket. Install the washers and capscrews. Tighten them 52±4 lbf·ft (71±4 N·m).
2. Make sure the air lines are clean. Replace any line or fitting that is crimped or damaged.
3. Connect the remaining air lines to the air dryer as previously marked. Tighten the nut on each fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance.
4. Connect the air dryer wiring harness.



1. Air Dryer
2. Mounting Screw
3. Washer

Fig. 1, Air Dryer Installation (left-hand forward frame mounting shown)

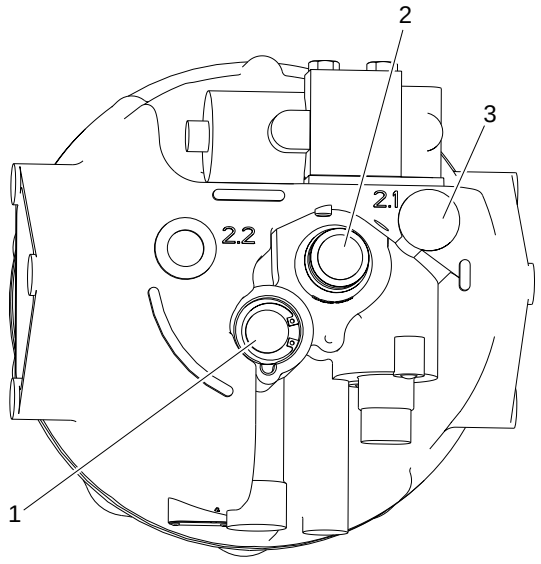
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: The turbocharger cutoff valve is optional on the WABCO System Saver 1200 Plus air dryer.

Replacement

1. Drain the air system.
2. Remove the snap ring at the bottom of the valve assembly. See **Fig. 1** for the location of the turbocharger cutoff valve and **Fig. 2** for an example of the turbocharger cutoff valve assembly.



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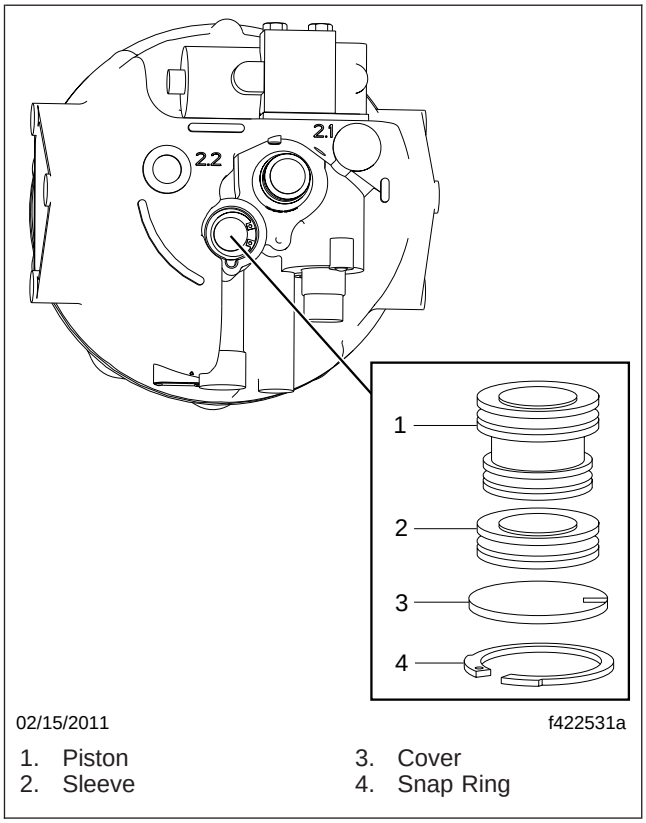
1. Turbocharger Cutoff Valve (has an orange cover)
2. Exhaust Port (Purge Valve Assembly)
3. Delivery/Outlet Port (to the air supply reservoir)

Fig. 1, Turbocharger Cutoff Valve

3. Clean the valve cavity with a commercial cleaning solvent.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer. See **Subject 110** for instructions.

4. Install new O-rings on the piston and the sleeve.



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1. Piston
2. Sleeve
3. Cover
4. Snap Ring

Fig. 2, Turbocharger Piston and Sleeve Assembly

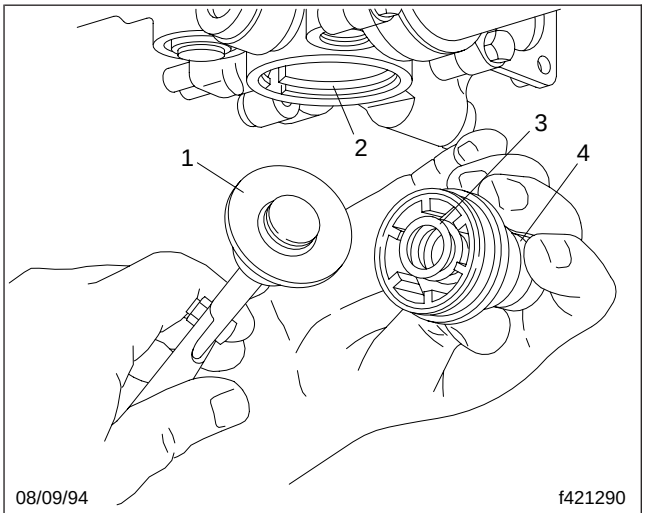
5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-rings and the valve cavity.
6. Press the piston into the sleeve.
7. Press the new piston and sleeve assembly into the air dryer.
8. Install the cover and snap ring to hold the components in place.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for purge valve replacement.



1. Valve Assembly
2. Exhaust Port
3. Spring
4. Valve Head

Fig. 1, Removing the Valve Assembly

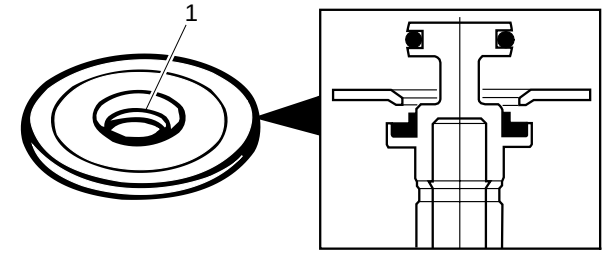
1. Drain the air system.
2. Remove the snap ring, valve head, and the spring from the exhaust port.
3. Pull the valve assembly out of the exhaust port.
4. Remove the O-ring from the base of the exhaust port.
5. Clean the purge valve cavity area with a commercial cleaning solvent.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the valve cavity and all of the new O-rings. Install the O-rings in the base of the exhaust port and on the valve head.
7. Install the new washer and O-ring in the dryer base and on the valve head.

NOTE: The lip on the washer must face the piston seat as shown in **Fig. 2**.

8. Assemble the piston assembly.
   - 8.1 Install the O-ring in the groove on the piston head.
   - 8.2 Install the piston seat in the groove on the piston base.
   - 8.3 Install the washer on the piston.
9. Position the new valve assembly in the valve cavity.



1. Lip

Fig. 2, Washer Lip Facing Piston Seat

10. Install the spring in the valve head, and position them in the valve cavity.
11. Install the snap ring to secure the valve head in position.

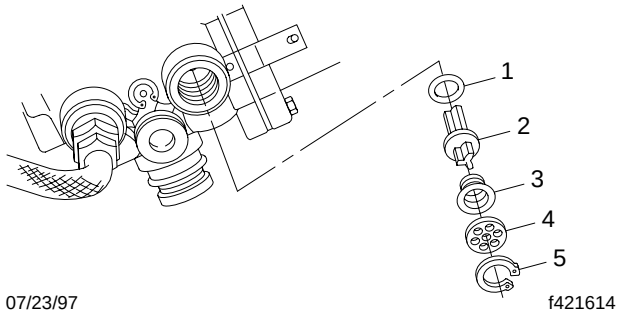
NOTE: Make certain the snap ring is fully seated or the assembly will leak from the purge valve.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for valve replacement.



1. O-Ring
2. Valve Body
3. Spring
4. Washer
5. Snap Ring

Fig. 1, Outlet Check Valve Assembly

1. Drain the air system.
2. Disconnect the air line from the outlet port.
3. Remove the snap ring, washer, valve body, and the O-ring.
4. Clean the cavity area with a commercial cleaning solvent.
5. Install a new O-ring on the valve body.
6. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the valve cavity.
7. Install the new valve body. Make sure that the long end of the body is inserted first into the valve cavity.
8. Install the new spring with its small end around the Y-shaped fins on the valve body.

IMPORTANT: If the valve cavity is damaged, preventing a tight seal, replace the air dryer.

9. Install a new washer and snap ring to secure the assembly in the valve cavity.
10. Connect the air line to the outlet port. Tighten the nut on the fitting finger-tight. Then, using two wrenches to prevent twisting the hose, further tighten the nut until there is firm resistance. Tighten the nut one-sixth turn more.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTICE

The WABCO System Saver 1200 Plus air dryer can use either a standard or oil coalescing desiccant cartridge. When replacing the desiccant cartridge, it is very important to use the same type of cartridge that was originally installed on the dryer. Oil coalescing cartridges can be used in any application, but require more frequent service intervals (every 1 to 2 years instead of every 2 to 3 years for a standard cartridge). Do not replace an oil coalescing cartridge with a standard cartridge, as this may result in contamination and malfunctioning of downstream air system components.

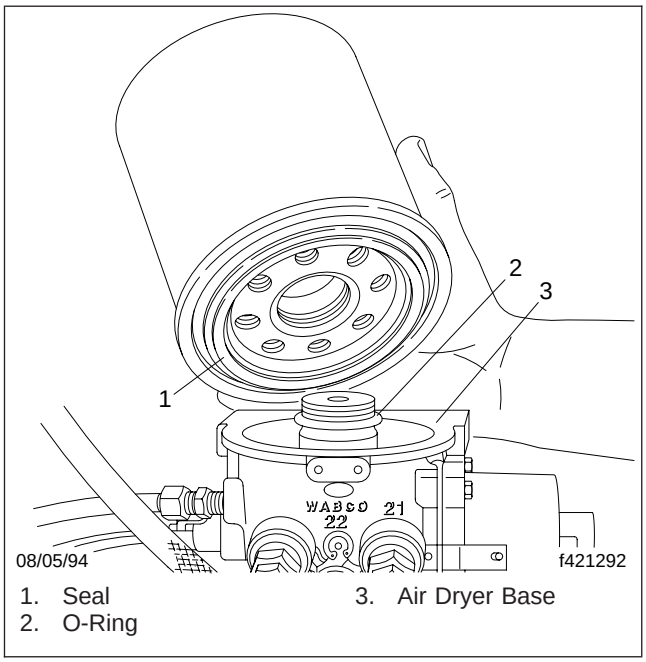
Replacement

Refer to **Fig. 1** for cartridge replacement.

1. Drain the air system.
2. Using a strap wrench, turn the desiccant cartridge counterclockwise and remove it.
3. Remove and discard the O-ring.
4. Clean the top surface of the dryer base with a commercial cleaning solvent.

IMPORTANT: If the air dryer base is damaged, preventing a tight seal, replace the air dryer.

5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the dryer base. Install the O-ring.
6. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not overtighten.



1. Seal
2. O-Ring
3. Air Dryer Base

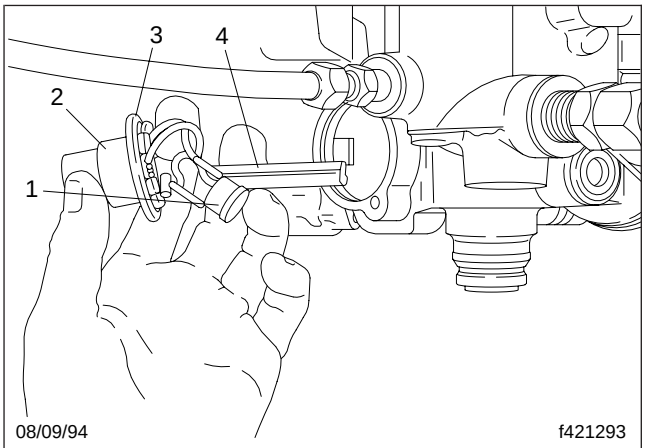
Fig. 1, Desiccant Cartridge Replacement

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for heater/thermostat assembly replacement.



1. Thermostat
2. Receptacle
3. O-Ring
4. Element

Fig. 1, Heater/Thermostat Replacement

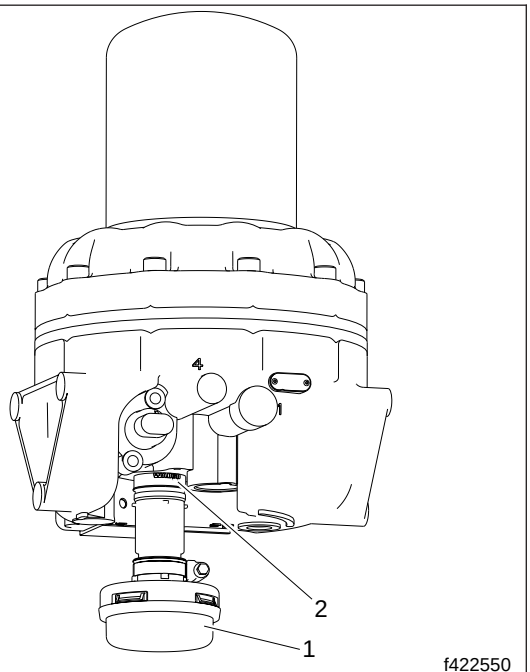
1. Drain the air system.
2. Disconnect the wiring harness.
3. Remove the screws that attach the heater/thermostat receptacle. Remove the receptacle and the O-ring.
4. Remove the retaining screw that holds the assembly in place. Remove and discard the heater/thermostat assembly.
5. Clean the heater/thermostat assembly area with a commercial cleaning solvent.
6. Position the new heater/thermostat assembly in the cavity. Install the retaining screw.
7. Position the new receptacle and O-ring, and install the screws. Tighten the screws securely.
8. Connect the wiring harness.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for silencer replacement.



1. Silencer
2. Purge Valve Head

Fig. 1, Silencer Replacement

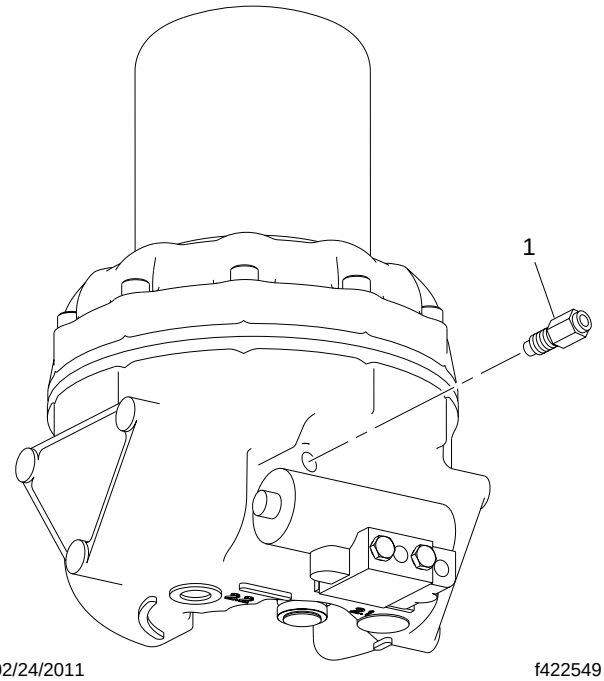
1. Using snap ring pliers, expand the snap ring and pull the silencer off of the purge valve head.
2. Push the new silencer onto the purge valve head until the silencer snaps into place.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for valve replacement.



1. Pressure Relief Valve

Fig. 1, Pressure Relief Valve Replacement

1. Drain the air system.
2. Unscrew and remove the old valve from the dryer.
3. Screw the replacement valve into the dryer base. Do not exceed a torque of 30 lbf·ft (41 N·m) for a 3/8-inch thread, or 65 lbf·ft (88 N·m) for a 1/2-inch thread.

NOTE: The threads on the replacement pressure relief valve provided by WABCO are coated with sealant. They do not require any additional sealant.

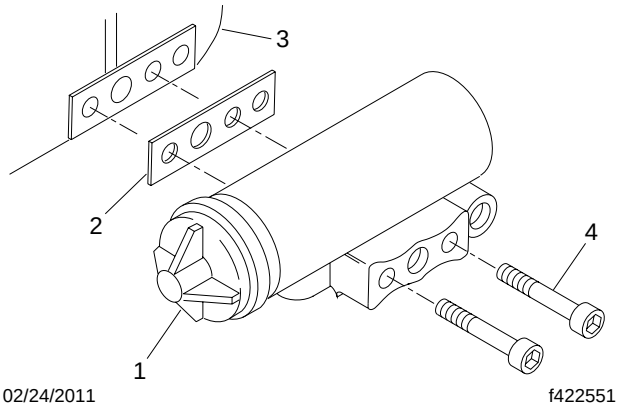
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

IMPORTANT: When replacing the governor, use only the Meritor WABCO governor specified for use with the System Saver 1200 Plus air dryer.

Replacement

1. Remove the mounting bolts, governor and gasket as shown in **Fig. 1**. Discard the gasket.



1. Governor
2. Gasket
3. Air Dryer
4. Mounting Bolt

Fig. 1, Replacing the Governor

2. Place the new governor and gasket into position on the air dryer.
3. Using the mounting bolts, install the governor. Tighten the bolts 15 lbf·ft (20 N·m).

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Air Dryer Operating Tests

1. Drain the air system.
2. Start the engine and build the air pressure to as close to cutout pressure as possible (about 125 psi [862 kPa]).
3. When the compressor reaches the unload cycle, the air dryer purges, beginning regeneration of the air dryer.
4. There should be no visible pressure drop on the vehicle dash gauges during regeneration. If there is a visible pressure drop, and there are no other air-operated components in use, then there are air leaks or other system problems. Refer to **Troubleshooting 300** for other possible causes.

Problem—Air Dryer Purges Too Often and Is Accompanied by Excessive Cycling of the Compressor

Problem—Air Dryer Purges Too Often and Is Accompanied by Excessive Cycling of the Compressor	
Possible Cause	**Remedy**
There is a leak in the line between the unloader port of the air compressor and dryer port 4.	Repair the air line.
There is a leak in the line between the supply tank and the delivery/outlet port.	Repair the air line.
Excessive air system leaks.	Repair all leaks.
Excessive air system demands.	Increase the air system capacity or reduce air demand.
The outlet check valve does not seal.	Inspect and replace the outlet check valve as needed.
There is a leak at the air governor gasket.	Replace the gasket.
The air governor has less than 16 psi (110 kPa) range.	Replace the air governor.
The air compressor's unloader(s) is leaking.	Inspect the air compressor and repair or replace it according to the manufacturer's instructions.

Problem—The Air Dryer Does not Purge When the Compressor Unloads (No Blast of Air from the Purge Valve)

Problem—The Air Dryer Does not Purge When the Compressor Unloads (No Blast of Air from the Purge Valve)	
Possible Cause	**Remedy**
The air line between the unloader port of the air compressor and air dryer port 4 is kinked or plugged.	Repair the air line.
The purge valve is stuck closed.	Replace the purge valve.
The air governor is not working properly.	Inspect the air governor and repair or replace it according to the manufacturer's instructions.
Cut-out pressure is never achieved by the air compressor.	Check for air leaks in the system and repair as needed. If no leaks are found, check the compressor output. Repair or replace the compressor according to the manufacturer's instructions.

Problem—There Is Rapid "Spitting" of Air from the Purge Valve in Small Amounts; Frequency Varies With Engine Speed

Problem—There Is Rapid "Spitting" of Air from the Purge Valve in Small Amounts; Frequency Varies With Engine Speed	
Possible Cause	**Remedy**
A Holset E-type compressor is being used, but a non-1200E air dryer is installed.	Replace the air dryer with an SS1200E air dryer.
The compressor does not completely unload when cut-out pressure is reached.	Inspect the compressor and repair or replace it according to the manufacturer's instructions.
This is normal for air dryers that are not equipped with an optional turbocharger cutoff valve.	Not applicable.

Troubleshooting

Problem—Air Leaks at the Turbo Cutoff Valve Vent; There Is a Hole Burned in the Piston

Problem—Air Leaks at the Turbo Cutoff Valve Vent; There Is a Hole Burned in the Piston	
Possible Cause	**Remedy**
The temperature of the air coming into the dryer is too high, and there is not enough cooling taking place before the air gets to the air dryer inlet.	Move the dryer farther from the compressor. Add additional compressor discharge line before the air dryer. Add a cooling coil or heat exchanger before the air dryer. NOTE: The inlet air temperature must not exceed 175°F (79°C).
The valve bore is worn excessively.	Inspect the valve bore for wear. If a new turbo cut-off valve does not seal in a clean, lubricated bore, replace the air dryer.
The piston is broken.	Replace the turbocharger cutoff valve. See **Subject 120**.

Problem—The Air Dryer Is Frozen (Water Collected in the Base of the Air Dryer Freezes)

Problem—The Air Dryer Is Frozen (Water Collected in the Base of the Air Dryer Freezes)	
Possible Cause	**Remedy**
There is no power to the heater connector.	Check for a blown fuse. Repair the heater circuit. NOTE: There must be power to the heater connector the entire time the vehicle's ignition is activated.
Low voltage to the heater connector.	Repair the cause of low voltage—poor electrical ground, bad connections, corroded wire splices, etc.
The heater assembly is not working.	Replace the heater assembly.
An incorrect voltage air dryer is being used (for example a 12V air dryer in a 24V system).	Replace with the correct voltage air dryer.

Problem—Air Pressure Will Not Build-Up in the System

Problem—Air Pressure Will Not Build-Up in the System	
Possible Cause	**Remedy**
The air dryer is not plumbed correctly.	Make certain the compressor discharge line is plumbed to air dryer port 1, and air dryer port 21 is connected to the vehicle's supply tank.
The wrong air line is connected to air dryer port 4.	Verify that the air dryer port 4 line is connected to the "UNL" port of the unloader port of the air compressor.
The air governor is not working properly.	Inspect the air governor and repair or replace it according to the manufacturer's instructions.
Air system components, such as the compressor discharge line, air dryer reservoirs, brake valves, or suspension valves leak.	Locate the leak(s) and repair as needed.
The air dryer leaks at the purge valve.	See *Air dryer purges too often and is accompanied by excessive cycling of the compressor* and *The air dryer leaks from the purge valve during a compressor loaded cycle (the leak may cause excessive compressor cycling or prevent the system from building air pressure).*

Problem—Water, Oil, or Sludge Is in the Air System Tanks

Problem—Water, Oil, or Sludge Is in the Air System Tanks	
Possible Cause	**Remedy**
Desiccant is contaminated with oil.	Replace desiccant. Inspect the compressor according to the manufacturer's instructions.

Problem—Water Is in the Air System Tanks

Problem—Water Is in the Air System Tanks	
Possible Cause	**Remedy**
The air dryer is not suitable for the vehicle.	Review the vehicle guidelines. Call the Meritor Customer Support Center for assistance at 1-800-535-5560.

Problem—The air dryer leaks from the purge valve during a compressor loaded cycle. The leak may cause excessive compressor cycling or prevent the system from building air pressure.

Problem—The air dryer leaks from the purge valve during a compressor loaded cycle. The leak may cause excessive compressor cycling or prevent the system from building air pressure.	
Possible Cause	**Remedy**
The purge valve is frozen open.	Check the heater, and repair or replace it if necessary. Make sure the air line between the unloader port of the air compressor and dryer port 4 is free of water and oil. Remove and inspect the purge valve, and clean any water or oil from the top of the piston.
Debris is under the purge valve seat.	Remove the purge valve and clean it. See **Subject 130** for instructions to remove the purge valve. Remove the desiccant cartridge and clean the dryer sump area. See **Subject 150** for instructions.
The purge valve washer is installed upside down.	Make certain the lip on the washer faces down, away from the air dryer.
The wrong air line is connected to air dryer port 4.	Verify that the dryer port 4 line is connected to the "UNL" port of the air compressor.
The purge valve snap ring is not fully seated in the groove.	Seat the snap ring fully into the groove.

Problem—The regeneration cycle is too long (more than 30 seconds), accompanied by loss of pressure in the supply tank

Problem—The regeneration cycle is too long (more than 30 seconds), accompanied by loss of pressure in the supply tank	
Possible Cause	**Remedy**
The outlet check valve is not seating.	Inspect the outlet check valve. Replace the valve if needed.

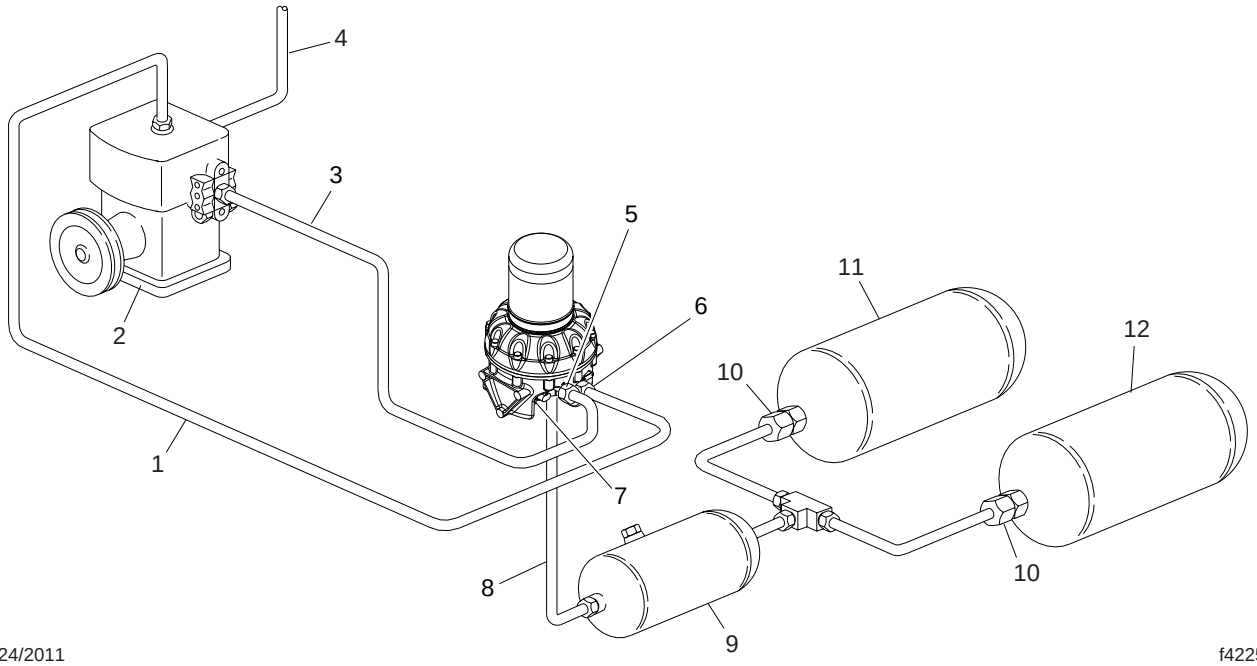
Problem—The regeneration cycle is too short (less than 20 seconds)

Problem—The regeneration cycle is too short (less than 20 seconds)	
Possible Cause	**Remedy**
There are high air system demands during a compressor unloaded cycle.	Increase the air system capacity or reduce air demands.

Troubleshooting

Problem—The regeneration cycle is too short (less than 20 seconds)	
Possible Cause	**Remedy**
The air governor is not working correctly.	Inspect the air governor and repair or replace it according to the manufacturer's instructions.

See **Fig. 1** for the plumbing diagram.



1. Compressor Discharge Line
2. Compressor
3. Signal Line
4. Compressor Intake Line (naturally aspirated or turbocharged)
5. Air Dryer Control Port
6. Air Dryer Inlet
7. Exhaust Port (Purge Valve Assembly)
8. Delivery Line (from the delivery/outlet port)
9. Supply Tank
10. Check Valve
11. System Reservoir
12. System Reservoir

Fig. 1, Air Dryer Plumbing Diagram

General Description

The Bendix PP-DC parking brake air valve is installed on non-towing trucks with air parking brakes, and is used to control the rear axle parking brakes. It is a push-pull type of valve, and is mounted on the right side of the dash.

Principles of Operation

When the valve knob is pulled out, air is exhausted from the parking brake chambers, releasing the springs, and applying the parking brakes. When the knob is pushed in, air flows into the parking brake chambers from one of the reservoirs, and compresses the springs, releasing the parking brakes.

The PP-DC has a double check valve feature. If the pressure drops in either air system (primary or secondary), the valve will automatically use air pressure from the system with the higher pressure for the parking brakes. This prevents the parking brakes from applying automatically unless pressure is lost from both systems.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

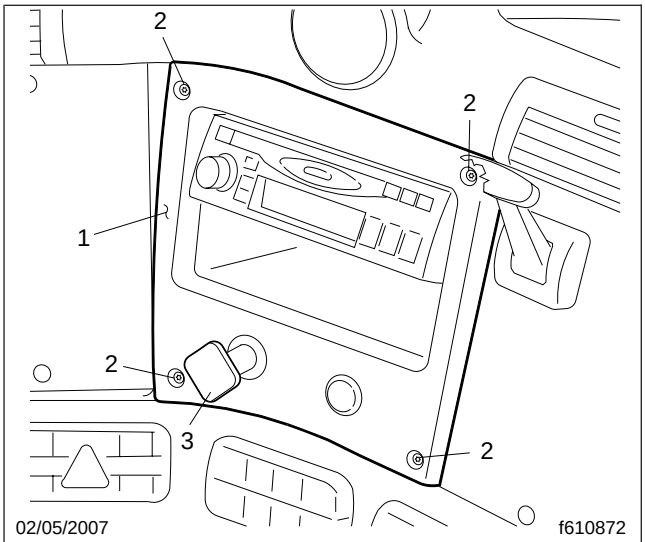
- Chock the tires and stop the engine before working under a vehicle. Keep hands away from brake chamber pushrods and slack adjusters; they may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understand the recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

Parking Brake Dash Valve Removal and Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to **Fig. 1** and **Fig. 2** for parking brake dash valve removal and installation.



1. Dash Center Panel
2. Fastener
3. Parking Brake Hand Valve Knob

Fig. 1, Parking Brake Hand Valve

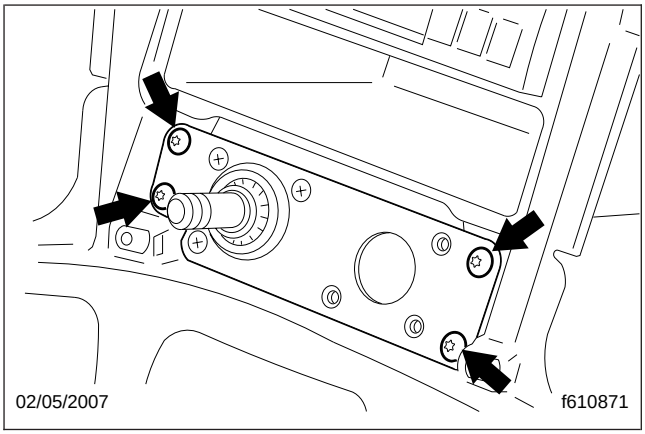


Fig. 2, Parking Brake Valve Mounting

Removal

1. Park the vehicle on a level surface, apply the parking brakes, chock the tires, and drain the air tanks.
2. Turn the valve knob counterclockwise and remove it from the valve stem.
3. Remove the fasteners from the dash center panel and remove the panel.
4. Remove and save the mounting screws and washers from the corners of the cover plate.
5. With the valve and cover plate assembly pulled out slightly from the dash panel, mark the air lines for later reference, then disconnect them from the valve assembly.

NOTE: The primary supply line is green; the secondary supply line is red; the exhaust line is silver and 3/8 inch (10 mm) in diameter; the delivery line is black and 3/8 inch (10 mm) in diameter.

6. Remove the valve.

Installation

1. Connect the air lines to the proper ports. The color of the air lines should match the colored collar at the valve fitting.
2. Attach the knob onto the threaded stem of the spool, making sure that it is oriented correctly as noted during removal.
3. Leak test the fittings, as instructed in **Subject 130**.
4. Align the valve in the dash and install the mounting screws and washers into the corners of the cover plate.
5. Remove the knob.
6. Position the dash center panel and install the fasteners.
7. Attach the knob onto the threaded stem of the spool, making sure that it is oriented correctly as noted during removal.

Parking Brake Dash Valve Disassembly and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to **Fig. 1** for valve disassembly and assembly.

Disassembly

1. Remove the valve assembly from the dash, as instructed in **Subject 110**.
2. Put the valve assembly in a soft-jawed or padded vise.
3. Remove the screws that attach the cover to the body. Remove the cover.
4. Pull the plunger stem and remove the plunger and guide spool from the body.
5. Remove and discard the plunger spring.
6. Using a screwdriver (if needed), carefully remove the check valve seat from the body. Use care to not damage either the check valve seat or the valve body.
7. Remove and discard the check valve seat O-rings.
8. Turn the body upside down and gently tap it on a flat surface to remove the check valve. Discard the check valve.
9. Remove the guide spool from the plunger. Remove and discard the O-ring.
10. Remove and discard the O-rings from the plunger. Also, remove and discard the exhaust seal.

Assembly

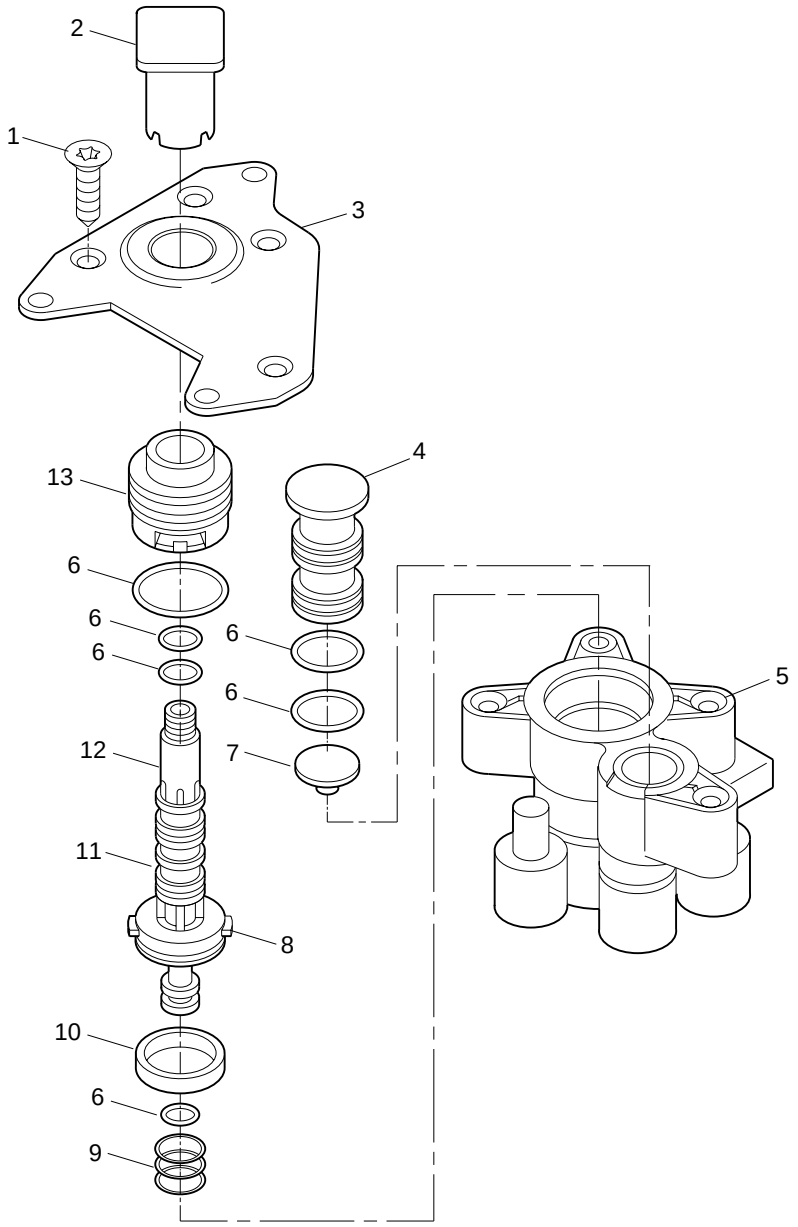
1. Clean and dry all the parts.
2. Check all the parts. Replace a part if any wear or damage is found.
3. Lightly grease all the parts—including the new parts from the maintenance kit—with Dow Corning 55 silicone pneumatic grease or equivalent.
4. Position the check valve in its seat in the body, with the flat surface of the valve facing up. If needed, reach into the body to make sure that the valve is seated evenly in the bore.
5. Install the O-rings on the check valve seat, and install the assembly into the body. Make sure that the check valve seat is even with the valve body surface.
6. Install the plunger spring into the body. Make sure that the spring is upright and seated properly in the body bore.

NOTE: The plunger spring should surround the protrusion or "lip" at the bottom of the body bore.

7. Install the O-rings onto the plunger, then install the plunger into the body.

   For ease of installation, line up the plunger's index tabs with the spaces in the body bore.
8. Install the O-ring on the guide spool. Install the spool over the plunger and into the body. Firmly press the guide spool into position.
9. Position the cover and install the screws that attach it to the body. Tighten the screws 35 lbf·in (395 N·cm).
10. Install the valve in the dash, then leak test it. Follow the instructions in **Subject 110** for installation, and in **Subject 130** for leak testing.

Parking Brake Dash Valve Disassembly and Assembly



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1. Screw
2. Valve Knob
3. Cover
4. Check Valve Seat
5. Valve Body
6. O-Ring
7. Check Valve
8. Index Tab
9. Plunger Spring
10. Exhaust Seal
11. Plunger
12. Plunger Stem
13. Guide Spool

Fig. 1, Bendix PP-DC Parking Brake Valve, Exploded View (typical)

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to **Fig. 1** for valve disassembly and assembly.

Operating Test

1. Chock the tires.
2. Start the engine and build the air pressure to the normal operating level.
3. With the valve knob pulled out, supply either supply port with 120 psi (827 kPa) of pressure. Push the valve knob in. Air pressure should rise in the delivery line, and should equal supply line pressure.

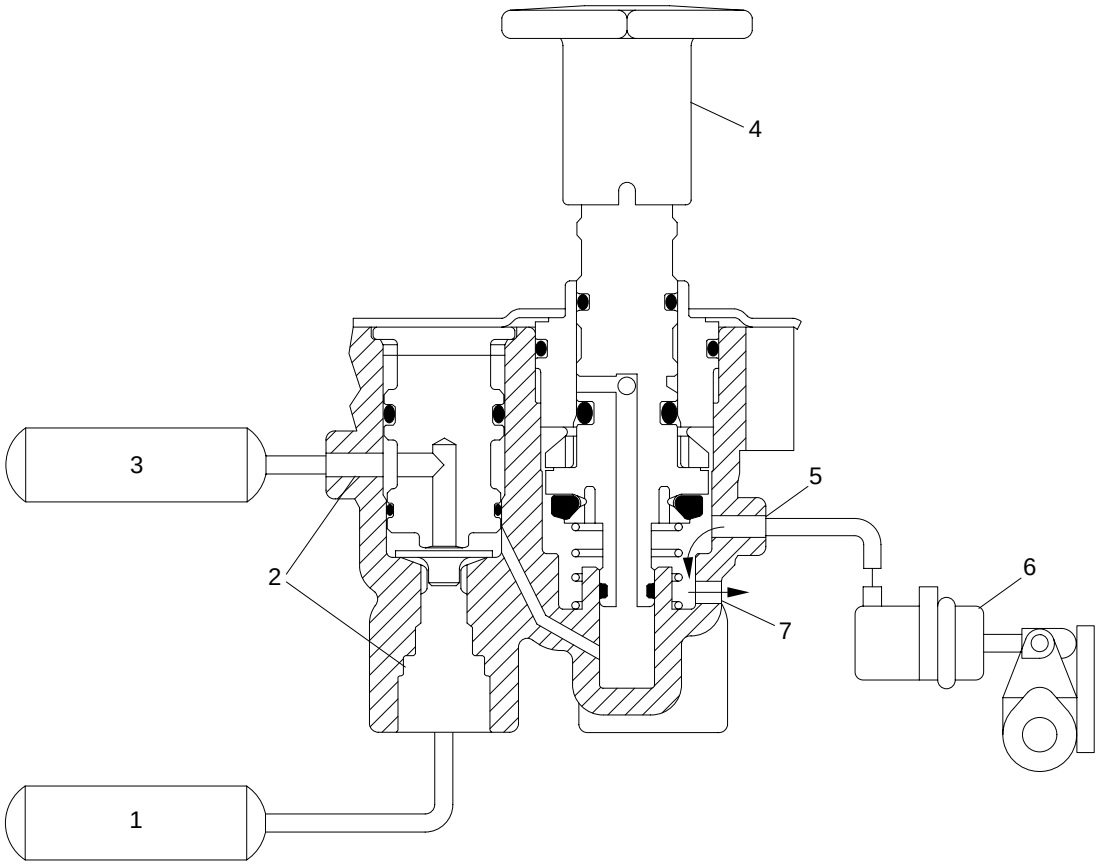
   Pull the valve knob out. Delivery pressure should exhaust to zero.
4. Build air pressure to each supply source to 120 psi (827 kPa). Decrease supply pressure at the secondary service reservoir supply port at a rate of 10 psi (69 kPa) per second.

   Primary supply pressure and delivery pressure should not drop below 100 psi (689 kPa). Repeat this step for decreasing primary service reservoir pressure.
5. Build air pressure to each supply source to 120 psi (827 kPa). Then decrease both supply pressures to below 20 to 30 psi (138 to 207 kPa). The valve knob should automatically pop out when the pressure is within that range.
6. If the valve does not work as described, repair the valve or replace it, as instructed in **Subject 120**.

Leak Testing

1. Chock the tires.
2. Supply the valve with 120 psi (827 kPa) from the primary reservoir supply port.
3. With the valve knob pulled out, coat the exhaust port and the plunger stem with a soapy solution. Leakage at either fitting should not exceed a 1-inch (2.5-cm) bubble every five seconds. There should be no leakage from the secondary reservoir supply port.
4. Supply the valve with 120 psi (827 kPa) from the secondary reservoir supply port. There should be no leakage from the primary reservoir supply port.
5. With the valve knob pushed in, coat the exhaust port and the plunger stem with a soapy solution. Leakage at the fittings should not exceed a 1-inch (2.5-cm) bubble every three seconds. If it does, replace or repair the valve, following instructions under **Subject 120**.

Parking Brake Dash Valve Tests



1. Primary Service Reservoir
2. Supply Port
3. Secondary Service Reservoir
4. Valve Knob
5. Delivery Port
6. Brake Chamber
7. Exhaust Port

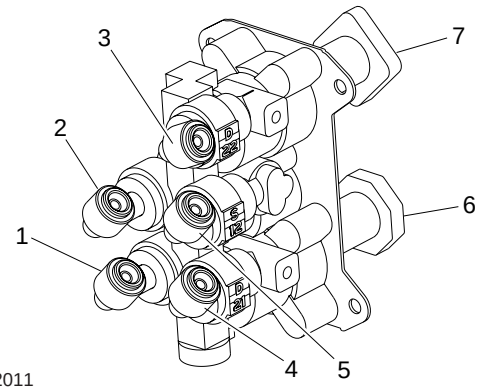
Fig. 1, Parking Brake Dash Valve (sectional view)

General Description

The dash-mounted MV-3 control module is a two-button, push-pull control valve housed in a single body, which includes a dual circuit supply valve and a check valve.

The valve body, plungers, and spools are made out of a nonmetallic, noncorrosive material. All air connections are at the back of the valve. See **Fig. 1**.

The MV-3 module has several functions: tractor protection; trailer service air control; system park; trailer park only; trailer charge with tractor spring brakes applied (tractor park only); and supply reservoir selection.

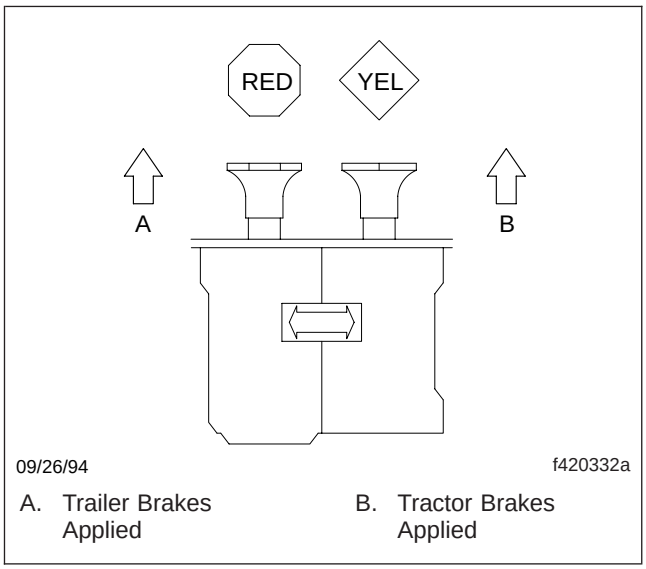


1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV-3 Parking Brake Valve

The MV-3 includes a spring-loaded, dual-circuit supply valve, which selects the primary air reservoir as the air source for both control valves, unless the pressure in the primary air reservoir falls below that of the secondary air reservoir. Then, the dual-circuit supply valve will shuttle and establish the secondary air reservoir as the air source.

The trailer air supply valve, actuated by the red knob and the yellow knob, delivers air to the trailer supply line. See **Fig. 2**. The parking brake valve, actuated by a yellow knob, controls the spring parking brakes on the tractor, and when exhausted, simultaneously causes the trailer supply valve to trip and exhaust, thus applying both the tractor and the trailer parking brakes as required by federal regulations. See **Fig. 2**. The trailer parking brakes may be independently released by pushing only the trailer air supply valve (red) knob in.



A. Trailer Brakes Applied
B. Tractor Brakes Applied

Fig. 2, Trailer and Tractor Delivery Air Discharged (control knobs out)

Principles of Operation

Initial Charge

With both the primary and the secondary systems completely discharged, both knobs are out. See **Fig. 2**. When system pressure reaches 65 psi (448 kPa), the red knob (trailer air supply) may be pushed in, and should stay in, charging the trailer system and releasing the trailer parking brakes. See **Fig. 3**. The yellow knob (parking brake) may now be pushed in, which will supply air to the tractor parking brakes, releasing them.

Normal Operation Position

When both knobs are pushed in, air is supplied to the trailer and the tractor parking brakes; all parking brakes are released. See **Fig. 4**. This is the normal operating mode.

General Information

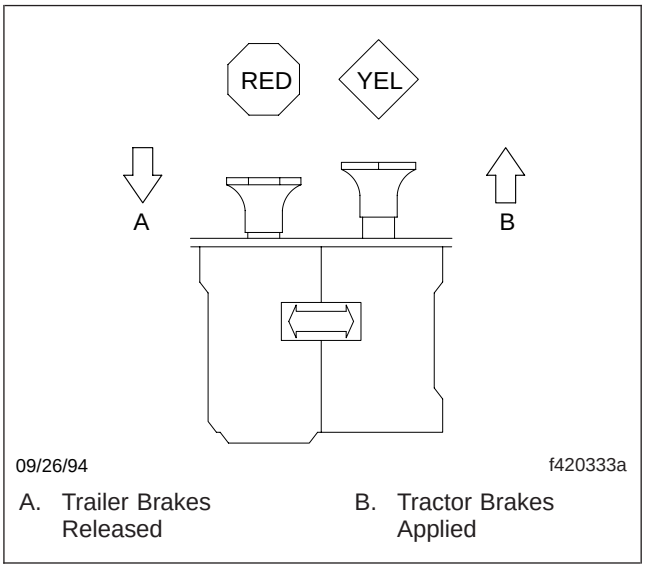


Fig. 3, Trailer Parking Brakes Released (red control knob pushed in)

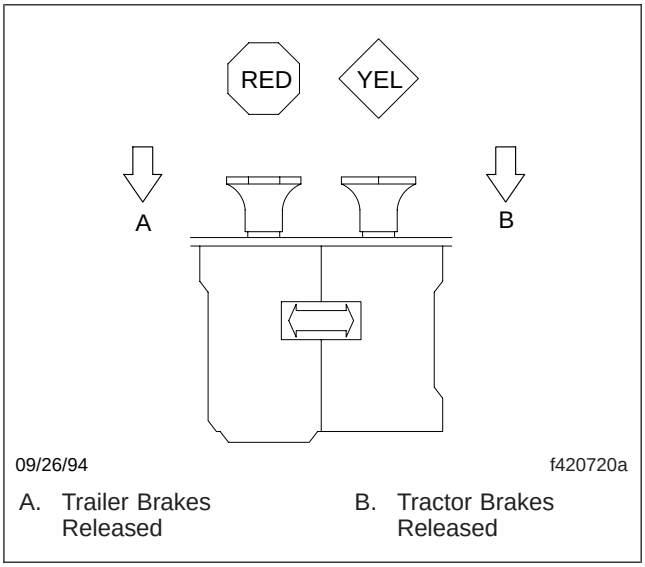


Fig. 4, Trailer and Tractor Brakes Released (both control knobs pushed in)

Actuation of Trailer Park or Emergency Brakes

To actuate the trailer parking brakes only, the red knob is pulled out, exhausting the trailer supply line. The trailer parking brakes are now applied, either by emergency air or parking brakes, depending on the type of trailer system. This mode would be used to uncouple from the trailer, and during bobtail operation. See **Fig. 5**.

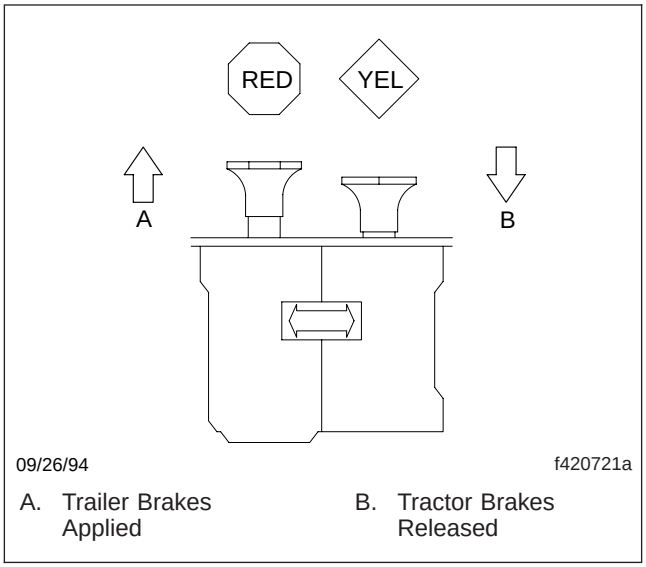


Fig. 5, Trailer Parking Brakes Applied (red control knob pulled out)

System Park

With both knobs pushed in, the parking brakes on both the tractor and the trailer may be actuated by pulling the yellow (parking brake) knob out. This exhausts the air from the tractor parking brakes and simultaneously causes the red (trailer air supply) knob to pop out, applying the trailer parking brakes (this complies with federal regulations that one control must apply all the parking brakes on the vehicle). See **Fig. 2**.

Trailer Charge

If both valves are out, parking the combination vehicle, and it is desired to recharge the trailer (leaving only the tractor parking brakes applied), the red knob may be pushed in, repressurizing the trailer supply line. This mode might also be used to park a combination vehicle with air-actuated emergency brakes on the trailer to provide demonstrated parking capability with the tractor spring brakes only. See **Fig. 3**.

Automatic Applications

If air pressure drops to 20 to 45 psi (138 to 310 kPa) in both the primary and the secondary systems, the

red knob (trailer air supply valve) will automatically pop out, applying the emergency or parking brakes on the trailer. If the red knob is held in manually and the pressure decreases to 25 to 35 psi (172 to 241 kPa), a tripper piston within the MV-3 valve will move upward, exhausting the trailer supply, and applying the trailer parking brakes. If air pressure drops in both the primary and the secondary systems, the yellow (parking brake) knob will pop out at about 20 to 40 psi (138 to 276 kPa), applying the tractor parking brakes.

A warning buzzer and light are activated when pressure in either the primary or the secondary system drops below 64 to 76 psi (441 to 524 kPa).

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

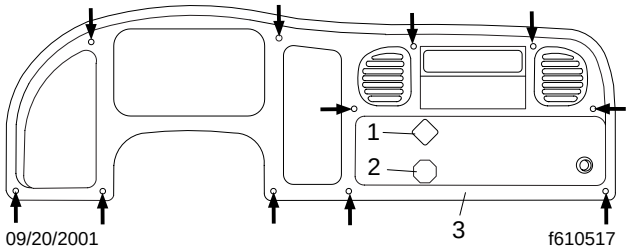
- Chock the tires and stop the engine before working under a vehicle. Keep hands away from brake chamber pushrods and slack adjusters; they may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

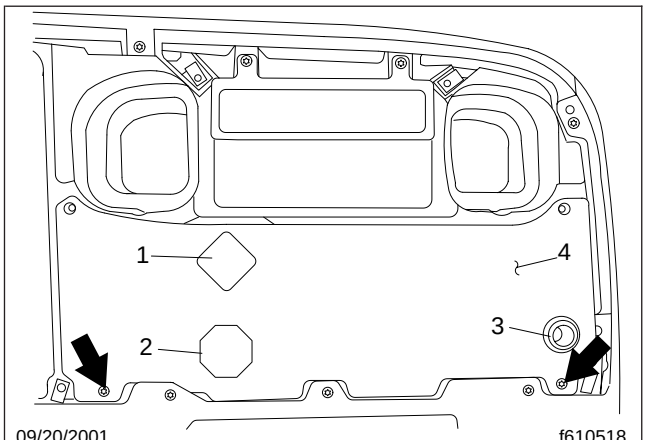
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system and disconnect the batteries.
3. Remove the 11 screws from the dash panel and remove the panel. See **Fig. 1**.



1. Tractor Brake Module Knob (yellow)
2. Trailer Brake Module Knob (red)
3. Dash Panel

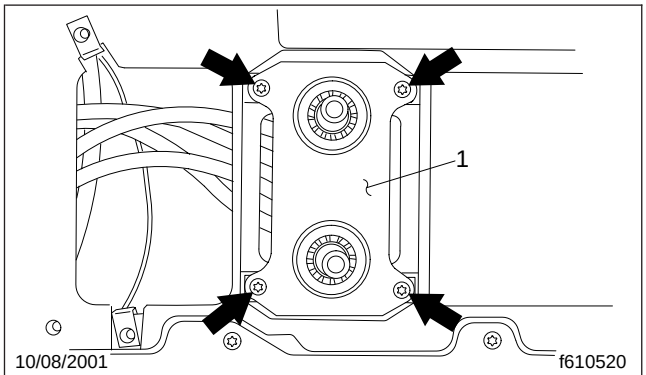
Fig. 1, Dash Panel Screws

4. Unscrew the red and yellow knobs from the stems of the spools on the MV–3 module by turning them in a counterclockwise direction. Mark the knobs in relation to the module for later reference.
5. Remove the interior panel. See **Fig. 2**.
   - 5.1 Remove the two remaining screws securing the panel to the dash.
   - 5.2 Remove the panel far enough to access the back of the cigarette lighter and mark and disconnect the two wires.
   - 5.3 Remove the panel.
6. Remove the four screws that attach the module to the mounting panel. See **Fig. 3**. Remove the module far enough to access the air line connections on the back.



1. Tractor Brake Module Knob (yellow)
2. Trailer Brake Module Knob (red)
3. Cigarette Lighter Receptacle
4. Interior Dash Panel

Fig. 2, Interior Dash Panel Screws



1. MV-3 Control Module

Fig. 3, Control Module Screws

7. Mark the air lines for later reference. Disconnect the lines from the module assembly and remove the module.

NOTE: The primary supply line is green. The exhaust line is yellow. The parking brake delivery line is black. The trailer charge delivery line is orange.

Installation

1. Position the module and connect the air lines to the applicable fittings.

Control Module Removal and Installation

2. Install the module and install the four mounting screws. See **Fig. 3**.
3. Install the interior panel.
   - 3.1 Position the interior panel and connect cigarette lighter to the power connections previous removed.
   - 3.2 Secure the panel using the Torx-head screws previously removed. See **Fig. 2**.
4. Attach the red and yellow knobs onto the threaded stems of the module spools, making sure they are correctly oriented as noted during removal.
5. Leak test the fittings following the instructions in **Subject 130**.
6. Install the dash panel and 12 screws. See **Fig. 1**.
7. Connect the batteries.
8. Remove the chocks from the tires.

Control Module Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Refer to **Fig. 1** for control module disassembly and assembly.

Disassembly

1. Remove the six screws from the cover plate, and carefully remove the cover plate from the valve.
2. Remove the cap and O-ring from the bore of the tripper valve. Remove the tripper piston, large spring, small spring, and check valve. These parts will all fall out of the cavity of the MV-3 by tilting the body forward. Remove the O-ring from its groove on the piston.
3. Remove the two main spools from the body of the MV-3 valve by grasping the stem and pulling firmly. Remove the spring from the bottom of each spool cavity.
4. Pull the guide cap and guide spool over the threaded end of one of the plungers. Remove the O-ring from the guide cap and the O-ring from the guide spool. Remove the other O-rings and the exhaust seal from the plunger.
5. Repeat the previous step on the remaining spool assembly.
6. Remove the retaining ring from the cavity of the MV-3 body that contains the dual circuit supply valve.
7. Using a pair of needlenose pliers, grasp the bar in the center of the cap and dual circuit supply valve and remove the dual circuit valve assembly. Remove the three O-rings from the valve or from the cavity of the body, if some have remained there. Other than the three external O-rings, don't disassemble the piston assembly further.

NOTE: If, during the removal of this assembly from the body, the cap dislodges from the rest of the valve, the remaining parts can be removed using bent wire. The spring, piston, and O-ring that are internal to the dual circuit valve assembly are nonserviceable.

Cleaning and Inspection

The nonmetallic components making up most of the parts of the MV-3 *should not be immersed in any solvent-type cleaner.* Old lubricant should be wiped out with a clean dry cloth.

If any visible damage to the body or the spools is found, replace the complete unit.

Assembly

Dual Circuit Supply Valve

1. Lubricate all O-rings, bores, and sliding surfaces with silicone lubricant Bendix 291126, Dow Corning 55-M, or equivalent.
2. Install O-rings onto the cap and dual circuit supply valve. Then install the assembly—small diameter first—into its cavity in the body.
3. Install the retaining ring making sure it is fully seated in its groove. See **Fig. 1**, Item 22.

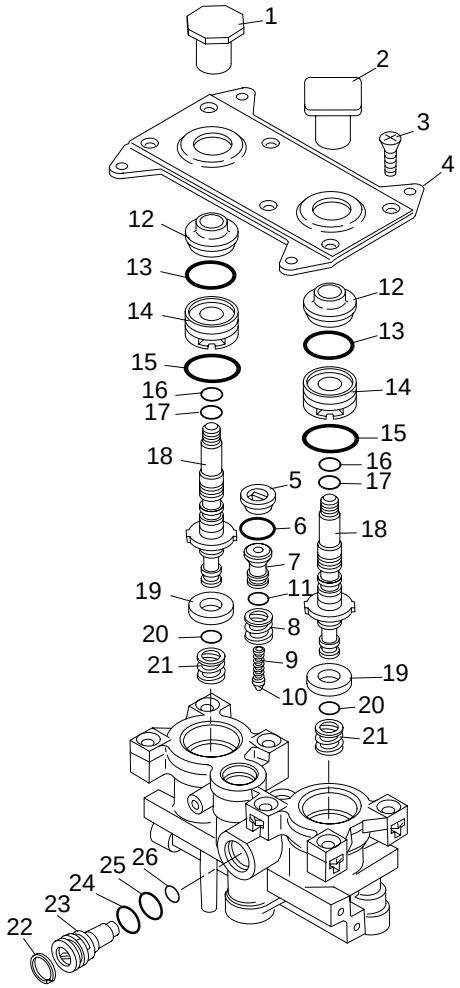
Spools

1. Install the O-rings and the exhaust seal onto the stem of the plunger.

IMPORTANT: The exhaust seal must be installed so that its beveled surface mates with the beveled surface of the plunger. See **Fig. 1**, Item 19.

2. Install the O-ring onto the guide spool and the O-ring onto the guide cap. See **Fig. 2**. Place the guide cap on top of the guide spool, and install the entire assembly over the threaded end of the plunger; press down firmly until it snaps into place.
3. Install the spring over the boss in the bottom of the spool cavity in the body of the MV-3 valve. Place the spool assembly into the body, keeping the spool square to the body. Press and turn the stem until the spool is fully seated in its cavity. The assembly is keyed and can be installed one way only.
4. Repeat the previous steps for the opposite spool.

Control Module Disassembly, Cleaning and Inspection, and Assembly



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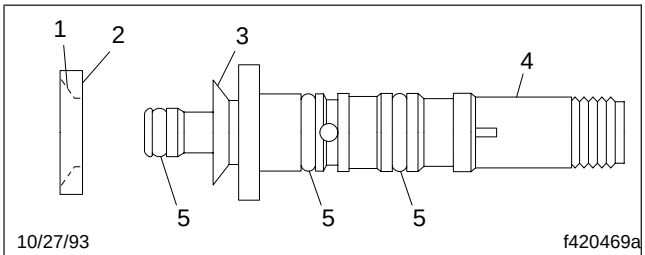
1. Red Knob
2. Yellow Knob
3. Screw
4. Cover Plate
5. Cap
6. O-Ring
7. Tripper Piston
8. Spring, Large Diameter
9. Spring, Small Diameter
10. Check Valve
11. O-Ring
12. Guide Cap
13. O-Ring
14. Guide Spool
15. O-Ring
16. O-Ring
17. O-Ring
18. Plunger
19. Exhaust Seal, Beveled
20. O-Ring
21. Spring
22. Retaining Ring
23. Cap and Dual Circuit Valve Assembly
24. O-Ring
25. O-Ring
26. O-Ring

Fig. 1, MV-3 Valve, Exploded View

Shuttle and Check Valve

1. Install the O-ring into its groove on the tripper piston; then install the O-ring onto the cap.
2. Install the large spring on the piston and the small spring on the boss of the check valve.
3. Install the spring and check valve into their cavity in the body of the MV-3 valve (tapered end of the valve to enter the cavity first). Make sure the spring is centered in the bore.



1. Inside Bevel
2. Exhaust Seal
3. Mating Exhaust Seal Bevel
4. Plunger
5. O-Rings

Fig. 2, Plunger Assembly

4. Install the piston assembly into the cavity, making sure the spring mates with the bore of the piston.
5. Install the cap with O-ring.
6. Attach the cover plate to the valve body using the six screws. Tighten them 25 lbf·in (282 N·cm).
7. Check the operation of the valve as instructed in **Subject 130**.

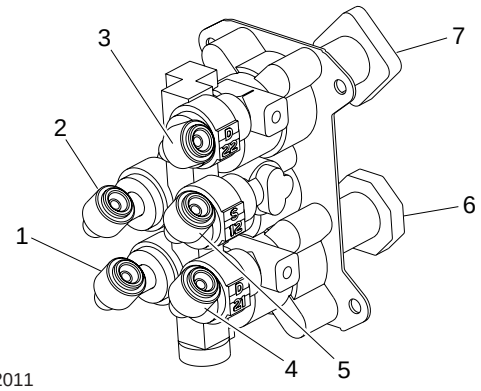
⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Tests

With the air brake system charged to 120 psi (827 kPa), check for leaks, using the following instructions. Repair or replace components as needed.

1. Apply a soap solution and check for leakage between the body and cover plate. Leakage at the exhaust port should produce less than a 1-inch (25-mm) bubble in five seconds.
2. With the trailer supply line sealed, push in the red knob. The knob must stay in. Leakage at the exhaust port must not exceed a 1-inch (25-mm) bubble in 5 seconds. See **Fig. 1**.



1. Exhaust
2. Primary Reservoir Supply
3. Delivery–Tractor Spring Brakes
4. Delivery–Trailer Supply
5. Secondary Reservoir Supply
6. Trailer Air Supply Knob
7. Parking Brake Control Valve Knob

Fig. 1, MV–3 Parking Brake Valve

3. Slowly reduce pressure in both service reservoirs. The red knob must pop out at 20 to 35 psi (138 to 310 kPa).

NOTE: Trip-on pressure is the pressure at which the valve automatically changes position or "pops out." It is advised to use an accurate pressure gauge other than those in the truck when performing tests.

4. Hold the red knob in and continue to reduce pressure in all service reservoirs. Air must start to escape from the exhaust port when the trailer line pressure reaches 20 to 35 psi (138 to 241 kPa).
5. Release the red knob and rebuild the supply pressure to 120 psi (827 kPa). Push in the yellow knob; the yellow knob must remain in. Leakage at the exhaust port should not exceed a 1-inch (25-mm) bubble in 5 seconds.
6. Pull the red knob out. Slowly reduce pressure in all service reservoirs. There is not a federal trip pressure requirement for the yellow knob, but it will pop out at 20 to 30 psi (138 to 207 kPa).
7. Charge the system to 120 psi (827 kPa), and push both knobs in. Pull the red knob out. The yellow knob must remain in. Push the red knob in and pull the yellow knob out. The red knob must pop out at once.
8. Install a gauge to monitor tractor spring brake delivery pressure. Build 120 psi (827 kPa) pressure in the primary and secondary air reservoirs. Push in the yellow knob. Delivery pressure should equal the pressure in the primary air reservoir. Reduce the pressure in the primary air reservoir. The dual-circuit supply valve shuttle should switch to the secondary air reservoir. After the primary air reservoir pressure is reduced to zero, there should not be audible leakage at the primary air reservoir opening. Stop the leak that was created in the primary air reservoir.
9. Leaving the yellow knob in, recharge the secondary air reservoir to 120 psi (827 kPa). The delivery pressure should also read 120 psi (827 kPa). Recharge the primary air reservoir to 100 psi (690 kPa). Slowly vent the secondary air reservoir. As the secondary air reservoir pressure and the delivery line pressure descend, pressure should stabilize at about 100 psi (690 kPa).
10. Close all leakage points and charge both reservoirs to 120 psi (827 kPa). Position the red knob out and the yellow knob in. Develop a leak in the spring brake delivery line and hold the yellow knob in. See **Fig. 1**. The air reservoir pressures will go to zero. The dual-circuit supply valve shuttle should cycle during the leak-down period.

Control Module Operating Tests

11. If the MV-3 fails to operate as described, or leakage exceeds the limits stated, replace or repair it using genuine Bendix parts.

General Information

The function of the Integrated Solution Air Dryer (AD-IS®) and reservoir system is to provide vehicles with an air dryer, purge reservoir, governor, and a number of the charging valve components in one system. See **Fig. 1**.

The AD-IS® air dryer and reservoir system collects and removes air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system.

Charge Cycle

Figure 2 shows the charge cycle.

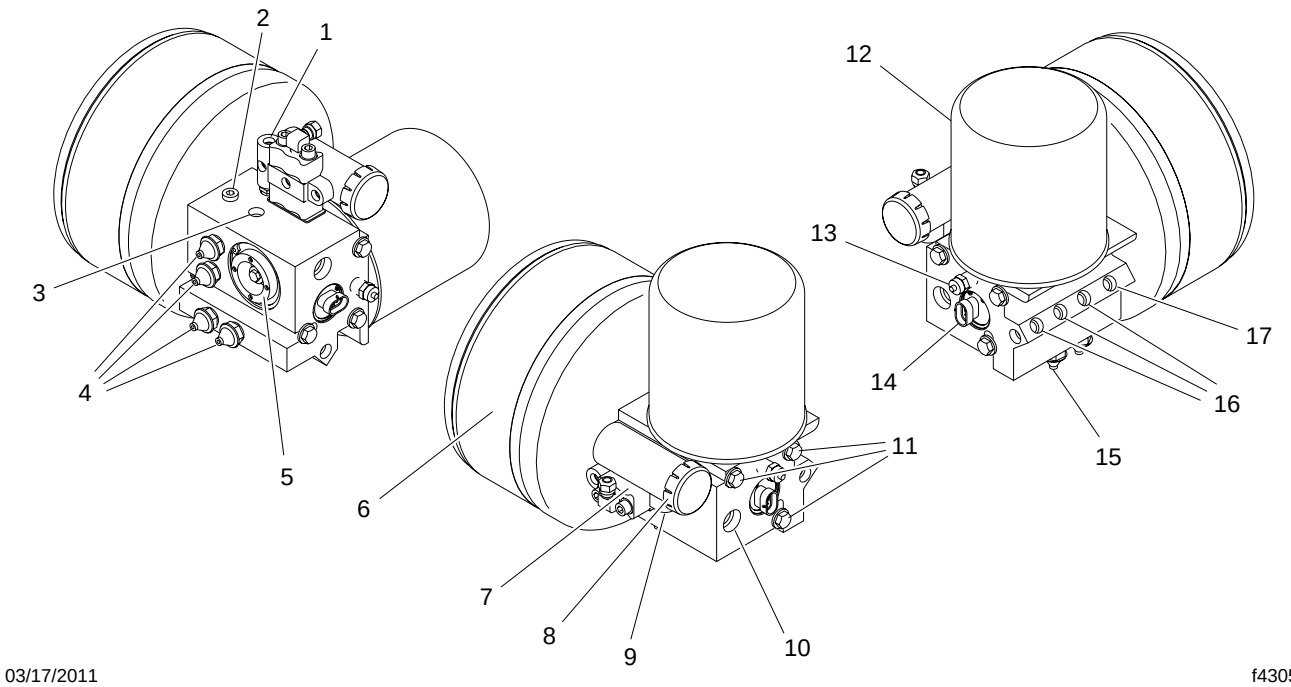
When the compressor is loaded, compressed air, oil, oil vapor, water, and water vapor flow through the compressor discharge line to the inlet port of the air dryer body.

As air travels through the air dryer assembly, its temperature falls, causing some of the contaminants to condense and drop to the bottom of the air dryer assembly, ready to be expelled at the next purge cycle.

The air then flows into the desiccant cartridge. Once in the desiccant cartridge, air flows through an oil separator which removes oil and solid contaminants.

Air then flows into the desiccant drying bed. Air flowing through the desiccant becomes progressively dryer as water vapor adheres to the desiccant material.

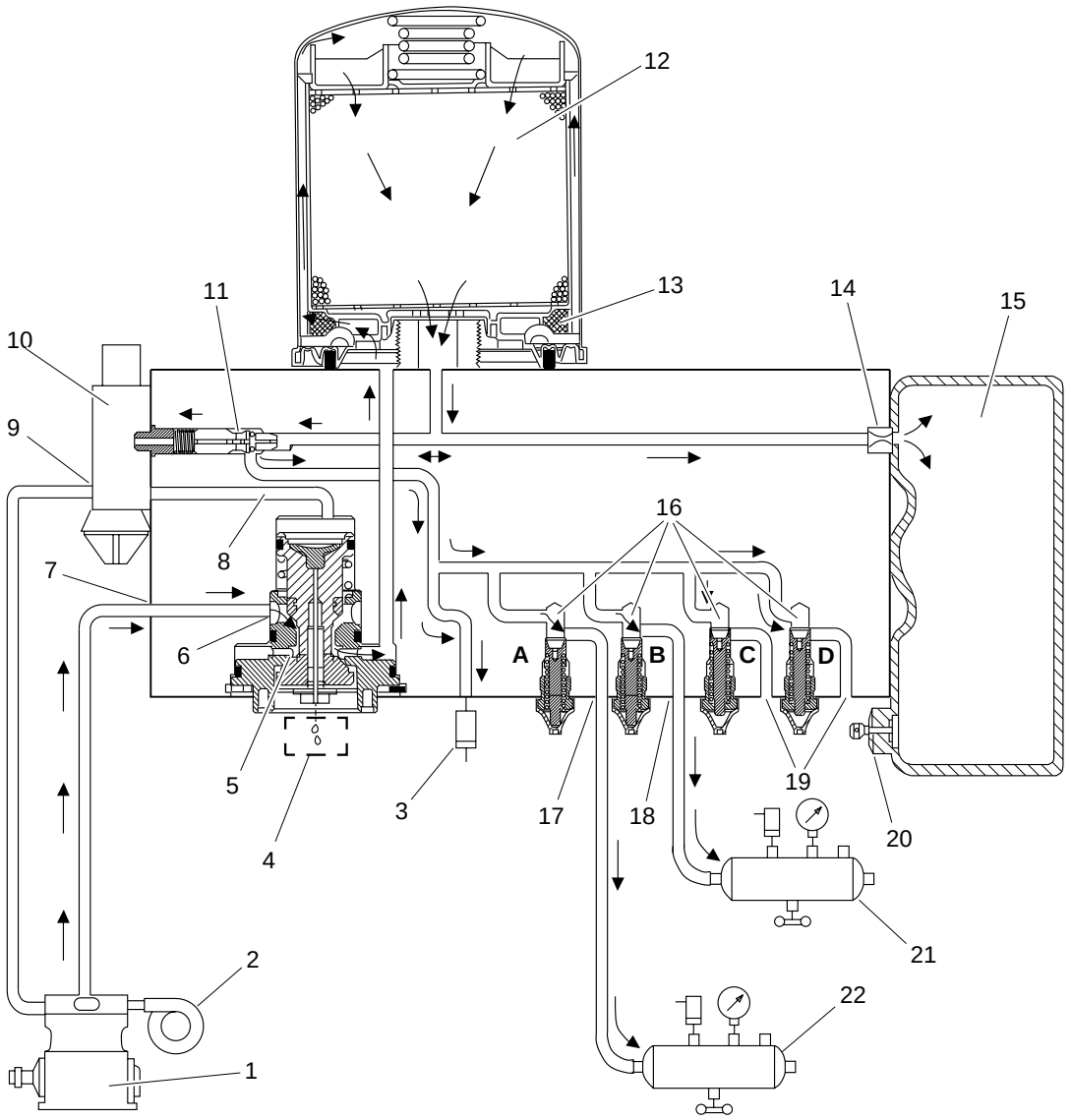
Dry air exits the bottom of the desiccant cartridge and flows through the center of the base assembly.



1. Governor Reservoir
2. Delivery to Secondary Reservoir
3. Delivery to Primary Reservoir
4. Pressure Protection Valves
5. Purge Valve
6. Purge Reservoir
7. Governor Unloader
8. Governor
9. Governor Exhaust
10. Supply from Compressor
11. Mounting Bolts (3)
12. Desiccant Cartridge
13. Safety Valve
14. Heater/Thermostat
15. Pressure Protection Valves (4)
16. Auxiliary Delivery Ports (4)
17. Auxiliary Delivery Ports (2)

Fig. 1, AD-IS Air Dryer

General Information



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1. Compressor
2. Engine Turbo
3. Safety Valve
4. Purge Control Channel Drain
5. Purge Valve (closed)
6. Turbo Cutoff Valve (open)
7. Inlet Port
8. Purge Control Channel
9. Unloader Port
10. Governor
11. Delivery Check Valve (open)
12. Desiccant Bed
13. Oil Separator
14. Purge Orifice
15. Purge Reservoir
16. Pressure Protection Valves
17. Primary Port
18. Secondary Port
19. Auxiliary Ports
20. Purge Reservoir Drain Valve
21. Secondary Reservoir
22. Primary Reservoir

Fig. 2, Air Dryer Charge Cycle

The air then flows to the delivery check valve, to the safety valve and also through an orifice plug into the purge reservoir. Air traveling through the delivery

check valve flows to the governor and the four pressure protection valves.

As pressure builds during the initial charge, the purge reservoir fills. When the air pressure reaches 106 psi (731 kPa), the four pressure protection valves open and air is supplied to the primary reservoir, secondary reservoir, and accessories. If the pressure protection valves are preset to different values, the valves open in order of the lowest to the highest setting when charging a flat system.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting of approximately 130 psi (896 kPa).

Purge Cycle

Figure 3 shows the purge cycle.

When air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor and the purge cycle begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the dryer control port. The purge piston moves in response to air pressure, causing the purge valve to open and the turbo cutoff valve to close. When the purge valve opens, water and contaminants are expelled. Air flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected in the oil separator are removed by air flowing from the purge reservoir, through the desiccant drying bed, and out through the open purge valve.

The purge cycle lasts only a few seconds and is detected by an audible burst of air at the air dryer exhaust.

The reactivation of the desiccant drying bed begins as dry air flows from the purge reservoir, through the purge orifice, and into the desiccant bed. Pressurized air from the purge reservoir expands after passing through the purge orifice; its pressure is lowered and its volume is increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Approximately 30 seconds is required for the entire purge reservoir of a standard air dryer to flow through the desiccant dryer bed.

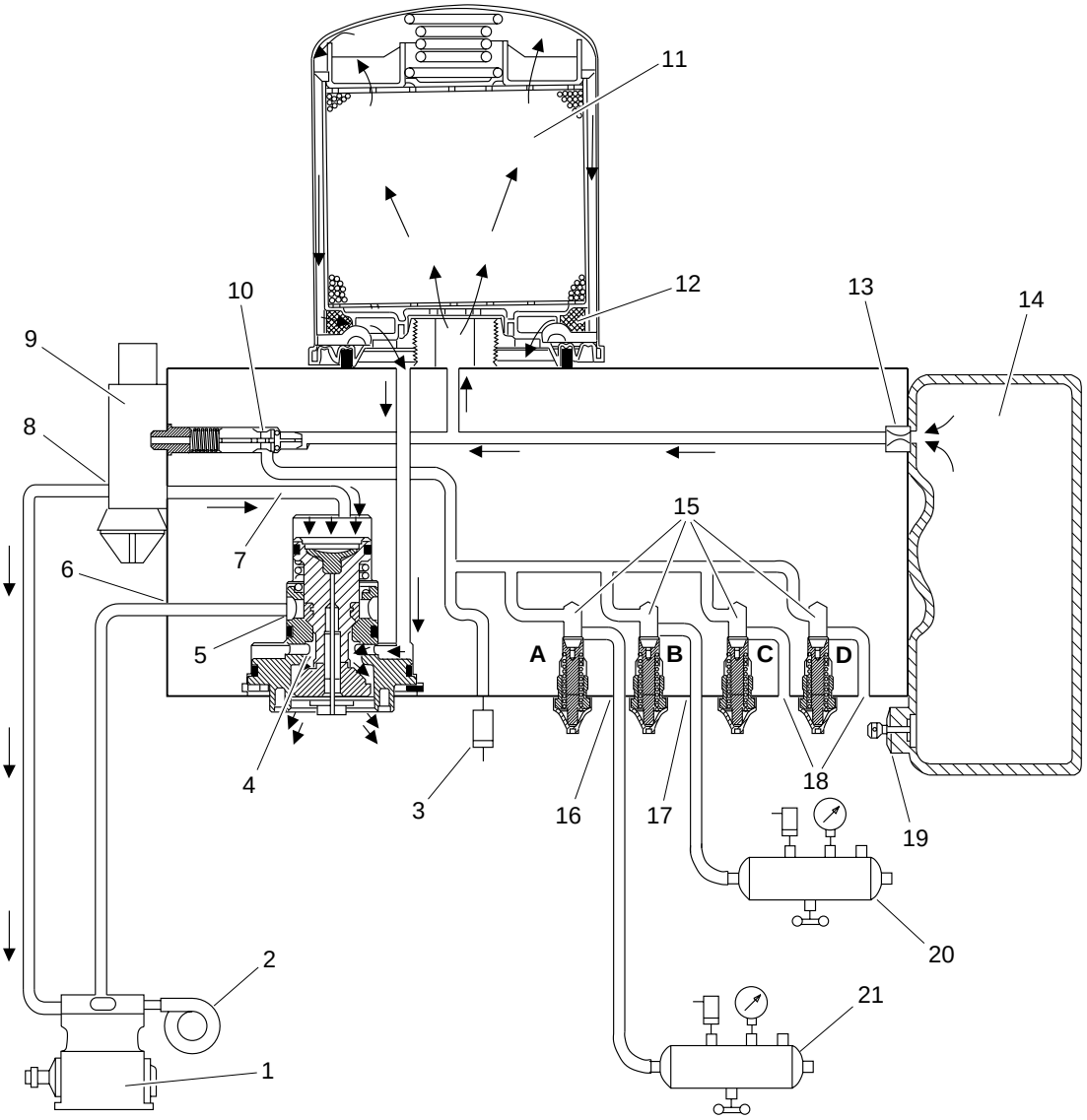
The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

Turbo Cutoff Feature

The primary function of the turbo cutoff valve is to prevent loss of turbocharger air pressure through the air dryer when the dryer is in the unloaded mode.

During the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and air dryer inlet port cannot enter the air dryer. This maintains turbocharger boost pressure to the engine.

General Information



NOTE: All pressure protection valves are shown open.

1. Compressor
2. Engine Turbo
3. Safety Valve
4. Purge Valve (open)
5. Turbo Cutoff Valve (closed)
6. Inlet Port
7. Purge Control Channel
8. Unloader Port
9. Governor
10. Delivery Check Valve (closed)
11. Desiccant Bed
12. Oil Separator
13. Purge Orifice
14. Purge Reservoir
15. Pressure Protection Valves
16. Primary Port
17. Secondary Port
18. Auxiliary Ports
19. Purge Reservoir Drain Valve
20. Secondary Reservoir
21. Primary Reservoir

Fig. 3, Air Dryer Purge Cycle

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Don't disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

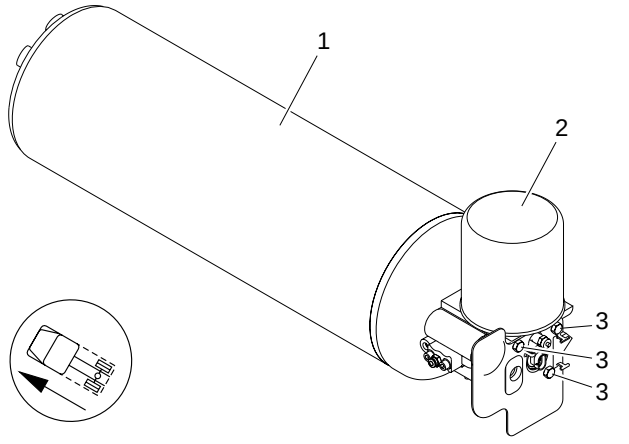
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Mark and remove the air lines from the air reservoir.
4. Unplug the wiring harness from the heater/thermostat assembly.
5. Remove the three capscrews that fasten the air dryer to the air reservoir. See **Fig. 1**. Remove the air dryer.



1. Air Reservoir
2. Air Dryer
3. Capscrews

Fig. 1, AD-IS Air Dryer

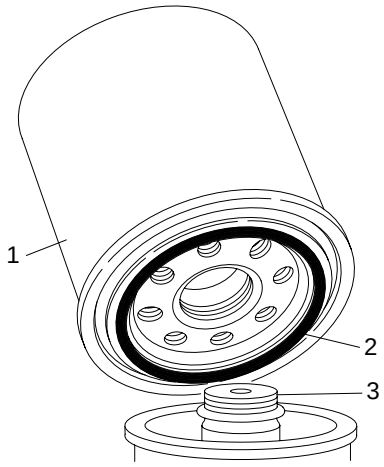
6. Remove the governor and delivery check valve from the air dryer. For instructions, see **Subject 130**.
7. Remove the desiccant cartridge. For instructions, see **Subject 120**.
8. Install the delivery check valve and governor onto the new air dryer. For instructions, see **Subject 130**.
9. If removed, install the desiccant cartridge. For instructions, see **Subject 120**.
10. Install the air dryer, making sure the two O-rings are installed between the air dryer and air reservoir. Use the three capscrews to fasten the air dryer to the reservoir. Tighten the capscrews 30 to 35 lbf·ft (41 to 47 N·m). See **Fig. 1**.
11. Connect the air lines and plug the wiring harness into the heater/thermostat assembly.
12. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for desiccant cartridge replacement.



1. Desiccant Cartridge
2. Cartridge Sealing Ring
3. Threaded Base Post

Fig. 1, Desiccant Cartridge Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Using a strap wrench or equivalent, loosen the desiccant cartridge. Spin the cartridge off by hand and discard it.
4. On the new desiccant cartridge, lubricate the sealing rings with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

5. Screw the desiccant cartridge onto the body, by hand, until the seal makes contact with the body. Rotate the cartridge clockwise about one full turn. If necessary, use a strap wrench to tighten the cartridge.

Delivery Check Valve and Governor Replacement

⚠ WARNING

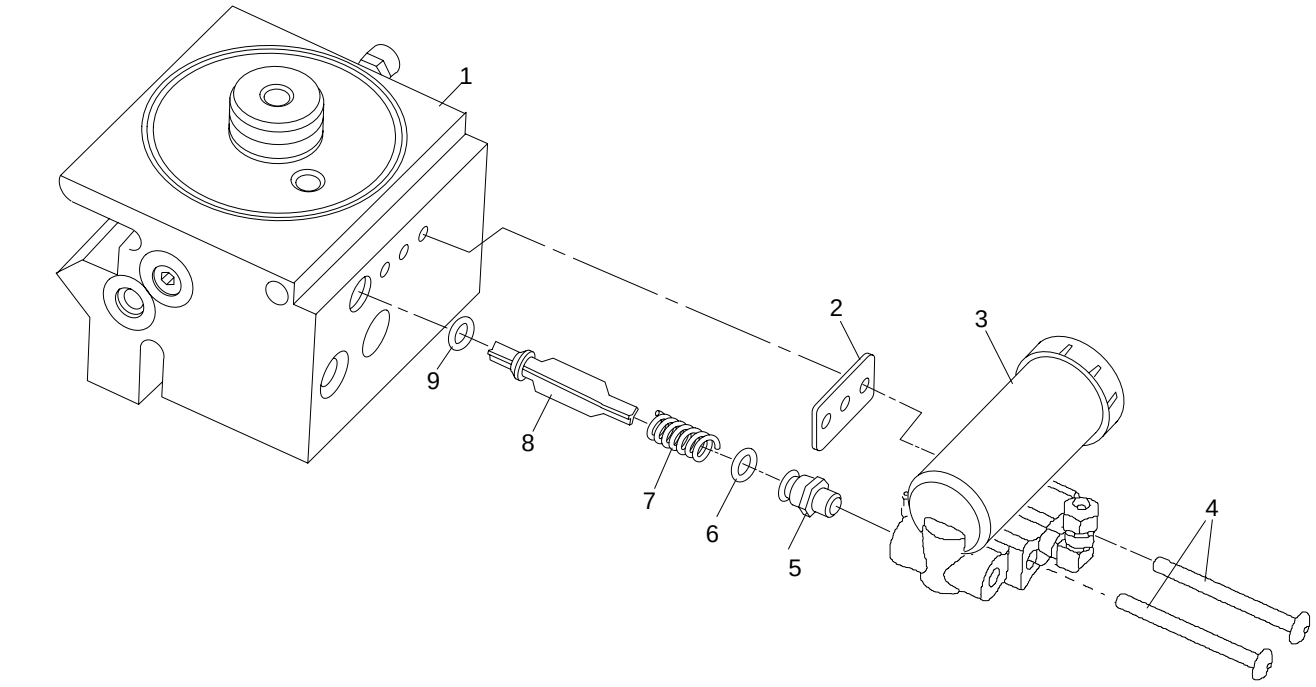
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air reservoirs.
3. Disconnect the air line from the governor and mark it for later reference. See **Fig. 1**. Remove the capscrews that attach the governor to the air dryer.
4. Remove the governor, adaptor fitting, and the adaptor O-ring. Remove the governor gasket and discard it.
5. Remove the spring and check valve.
6. Lubricate the new smaller O-ring and check valve body with silicone grease.

IMPORTANT: Only use the silicone grease supplied with AlliedSignal replacement kits.

7. Install the O-ring on the check valve body and push the O-ring down, over the longer set of three guide lands, until it is in the O-ring groove of the check valve body.
8. Install one end of the check valve spring over the check valve's shorter set of three guide lands. Turn the valve about 1/4 turn while holding the spring, if necessary, to secure the valve in place. Install the assembled check valve body, O-ring, and spring in the delivery port, so the O-ring rests on its seat and the free end of the spring is visible.



1. Air Dryer Base
2. Gasket
3. Governor
4. Capscrews
5. Adaptor
6. O-Ring
7. Spring
8. Check Valve Body
9. O-Ring

Fig. 1, Delivery Check Valve Replacement

Delivery Check Valve and Governor Replacement

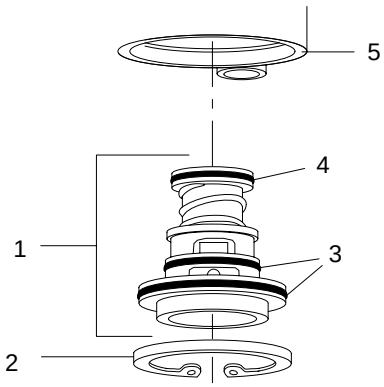
9. Install the adaptor fitting into the governor. Using the silicone grease, lubricate the remaining larger O-ring, and install it into the groove of the adaptor. Install the gasket supplied in the kit. Install the governor, and torque the capscrews 10 lbf·ft (14 N·m).
10. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

Refer to **Fig. 1** for purge valve replacement.



1. Purge Valve Assembly
2. Retaining Ring
3. O-Rings
4. Quad-Ring
5. Air Dryer

Fig. 1, Purge Valve Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the vehicle air reservoirs.
3. Remove and discard the snap ring that secures the purge valve assembly in the end cover.
4. Remove the purge valve assembly from the air dryer end cover.
5. Lubricate the new O-rings, and O-ring grooves of the new purge valve assembly.
6. Lubricate the end cover bore of the new purge valve assembly.

IMPORTANT: Use only the silicone grease supplied with the AlliedSignal replacement kit.

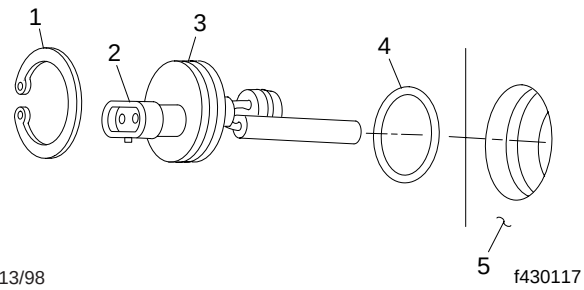
7. Install the two new O-rings on the purge valve housing cover, and the new quad-ring on the purge piston.
8. Install the new purge valve assembly in the end cover while making sure the purge valve housing is fully seated against the end cover.
9. Install the new retaining ring in its groove in the end cover.
10. Perform the operational tests in **Subject 170**.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Lift the lock tab on the vehicle wiring harness connector and disconnect it from the air dryer base. See **Fig. 1**.



1. Retaining Ring
2. Heater/Thermostat Connector Plug
3. Heater/Thermostat Assembly
4. O-Ring
5. Air Dryer Body

Fig. 1, Heater and Thermostat Assembly

3. Remove and discard the retaining ring that secures the heater and thermostat assembly in the air dryer body.
4. Carefully pull the heater and thermostat assembly straight out of the air dryer body and discard it.
5. Using the silicone grease provided with the AlliedSignal replacement kit, lubricate the O-ring groove and O-ring of the new assembly.

IMPORTANT: Do not lubricate the heater stick or thermostat.

6. Install the O-ring on the heater/thermostat assembly. Then, slide the assembly into the air dryer body, making sure not to scrape insulation from the wires.
7. Install the retaining ring in the groove of the air dryer body, making certain that it is fully seated in the groove.
8. Remove the protective cover from the assembly.
9. Turn the ignition on without starting the engine. Make sure vehicle power is present at the contacts of the vehicle wire harness.

WARNING

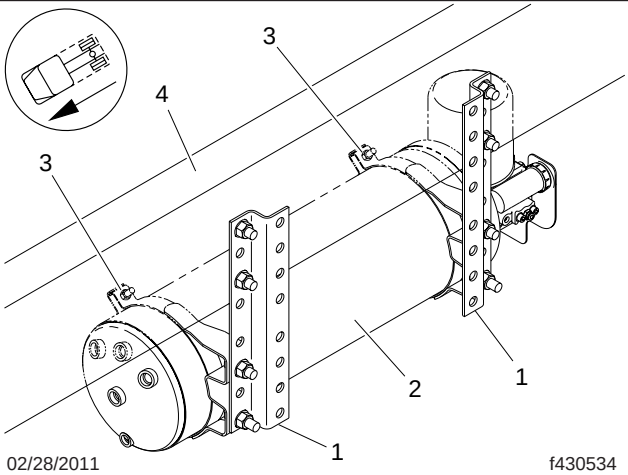
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the air system.
3. Mark and disconnect all reservoir air lines and couplers for later assembly. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the air dryer. For instructions, see **Subject 110**.

NOTE: Loosen the bottom strap fastener first. See **Fig. 1**.

5. Remove the reservoir strap fasteners. Remove the reservoir.



1. Mounting Bracket
2. Air Reservoir
3. Strap Fastener
4. Frame Rail

Fig. 1, Air Reservoir, Frame Rail Mounting

6. If access is limited, do the next step first. If not, place a new reservoir in the mount, and install the strap fasteners. Tighten the fasteners 35 lbf·ft (47 N·m). Tighten the bottom strap fastener 136 lbf·ft (184 N·m).
7. As marked earlier, connect all air lines and couplers to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.

   Install the air dryer. For instructions, see **Subject 110**.
8. Perform the operational test in **Subject 170**.

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Operational Tests

1. Shut down the engine, and chock the tires.
2. Install a pressure gauge in one of the spare governor ports labeled "RES."
3. Close all drain cocks and start the engine. Build the air system to governor cutout, then shut down the engine.
4. Check all air lines and fittings leading to and from the air dryer for leakage. Note the pressure on the air gauge after the governor cutout pressure is reached, a rapid loss of pressure could indicate a leaking delivery port check valve or turbo cut-off valve.
5. To check for delivery check valve leakage, allow the system air pressure to charge and listen for the air dryer to purge. The purge should last about 30 seconds.
6. Gradually open the drain cock on the purge tank and exhaust any residual pressure.
7. Coat the drain cock with a soap solution. If leakage does not exceed a 1-inch (25-mm) bubble in 1 second, go to step 9.

   If leakage does exceed a 1-inch (25-mm) bubble in one second, proceed with the following step.
8. Apply the brakes a few times, bring the air pressure to a point below governor cut-in (about 95 psi [655 kPa]). The governor will then signal the end of the purge cycle, closing the turbo cut-off valve. Allow any delivery line air pressure to drain, then check again for leakage at the purge tank drain cock. If excessive leakage has stopped, the turbo cut-off valve should be checked.

NOTE: If after replacing the delivery check valve, rapid loss of system air pressure continues, the delivery check valve and turbo cut-off valve are still leaking. Check the valves.

9. Check the operation of the end cover heater and thermostat assembly during cold-weather operation as follows:

   9.1 Check the electric power to the air dryer. With the ignition or engine kill switch in the ON position, check for voltage to the heater and thermostat assembly using a voltmeter or test-light. Unplug the electrical connector at the air dryer and place the test leads on each of the connections of the female connector on the vehicle power lead. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check to see if a good ground path exists.

   9.2 Test the thermostat and heater operation. Turn off the ignition switch and cool the thermostat and heater assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the air dryer connector half. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly and 6 to 9 ohms for the 24-volt heater assembly.

   Warm the thermostat and heater assembly to about 90°F (32°C) and check the resistance again. The resistance should exceed 1000 ohms. If the resistance values obtained are within the stated limits, the thermostat and heater assembly is operating properly. If the resistance values obtained are outside the stated limits, replace the heater and thermostat assembly. For instructions, see **Subject 150**.
10. Check the pressure protection valves. Observe the pressure gauges of the vehicle as system pressure builds from zero. The primary gauge should rise until it reaches approximately 109 psi (752 kPa), then level off as the second pressure protection valve opens and allows the secondary volume to build. When the secondary pressure gauge passes through approximately 55 and 85 psi (379 and 586 kPa) there should be an associated leveling off of pressure as the third and fourth pressure protection valves open. Then, both the primary and secondary gauges should reach their full pressure of about 130 psi (896 kPa).

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
The check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at the opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
The air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Troubleshooting

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
The check valve is defective.	Test to determine if air is passing through the check valve. Repair or replace as needed.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.
System pressure is too high.	Using an accurate gauge, test the system. Replace the governor if needed.
There are excessive pressure pulsations from the compressor.	Increase the volume in the discharge line. This can be done by adding a 90 in_3 (1475 $cm_{3)}$ [or larger] reservoir between the compressor and the air dryer and reservoir system.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
The check valve is inoperative.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
The turbo cut-off valve is leaking.	Repair or replace the purge valve assembly.
The purge valve control piston quad-ring is leaking.	Repair or replace the purge valve assembly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
Pressure protection valves in the air dryer will not open.	Replace the air dryer; pressure protection valves are not serviceable.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The air dryer purge valve is not working.	Make certain that air reaches the purge valve control port by installing a T-fitting with a pressure gauge into the governor unloader port. Repair the purge valve if needed.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat. Refer to **Subject 170** for instructions.

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
The purge valve control piston quad-ring is leaking.	Repair or replace the purge valve assembly.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
The air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat. Refer to **Subject 170** for instructions.
Desiccant cartridge is not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

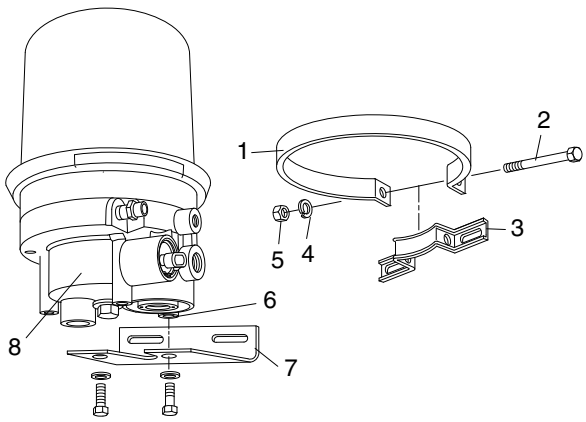
Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the air hose from the governor to the compressor for a missing, kinked, or restricted line. Repair or replace the air hose as needed. Repair or replace the compressor unloader.

General Information

The function of the AD-IP Integral Purge Air Dryer, shown in **Fig. 1**, is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. It provides clean, dry air to the components of the brake system, which increases the life of the system and reduces maintenance costs.



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1. Mounting Strap
2. 5/16-Inch Bolt
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

The AD-IP air dryer consists of a desiccant cartridge secured to a die-cast aluminum end cover with a single, central bolt. The end cover contains a check valve assembly, safety valve, heater and thermostat assembly, three pipe thread air connections, and the purge valve assembly. The removable purge valve assembly incorporates the purge valve mechanism and a turbocharger cutoff feature that is designed to prevent loss of engine turbocharger boost pressure during the purge cycle of the AD-IP air dryer. For ease of serviceability, all replaceable assemblies can be replaced without removal of the air dryer from its mounting on the vehicle.

To ease servicing, the desiccant cartridge and discharge check valve assembly are screw-in types.

The purge valve housing assembly, which includes the heater and thermostat assembly, and the discharge check valve assembly, can be serviced **without** removing the air dryer from the vehicle. The screw-in desiccant cartridge requires removal of the air dryer assembly from the vehicle.

The AD-IP has three female pipe thread air connections identified in **Table 1**.

Air Dryer Port Identification	
Port I.D.	**Function/Connection**
CON 4	Control Port (purge valve control and turbo cutoff)
SUP 11	Supply Port (air in)
DEL 2	Delivery Port (air out)

Table 1, Air Dryer Port Identification

Principles of Operation

The AD-IP air dryer alternates between two operational modes or cycles during operation: the charge cycle, shown in **Fig. 2**, and the purge cycle, shown in **Fig. 3**.

Charge Cycle

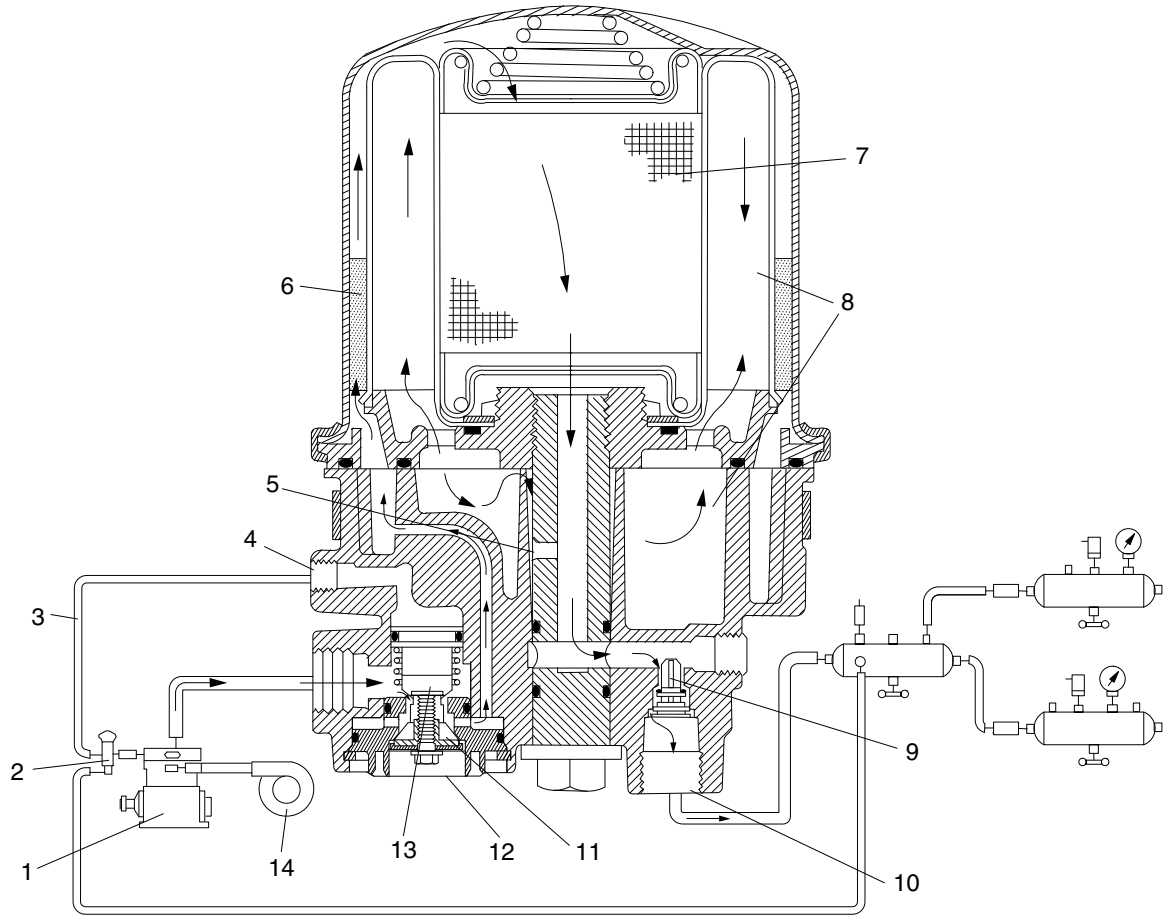
When the compressor is loaded (compressing air), compressed air, along with oil, oil vapor, water, and water vapor flows through the compressor discharge line to the supply port of the air dryer body.

As air travels through the end cover assembly, its direction of flow changes several times, reducing the temperature, causing contaminants to condense, and to drop to the bottom or sump of the air dryer end cover.

After exiting the end cover, the air flows into the desiccant cartridge. Once in the desiccant cartridge, air first flows through an oil separator located between the outer and inner shells of the cartridge. The separator removes water in liquid form as well as oil and solid contaminants.

Air, along with the remaining water vapor, is further cooled as it exits the oil separator and continues to flow upward between the outer and inner shells. Upon reaching the top of the cartridge the air reverses its direction of flow and enters the desiccant drying bed. Air flowing down through the column of desiccant becomes progressively dryer as water

General Information



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbocharger

Fig. 2, AD-IP Charge Cycle

vapor adheres to the desiccant material in a process known as adsorption. The desiccant cartridge, using the adsorption process, typically removes most of the water vapor from the pressurized air.

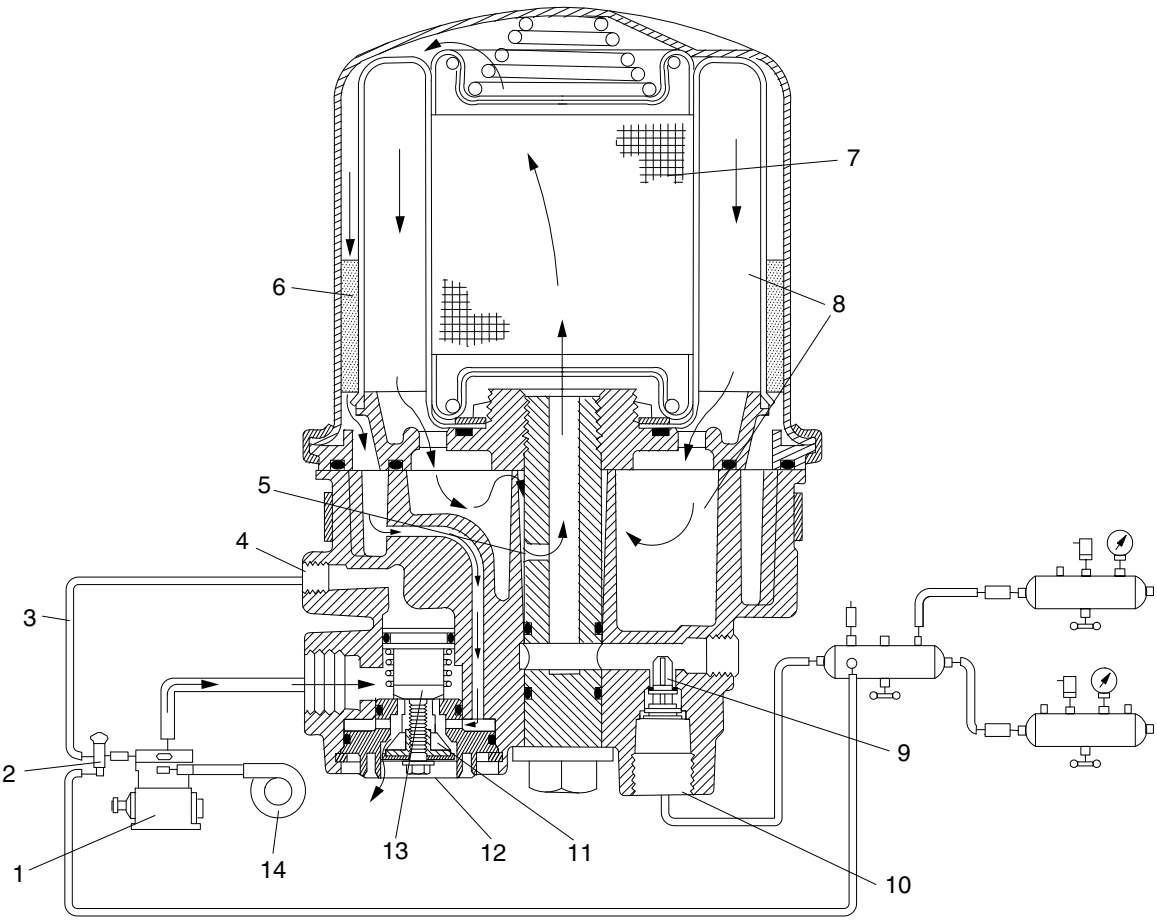
Dry air exits the bottom of the desiccant cartridge and flows through the center of the bolt used to secure the cartridge to the end cover. Air flows down the center of the desiccant cartridge bolt, through a cross-drilled passage and exits the air dryer delivery port through the delivery check valve.

Dry air flowing through the center of the desiccant cartridge bolt also flows out the cross-drilled purge orifice and into the purge volume.

The air dryer will remain in the charge cycle until the air brake system pressure builds to the governor cutout setting.

Purge Cycle

As air brake system pressure reaches the cutout setting of the governor, the governor unloads the compressor (air compressor stops compressing air) and



1. Compressor
2. Governor
3. Purge Control Line
4. Control Port
5. Purge Orifice
6. Oil Separator
7. Desiccant Bed
8. Purge Volume
9. Delivery Check Valve
10. Discharge Port
11. Purge Valve
12. Exhaust
13. Turbo Cutoff Valve
14. Engine Turbo

Fig. 3, AD-IP Purge Cycle

the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the compressor unloader mechanism and the line connecting the governor unloader port to the AD-IP end cover control port. The purge piston moves in response to air pressure, causing the purge valve to open to the atmosphere and the turbo cutoff valve to close off the supply of air from the compressor (this will be further discussed under the *Turbocharger Cutoff Feature* heading). Water and contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air which was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the purge volume through the desiccant drying bed to the open purge valve.

The initial purge and desiccant cartridge decompression lasts only a few seconds and is evidenced by an audible burst of air at the AD-IP exhaust.

The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume

General Information

through the purge orifice in the desiccant cartridge bolt, then through the center of the bolt and into the desiccant bed. Pressurized air from the purge volume expands after passing through the purge orifice; its pressure is lowered and its volume increased. The flow of dry air through the drying bed reactivates the desiccant material by removing the water vapor adhering to it. Generally 30 seconds are required for the entire purge volume of a standard AD-IP to flow through the desiccant drying bed.

The delivery check valve assembly prevents air pressure in the brake system from returning to the air dryer during the purge cycle. After the 30-second purge cycle is complete, the desiccant has been reactivated or dried. The air dryer is ready for the next charge cycle to begin. However, the purge valve will remain open and will not close until air brake system pressure is reduced and the governor signals the compressor to charge the system.

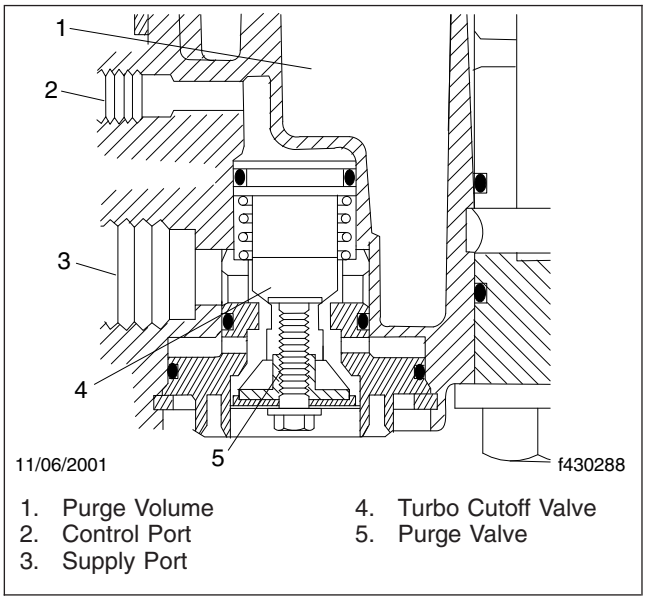
NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the vehicle maintenance manual for intervals and procedures.

Turbocharger Cutoff Feature

NOTE: The air compressor is naturally aspirated; the air passes from the vehicle air filter directly to the air compressor intake.

The primary function of the turbo cutoff valve is to prevent loss of engine turbocharger air pressure through the AD-IP in systems where the compressor intake is connected to the engine turbocharger. The turbo cutoff valve also removes the "puffing" of air out of the open purge exhaust, when a naturally aspirated, single-cylinder compressor, equipped with an inlet check valve, is in use. See **Fig. 4**.

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the compressor discharge line and AD-IP inlet port cannot enter the air dryer. In this manner, the turbo cutoff effectively maintains turbocharger boost pressure to the engine.



1. Purge Volume
2. Control Port
3. Supply Port
4. Turbo Cutoff Valve
5. Purge Valve

Fig. 4, AD-IP Turbo Cutoff

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

- Chock the tires and shut down the engine before working under a vehicle. Depleting air system pressure may cause the vehicle to roll. Keep hands away from brake chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure, and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not disassemble a component until you have read and understood the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools, and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc., should be the equivalent size, type, length, and strength of the original equipment.

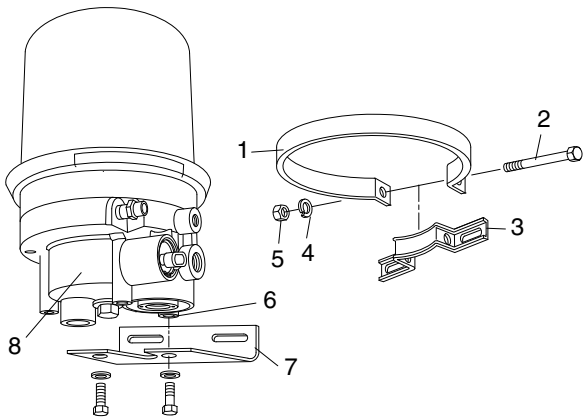
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Completely drain all of the reservoirs.
3. Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle.
4. Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the purge valve assembly.
5. Remove the four bolts that secure both the upper and lower mounting brackets to the vehicle, and remove the air dryer from the vehicle. See Fig. 1.



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1. Mounting Strap
2. 5/16-Inch Bolt
3. Saddle Bracket
4. Lockwasher
5. Nut
6. End Cover Mounting Holes
7. Lower Mounting Bracket
8. Air Dryer

Fig. 1, Bendix AD-IP Air Dryer

6. Mark the relationship of the saddle bracket to the end cover assembly. Remove the 5/16-inch bolt, washer, and nut that secures the upper mounting strap to the saddle bracket. Remove the upper mounting strap from the end cover assembly.
7. Mark the relationship of the lower bracket to the end cover assembly. Remove the two 3/8-inch end cover capscrews and two washers that retain the lower mounting bracket to the end cover.
8. Remove the air dryer from its mounting brackets.

Installation

1. Install the lower mounting bracket on the end cover and secure it using the two 3/8-inch capscrews and washers. Tighten the capscrews 25 to 30 lbf·ft (34 to 41 N·m). See Fig. 1.
2. Install the saddle bracket and mounting strap on the end cover, and using the 5/16-inch bolt, washer, and nut secure the strap to the saddle bracket. Tighten the 5/16-inch nut on the upper mounting bracket 60 to 100 lbf·in (678 to 1130 N·cm).
3. Install the AD-IP on the vehicle using the four bolts that secure both the upper and lower mounting brackets.
4. As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
5. Connect the vehicle wiring harness to the air dryer heater and thermostat assembly connector by plugging it into the air dryer connector until its lock tab snaps in place.
6. Test the air dryer, following instructions in **Group 42** of the vehicle maintenance manual.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

NOTE: As a convenience when rebuilding the air dryer, several replacement parts and maintenance kits are available that do not require full disassembly. Use the instructions provided with these parts or kits.

Disassembly

NOTE: Refer to **Fig. 1** during disassembly.

NOTICE

While servicing the air dryer, do not use a clamping device (vise, C-clamp, etc.) to hold any die cast aluminum part, as damage may result. To hold the end cover, install a pipe nipple in the supply port, and clamp the nipple in a vise.

1. Remove the air dryer from the vehicle. See **Subject 110**.
2. Loosen the desiccant cartridge bolt, then separate the desiccant cartridge from the end cover. Pull the desiccant cartridge bolt out of the end cover. See **Fig. 1**.

⚠ CAUTION

Disassembly of the desiccant cartridge assembly should not be attempted! Detail parts for the cartridge are not available and the cartridge contains a 150 lb spring which can not be mechanically caged. Releasing the spring could cause serious personal injury.

3. Remove both O-rings from the desiccant cartridge bolt.
4. Remove the retaining ring that secures the purge valve assembly in the end cover.
5. Remove the 1/4-inch shoulder bolt from the bottom of the purge valve housing assembly, using a 3/8-inch socket wrench and a large blade screwdriver, inserted in the slot on top of the purge piston. Remove the exhaust diaphragm, and the purge valve from the purge valve housing.
6. Remove the O-rings from the purge valve housing.
7. Remove the purge piston and the return spring. Remove the O-ring from the purge piston.
8. Remove the retaining ring that secures the delivery check valve assembly in the end cover. Remove and separate the perforated plate, spring, check valve body, and O-ring.
9. Remove the retaining ring that secures the heater and thermostat assembly in the end cover. Gently pull the heater and thermostat out of the end cover and remove the O-ring.
10. Using a 9/16-inch wrench, remove the safety valve assembly from the end cover.

Cleaning and Inspection

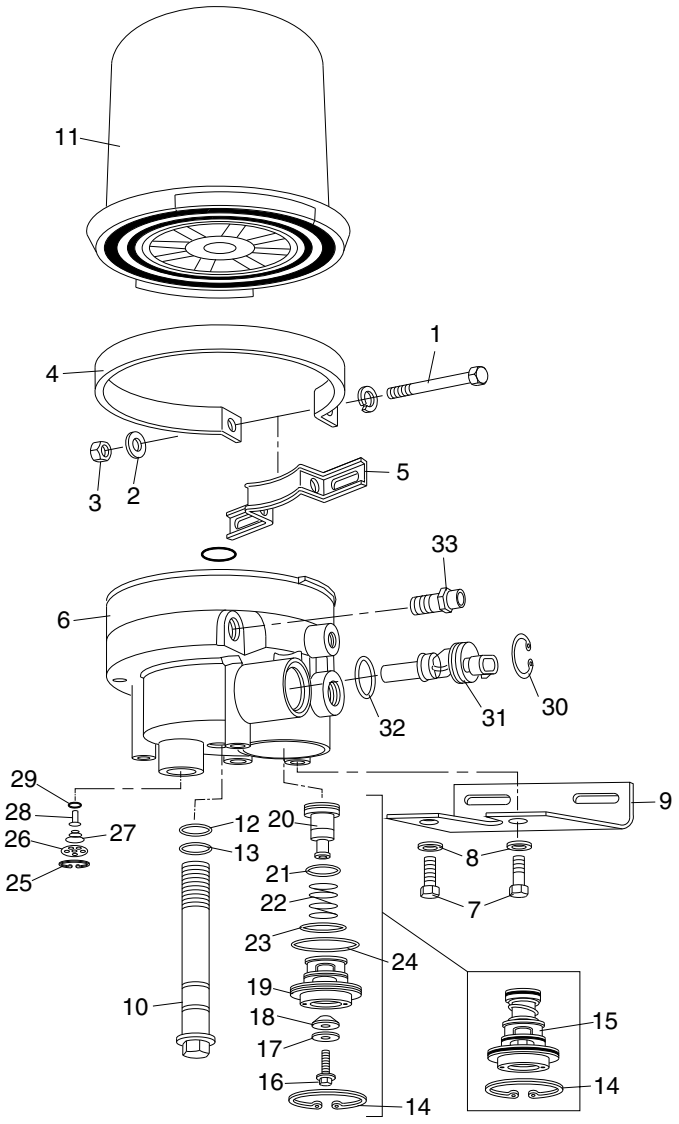
1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.

NOTE: Do not clean the desiccant cartridge.

2. Check for severe corrosion, pitting, and cracks on the inside and outside of all metal parts that will be reused. Superficial corrosion and pitting on the outside of the upper and lower body halves is acceptable.
3. Inspect the bores of both the end cover and the purge-valve housing for deep scuffing or gouges.
4. Make sure that all purge-valve housing and end cover passages are open and free of blockages.
5. Inspect the pipe threads in the end cover. Make sure they are clean and free of thread sealant.
6. Inspect the purge-valve housing bore and seats for excessive wear and scuffing.
7. Inspect the purge valve piston seat for excessive wear.
8. Make certain that the purge orifice in the cartridge bolt is open and free of obstructions.
9. Inspect all air line fittings for corrosion. Clean all old thread sealant from the pipe threads.
10. Replace all removed O-rings with new ones that are provided in the kits.

    Replace parts that show any of the conditions described in the previous steps.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



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1. 5/16-Inch Bolt
2. 5/16-Inch Lockwasher
3. 5/16-Inch Locknut
4. Upper Bracket Strap
5. Saddle Bracket
6. End Cover
7. 3/8-Inch Capscrew
8. 3/8-Inch Lockwasher
9. Lower Mounting Bracket
10. Cartridge Bolt
11. Desiccant Cartridge
12. O-Ring
13. O-Ring
14. Retaining Ring
15. Purge Valve Cartridge Assembly
16. Shoulder Bolt
17. Exhaust Diaphragm
18. Purge Valve
19. Purge Valve Housing
20 Purge Valve Piston
21 O-Ring
22. Piston Return Spring
23. O-Ring
24. O-Ring
25. Retaining Ring
26. Perforated Plate
27. Check Ring Spring
28. Check Valve
29. O-Ring
30. Retaining Ring
31. Heater/Thermostat Assembly
32. O-Ring
33. Safety Valve Assembly

Fig. 1, AD-IP (exploded view)

Assembly

1. Before assembly, coat all O-rings, O-ring grooves, and bores with a generous amount of barium-base lubricant. See **Fig. 1** during assembly unless otherwise advised.
2. Install and center the exhaust diaphragm over the shoulder bolt, making certain that the diaphragm ID is over the bolt shoulder. Then install the purge valve on the shoulder bolt, making certain its metal support side is against the diaphragm.
3. Push the purge piston into the housing until it bottoms, and insert a large blade screwdriver in the piston's slotted head. While depressing the purge piston with the screwdriver, install the shoulder bolt with exhaust diaphragm and purge valve in the piston. Tighten the shoulder bolt 60 to 80 lbf·in (678 to 904 N·cm).
4. Install the two O-rings on the purge valve housing, placing each in its appropriate location. Install the assembled purge valve housing in the end cover while making certain the purge valve housing is fully seated against the end cover. Secure the purge valve housing in the end cover, using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
5. Using a 9/16-inch wrench, install the safety valve assembly into the end cover.
6. Install the O-ring on the check valve body, and push the O-ring down, over the three guide lands until it is in the O-ring groove of the check valve body. Install the check valve spring on the check valve body so that the small coils of the spring slip over the check valve body. Install the assembled check valve body, O-ring, and spring in the end cover so that the O-ring rests on its seat in the end cover, and the spring is visible.
7. Install the O-ring on the heater and thermostat assembly. After making certain the sponge-rubber cushion is positioned between the connector body and thermostat, gently push the heater and thermostat assembly into the end cover, making certain the heating element enters the small diameter bore in the larger heater and thermostat bore in the end cover. Secure the heater and thermostat assembly in the body, using the retaining ring. Make certain the retaining ring is fully seated in its groove in the end cover.
8. Install both O-rings on the desiccant cartridge bolt, and using a twisting motion, insert the assembled desiccant cartridge bolt in the end cover.
9. Install the desiccant cartridge on the end cover, making certain the cartridge is properly seated and flush on the end cover.

NOTE: It may be necessary to rotate the cartridge slightly until the anti-rotation lugs are properly aligned and they allow the cartridge to rest flush against the end cover.

10. Tighten the desiccant cartridge bolt 50 lbf·ft (68 N·m), to secure the desiccant cartridge to the end cover.
11. Install the air dryer. For instructions, see **Subject 110**.

Testing

During cold-weather operation, check the operation of the end cover heater and thermostat assembly.

1. With the ignition on, check for voltage to the heater and thermostat assembly. Unplug the electrical connector at the air dryer, and place the test leads on each of the pins of the male connector. If there is no voltage, look for a blown fuse, broken wires, or corrosion in the vehicle wiring harness. Check that a good ground path exists.
2. Check the thermostat and heater operation. Turn off the ignition switch and cool the end cover assembly to below 40°F (4°C). Using an ohmmeter, check the resistance between the electrical pins in the female connector. The resistance should be 1.5 to 3.0 ohms for the 12-volt heater assembly, and 6.8 to 9.0 ohms for the 24-volt heater assembly.
3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.
Governor is inoperative.	Test the governor for proper cut-in or cut-out pressures and excessive leakage in both positions.
Leaking purge-valve housing assembly or O-rings in the air dryer end cover.	With the supply port open to atmosphere, apply 120 psi (830 kPa) at the control port. Apply a soap solution to the supply port and exhaust port (purge valve seat area). Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. Repair or replace as needed.
Compressor unloader mechanism is leaking excessively.	Remove the air strainer or fitting from the compressor inlet cavity. With the compressor unloaded, check for unloader piston leakage. Slight leakage is allowed.
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8 m) of wire braid Teflon hose, copper tubing, or a combination of both between the discharge port of the compressor and the air dryer supply port. Discharge line lengths and inside diameter requirements are dependent on the vehicle application. Contact your local Bendix representative for further information.
Air system was charged from an outside air source that did not pass through an air dryer.	If the system must have an outside air fill provision, the outside air should pass through an air dryer. This practice should be minimized.
Air dryer is not purging.	Refer to "Problem—Air Dryer Does Not Purge or Exhaust Air."
Purge (air exhaust) is insufficient due to excessive system leakage.	Refer to "Problem—Air Dryer Is Constantly Cycling or Purging."
Air bypasses the desiccant cartridge assembly.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed.

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Purge (air exhaust) time is significantly less than the minimum allowable.	Replace the desiccant cartridge/end cover O-ring. Make sure the desiccant cartridge assembly is properly installed. Replace the desiccant cartridge assembly.
Excessive air usage—air dryer not compatible with vehicle air system.	Install an accessory bypass system. Consult your Bendix representative for additional information.

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air

Problem—Safety Valve on Air Dryer Is Popping Off or Exhausting Air	
Possible Cause	**Remedy**
Desiccant cartridge is plugged or saturated.	Check the compressor for excessive oil passing, or incorrect installation. Repair or replace as needed.
The check valve in the air dryer end cover is inoperative.	Test to determine if air is passing through the check valve. Repair or replace as needed.
There is a problem in the fittings, hose, or tubing between the air dryer and the wet tank.	See if air is reaching the first reservoir. Inspect for kinked tubing or hose. Check for undrilled or restricted hose or tubing fittings.
Safety valve setting is lower than the maximum system pressure.	Reduce the system pressure, or install a safety valve with a higher pressure setting.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
Air dryer purge valve is leaking excessively.	With the compressor loaded, apply a soap solution on the purge valve exhaust to test for excessive leakage. Repair the purge valve as needed.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Purge control line is connected to the reservoir or exhaust port of the governor.	Connect the purge control line to the unloader port of the governor.
Purge valve is frozen open due to an inoperative heater or thermostat, bad wiring, or a blown fuse.	Test the heater and thermostat, following instructions in this manual.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir.
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
Air dryer purge valve isn't working.	See if air reaches the purge valve. If it does, repair the purge valve.
The governor is inoperative.	Check the governor for proper cut-in and cut-out pressures, and excessive leakage in both positions. Repair or replace as needed.
Inlet and outlet air connections are reversed—unable to build system pressure.	Reconnect the lines properly.
Discharge line is kinked or blocked.	See if air passes through the discharge line. Check for kinks, bends, or excessive carbon deposits.
There are excessive bends in the discharge line. Water is collecting and freezing.	Discharge line should be constantly sloping from the compressor to the air dryer with as few bends as possible.

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (may look like whitish liquid, paste, or small beads) or Unsatisfactory Desiccant Life	
Possible Cause	**Remedy**
This problem usually occurs with one or more of the previous problems.	Refer to the appropriate corrections listed previously.
Air dryer is not securely mounted; there is excessive vibration.	Vibration should be held to a minimum. Tighten the mounting fasteners.
Cloth-covered perforated plate in the air dryer desiccant cartridge is damaged, or the cartridge was rebuilt incorrectly.	Replace the plate or cartridge as needed. High operating temperatures may cause deterioration of filter cloth. Check the installation.
Compressor is passing excessive oil.	Check for proper compressor installation; if symptoms persist, replace the compressor.
Heater and thermostat, wiring, or a fuse is at fault, and isn't allowing the air dryer to purge during cold weather.	Test the heater and thermostat. See **Group 83** in this manual.
Desiccant cartridge not attached properly to the end cover.	Check the torque and tighten if necessary. Refer to **Subject 120** for instructions.

Troubleshooting

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle

Problem—Pinging Noise Is Excessive During Compressor Loaded Cycle	
Possible Cause	**Remedy**
Pinging noise is due to a single cylinder compressor with high pulse cycles.	A slight pinging sound may be heard during system build-up when a single cylinder compressor is used. If this sound is deemed objectionable, it can be reduced substantially by increasing the discharge line volume. This is done by adding a 90 in^3 (1475 cm^3) reservoir between the compressor and the air dryer.

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)

Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss of air will not affect the engine or turbocharger performance.
Check valve assembly in the air dryer end cover is not working.	Remove the check valve assembly from the end cover. Apply compressed air to the delivery side of the valve. Apply a soap solution at opposite end, and check for leakage. Permissible leakage is a 1-inch (2.5-cm) bubble in 5 seconds. If there is excessive leakage, replace the check valve assembly.

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode

Problem—Air Dryer Purge Piston Cycles Rapidly in the Unloaded Mode	
Possible Cause	**Remedy**
Compressor does not "unload."	Check the governor installation: there is no air line from the governor to the compressor, or the line is restricted. Repair or replace as needed.

General Information

A *Checklist for Troubleshooting Power Steering Problems*, form STI-492, has been developed to accompany the procedures below. Form STI-492 can be downloaded or printed **here** after logging into **www.AccessFreightliner.com**.

Each step and substep in these troubleshooting procedures corresponds to a step or substep on form STI-492. Use **Table 1** to determine which steps should be completed, based on the customer's complaint. It is very important that the information provided by the driver is communicated accurately to prevent wasting of diagnostic time. For example, if complaints include "Pulling to one side" and "Noisy steering," steps 1, 3, 4, 5, and 6 will be the tests for the most likely failure modes.

Start with the lowest test number and work up to the highest. For example, when completing steps 1, 3, and 6 to determine the cause of a vehicle pulling to one side, start with step 1 and finish with step 6.

Troubleshooting Steps

NOTE: Some of these inspections and procedures can be found in the Pretrip and Post-Trip Inspections and Maintenance chapter in the vehicle driver's/operator's manual.

Steps 1 through 4 may have been performed by the customer. Verify the vehicle service history with the customer to prevent redundant testing.

All measurements and readings must be recorded on STI-492.

Refer to the applicable section in this manual to repair or replace steering system components.

1. Check the tire pressure and load.

   1.1 Check the tires for damage.

   1.2 Check that the front tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

   Low pressure causes increased steering effort due to friction with the road surface. Unequal tire pressure causes unequal friction between the tire and the road. This can cause pulling to one side.

Steering Complaint and Troubleshooting Steps Checklist												
LH	RH	Both	Complaint	Troubleshooting Steps								
				1	2	3	4	5	6	7	8	9
			Hard or heavy steering									
			Low assist									
			Binding	•	•		•	•	•	•	•	•
			Locking									
			Occasional loss of assist									
			Reduced wheel cut								•	
			Pulling to one side*	•		•			•			
			Darting/oversteering	•	•	•	•		•			
			Wandering									
			Noisy steering				•	•	•			
			External seals leaking					•	•			•
			Excessive heat									

* If there is consistent pull to one side, a braking issue could feel like a steering assist problem. Refer to **Group 42** in this manual to ensure the brake system is functioning properly.

Table 1, Steering Complaint and Troubleshooting Steps Checklist

Troubleshooting Procedures

1.3 Check that the rear tires are inflated to the correct pressure, and the tire pressure is equal on both sides. Correct the pressure if needed.

1.4 Check that the tire sizes are correctly matched, and whether duplex or oversized tires (that were not originally specified for the vehicle) have been installed.

Extra tire width causes increased steering effort due to extra friction with the road surface. If the axle stops were turned out to reduce wheel cut due to a change in tires, the power steering gear poppets may need to be adjusted.

1.5 Communicate with the driver or operator to determine whether the vehicle is operated at or over the rated load.

Increased load causes greater steering effort. Make sure the vehicle is being operated within rated capacities.

2. Check fifth wheel lubrication and condition.

A dry fifth wheel plate makes it difficult to change direction. Check the plate surface for burrs, gouges, and irregularities.

3. Check vehicle alignment and wheel bearing adjustment.

3.1 Check the vehicle service history for the last known alignment, and inspect tire wear for indications that an alignment needs to be completed.

3.2 Check front axle caster and camber measurements.

3.3 Ensure wheel bearings and rear axle are in good condition, and that toe is set correctly.

3.4 Ensure the rear axle is properly aligned.

4. Check for loose and binding components. Check whether any steering components need maintenance or adjustment.

4.1 Check for proper lubrication of the drag link, tie rods, and knuckle pins. Apply lubrication as needed.

4.2 Check the COE steering column, if equipped. Chock the rearmost tires. With the engine shut down, turn the steering wheel and check for looseness or binding. Make sure all components are free to move, but are not excessively loose.

4.3 Check the steering driveline U-joints for looseness or binding. Lubricate them if needed.

4.4 Check the sector shaft adjustment.

- With the vehicle on the ground, the engine idling, and the front tires pointed straight ahead, turn the steering wheel until slight motion is observed at the front wheels.
- Align a reference mark on the steering wheel to a rule, then, with the engine running, slowly turn the steering wheel in the opposite direction until motion is again detected at the wheels.
- Measure the lash (free play) at the rim of the steering wheel.

Excessive lash exists if steering wheel movement exceeds 2-1/2 inches (64 mm) with a 20-inch (508-mm) steering wheel, or 2-1/4 inches (57 mm) with an 18-inch (457-mm) steering wheel.

4.5 Check that the front wheels self-return without binding.

- With the engine off, chock the rearmost tires and place the front tires on radius plates (turntables).
- Disconnect the drag link from the steering arm.
- By hand, pull one tire to the axle stop and release. The tire should self-return to almost straight ahead.
- Repeat with the opposite tire.

If a tire does not return to near straight ahead, check for binding or lack of lubrication in the steering axle kingpin bushings or tie rod linkage.

- Connect the drag link and tighten the castle nut, then install a new cotter pin.

4.6 Inspect all suspension fasteners and components for wear or looseness.

5. Check the steering system for leaks and restrictions, and test the system back pressure.

5.1 Inspect hoses, fittings, and seals for damage or leaks.

- With the engine idling, inspect for kinked or collapsed hoses. Repair or replace any collapsed or kinked hoses. If collapsed hoses are found, ensure the steering system is filled with the correct automatic transmission fluid.
- Inspect fittings for leaks. Repair leaking fittings; replace parts as needed.
- Inspect all external seals. Replace leaking seals.

  Inspect the seal bores and sealing surfaces for scrapes or burrs. Make sure the seals are installed correctly using the recommended tools.
- If you replaced the steering gear input shaft seal and found it to be excessively hard, test the system operating temperature in step 6.

5.2 Inspect the steering gear for external leakage.

- Clean the area around the input shaft and inspect the input shaft for signs of leakage after operating the vehicle under normal conditions through steering maneuvers.
- Inspect the sector shaft for signs of leakage. A well greased or heavily used steering gear may weep oil from the grease seal, but a confirmed leak will be evidenced by fluid collecting while the vehicle is being operated under normal conditions.
- Inspect the vent plug in the trunnion housing for signs of leakage. Any fluid in or around the rubber vent plug indicates leakage from an internal steering gear seal.

NOTICE

Do not turn the steering wheel or allow system pressure to exceed the rating of the gauge during the following test. Damage to the gauge could occur.

5.3 Check total steering system back pressure.

- Install a low pressure gauge—300 psi (2068 kPa) maximum—between the steering pump and the steering gear.
- Check for correct fluid level. If necessary, add fluid. If bubbles or foam appear in the reservoir, check hose fittings for looseness or leaks.
- With the engine idling, read the total system back pressure on the pressure gauge.
- If the total system back pressure is greater than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, replace the steering fluid filter and re-test the system. If the system back pressure is still excessive, go to the next substep.

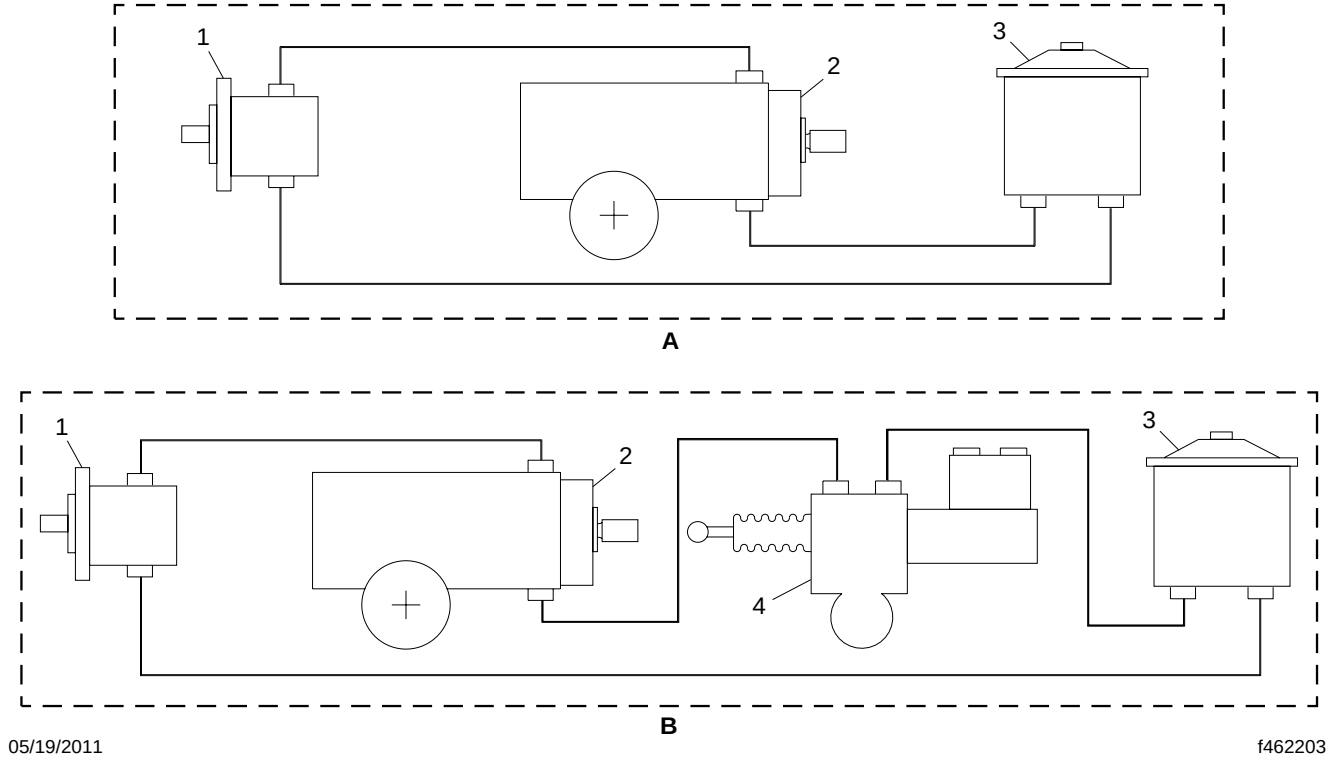
  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

5.4 Leave the low pressure gauge in place and check individual steering system components for excessive restriction. See **Fig. 1** for a plumbing diagram.

- Bypass the steering gear by disconnecting the steering gear input and output lines from the gear and coupling them together. See **Fig. 2** for an example.

  If the drop in system pressure from the value found in substep 5.3 is greater than 55 psi (379 kPa), the steering gear has excessive restriction. If the drop in pressure is less than 55 psi (379 kPa), reconnect the

Troubleshooting Procedures



A. Vehicles With Air Brakes
1. Steering Pump
2. Steering Gear

B. Vehicles With Hydraulic Brakes
3. Reservoir
4. Brake Booster

Fig. 1, Plumbing Diagrams

gear input and output lines to the gear and continue with this substep.

- If the vehicle is equipped with hydraulic brakes, bypass the brake booster by disconnecting the booster input and output lines and coupling them together.

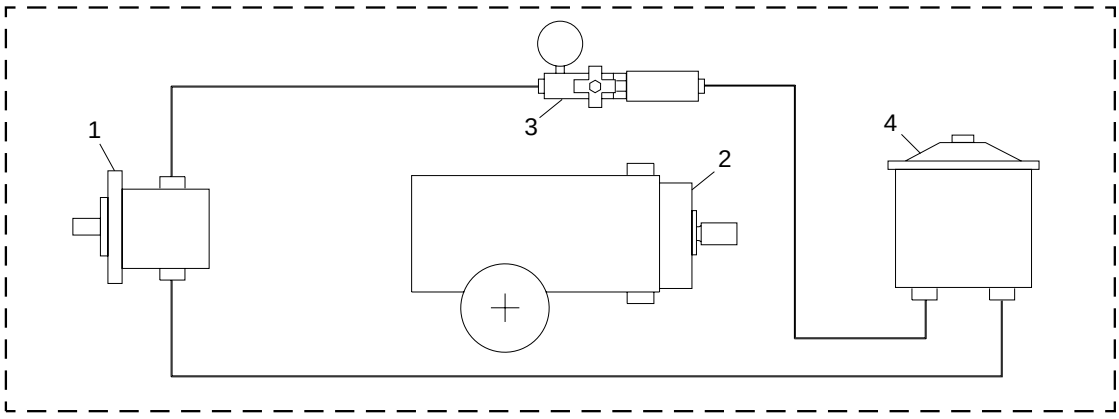
  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

- Test each hydraulic line in the power steering system individually by bypassing them one at a time, as was done with the steering gear and brake booster, if equipped.

  If the drop in system pressure from the value found in substep 5.3 is greater than 12 psi (83 kPa) for any one line, replace the line and test total system back pressure again.

6. Check steering pump performance. Power steering fluid temperature should be approximately 180°F (82°C) to best replicate fluid temperatures under normal driving conditions.

   If the system fails the tests in the following substeps, replace the pressure relief valve (PRV) and complete the tests in the substeps below again. If the system fails again, replace the pump.



1. Steering Pump
2. Steering Gear
3. Low Pressure Gauge
4. Reservoir

Fig. 2, Testing Steering Gear Restriction

Install the PSSA between the steering pump and the gear for the following substeps. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.

NOTICE

Do not leave the load valve closed for longer than five seconds during the following test. Doing so could damage the power steering system.

6.1 Check for erratic pump response.

- Slowly close the load valve and watch the pressure and flow readings as the valve closes, then open the valve immediately.
- If the pressure rises rapidly or appears uncontrolled, open the load valve immediately.
- If the response was erratic, replace the PRV or pump, as required. If the response was smooth and controlled, go to the next substep.

6.2 Check the pump relief pressure.

- Slowly close the load valve. When the valve is completely closed, read the pressure gauge, then open the valve.
- If the pump relief pressure does not exceed the relief pressure in **Table 2** or **Table 3**, refer to the pump manufacturer's service literature to verify the exact relief pressure for the pump.
- If the pump relief pressure does not exceed the relief pressure in **Table 2**, **Table 3**, or the pump manufacturer's specifications, replace the PRV or pump, as required.
- If the pump relief pressure exceeds the relief pressure in **Table 2** or **Table 3**, it is acceptable. Go to the next substep.

6.3 Test the pump relief valve reaction at idle.

- Run the engine at idle and note the flow rate with the load valve open.

Troubleshooting Procedures

Minimum Measured Pump Flow and Relief Pressure at Engine Idle				
Power Steering Gear	**Flow at 1500 rpm, No Load: gpm (L/min)**	**Flow at 1000 psi (6900 kPa): gpm (L/min)**	**Flow at 1800 psi (12 400 kPa): gpm (L/min)**	**Typical Relief Pressure: psi (kPa)**
Sheppard M100	3.7 (14.0)	2.8 (10.6)	2.3 (8.7)	2175 ± 100 (15 000 ± 700)*
TRW TAS40	3.7 (14.0)	2.1 (7.9)†	1.6 (6.1)	
TRW TAS55		2.4 (9.1)†	1.9 (7.2)	
TRW TAS65		2.8 (10.6)†	2.3 (8.7)	
TRW TAS85		3.3 (12.5)	2.8 (10.6)	
TRW TAS65 With C28 or C32 Linear Cylinder	5.8 (22.0)	4.9 (18.5)	4.4 (16.7)	
TRW TAS65 With RCS65				
TRW TAS85 With C28 or C32 Linear Cylinder		5.4 (20.4)†	4.9 (18.5)	
TRW TAS85 With RCS65				
ThyssenKrupp LZS5 Rack and Pinion	3.7 (14.0)	3.3 (12.5)	2.8 (10.6)	2300 ± 116 (15 500 ± 800)

* On vehicles with TRW TAS steering gears and hydraulic brakes, typical relief pressure is 2375 ± 100 psi (16 375 ± 690 kPa).

† Approximate value based on flow at 1800 psi (12 400 kPa).

Table 2, Minimum Measured Pump Flow and Relief Pressure at Engine Idle

Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle				
Power Steering Gear	**Flow at 1500 rpm, No Load: gpm (L/min)**	**Flow at 1000 psi (6900 kPa): gpm (L/min)**	**Flow at 2300 psi (15 860 kPa): gpm (L/min)**	**Typical Relief Pressure: psi (kPa)**
Sheppard HD94	3.7 (14.0)	2.6 (9.8)	1.8 (6.8)	2683 ± 100 (18 500 ± 700)
TRW THP45		2.2 (8.3)	1.4 (5.3)	
TRW THP60 or PCF60		2.6 (9.8)	1.8 (6.8)	
TRW THP60 With Linear Cylinder	5.8 (22.0)	4.1 (15.5)	3.3 (12.5)	
TRW THP60 With RCH45				

Table 3, Minimum Measured Pump Flow and Relief Pressure for High-Pressure Gears at Engine Idle

- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this action three times. The flow rate should return to the flow rate first noted with the load valve open.
- If the flow rate does not return smoothly and quickly, the pump relief valve is not working correctly. Replace the replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.4 Test the pump relief valve reaction at 1500 rpm.

- Run the engine at 1500 rpm and note the flow rate with the load valve open.
- Close the load valve until the pump relief pressure is reached. Smoothly and quickly open the load valve and note the flow rate. Repeat this ac-

tion three times. The flow rate should return to the flow rate first noted with the load valve open.

- If the flow rate does not return smoothly and quickly, replace the PRV or pump, as required.
- If the flow rate returns smoothly and quickly, the pump relief valve is acceptable. Go to the next substep.

6.5 Test the flow of the pump at idle with a load applied.

For vehicles with low-pressure steering gears, run the engine at idle and slowly close the load valve until the pressure gauge reads 1000 psi (6900 kPa). Read the flow rate on the gauge, then set the pressure to 1800 psi (12 400 kPa). Read the flow gauge, then open the load valve. Compare the values to those in **Table 2**.

For vehicles with high-pressure steering gears, use 1000 psi (6900 kPa) and 2300 psi (15 860 kPa) as the test load pressures. See **Table 3** for minimum flow rate.

6.6 Test the maximum flow of the pump with no load applied.

- Run the engine at 1500 rpm, make sure the load valve is completely open, and read the flow gauge.
- If the flow rate is below the minimum indicated in **Table 2** or **Table 3**, replace the PRV or pump, as required.
- If the flow rate is above 5.5 gpm (20.8 L/min) on a vehicle with a single steering gear, or 7.7 gpm (28.8 L/min) on a vehicle with an assist cylinder installed, replace the pump.

7. Test the steering gear internal leakage.

Select TRW integral steering gears and all ThyssenKrupp rack and pinion steering gears are equipped with an internal PRV that significantly limits maximum supply pressure to protect the steering gear. These gears, unlike gears on vehicles fitted with hydraulic brake boosters, cannot be tested for internal leakage by plugging the internal PRV in the gear. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® for the specific VIN to determine if the steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If a TRW steering gear has an internal PRV but no hydraulic brake booster, see the following heading, **Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV**, for instructions on setting up the necessary test components before proceeding with the following substeps.

ThyssenKrupp rack and pinion steering gears are also equipped with an internal PRV, but cannot be tested for internal leakage.

IMPORTANT: Make sure the fluid temperature is approximately 180°F (82°C) and the vehicle is stationary with the front wheels pointing forward.

7.1 Run the engine at idle with the load valve open.

⚠ WARNING

Keep fingers clear of the stop bolt and spacer block during the following test. Make sure that the spacer block contacts the axle stop squarely. Contact that is not square could break the stop bolts or eject the spacer block, which could cause serious personal injury.

7.2 Place an unhardened steel spacer, 1-inch (25-mm) thick, between the axle and the stop bolt on one side of the axle.

The spacer should have an extension or handle long enough to keep fingers clear of the axle stop area. A brazing rod or welding rod works well for this purpose.

NOTICE

While running the following test, do not hold the steering wheel in the full-turn position for more than five seconds. Doing so could damage the pump.

Troubleshooting Procedures

7.3 Have someone turn the steering wheel, applying enough force to completely close the rotary valve.

Complete closure of the rotary valve requires approximately 20 lbf (27 N) pull on the steering wheel, and will be indicated by a pressure reading nearly equal to the system relief pressure (tested in substep 6.2).

7.4 Hold the steering wheel in the full-turn position. Note the steering gear internal leakage on the PSSA.

7.5 Repeat the previous substeps for the opposite turn.

The maximum permissible internal leakage for a single gear is 1.0 gpm (3.8 L/min). If leakage is greater in either turning direction, replace the steering gear components as needed.

For systems with two or more steering gears and/or linear cylinders, the total acceptable internal leakage is 1.0 gpm (3.8 L/min) for each steering gear/ram in the system. Maximum internal leakage on a dual-gear system is 2.0 gpm (7.6 L/min). If the leakage is more than 2.0 gpm (7.6 L/min) on a dual-gear system, isolate the auxiliary cylinder from the system using the substeps that follow.

7.6 Disconnect the auxiliary cylinder hydraulic lines at the main gear auxiliary ports.

7.7 Plug the main steering gear ports with suitable steel or high-pressure plugs or caps.

7.8 Repeat the internal leakage test.

If the internal leakage is less than 1 gpm (3.8 L/min), repair or replace the auxiliary gear or linear cylinder. If the internal leakage is greater than 1 gpm (3.8 L/min), repair or replace the main gear.

8. Check the steering gear poppet relief valve and stop bolt adjustment.

NOTE: Poppets limit the steering assist when the front wheels approach the stop bolts. Improper adjustment can apply excessive force to the steering linkage, or cause loss of assist, as the steering wheel approaches either full-left or full-right turn.

8.1 Check the steering system for stop bolt adjustment.

Make sure the stop bolt settings limit the steering travel so there is ½-inch (13-mm) clearance from all stationary components, and 3/4-inch (19-mm) clearance from all moving components.

8.2 Make sure the pitman arm is situated on the steering gear sector shaft correctly. Check that the pitman arm and sector shaft timing marks are aligned.

NOTICE

If power steering pump relief pressure is reached while the steering wheel is at full lock, release the steering wheel from this position. Do not allow the pump relief pressure to be maintained for longer than five seconds or damage to the pump may result.

8.3 Check the poppet relief pressure.

- Install the PSSA between the steering pump and the steering gear. See the following heading, **Power Steering System Analyzer Setup**, for instructions on PSSA installation.
- Run the engine at idle with the load valve open. Turn the steering wheel to either full-lock position. Note the pressure gauge reading, then repeat for the opposite turn.
- The pressure should drop slightly before the stop bolts are contacted. If the pressure increases (from contact with the stop bolts), the poppets must be manually reset.

  If the pressure is relieved and assist is lost when the wheel is too far from the axle stop bolts, refer to the applicable section in this manual for gear-specific information.
- After poppet replacement or adjustment, test again for correct poppet relief function and record the new pressure.

8.4 Check for normal hissing sound at full turn.

NOTE: Noise from the power steering system does not necessarily mean there is a problem. Some noises are normal and are the result of proper operation.

See **Table 4** for possible causes and remedies for common noises associated with the power steering system and power steering pump.

8.5 Check for abnormal power steering noise.

Listen for a hissing sound at less than full turn. If a hissing sound is heard, check the steering gear poppet and the axle stop adjustment.

NOTICE

If the temperature exceeds 250°F (121°C), damage to hoses, seals, and other components may result if the vehicle continues to operate at excessive steering system temperatures. If this temperature is exceeded, stop the test and record the last noted temperature on STI-492.

9. Test the system operating temperature.

- Run the engine at governed speed.
- Observe the power steering fluid temperature until it stabilizes.
- Record the power steering fluid temperature in 10-minute intervals until 40 minutes have passed.
- If the temperature does not exceed 250°F (121°C) during the test, excessive heat due to system components is probably not the cause of the complaint. The system may still experience overheating due to driving and load conditions.

  If the temperature exceeds 250°F (121°C), excessive steering system back pressure or excessive pump flow may be the cause of the high temperature problem. If system back pressure or restriction values found in substeps 5.3 and 5.4 above were close to the maximum allowable, complete step 5 again. If steering pump flow and relief pressures found in step 6 above were close to the maximum allowable, complete step 6 again.
- If excessive heat continues to be a problem, a cooler may need to be added to the system.

Power Steering System Noise	
Noise	**Remedy**
Growling or other abnormal steering noise	Check the fluid level. Check for air bubbles and foam. Check for hose and fitting leaks. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
A change from the usual pump sound	Check the steering fluid reservoir for air bubbles and foam. If there is air in the fluid, check for inlet tube and hose leaks. Correct all leaks.
Clicking noise during a turn	Check for loose steering components. Tighten any loose steering components. Check the front suspension for insufficient spring pin shims. Add front spring pin shims if needed.
Hissing when the steering wheel is at or near full turn	This is normal; no action is needed.
Steering Pump intake line is plugged	Drain the system. Clear the intake line if needed. Fill the system.
Air leak at the pump or reservoir connections, fittings, or shaft seal	Check all the connections by pouring power steering fluid over them, and listening for a reduction in sound. Tighten all connections as needed.
Pump input shaft is misaligned	Replace the pump.

Table 4, Power Steering System Noise

Troubleshooting Procedures

Power Steering System Analyzer Setup

The hydraulic power steering system is tested with a Power Steering System Analyzer (PSSA), and with the hydraulic fluid at operating temperature. The PSSA and adaptor kit are available from SPX Kent-Moore.

A PSSA is a combination of a flow meter, a shutoff valve, and a high-pressure gauge. See **Fig. 3**. The PSSA will allow you to measure flow and pressure, and provide a load on the pump in the hydraulic lines of the steering system.

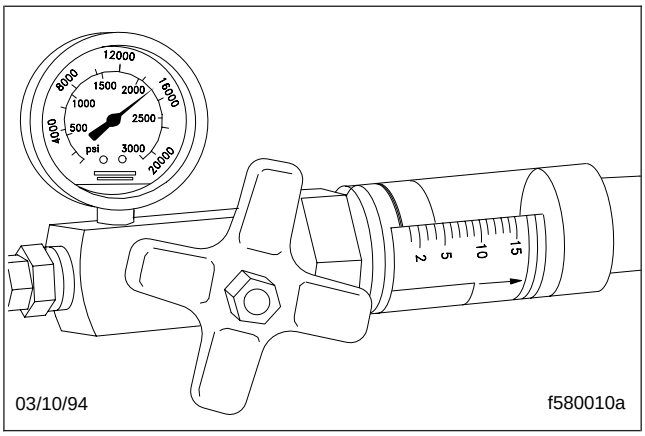


Fig. 3, Power Steering System Analyzer

1. Install a PSSA between the pump high-pressure line and the steering gear.
2. Fill and bleed the steering system as needed.

NOTICE

Do not leave the load valve fully closed for longer than five seconds. Doing so could damage the power steering system.

3. Run the engine at idle.
4. Partially close the load valve on the PSSA until the pressure gauge reads 1000 psi (6895 kPa).
5. Open the valve when the fluid temperature reaches about 180°F (82°C).

Internal Leakage Test Setup, TRW Steering Gears With an Internal PRV

Select TRW steering gears are equipped with an internal PRV that limits maximum supply pressure to protect the steering gear. These gears cannot be tested for internal leakage using the standard procedure. The pump output must be limited to prevent excessive pressure from damaging the gear, and the internal PRV passage must be blocked to direct oil flow through the gear.

Use PartsPro® to determine if a specific TRW steering gear is equipped with an internal PRV, which will be listed as a serviceable part under module 536.

If your TRW steering gear has an internal PRV, complete the following steps to set up the necessary internal leakage test components. See **Table 5** for a list of required leakage test components. The plumbing fittings and hose part numbers are recommended, but may be replaced with identical parts from other suppliers, if necessary.

The ThyssenKrupp rack and pinion steering gear is also equipped with an internal PRV, but cannot currently be tested for internal leakage.

IMPORTANT: The front wheels must be raised or on turnplates during this procedure.

1. Turn the engine off. Remove the relief valve cap, O-ring, and relief valve from the steering gear. See **Fig. 4**.
2. Install the relief valve plug, J-37130, in the internal PRV hole. Install the relief valve cap and O-ring over the plug.
3. Assemble the relief valve cartridge body, relief valve, and tee fittings as shown in **Fig. 4**.
4. Install the PSSA and other test components as shown in **Fig. 4**.
5. Open the external relief valve (**Fig. 4**, Item 15) on the relief valve cartridge. Ensure the PSSA shutoff valve is fully open.
6. Raise the front wheels off the ground and turn the steering wheel to the right and left full-lock positions five times to bleed air from the system.
7. Start the engine and bleed the remaining air out of the system by continuing to turn the wheel from side to side.

NOTICE

Do not leave the PSSA shutoff valve fully closed for longer than five seconds. Doing so could damage the power steering system.

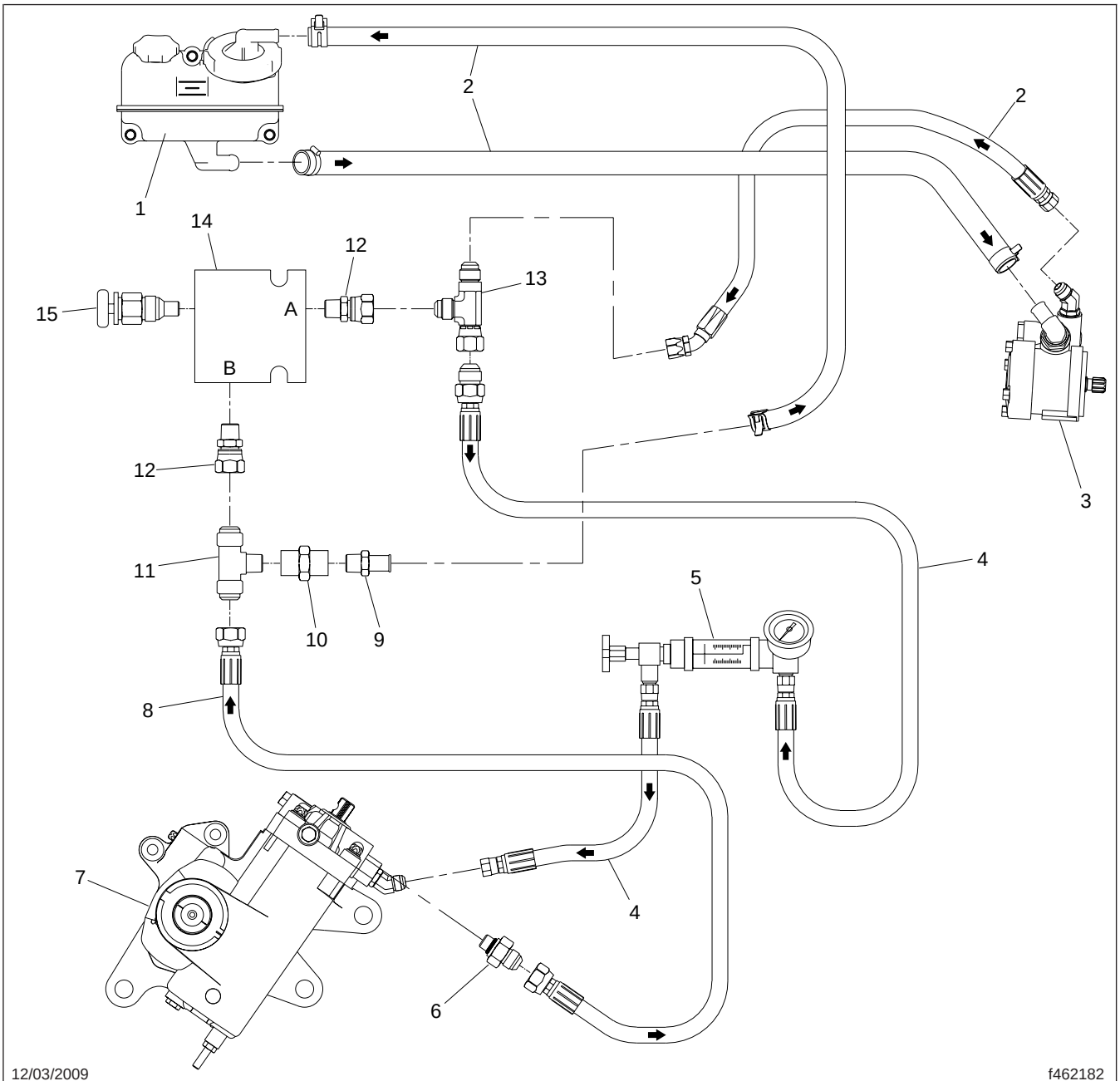
8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal leakage test (step 9 of the **Troubleshooting Steps** heading above).

Internal Leakage Test Components			
Part	**Available From**	**Part Number (Vendor P/N)**	**Item #, Fig. 4**
Power Steering System Analyzer (PSSA)	SPX Kent-Moore	J-26487	5
PSSA Adaptor Kit	SPX Kent-Moore	J-28593	—
Relief Valve Plug	SPX Kent-Moore	J-37130	—
Connector, Straight Thread with O-Ring	Daimler Trucks PDC	23-11470-088	6
Power Steering Hose, 42"	Daimler Trucks PDC	14-12694-042	8
Connector, 3/8" Male NPT to 5/8" Beaded Hose Barb	Daimler Trucks PDC	23-11321-001	9
Pipe Coupling, 3/8" NPT	Parker Hannifin	PH 3/8 GG S (3/8 GG-S)	10
Tee, Male JIC with Male NPT Branch*	Parker Hannifin	PH 8STXS (8 STX-S)	11
Swivel Adaptor, 3/8" Male NPT to Female 37 degree JIC (qty 2)	Weatherhead	WH 9100X8X6 (9100x8x6)	12
Swivel Nut Run Tee	Parker Hannifin	PH 8 R6X S (8 R6X-S)	13
3/8" Female NPT Aluminum Relief Valve Threaded Cartridge Body	Parker Hannifin	B10-2-A6P (PH B102A6P)	14
Aluminum Hydraulic Threaded Cartridge Relief Valve with Knob	Parker Hannifin	PH RAH101K30 (RAH101K30)	15

* Use steel 37 degree JIC fittings only.

Table 5, Internal Leakage Test Components

Troubleshooting Procedures



A. High-Pressure Input Port
B. Low-Pressure Output Port

1. Power Steering Fluid Reservoir
2. Existing Power Steering Fluid Lines (Qty 3)
3. Power Steering Pump
4. PSSA Fluid Lines (Qty 2)
5. PSSA
6. Connector, Straight Thread with O-Ring
7. Power Steering Gear (TAS85 shown)
8. Power Steering Hose, 42"
9. Connector, Male NPT to Beaded Hose Barb
10. Pipe Coupling
11. Tee, Male JIC with Male NPT Branch
12. Swivel Adaptor (Qty 2)
13. Swivel Nut Run Tee
14. Relief Valve Threaded Cartridge Body
15. External Relief Valve, Threaded Cartridge Type

Fig. 4, Internal Leakage Test Component Installation

General Description

The TRW EV Series power steering pump supplies power steering fluid for the operation of the power steering gear. The EV Series power steering pump is a balanced, positive displacement, sliding-vane, two-line pump with an internal pilot-operated flow control and relief valve.

Principles of Operation

As the input shaft turns the rotor inside the cam ring, the centrifugal force pushes the vanes out toward the surface of the cam ring. The pumping element has two pumping pockets opposed 180 degrees from each other that balance the internal forces using the pressure generated by the pumping action. Fluid entering via the inlet port is forced by the vanes through the pumping pockets in the cam ring, and out through the outlet port, to the steering gear. Once through the steering gear, the fluid returns to the power steering reservoir, then back to the power steering pump.

The pump outputs a fixed volume for each revolution of the input shaft. This volume is determined by the internal contour of the cam ring.

The pump has a pilot-operated valve built into the pump housing that controls the amount of fluid that is output to the steering gear. This allows the output flow to remain within specification for almost any input speed variation.

Removal

1. Shut down the engine, apply the parking brake, and chock the tires. Open the hood.
2. Clean all dirt from around the fittings and hose connections.
3. Place a container under the pump, then disconnect the hoses from the fittings on the pump. Plug the hoses and cap the fittings to keep out dirt and to prevent fluid leakage.
4. Remove and discard the capscrews and washers that attach the pump to the engine accessory drive mounting flange. Support the pump as you remove the second mounting bolt.
5. Pull the pump straight out from the engine. Keep it level to avoid spilling fluid.
6. Turn the pump upside down over the container and let the fluid drain out.
7. Discard the gasket from the pump mounting flange.

Installation

1. Install a new gasket on the pump mounting flange, then place the pump on the engine accessory drive mounting.
2. Install new mounting fasteners and tighten them 27 to 32 lbf·ft (37 to 43 N·m).
3. Connect the inlet hose from the power steering reservoir to the inlet port adaptor. Tighten the adaptor 38 lbf·ft (52 N·m).
4. Connect the outlet hose from the power steering gear to the outlet port. Tighten the adaptor 47 lbf·ft (64 N·m).
5. Bleed the power steering system.
   - 5.1 Check the fluid level in the power steering reservoir. If necessary, fill the reservoir with automatic transmission fluid that meets Dexron III or TES-389 specifications.
   - 5.2 Start the engine and let it idle for several minutes.
   - 5.3 Turn the wheels fully left and right five times.
   - 5.4 Check the fluid level in the power steering reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, fill the reservoir with automatic transmission fluid that meets Dexron III or TES-389 specifications.
   - 5.5 Shut down the engine.

Specifications

TRW EV Series pumps use ATF fluid that meets TES-389 or Dexron III specifications.

The TRW part number is located as shown in **Fig. 1**.

Pump specifications by TRW part number are listed in **Table 1**.

Specification Codes for Fourteen-Character TRW Part Number								
Character Position	**1, 2**	**3, 4**	**5, 6**	**7, 8**	**9**	**10**	**11, 12**	**13, 14**
Typical TRW Part Number	**EV**	**22**	**16**	**18**	**L**	**1**	**01**	**01**
Code Description								
Family Designation EV = EV Series Pump								
Displacement per Revolution 18 = 18 cc (1.10 cir) 22 = 22 cc (1.34 cir) 25 = 25 cc (1.53 cir) 28 = 28 cc (1.71 cir)								
Flow Control 12 = 12 lpm (3.17 gpm) 14 = 14 lpm (3.70 gpm) 16 = 16 lpm (4.23 gpm)								
Relief Setting 09 = 90 bar (1305 psi) 15 = 150 bar (2175 psi) 16 = 160 bar (2320 psi) 17 = 170 bar (2465 psi) 18 = 185 bar (2683 psi)								
Direction of Rotation R = clockwise rotation L = counterclockwise rotation								
Shaft Type 1 = 11 tooth 16/32 spline								
Housing 01 = SAE A Flange - JIC ports 02 = SAE A Flange - Metric ports								
Customer Version 01 = Freightliner								

Table 1, Specification Codes for Fourteen-Character TRW Part Number

Specifications

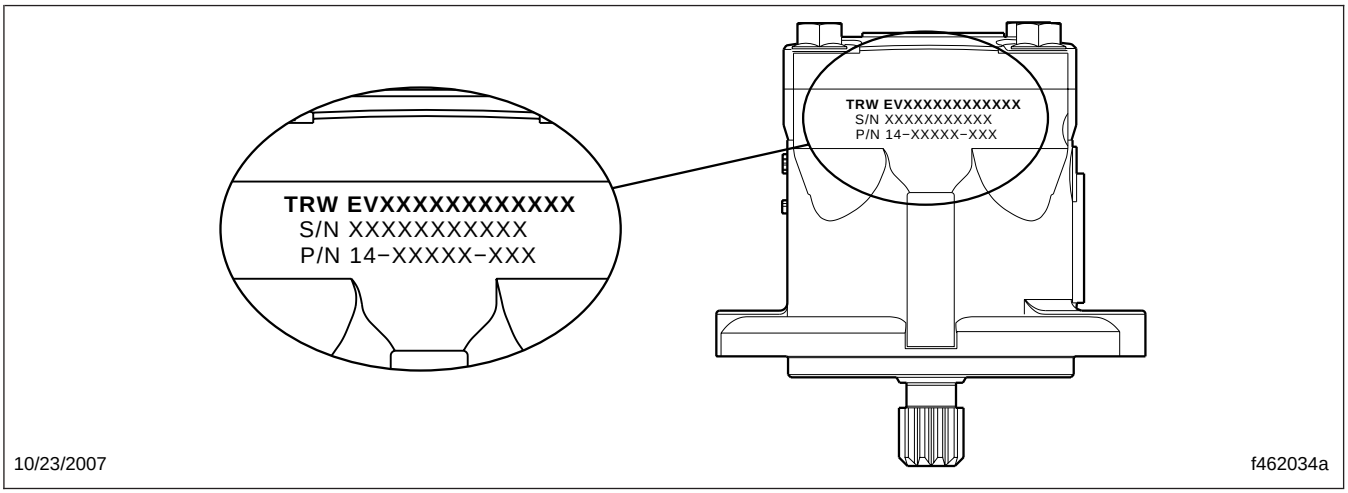


Fig. 1, Power Steering Pump Identification Numbers

Removal

WARNING

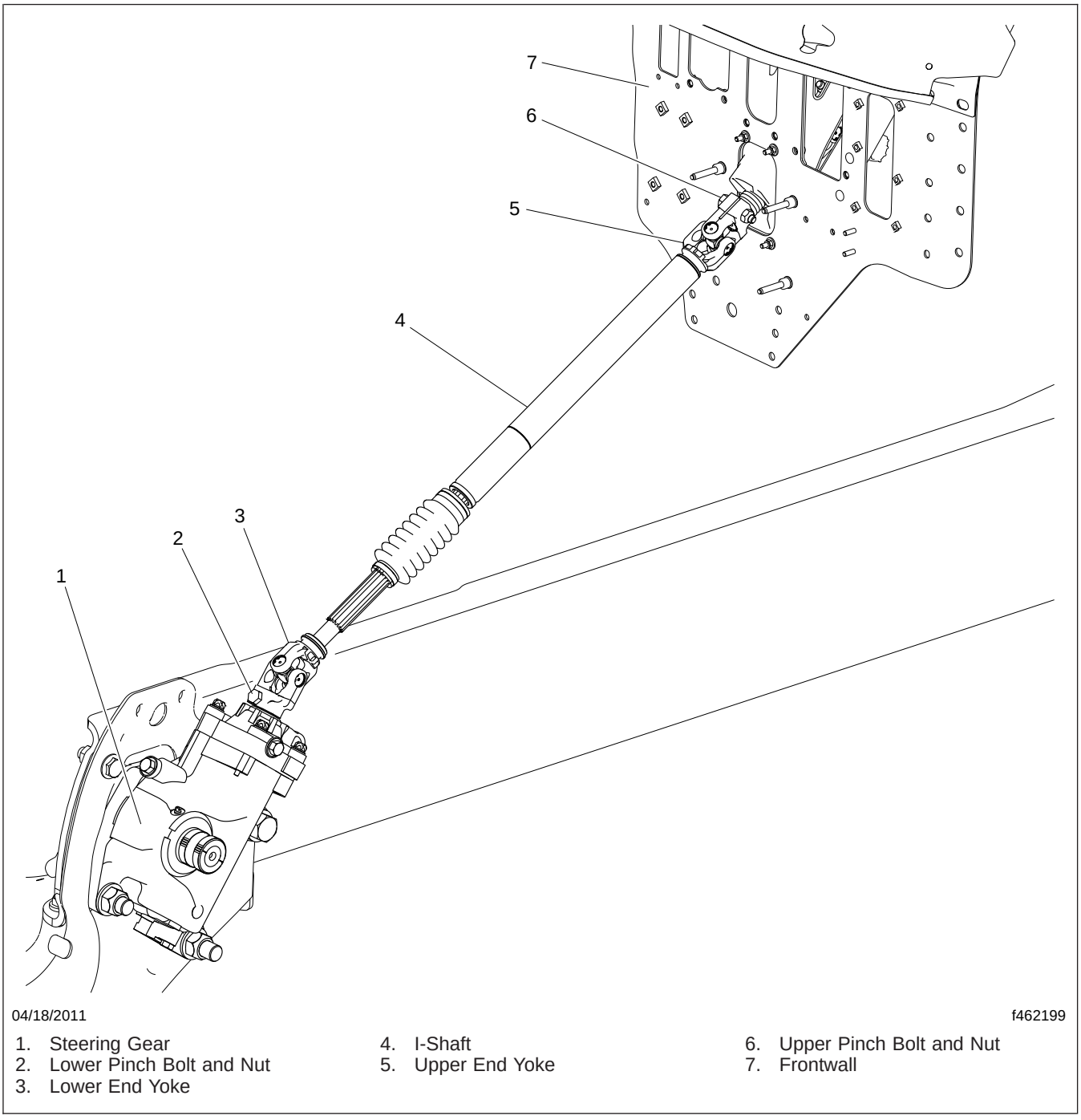
All steering mechanisms are essential to the safe operation of the vehicle. Follow the instructions in this subject exactly. Failure to do so may result in loss of steering, which could cause personal injury or property damage.

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service operations will be done.
2. Shut down the engine, apply the parking brakes, chock the tires, and open the hood.
3. Remove and discard the pinch bolt and nut from the lower end of the steering intermediate shaft (I-shaft). See **Fig. 1**.
4. Remove and discard the pinch bolt and nut from the upper end of the steering I-shaft.
5. Remove the steering I-shaft.

Installation

1. Using a new M10 x 1.25 pinch bolt and nut, attach the steering I-shaft to the steering gear input shaft. Tighten the bolt 30 to 35 lbf·ft (41 to 47 N·m).
2. Using a new M10 x 1.25 pinch bolt and nut, attach the steering I-shaft to the steering column shaft end. Tighten the bolt 30 to 35 lbf·ft (41 to 47 N·m).
3. Apply torque seal, OGP F900WHITE, to the exposed pinch bolt threads and nuts.

Removal and Installation



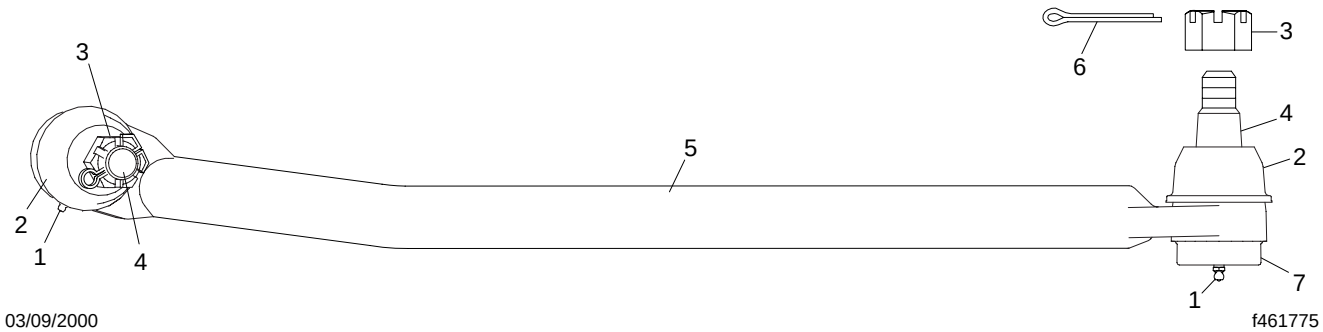
1. Steering Gear
2. Lower Pinch Bolt and Nut
3. Lower End Yoke
4. I-Shaft
5. Upper End Yoke
6. Upper Pinch Bolt and Nut
7. Frontwall

Fig. 1, I-Shaft Assembly

General Description

A fixed-length drag link assembly connects the steering gear pitman arm to the axle steering arm. The ball stud and socket assemblies at each end of the drag link prevent binding when the relative angles of the pitman arm and steering arm change as the vehicle is steered or the front axle moves up or down.

Both ball stud sockets of a fixed-length drag link assembly are an integral part of the drag link; they cannot be moved to change its length. See **Fig. 1**. The ball studs and sockets are a dual-seat design.



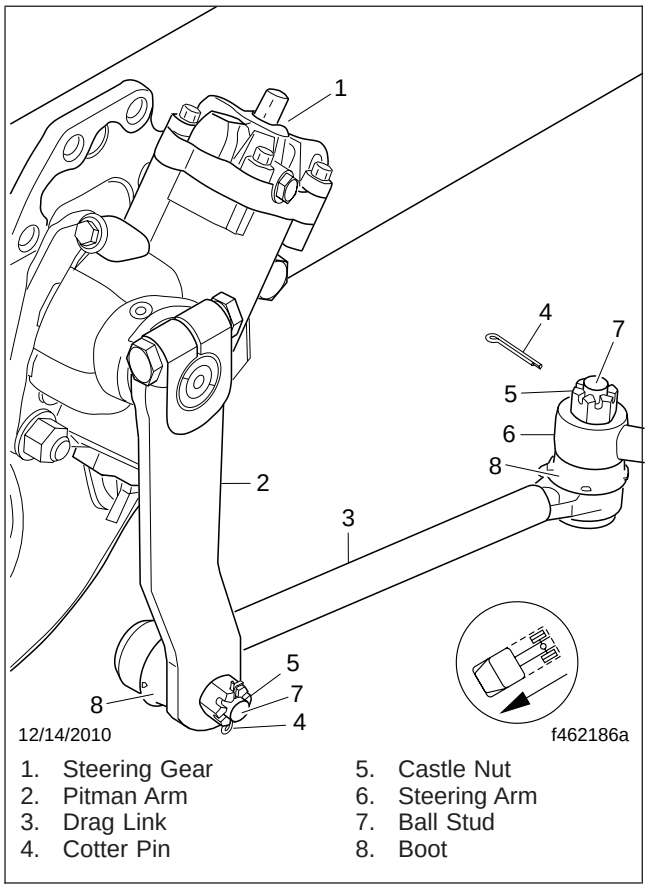
1. Grease Fitting
2. Ball Stud Cover
3. Castle Nut
4. Tapered Ball Stud
5. Drag Link
6. Cotter Pin
7. Dust Cap

Fig. 1, Fixed-Length Drag Link Assembly

Drag Link Removal and Installation

Removal

1. Position the front tires straight ahead. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where service work will be done. *Do not move the tires from the straight-ahead position during removal or at any time while the drag link is removed.*
2. Apply the parking brakes, chock the tires, and open the hood.
3. At both ends of the drag link, remove the cotter pins and castle nuts from the ball studs. See **Fig. 1**.



1. Steering Gear
2. Pitman Arm
3. Drag Link
4. Cotter Pin
5. Castle Nut
6. Steering Arm
7. Ball Stud
8. Boot

Fig. 1, Drag Link Assembly

4. Using a ball stud removal tool, remove the ball studs from the pitman arm and the axle steering arm.
5. Check the ball stud cover for damage. If necessary, replace the cover using the instructions in **Subject 120**.

Installation

1. Insert the axle-end ball stud up through the bottom of the axle steering arm, then install the castle nut and tighten it finger-tight. See **Fig. 1**.
2. Align the hole in the lower end of the pitman arm with the forward ball stud. Insert the ball stud in the pitman arm from the inboard side. Install the castle nut.
3. Tighten the ball stud castle nuts according to the values in **Table 1**.

Torque Values	
Size	**Torque: lbf·ft (N·m)**
3/4–16	90 to 170 (122 to 230)
7/8–14	160 to 300 (217 to 407)

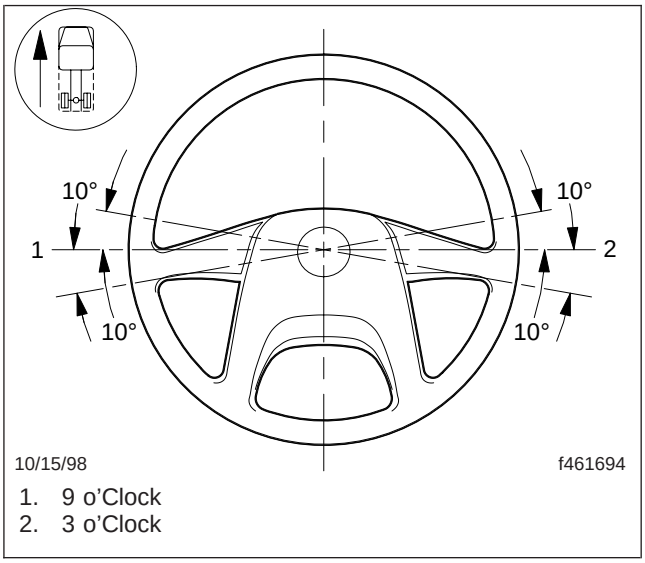
Table 1, Torque Values

WARNING

Install and lock new cotter pins in the ball studs and nuts. Failure to do so could result in disengagement of the components, causing loss of steering control, which could result in personal injury and property damage.

4. Install and lock a new cotter pin in each of the ball studs and nuts.
5. Check the *108SD and 114SD Maintenance Manual* to determine if lubrication of the drag link is required. If so, follow the instructions in the maintenance manual.
6. Check the axle stop settings, and adjust them if needed. For instructions, see **Group 33**.
7. Check the settings of the steering gear poppet valves. Adjust them if needed. For instructions on checking and adjusting, see the applicable steering gear section in **Group 46**.
8. With the front tires pointing straight ahead and no load on the vehicle, the steering wheel spokes should be within ±10 degrees of center. See **Fig. 2**. If not, remove the steering wheel and install it in the correct position.

Drag Link Removal and Installation



1. 9 o'Clock
2. 3 o'Clock

Fig. 2, Center the Steering Wheel

Testing

WARNING

All steering mechanisms are essential to the safe operation of the vehicle. Follow the instructions in this subject exactly. Failure to do so may result in loss of steering, which could cause personal injury or property damage.

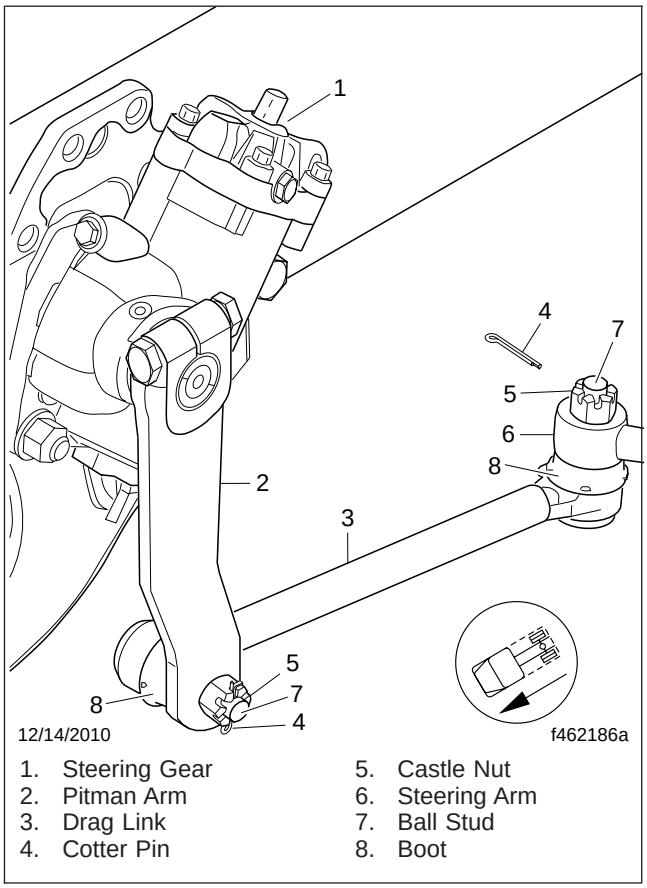
1. Shut down the engine and chock the rear tires.
2. Have someone turn the steering wheel from left to right. As the steering wheel is turned, check for looseness between the ball stud and the pitman arm, and between the other ball stud and the steering arm. See **Fig. 1**.

   If there is looseness, replace the drag link. If there is 1/8-inch (3-mm) looseness or more, do not drive the vehicle until the drag link is replaced. See **Subject 100** for replacement instructions.
3. Check for loose ball stud castle nuts.If the ball stud *castle nut* is loose, replace the castle nut and cotter pin. Tighten the ball stud castle nut according to the values in **Table 1**.

Torque Values	
Size	**Torque: lbf·ft (N·m)**
3/4–16	90 to 170 (122 to 230)
7/8–14	160 to 300 (217 to 407)

Table 1, Torque Values

4. Inspect the drag link boots (at both the pitman arm and the steering arm ends) for cracks, splits, or other damage. Replace boots as needed. See **Subject 100** for drag link removal and installation instructions.
5. Pump fresh grease into the drag link until the old grease is purged.



1. Steering Gear
2. Pitman Arm
3. Drag Link
4. Cotter Pin
5. Castle Nut
6. Steering Arm
7. Ball Stud
8. Boot

Fig. 1, Drag Link Assembly

Replacement

1. Remove the drag link. For removal instructions, see **Subject 100**.

NOTICE

Use care when removing the ball stud cover. Damage to the sealing surface of the socket forging could occur.

2. Using a screwdriver, press or tap on the flanged portion of the cover and remove it from the ball stud socket assembly. See **Fig. 1**.
3. Using a clean rag, wipe off all grease and dirt from around the ball stud and socket throat.
4. Grease the socket throat and ball stud with a multipurpose chassis grease NLGI Grade 2 (8% 12-hydroxy lithium stearate grease) or NLGI Grade 1 (6% 12-hydroxy lithium stearate grease); Grade 2 is preferred. Using the same grease, fill the new ball stud cover three-quarters full.
5. Position the socket assembly in a large vise, or on a press so that the ball stud is perpendicular to the socket stem.

NOTICE

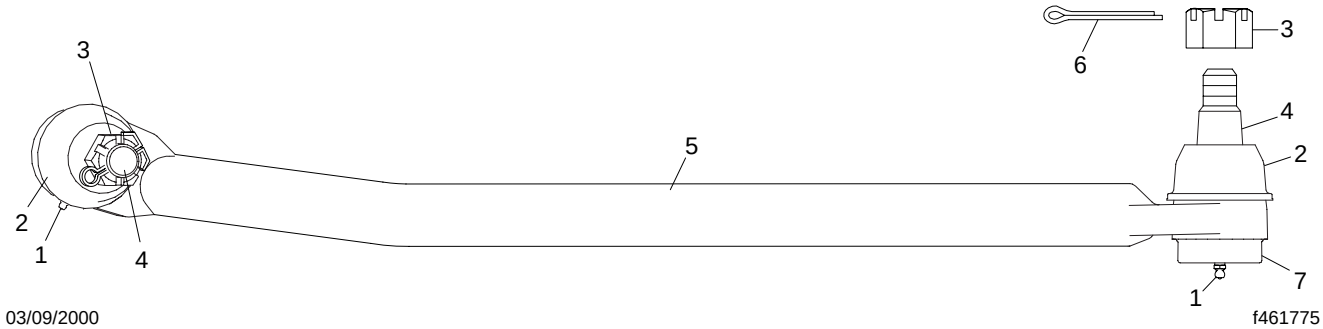
Do not use a screwdriver, chisel, punch, or any other sharp-pointed tool to install the ball stud cover. Using these types of tools could cut and damage the cover.

Do not apply excessive pressure when pressing on the seal. Too much pressure during installation could deform the cover and result in incorrect sealing.

IMPORTANT: To install the stud cover, use a section of tubing that has an inside diameter as close as possible to the outside diameter of the stud cover. Also, make sure that the inside edge of the tube is chamfered (angled) to avoid cutting the rubber stud cover.

6. Using a section of tubing, press on the new stud cover. The cover is in place when the flanged portion of the cover is seated on the machined section (sealing face) of the socket forging.
7. Install the drag link. For instructions, see **Subject 100**.

Ball Stud Cover Replacement



1. Grease Fitting
2. Ball Stud Cover
3. Castle Nut
4. Tapered Ball Stud
5. Drag Link
6. Cotter Pin
7. Dust Cap

Fig. 1, Drag Link Assembly

General Description

NOTE: Procedures in this section are slightly modified from the original component manufacturer's service literature. Consult the manufacturer's service literature for additional information.

The THP60 and PCF60 power steering gears are integral hydraulic power steering gears that contain a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The pressure required for the steering gear to overcome resistance at the steered wheels is provided by the power steering pump. The rotary control valve directs the flow of hydraulic fluid to the appropriate cylinder cavity in the steering gear (and in the auxiliary cylinder in a dual steering gear system) at the proper flow rate and pressure. As the steering wheel is turned faster or slower, more or less fluid will be required by the gear.

If the rotary control valve is controlling an auxiliary cylinder, increased minimum flow is required (generally at least 75 percent) based on the size of the auxiliary cylinder and the steering geometry of the vehicle.

Principles of Operation

When the driver turns the steering wheel, that force travels from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to the force exerted by the torsion bar, the worm shaft moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. Grooves in the rack piston mesh with teeth in the sector shaft and, as the piston slides back and forth, it turns the sector shaft. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is linked to the steered wheels. Because of this resistance, the torsion bar activates the control valve, which directs pressurized fluid to the upper or lower cylinder cavity (depending on the direction of turn). The pressurized fluid assists in moving the rack piston up or down in the cylinder bore by providing the extra force needed to overcome the resistance from the front wheels and allows the worm shaft to slide the rack piston in the cylinder bore.

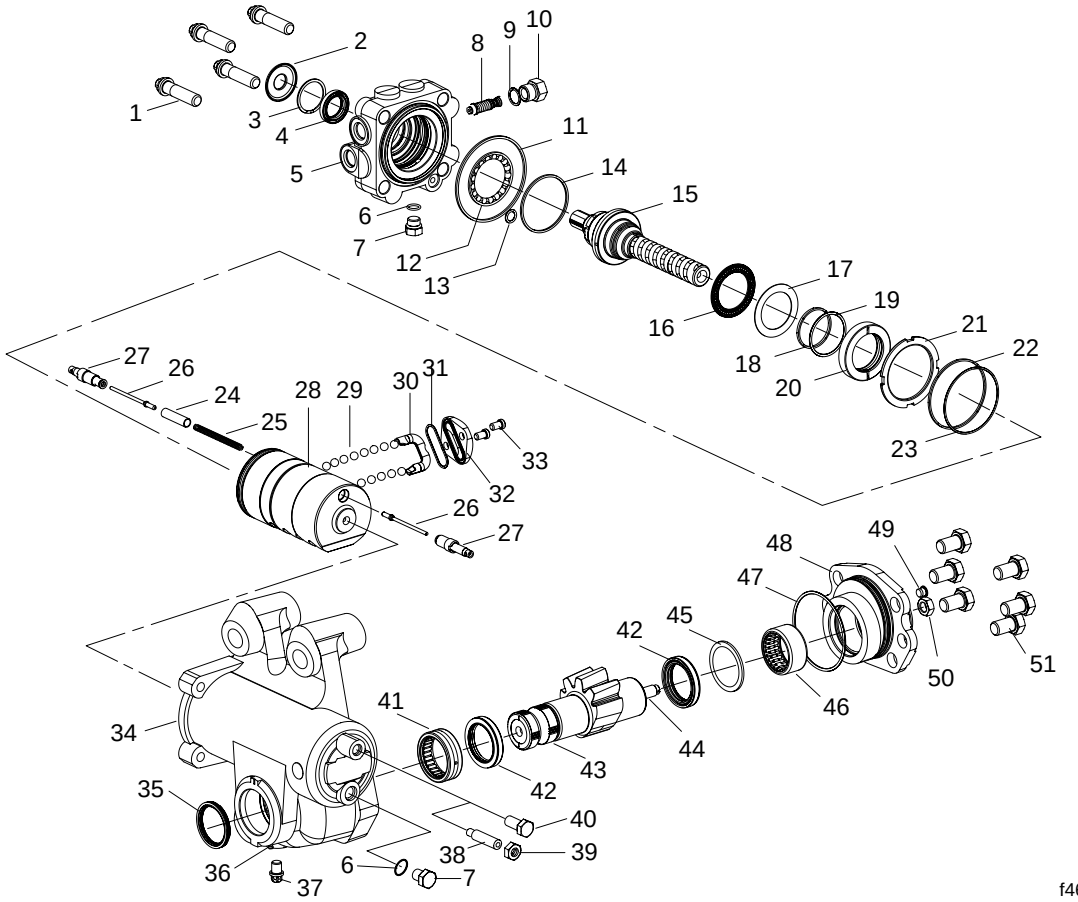
If the steered wheels receive a shock load, the shock forces are transmitted through the sector shaft to the rack piston and on to the worm shaft. The internal construction of the steering gear causes the control valve to send pressurized fluid to the correct cylinder cavity to resist the shock forces. By absorbing the shock forces hydraulically, the steering gear prevents kickback at the steering wheel.

Most THP60 and PCF60 steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. As the front wheels reach the axle stop—the farthest the wheels can turn in either direction—one poppet or the other, depending on the direction of the turn, will trip to prevent steering gear damage. The tripped poppet reduces pressure in the gear, heat generated by the power steering pump, and outside forces acting on the steering linkage.

SomeTHP60 and PCF60 steering gears are also supplied with a relief valve. The relief valve limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

See **Fig. 1** for an exploded view of the steering gear.

General Information



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, TRW THP/PCF Steering Gear

Removal

1. Verify that the axle stops are adjusted correctly. Ensuring correct axle stop adjustment will eliminate the possibility of resetting steering gear poppet valves after the gear is installed. See **Group 33** for instructions.
2. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work is to be done.
3. Turn off the engine, apply the parking brakes, and chock the tires.
4. Disconnect the batteries and open the hood.
5. Remove all dirt from all fittings and hose connections on the steering gear.
6. Drain the fluid from the power steering system. Disconnect the hydraulic lines from the steering gear, marking the lines for later reference. Plug the lines and fittings to keep out dirt and debris.
7. Remove the pitman arm.
   - 7.1 Remove and discard the pinch bolt, nut, and washer (if equipped) that attach the pitman arm to the steering gear sector shaft.
   - 7.2 Using a two-jaw puller, remove the pitman arm from the steering gear sector shaft. See **Fig. 1**.
8. Disconnect the steering driveline from the steering gear input shaft.
   - 8.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   - 8.2 Remove the end yoke from the input shaft.

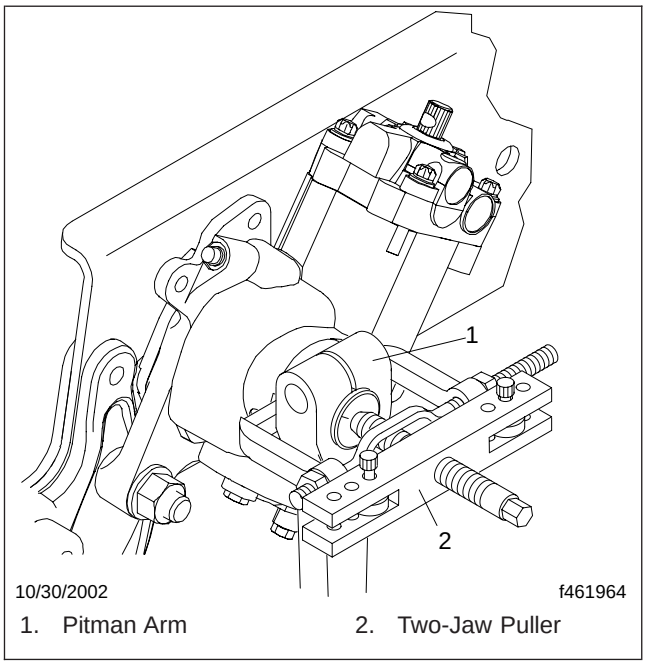


Fig. 1, Pitman Arm Removal

WARNING

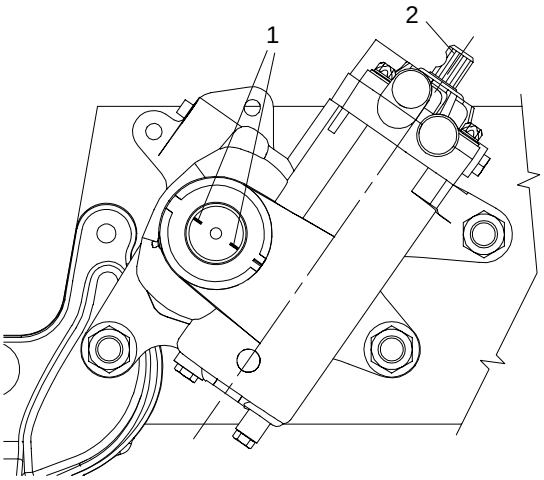
The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

9. Remove the fasteners that secure the steering gear to the frame rail. Remove the steering gear.

Installation

1. Mount the steering gear on the frame rail and install the mounting fasteners. Tighten the fasteners 342 to 434 lbf·ft (464 to 588 N·m).
2. Center the steering gear so that the sector shaft alignment mark is at a 90-degree angle to the steering gear input shaft centerline. Make sure that the timing mark on the sector shaft is aligned with the timing mark on the steering gear, and that the steering gear remains centered as the installation continues. See **Fig. 2**.
3. Connect the steering driveline to the steering gear input shaft.
   - 3.1 Align the hole in the steering driveline lower end yoke with the indentation on the input shaft.

Steering Gear Removal and Installation



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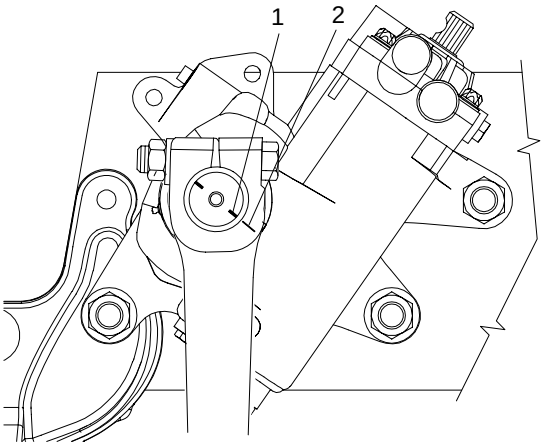
1. Sector Shaft Alignment Mark
2. Input Shaft

Fig. 2, Sector Shaft Aligned With Input Shaft Centerline



11/04/2002 f461966

1. Sector Shaft Timing Mark
2. Pitman Arm Timing Mark

Fig. 3, Timing Mark Alignment

3.2 Using a new pinch bolt and nut, attach the driveline lower end yoke to the input shaft. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

3.3 Apply torque seal, OGP F900WHITE, to the pinch bolt and nut.

4. Install the pitman arm.

4.1 Make sure that the timing mark on the pitman arm is aligned with the timing mark on the sector shaft. See **Fig. 3**.

⚠ WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, wear safety glasses and maintain a firm grip on the chisel at all times. Otherwise, the chisel may fly loose, which could cause an injury.

NOTE: The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the arm. To wedge the slot open, drive a chisel into the slot using a ball-peen hammer. Hold the chisel in place and install the pitman arm on the sector shaft. Remove the chisel from the slot.

4.2 Using a new pinch bolt, nut, and washer (if applicable), attach the pitman arm to the steering gear sector shaft.

4.3 Tighten the nut 230 lbf·ft (312 N·m).

5. If the hydraulic line fittings were removed, attach them to the steering gear. Tighten the fittings 37 lbf·ft (50 N·m). Tighten the jam nut on the pressure line fitting to a maximum 41 lbf·ft (56 N·m).
6. Remove the plugs from the hydraulic lines. Connect the hydraulic lines to the steering gear. Tighten the nut on each fitting finger tight. Then use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.
7. Connect the batteries.
8. Fill and bleed the steering system. For instructions, refer to **Subject 110**.
9. Close the hood and perform the post-service checks in **Subject 150**.

Air Bleeding the System

IMPORTANT: Make sure the poppets are set correctly before beginning this procedure. If the poppets are not set correctly, see **Subject 140** for instructions.

⚠ WARNING

Do not mix hydraulic fluid types or use unapproved fluids. Doing so could cause seal deterioration, leaks, loss of steering assist, and spillage on the roadway, which could result in serious personal injury or death.

1. Fill the power steering reservoir nearly full with automatic transmission fluid that meets Dexron III or TES-389 specifications. Do not turn the steering wheel.
2. Start the engine and let it idle for ten seconds, then shut it off. Check and fill the reservoir. Repeat this step at least three times, checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

3. Start the engine and let it idle for two minutes. Do not turn the steering wheel. Shut off the engine and check the fluid level in the reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add more fluid.
4. Start the engine again. Turn the steering wheel from full left to full right several times. If needed, add more fluid to the reservoir.

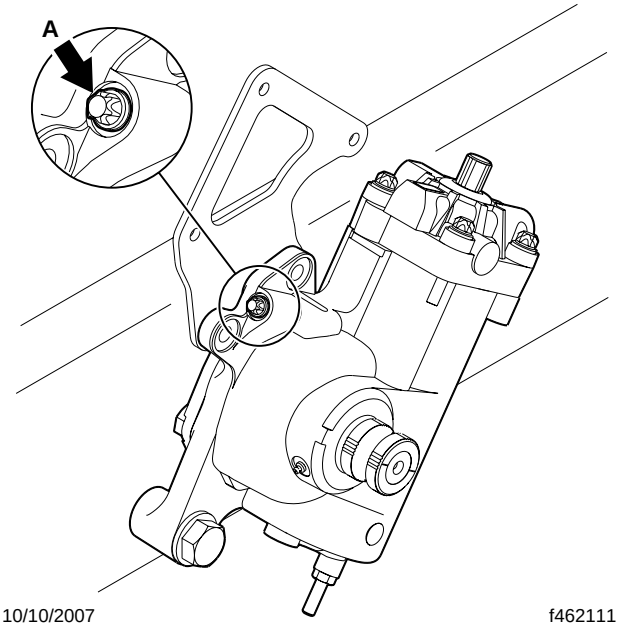
   Automatic bleed systems should now be free of trapped air. See **Fig. 1**

   If the vehicle has a manual bleed system (**Fig. 2**), proceed to the next step.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

5. With the wheels in the straight-ahead position, loosen the manual bleed screw two to three turns. Allow air and aerated fluid to bleed out until only clear fluid is seen. Close the bleed screw and add fluid to the reservoir if needed.

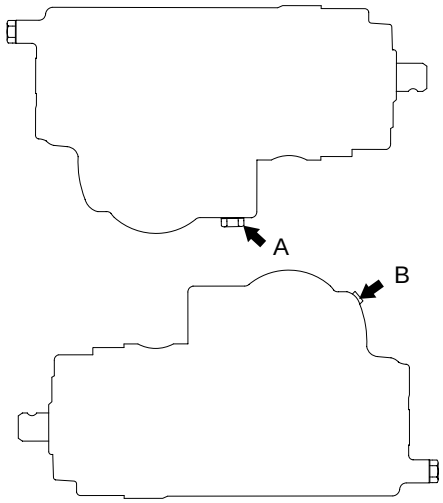
   Repeat this step until all air is out of the system. Tighten the bleed screw 40 to 50 lbf·in (452 to 565 N·cm).



A. Location of automatic bleed plug.

Fig. 1, Steering Gear with Automatic Bleed Plug

Air Bleeding the System



12/07/2001 f461929

A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 2, Steering Gears With Bleed Systems

Replacement

NOTE: The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, the power steering pump should have a minimum of 1500 psi (10 342 kPa) available.

1. Turn off the engine, apply the parking brake, and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. Cap the return port of the steering gear with a high pressure fitting.
3. Remove the steering driveline from the steering gear input shaft.
4. Remove the dirt and water seal (**Fig. 1**, Item 2) from the steering gear. Save this seal to determine the correct size of the new seal.
5. Using a clean cloth, remove all grease from around the input shaft.
6. Using a screwdriver inserted into the notch formed in the end of the retaining ring (**Fig. 1**, Item 3), remove the retaining ring. Be careful not to scratch the bore with the screwdriver.
7. Using a pinch bolt and nut, attach the steering driveline to the input shaft but do not tighten the nut.
8. Tie or wrap a shop towel around the input shaft and place a drain pan under the steering gear to catch the oil.

⚠ WARNING

Do not mix hydraulic fluid types or use unapproved fluids. Doing so could cause seal deterioration, leaks, loss of steering assist, and spillage on the roadway, which could result in serious personal injury or death.

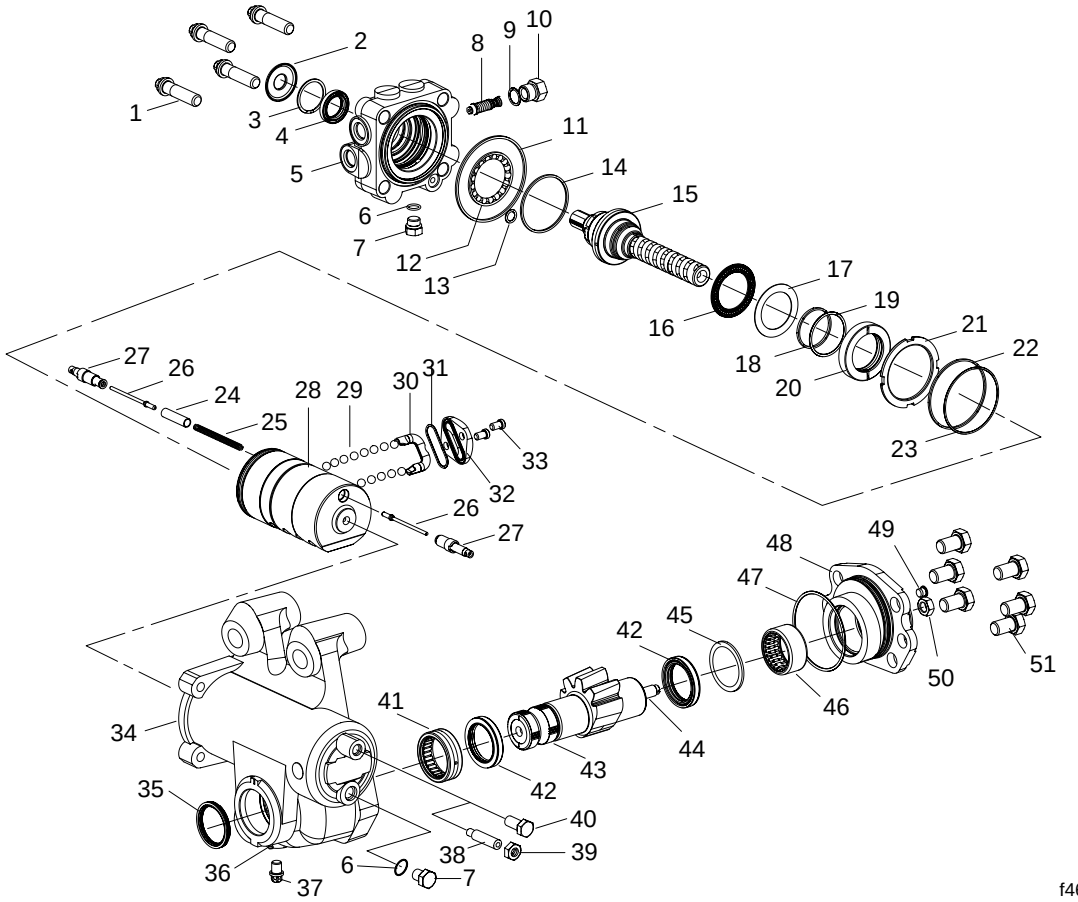
9. If needed, fill the power steering reservoir with automatic transmission fluid that meets Dexron III or TES-389 specifications.
10. With the vehicle in neutral, momentarily turn the starter. If the engine starts, quickly turn it off. This should force out the input shaft seal.
11. Remove the shop towel. Disconnect the steering driveline from the steering gear and remove the input shaft seal (**Fig. 1**, Item 4).
12. Inspect the seal area of the valve housing for seal fragments. Remove all seal fragments.
13. Check the input shaft seal for heat damage. If the seal is stiff and brittle, it is probably heat damaged. Determine and fix the cause of excessive heat in the vehicle.

⚠ WARNING

Do not use a socket to install the input shaft seal. You will not be able to control the seal installation depth with a socket and this could lead to leaks. Leaks could result in loss of steering assist and spillage on the roadway, which could result in serious personal injury or death.

14. Install a new input shaft seal.
    - 14.1 Using Exxon Polyrex® EP2 grease (045422), lubricate the inside diameter of the new input shaft seal and install it on the input shaft.
    - 14.2 Using a hammer and seal driver (J37073), tap the driver until the shoulder of the driver is square against the valve housing. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.
15. Install a new retaining ring in the groove.
16. Using Exxon Polyrex EP2 grease, pack the end of the valve housing bore.
17. Install a new dirt and water seal.
    - 17.1 Compare the replacement seals to the old seal to determine the correct size, or measure the major diameter of the input shaft serrations. See **Table 1** for the major serration diameter and the corresponding seal part number.
    - 17.2 Apply Exxon Polyrex EP2 grease to the new dirt and water seal and install it on the input shaft. Seat it in the groove behind the serrations and against the valve housing.
18. Using a new pinch bolt and nut, attach the steering driveline to the input shaft. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).
19. Attach the return line to the steering gear return port.

Input Shaft Seal Replacement



10/21/2003 f461925

1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
33. Torx® Capscrew
34. Gear Housing
35. Dirt and Water Seal
36. Grease Fitting
37. Automatic Bleed Plug
38. Poppet Adjusting Screw
39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, TRW Steering Gear

20. Bleed the air from the system. For instructions, see **Subject 110**.

Major Serration Diameters and Corresponding Seal Part Numbers		
Major Serration Diameter: inch (mm)	**Serration Size**	**Part Number**
0.807/0.799 (20)	13/16 in (21 mm) x 36	478044
0.866/0.857 (22)	7/8 in (22 mm) x 36	478060
0.987/0.977 (25)	1 in (25 mm) x 36	478050
1.008/1.000 (25)	1 in (25 mm) x 79	478050

Table 1, Major Serration Diameters and Corresponding Seal Part Numbers

Adjustment

NOTE: The jam nut is located on the side cover.

If the steering gear is installed on the frame rail, sector shaft adjustment can only be completed if the adjusting screw jam nut is accessible. If the adjusting screw jam nut is not accessible, the steering gear must be removed. For instructions, see **Subject 100**.

1. Apply the parking brakes and chock the rear tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the housing. The line on the sector shaft should be at a 90-degree angle to the input shaft. The sector shaft is now on its center of travel. Turn the engine off.
3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Remove the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

4. From the center-of-travel position, grasp the pitman arm at the lower end of the arm and gently try to move the arm back and forth. If the pitman arm is loose or lash (free play) is detected, the sector shaft is out of adjustment.
5. Loosen the adjusting screw jam nut.
6. Slowly turn the shaft adjusting screw clockwise until you feel no lash at the sector shaft without using more than 10 lbf·ft (14 N·m) of torque. See **Fig. 1**. From this position, turn the screw clockwise 1/8 to 3/16 of a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).
7. Turn the steering wheel 1/4 turn each side of center then back to center and check the pitman arm for lash. There should be no lash. If lash is detected, loosen the jam nut and repeat the previous step as well as this step.
8. If the steering gear was removed from the frame rail, install the steering gear. For instructions, see **Subject 100**.

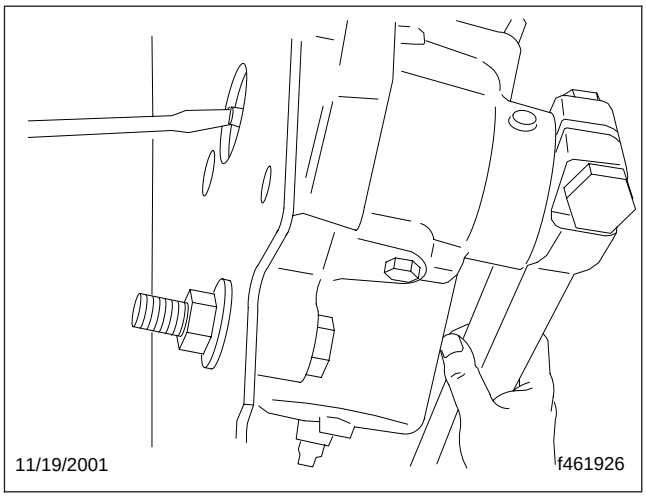


Fig. 1, Adjusting the Sector Shaft

9. Using a castle nut, attach the drag link to the pitman arm. Tighten the castle nut using the appropriate torque value.
   - 3/4–16: 90 to 170 lbf·ft (122 to 230 N·m)
   - 7/8–14: 160 to 300 lbf·ft (217 to 407 N·m)

⚠ WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in serious personal injury or property damage.

10. Continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** reverse the tightening direction of the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut, then lock the cotter pin in place.

NOTICE

Do not use a power grease gun to add grease to the sector shaft bearing. Doing so could damage the high-pressure seal and contaminate the hydraulic fluid.

11. Using only a hand-operated grease gun, add grease to the sector shaft bearing through the grease fitting in the housing until grease begins to extrude past the dirt and water seal.

Poppet Adjustment

The poppet adjustment will work in most cases with at least 1-3/4 turns of the steering wheel from each side of center.

If a large reduction in wheel cut is being made and this procedure does not work, you may have to replace or reset the poppets.

1. Check that the axle stops are adjusted appropriately. See **Group 33** for instructions.
2. Start the engine and allow the vehicle to idle for 5 to 10 minutes to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the rear tires.
4. If a new poppet adjusting screw and nut (**Fig. 1**, Items 38 and 39) are being used, turn the screw into the non-sealing end of the nut until the drive end of the screw is flush with the nut.

NOTE: The steering gear will have either a poppet fixed stop screw or a poppet adjusting screw. See **Fig. 1**. If the adjusting screw is already part of the steering gear, back the nut off of the adjusting screw until it is flush with the end of the adjusting screw.

5. Make sure that the engine is off and the wheels are in the straight-ahead position.

NOTICE

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

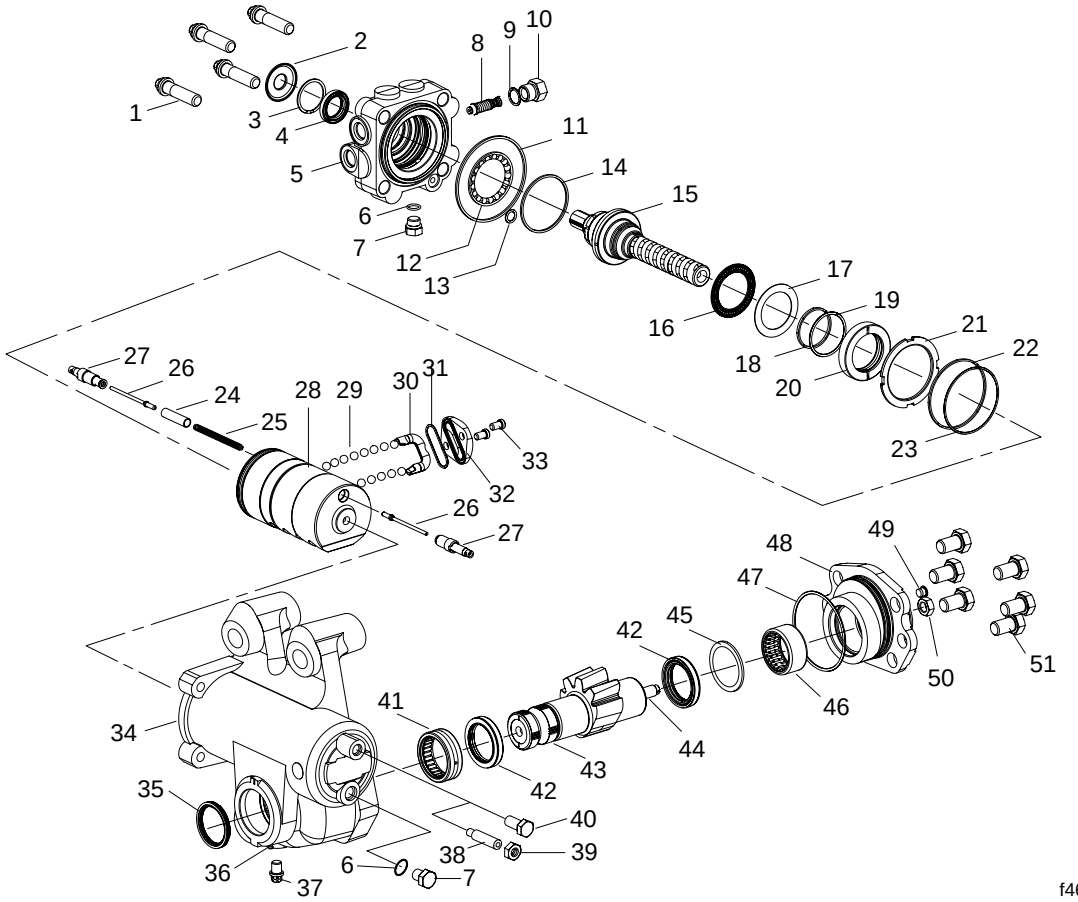
6. Using a 7/32-inch Allen wrench, turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing.
7. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.
8. Push the upper poppet out to prepare it for setting.
   - 8.1 Start the engine and let it run at idle speed.
   - 8.2 Note which sector shaft timing mark is nearest the housing piston bore.

NOTICE

Do not hold the steering wheel at full turn for more than 10 seconds at a time. The heat buildup at pump relief pressure may damage components.

   - 8.3 Turn the steering wheel in the direction that makes this timing mark move toward the adjusting screw just installed. Turn the steering wheel in this direction until axle stop contact is made.
   - 8.4 Pull hard on the steering wheel. Put up to 30 lb (133 N) of pull on a 18-inch diameter steering wheel after the axle stop is contacted.
9. Set the upper poppet.
   - 9.1 Turn the steering wheel in the opposite direction (the end of the timing mark away from the adjusting screw) until the other axle stop is contacted.
   - 9.2 Pull hard on the steering wheel. Put up to 30 lb (133 N) of pull on a 18-inch diameter steering wheel.
   - 9.3 Release the steering wheel and shut off the engine.
10. Loosen the nut and back out the adjusting screw until the adjusting screw is one inch (2.5 cm) past the nut. Tighten the nut against the housing.
11. Set the lower poppet.
   - 11.1 Start the engine and let it idle.
   - 11.2 Turn the steering wheel in the original direction (the end of the timing mark is toward the adjusting screw) until axle stop contact is made.
   - 11.3 Hold the steering wheel in this position with up to 30 lb (133 N) of pull for 10 seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.
12. Position the adjusting screw.

Poppet Adjustment on a Single Gear



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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
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7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
13. O-Ring
14. Seal Ring
15. Input Shaft Assembly
16. Thrust Bearing
17. Thrust Washer
18. Seal Ring
19. O-Ring
20. Bearing Adjuster
21. Adjuster Locknut
22. O-Ring
23. Seal Ring
24. Push Tube
25. Poppet Spring
26. Poppet
27. Poppet Seat and Sleeve Assembly
28. Rack Piston
29. Ball
30. Ball Return Guide
31. Cap Seal
32. Ball Return Guide Cap
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37. Automatic Bleed Plug
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39. Poppet Adjusting Screw Nut
40. Poppet Fixed Stop Screw
41. Roller Bearing
42. Output Seal
43. Sector Shaft Assembly
44. Sector Shaft Adjusting Screw
45. Washer
46. Roller Bearing
47. Side Cover O-Ring
48. Side Cover Assembly
49. Vent Plug, Side Cover
50. Adjusting Screw Jam Nut
51. Capscrew

Fig. 1, THP/PCF Steering Gear

12.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.

12.2 Using an Allen wrench and finger pressure only, turn the adjusting screw clockwise until the Allen wrench stops. Do not attempt to turn the adjusting screw in any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.

12.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

⚠ WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

IMPORTANT: Once the poppet adjusting screw and sealing nut are in place, and the poppet valves have been manually adjusted, the adjustment procedure must be repeated if steering travel is increased or decreased in the future.

13. The poppets have now been completely reset. Check the power steering reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add fluid that meets Dexron III or TES-389 specifications.
14. Lower the vehicle.

Post-Service Checks

After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

⚠ WARNING

Failure to check the following items could result in damage to the power steering system. This could cause loss of steering assist and spillage on the roadway, which could cause personal injury or property damage.

1. Operate the engine at low idle while turning the steering wheel through several full-left and full-right turns. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (signs that air is trapped in the system).

   If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system.

2. With the engine turned off and warm, check the power steering reservoir fluid level. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add fluid that meets Dexron III or TES-389 specifications.

3. At full-left and full-right wheel cuts, be sure the axle stops on the rear side of the spindle are set so there is at least 1/2-inch (13-mm) of clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be at least 3/4-inch (19-mm). If clearance is less, reset the axle stops.

4. Check that the poppets are set correctly. If needed, adjust them. For instructions, refer to **Subject 140**.

5. Test drive the vehicle. Check the steering wheel spoke position. If, during straight-ahead driving on a level road, the steering wheel spokes are not within ±10 degrees of the 9 o'clock and 3 o'clock positions, remove the steering wheel and reposition it. See **Fig. 1**.

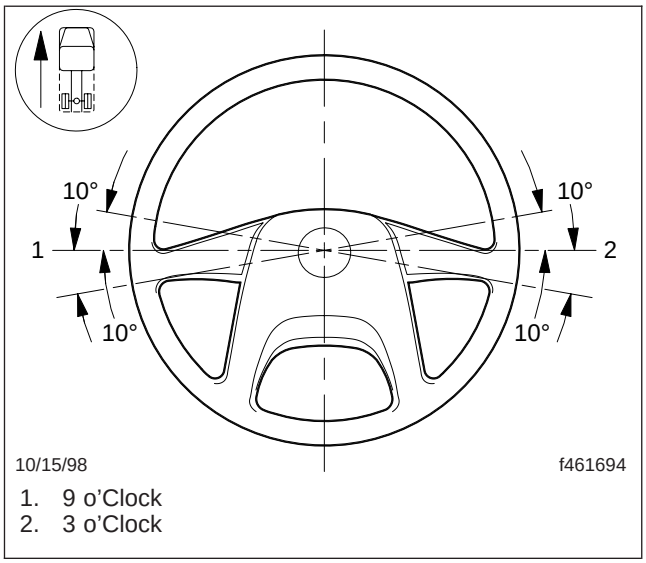


Fig. 1, Center the Steering Wheel

⚠ WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

TRW power steering gears use ATF fluid that meets Dexron III or TES-389 specifications.

Exxon Polyrex® EP2 Grease (045422) is approved for use on steering gear components.

Special tools can be ordered from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

SPX Kent-Moore Tools	
Tool Name	**Part Number**
Bearing and Seal Tool	J37071 and J37071–A
Special Tool	J36452–A
Bearing Adjuster Tool	J37070
Seal Driver Tool	J37073
Adjuster Locknut Tool	J37464

Table 1, SPX Kent-Moore Tools

Specifications	
Front Axle Capacity	14,300 pounds (6500 kg)
Minimum Flow Rate (at 1.5 steering wheel turns per second)	2.6 gpm (9.8 L/min)
Maximum Flow Rate	6 gpm (22.7 L/min)
Maximum Internal Leakage	1.2 gpm (4.5 L/min)
Maximum Operating Pressure	2685 psi (18 512 kPa)

Table 2, Specifications

General Description

NOTE: Procedures in this section have been slightly modified from the original component manufacturer's service manual. See manufacturer's service literature for additional information.

The TRW TAS85 power steering gear uses pressurized hydraulic fluid to help the driver turn the front wheels. It is an integral hydraulic power steering gear that contains a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The pressure required for the steering gear to steer the vehicle is created by the power steering pump to overcome resistance at the steered wheels. The control valve senses these requirements and directs fluid to the appropriate cylinder cavity in the steering gear at the proper flow rate and pressure.

The maximum operating pressure for the TAS85 gear is 2175 psi (14 966 kPa). The maximum flow rate is 8 gpm (30.3 L/min). The recommended minimum flow at 1.5 steering wheel turns per second is 3.9 gpm (14.8 L/min). The TAS85 power steering gear is used for front axle capacities up to 18,000 pounds (8200 kg).

Maximum internal leakage for the TAS85 gear is 1 gpm (3.8 L/min).

Principles of Operation

When the driver turns the steering wheel, that force travels from the steering wheel to the steering gear input shaft. A torsion bar, pinned at one end to the input shaft and at the other end to the worm shaft, turns with the input shaft and exerts a rotational force on the worm shaft. In response to the rotational force exerted by the torsion bar, the worm shaft moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. Grooves in the rack piston mesh with teeth in the sector shaft and, as the piston slides back and forth, it turns the sector shaft. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is linked to the steered wheels. Because of this resistance, the torsion bar activates the control valve, which directs pressurized fluid to the upper or lower cylinder cavity (depending on the direction of turn). The pressurized fluid provides the extra force needed to overcome the resistance from the steered wheels and allows the worm shaft to slide the rack piston in the gear housing.

Most TAS steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. As the front wheels reach the axle stop—the farthest the wheels can turn in either direction—one poppet or the other, depending on the direction of the turn, will trip to prevent steering gear damage. The tripped poppet reduces pressure in the gear, heat generated by the power steering fluid pump, and outside forces acting on the steering linkage.

Some TAS steering gears are supplied with a relief valve. The relief valve limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

TAS steering gears that are mounted with the sector shaft above the rack piston bore are equipped with an automatic bleed system or a manual bleed screw.

Removal

1. Place the front tires in the straight-ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work is to be done.
2. Turn off the engine, apply the parking brakes, and chock the tires.
3. Remove all dirt from all fittings and hose connections on the steering gear.
4. Drain the fluid from the power steering system. Disconnect all hydraulic lines from the gear, marking the lines for later installation reference. Seal the lines and the fittings to keep out dirt.
5. Disconnect the pitman arm from the steering gear sector shaft.
   - 5.1 Remove and discard the pinch bolt, nut, and washer (if equipped) that attach the pitman arm to the steering gear sector shaft.
   - 5.2 Remove the pitman arm using a two-jaw puller, then swing the pitman arm and drag link out of the way.
6. Disconnect the steering driveline from the steering gear input shaft, as follows.
   - 6.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

NOTICE

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   - 6.2 Remove the lower end yoke from the input shaft.

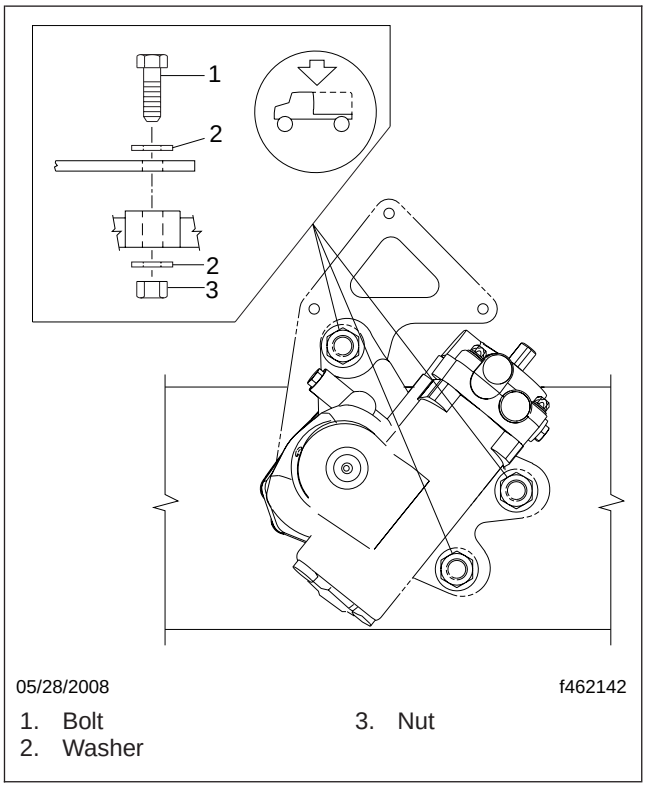
WARNING

The steering gear is heavy. Use caution when removing, lifting, or carrying the steering gear. Failure to do so could cause personal injury.

7. Remove the fasteners that attach the steering gear to the frame rail. Remove the steering gear.

Installation

1. Verify correct axle stop adjustment. For instructions, refer to **Group 33**. Ensuring correct axle stop adjustment now will eliminate the need to reset the steering gear poppet valves after the gear is installed.
2. Install the steering gear and fasteners as shown in **Fig. 1**. Tighten the fasteners 427 lbf·ft (579 N·m).



1. Bolt
2. Washer
3. Nut

Fig. 1, Steering Gear Installation

3. Center the steering gear so that the sector shaft alignment mark is at a 90-degree angle to the steering gear input shaft centerline. Make sure that the timing mark on the sector shaft is aligned with the timing mark on the steering gear, and that the steering gear remains centered as the installation continues.
4. Connect the steering driveline to the steering gear input shaft.
   - 4.1 Clean the steering gear input shaft and the inside of the driveline yoke.

Steering Gear Removal and Installation

4.2 Apply a thin film of grease to the yoke spline.

4.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).

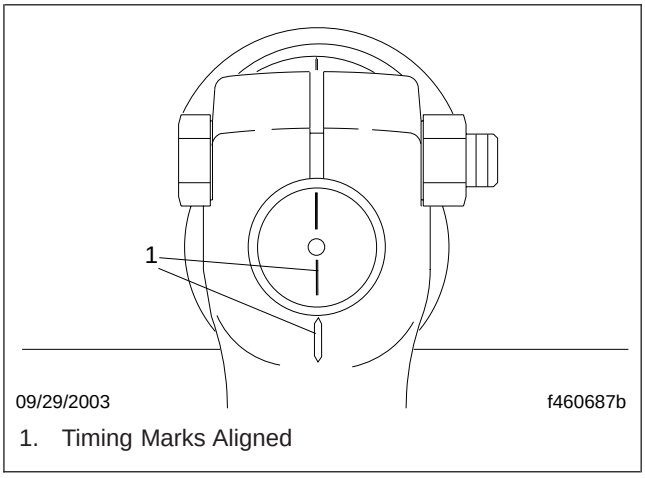
4.4 Apply Torque Seal to the exposed bolt threads and to the nut.

⚠ WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

5. Install the pitman arm.

5.1 Position the pitman arm on the steering gear, aligning the timing mark as shown in **Fig. 2**.



1. Timing Marks Aligned

Fig. 2, Typical Pitman Arm and Timing Marks

NOTE: The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the arm. Use a ball-peen hammer to drive a chisel into the slot. Hold the chisel in place. Install the pitman arm on the sector shaft. Remove the chisel from the slot.

5.2 Install a new pinch bolt, washer, and nut. Tighten the nut 200 to 230 lbf·ft (272 to 313 N·m).

5.3 Apply Torque Seal to the exposed bolt threads and to the nut.

6. If the hydraulic line fittings were removed, attache them to the steering gear. Tighten the fittings 38 lbf·ft (52 N·m). Tighten the pressure line fitting jam nut 41 lbf·ft (56 N·m).

7. Remove the plugs from the hydraulic lines. Connect the lines to the steering gear as previously marked. Tighten the nut on each fitting finger tight. Then, use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.

8. Connect the batteries.

9. Fill and bleed the steering system. For instructions, see **Subject 110**.

10. Perform the post-service checks in **Subject 150**.

Air Bleeding the System

IMPORTANT: Make sure the poppets are set correctly before beginning this procedure. If the poppets are not set correctly, see **Subject 140** for instructions.

⚠ WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist and spillage on the roadway, which could cause personal injury and property damage.

1. Fill the power steering reservoir nearly full with automatic transmission fluid that meets Dexron III or TES-389 specifications. Do not turn the steering wheel.

   Start and run the engine for ten seconds, then shut it off. Check and, if necessary, refill the reservoir.

2. Start the engine and let it idle for ten seconds, then shut it off. Check and fill the reservoir. Repeat this step at least three times, checking the fluid level in the reservoir each time.

IMPORTANT: Do not let the fluid level drop significantly or allow the reservoir to empty. Doing so may introduce air into the system.

3. Start the engine and let it idle for two minutes. Do not turn the steering wheel. Shut off the engine and check the fluid level in the reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add more fluid.

4. Start the engine again. Steer the vehicle from full left to full right several times.If needed, add more fluid to the reservoir.

   Automatic bleed systems should now be free from trapped air.

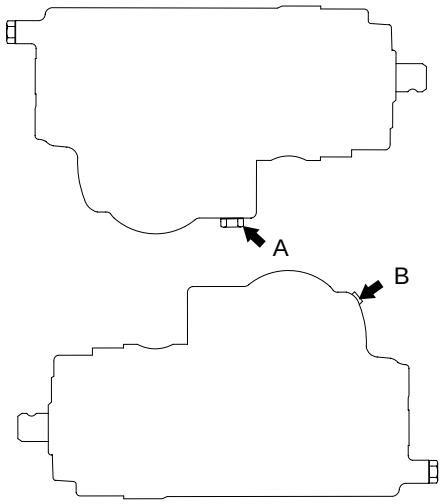
   If the vehicle has a manual bleed system (**Fig. 1**), proceed to the next step.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

5. Allow the engine to idle. Loosen the manual bleed screw one turn. Allow air and aerated fluid to bleed out until only clear fluid is seen. Tighten the manual bleed screw.

   Check and, if necessary, refill the reservoir. Repeat this step three or four times, each time checking and filling the reservoir, until the air is discharged.

6. Tighten the manual bleed screw 45 lbf·in (500 N·cm).



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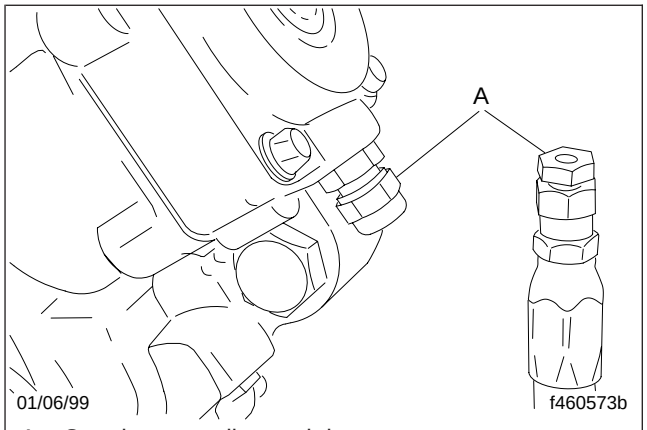
A. Steering gear with automatic bleed plug. Do not remove the bleed plug.
B. Steering gear with manual bleed plug.

Fig. 1, Steering Gears With Bleed Systems

Replacement

NOTE: The power steering pump is used in this procedure to force out the input shaft seal. To use this procedure, the power steering pump should have a minimum of 1500 psi (10 342 kPa) available.

1. Turn off the engine, apply the parking brake, and chock the tires.
2. Disconnect the return line from the steering gear and plug the line. See **Fig. 1**. Cap the return port of the gear with a high-pressure fitting.



A. Cap the return line and the return port.

Fig. 1, Disconnected Return Line

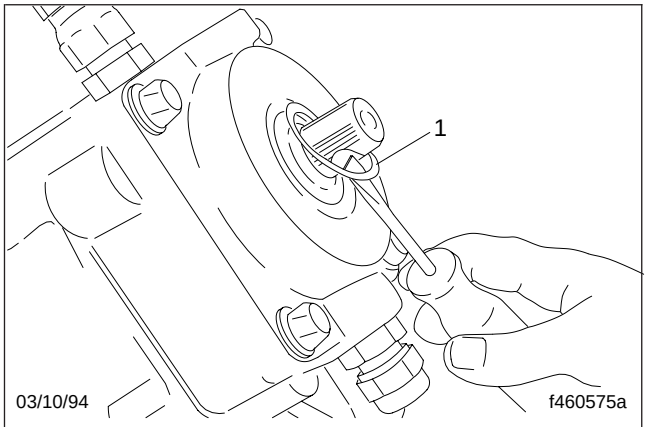
3. Disconnect the steering driveline from the steering gear input shaft as follows.

   3.1 Remove and discard the pinch bolt and nut from the steering driveline lower end yoke.

   Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   3.2 Remove the lower end yoke from the input shaft. Do not turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft into the driveline tube as you remove the lower end yoke.

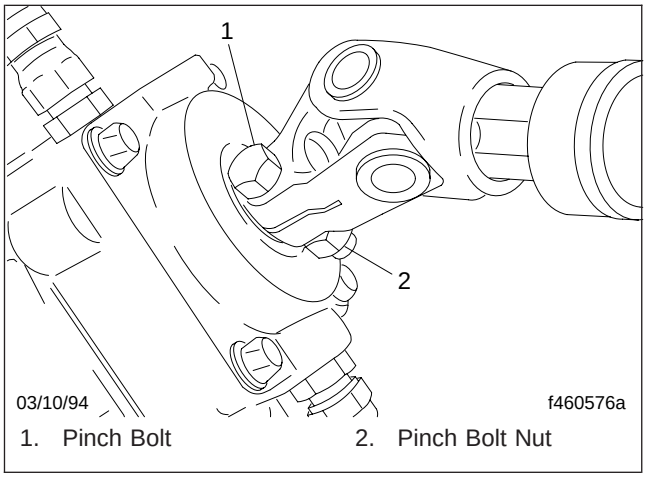
4. Remove the dirt and water seal from the steering gear. Save this seal to determine the correct size of the new seal.
5. Using a clean cloth, remove all grease from around the input shaft.
6. Using a screwdriver inserted into the notch formed in the end of the retaining ring, remove the retaining ring. Be careful not to scratch the bore with the screwdriver. See **Fig. 2**.



1. Retaining Ring

Fig. 2, Retaining Ring Removal

7. Slip the input yoke back on the input shaft, then insert but do not tighten the pinch bolt. See **Fig. 3**.



1. Pinch Bolt
2. Pinch Bolt Nut

Fig. 3, Pinch Bolt Installation

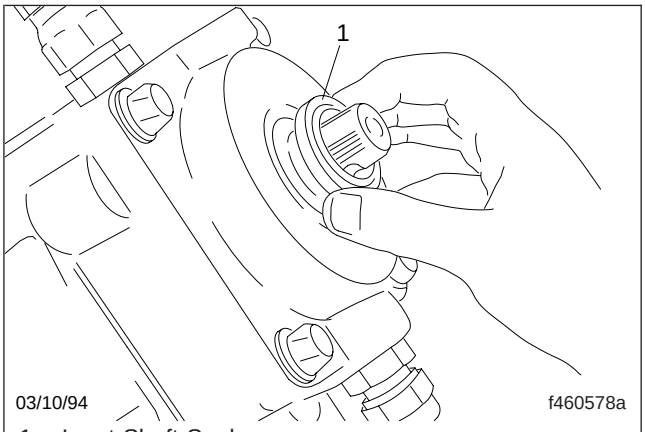
8. Tie or wrap a shop towel around the input shaft and place a drain pan under the steering gear to catch the oil.

Input Shaft Seal Replacement

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist and spillage on the roadway, which could cause personal injury and property damage.

9. If needed, fill the power steering reservoir with automatic transmission fluid that meets Dexron III or TES-389 specifications.
10. With the vehicle in neutral, momentarily turn the starter. If the engine starts, quickly turn it off. This should force out the input shaft seal.
11. Remove the shop towel, pinch bolt, and input yoke. Remove the input shaft seal. See **Fig. 4**.



1. Input Shaft Seal

Fig. 4, Input Shaft Seal Removal

12. Inspect the seal area of the valve housing for seal fragments. Remove any seal fragments.

    Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. Determine and fix the cause of any excessive heat in the vehicle. Discard the old seal.
13. Check the input shaft seal for heat damage. If the seal is stiff and brittle, it is probably heat damaged. Determine and fix the cause of excessive heat in the vehicle.

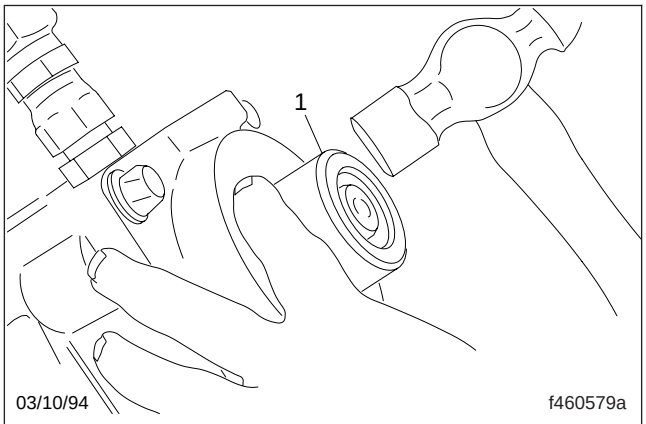
WARNING

Do not use a socket to install the input shaft seal. You will not be able to control the seal installation depth with a socket and this could lead to leaks. Leaks could result in loss of steering assist and spillage on the roadway, which could result in serious personal injury or death.

14. Install a new input shaft seal.

    14.1 Using Exxon Polyrex® EP2 grease (045422), lubricate the inside diameter of the new input shaft seal and install it on the input shaft.

    14.2 Using a hammer and seal driver (J37073), tap the driver until the shoulder of the driver is square against the valve housing. See **Fig. 5**. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.

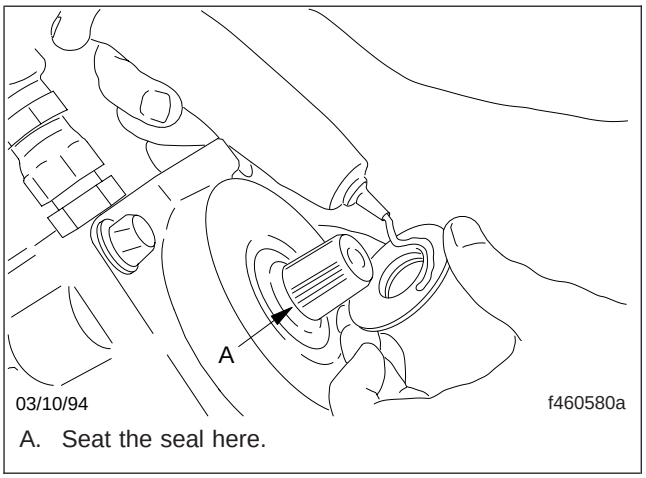


1. Seal Installer Tool

Fig. 5, Seal Installer Tool Position

15. Install the new retaining ring into the groove.
16. Using Exxon Polyrex EP2 grease, pack the end of the valve housing bore and around the input shaft with clean grease.
17. Apply more of the grease to a new dirt and water seal and install the seal over the input shaft. See **Fig. 6**. Seat it in the groove behind the serrations and against the valve housing.

    Wipe any excess grease from the valve housing bore and input shaft once the seal has been installed.



A. Seat the seal here.

Fig. 6, Dirt and Water Seal Installation

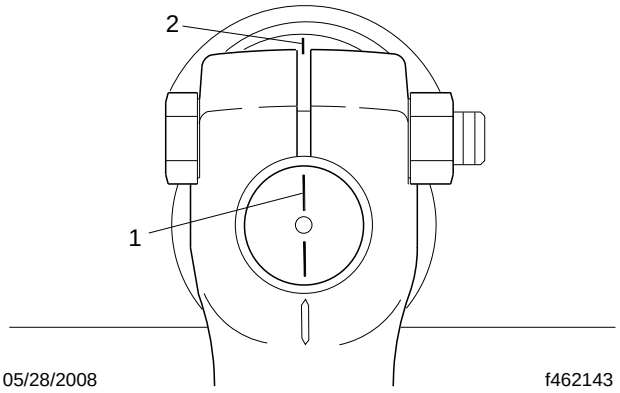
18. Connect the steering driveline to the steering gear input shaft, as follows.
    - 18.1 Clean the input shaft and the inside of the driveline yoke.
    - 18.2 Apply a thin film of grease to the yoke splines.
    - 18.3 Slide the yoke on the input shaft and install a new pinch bolt and nut. Tighten the nut 30 to 35 lbf·ft (41 to 47 N·m).
    - 18.4 Apply Torque Seal to the exposed bolt threads and to the nut.
19. Connect the return line to the steering gear return port.
20. Bleed the air from the system. For instructions, see **Subject 110**.
21. Perform the post-service checks in **Subject 150**.

Adjustment

NOTE: The jam nut is located on the side cover.

If the steering gear is installed on the frame rail, sector shaft adjustment can only be completed if the adjusting screw jam nut is accessible. If the adjusting screw jam nut is not accessible, the steering gear must be removed. For instructions, see **Subject 100**.

1. Apply the parking brakes and chock the tires.
2. With the engine on, turn the steering wheel until the timing mark on the sector shaft lines up with the timing mark on the housing. The line on the sector shaft should be at a 90-degree angle to the input shaft. The sector shaft is now on its center of travel. See **Fig. 1**.



1. Housing Trunnion Timing Mark
2. Sector Shaft Alignment Mark

Fig. 1, Timing Mark Placement

3. Turn the engine off.
4. Remove the cotter pin and castle nut that attach the drag link to the pitman arm. Remove the drag link from the pitman arm.

IMPORTANT: To avoid resetting the poppets, do not turn the input shaft more than 1-1/2 turns from the center-of-travel position while the drag link is disconnected.

5. From the center-of-travel position, grasp the pitman arm and gently try to move it back and forth. Finger pressure is adequate to detect lash (free play) of a loose sector shaft. See **Fig. 2**. If the pitman arm is loose, or lash is detected, the sector shaft is out of adjustment.
6. Loosen the sector shaft adjusting screw jam nut. See **Fig. 3**, Item 57.

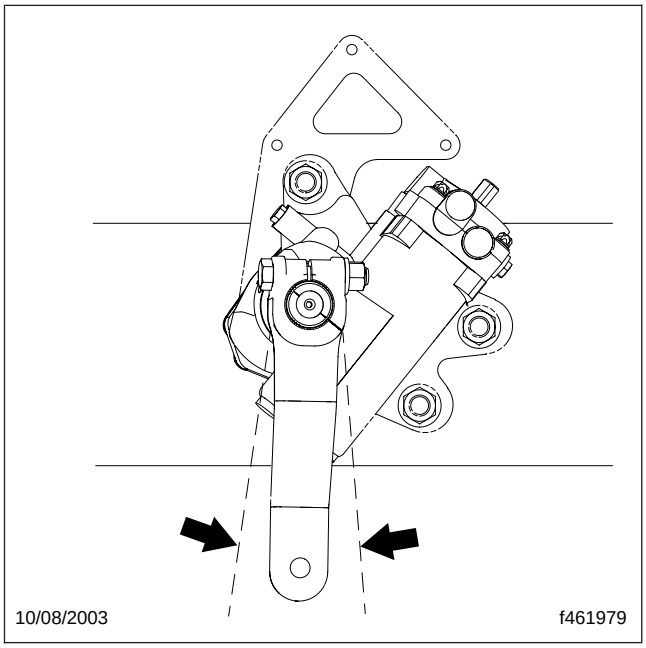
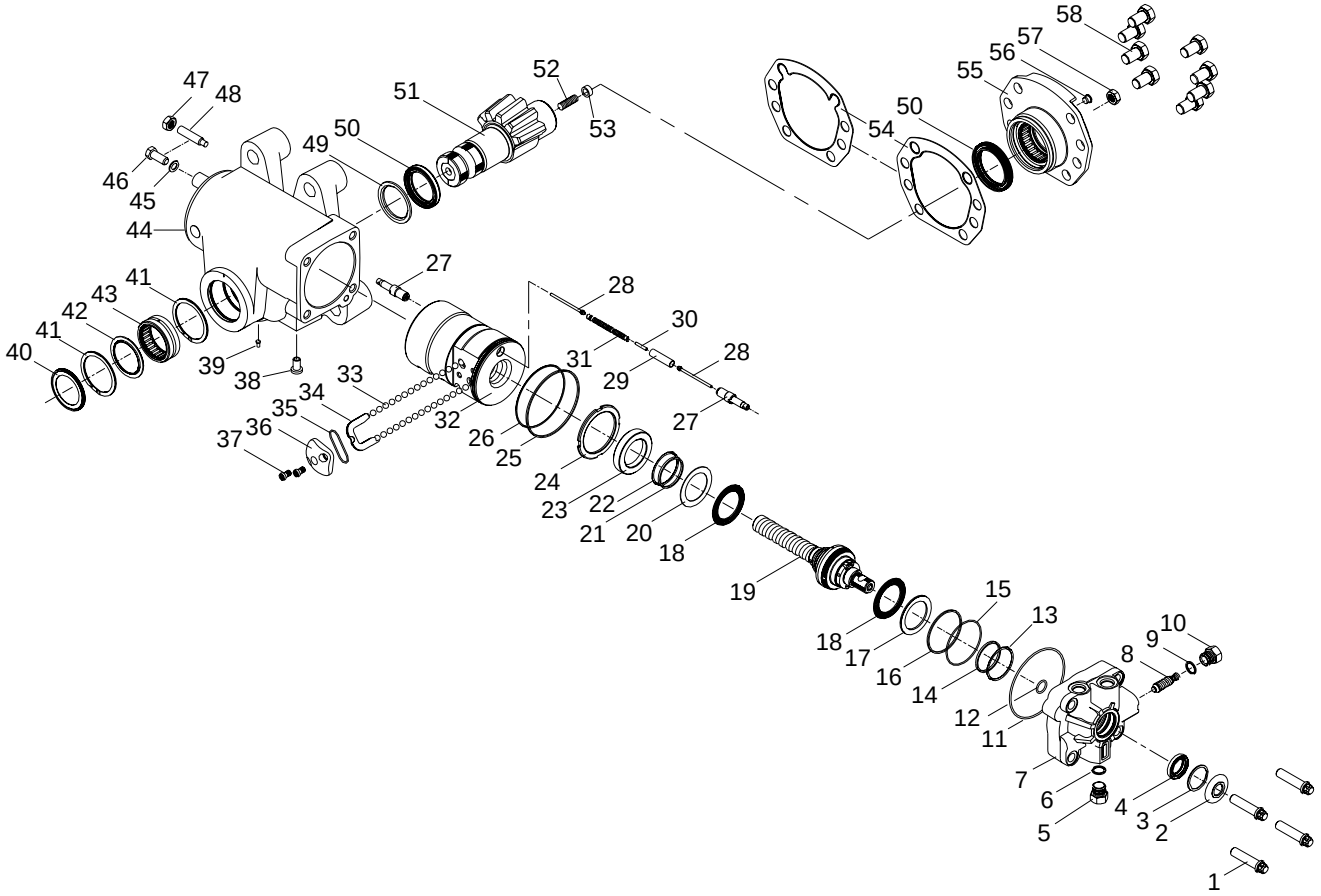


Fig. 2, Lash Check

7. Slowly turn the shaft adjusting screw clockwise until no lash is felt at the pitman arm. Use no more than 10 lbf·ft (14 N·m) of torque.

   From this position, slowly turn the adjusting screw clockwise 1/8 to 3/16 of a turn more. Hold the adjusting screw in place and tighten the jam nut 43 lbf·ft (58 N·m).
8. Turn the steering wheel 1/4 of a turn to each side of center and recheck the pitman arm for lash. If lash is detected, adjust the sector shaft again.
9. If the steering gear was removed from the frame rail, install the steering gear. For instructions, see **Subject 100**.
10. Using a castle nut, attach the drag link to the pitman arm. Tighten the castle nut using the appropriate torque value.
    - 3/4–16: 90 to 170 lbf·ft (122 to 230 N·m)
    - 7/8–14: 160 to 300 lbf·ft (217 to 407 N·m)

Sector Shaft Adjustment



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1. Bolts, Valve Housing
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Auxiliary Port Plug
6. O-Ring, Auxiliary Port Plug
7. Valve Housing
8. Relief Valve
9. O-Ring, Relief Valve
10. Relief Valve Cap
11. Seal Ring, Large
12. Seal Ring, Small
13. Seal Ring
14. O-Ring
15. Seal Ring
16. O-Ring, Valve Housing
17. Thrust Washer, Thick
18. Roller Thrust Bearing
19. Input Shaft/Valve/Worm Assembly
20. Thrust Washer, Thin
21. Seal Ring
22. O-Ring
23. Bearing Adjuster
24. Adjuster Locknut
25. Seal Ring, Rack Piston
26. O-Ring, Backup
27. Poppet Adjuster Seat and Sleeve Assembly
28. Poppet
29. Push Tube
30. Spacer Rod
31. Poppet Spring
32. Rack Piston
33. Steel Balls
34. Ball Return Guide Halves
35. Seal, Ball Return Guide Cap
36. Ball Return Guide Cap
37. Torx® Screws
38. Plug, Auto-Bleed
39. Grease Fitting
40. Dirt and Water Seal, Trunnion
41. Retaining Ring
42. Dirt Seal
43. Roller Bearing
44. Gear Housing
45. Washer, Stopscrew
46. Fixed Stop Screw, Poppet
47. Service Sealing Jam Nut
48. Service Poppet Adjusting Screw
49. Washer, Spacer
50. Output Seal
51. Sector Shaft
52. Adjusting Screw, Shaft
53. Retainer, Adjusting Screw
54. Gasket, Side Cover
55. Side Cover and Bushing/Bearing Assembly
56. Vent Plug, Side Cover
57. Jam Nut
58. Special Bolts, Side Cover

Fig. 3, TRW TAS85 Power Steering Gear Components

⚠ WARNING

Failure to install and lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control, which could result in serious personal injury or property damage.

11. Continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** reverse the tightening direction of the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut, then lock the cotter pin in place.
12. Perform the post-service checks in **Subject 150**.

Adjustment

The TAS85 steering gear has automatic poppet valves that reset themselves if the axle stops are reset for increased steering travel. However, if the axle stops are reset for **decreased** steering travel, the poppet valves must be reset manually using a special service poppet adjusting screw and sealing jam nut kit.

Use the following procedure to manually reset the poppet valves.

1. Verify that the axle stops are adjusted to the specifications in **Group 33**.

IMPORTANT: The axle stops must be set so that there are at least 1-3/4 steering wheel turns from a straight-ahead position to both a full-left and a full-right turn; otherwise the poppet valves will not work.

2. Start the engine and allow the vehicle to idle to warm the hydraulic fluid.
3. Shut down the engine, apply the parking brakes, and chock the tires.
4. If a new poppet adjusting screw and nut are being used, turn the screw into the non-sealing end of the nut until the drive end of the screw is flush with the nut.

NOTE: The steering gear will have either a poppet fixed stop screw or a poppet adjusting screw. If the adjusting screw is already part of the steering gear, back the nut off of the adjusting screw until it is flush with the end of the adjusting screw.

5. Make sure that the engine is off and the wheels are in the straight-ahead position.
6. Remove the fixed stop screw and washer, or the poppet adjusting screw and sealing nut, and discard both items.

NOTICE

Make sure the drive end of the adjusting screw is not below the face of the nut. If the drive end of the adjusting screw is below the face of the nut, the poppet seat flange will break when the upper poppet is prepared for setting.

7. Using a wrench, turn the adjusting screw and nut assembly (without turning the nut on the screw) into the housing until the nut is firmly against the housing. Tighten the nut against the housing. See **Fig. 1**.

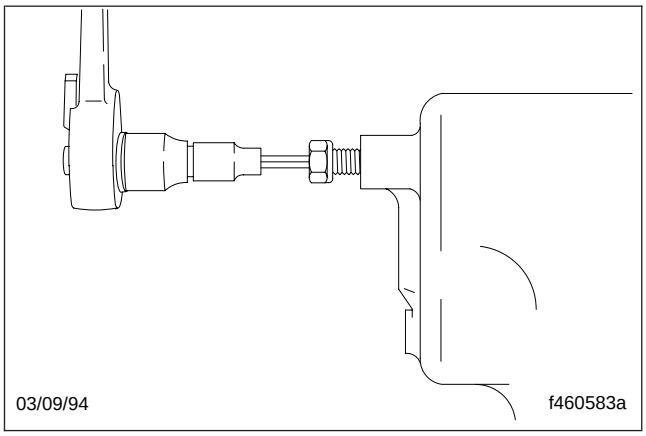


Fig. 1, Adjusting Screw and Nut Assembly

WARNING

Fill the power steering reservoir with approved, clean fluid only. Do not mix automatic transmission fluid types. If you are changing fluid types, completely flush the steering system with the fluid type being added. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist and spillage on the roadway, which could cause personal injury and property damage.

8. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.

NOTICE

Do not hold the steering wheel at full turn for more than ten seconds at a time. The heat buildup at pump relief pressure may damage components.

9. Push the upper poppet out to prepare it for setting, as follows.
   - 9.1 Start the engine and let it idle.
   - 9.2 Note which sector shaft timing mark is nearest the housing piston bore.

Poppet Adjustment

9.3 Turn the steering wheel in the direction that makes the timing mark move toward the adjusting screw just installed. Turn the steering wheel in this direction until contact is made with the axle stop.

9.4 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel after contacting the axle stop.

10. Set the upper poppet.

10.1 Turn the steering wheel in the opposite direction (the timing mark should move away from the adjusting screw) until the other axle stop is contacted.

10.2 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.

10.3 Release the steering wheel and shut off the engine.

11. Loosen the sealing nut and back out the adjusting screw until the adjusting screw is 1 inch (2.5 cm) past the nut; see **Fig. 2**. Tighten the nut against the housing.

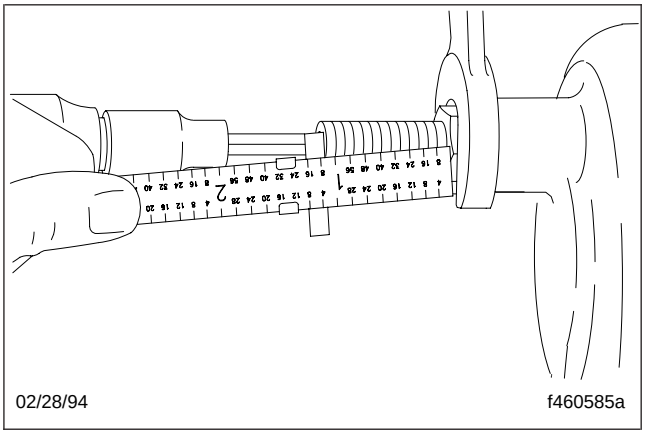


Fig. 2, Adjusting Screw Position

12. Set the lower poppet.

12.1 Start the engine and let it idle.

12.2 Turn the steering wheel in the original direction (the end of the timing mark will move toward the adjusting screw) until contact is made with the axle stop.

12.3 Hold the steering wheel in this position with up to 40 lbf (178 N) pull for ten seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.

13. Position the adjusting screw.

13.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.

13.2 Using a wrench and finger pressure only, turn the adjusting screw clockwise until the wrench stops. Do not attempt to turn the adjusting screw any farther. Pause the turning-in process each time the driver releases the steering wheel. Continue turning only while the steering wheel is held at full turn.

13.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).

⚠ WARNING

If the adjusting screw protrudes more than 1-1/16 inches (27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

14. The poppets have now been completely reset. Check the power steering reservoir. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add fluid that meets Dexron III or TES-389 specifications.

15. Lower the vehicle.

16. Perform the post-service checks in **Subject 150**.

Post-Service Checks

After power steering components have been worked on and before the vehicle is placed into service, the following items must be checked.

⚠ WARNING

Failure to check the following items could result in damage to the power steering system. This could cause loss of steering assist and spillage on the roadway, which could cause personal injury or property damage.

1. Operate the engine at low idle while turning the steering wheel through several full-left and full-right turns. With the engine running and the power steering system at operating temperature, turn the steering wheel slowly from stop to stop while checking the power steering reservoir for frothing or a change in the fluid level (signs that air is trapped in the system).

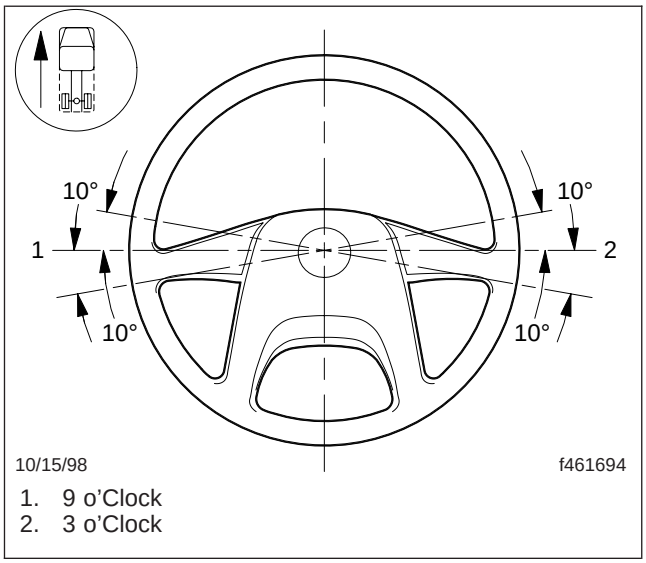
   If air is present, inspect the system for leaking hoses or loose fittings. Replace the hoses or tighten the fittings as necessary. Bleed the air from the system.

2. With the engine turned off and warm, check the power steering reservoir fluid level. The power steering fluid level should be between the MIN COLD mark and the middle mark just above it. If needed, add fluid that meets Dexron III or TES-389 specifications.

3. At full-left and full-right wheel cuts, be sure the axle stops on the rear side of the spindle are set so there is at least 1/2-inch (13-mm) of clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be at least 3/4-inch (19-mm). If clearance is less, reset the axle stops.

4. Check that the poppets are set correctly. If needed, adjust them. For instructions, refer to **Subject 140**.

5. Test drive the vehicle. Check the steering wheel spoke position. If, during straight-ahead driving on a level road, the steering wheel spokes are not within ±10 degrees of the 9 o'clock and 3 o'clock positions, remove the steering wheel and reposition it. See **Fig. 1**.



1. 9 o'Clock
2. 3 o'Clock

Fig. 1, Center the Steering Wheel

⚠ WARNING

Fill the power steering system with only approved, clean hydraulic fluid. Mixing hydraulic fluids and using unapproved hydraulic fluid could lead to seal deterioration and leaks. Leaks could result in loss of power steering assist and spillage on the roadway, which could cause personal injury or property damage.

TRW power steering gears use ATF fluid that meets Dexron III or TES-389 specifications.

Exxon Polyrex® EP2 Grease (045422) is approved for use on steering gear components.

Special tools can be ordered from:

SPX Kent-Moore
28635 Mount Road
Warren, Michigan 48092-3499
1-800-328-6657

SPX Kent-Moore Tools	
Tool	**Part Number**
Bearing Adjuster Tool	J37070
Poppet Adjuster Seat Tool	J36452
Seal Installer Tool	J37073

Table 1, SPX Kent-Moore Tools

General Description

The vehicle fuel system delivers fuel to the engine and consists of fuel tanks, tank mounting components, fuel lines, and shutoff valves.

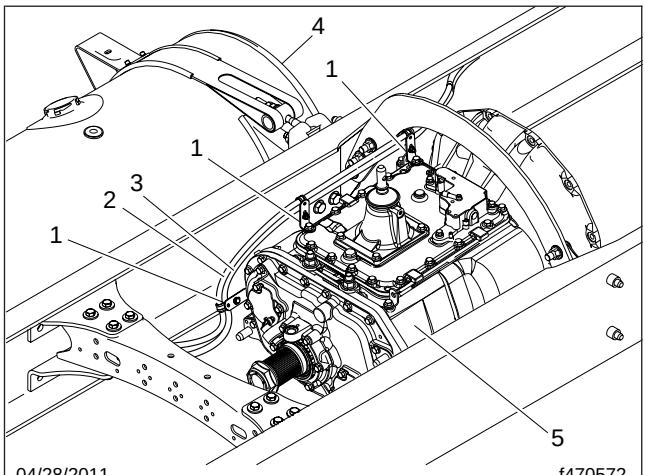
NOTE: Fuel filters, injectors, transfer pumps, and governors are considered to be parts of the **engine fuel system**, which is considered separate from the **vehicle fuel system**. For service and maintenance information on the engine fuel system, refer to the engine manufacturer's manuals.

The fuel tanks are held in place by metal straps and brackets that transfer the load to the vehicle frame. Flexible, high-temperature nylon fuel lines carry fuel from the tank to the engine, and return any surplus fuel back to the tank.

The EquiFlo® fuel system is standard on all vehicles (see **Fig. 1** and **Fig. 2**). The EquiFlo system includes the following components:

- supply and return lines;
- tank vent and line located on the top of the tank;
- quarter-turn, non-vented fuel cap.

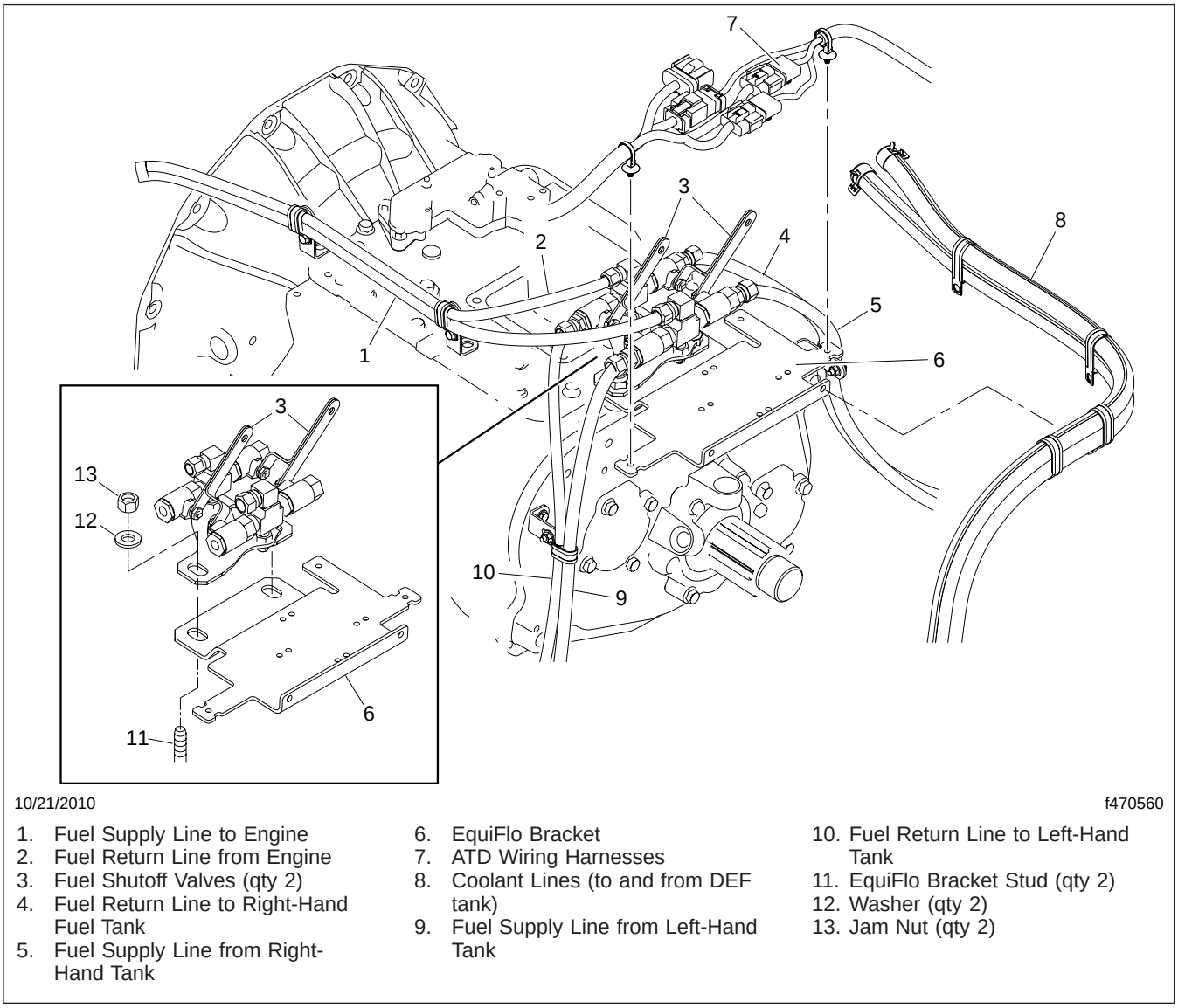
On dual-tank installations, the fuel lines are routed inboard of the frame rails to the shutoff valves, which are located on the transmission. Fuel is drawn equally from and returned equally to each tank so that their levels remain equal. The return fuel line directs fuel flow to the bottom of the tank to ensure thorough mixing of the fuel and vapor dispersal before the fuel is drawn up by the supply line. It also prevents warm fuel from recirculating through electronically-controlled engines.



1. Standoff Brackets
2. Fuel Supply Line to Engine
3. Fuel Return Line from Engine
4. Fuel Tank
5. Transmission

Fig. 1, Fuel Line Routing (single-tank installation)

General Information



1. Fuel Supply Line to Engine
2. Fuel Return Line from Engine
3. Fuel Shutoff Valves (qty 2)
4. Fuel Return Line to Right-Hand Fuel Tank
5. Fuel Supply Line from Right-Hand Tank
6. EquiFlo Bracket
7. ATD Wiring Harnesses
8. Coolant Lines (to and from DEF tank)
9. Fuel Supply Line from Left-Hand Tank
10. Fuel Return Line to Left-Hand Tank
11. EquiFlo Bracket Stud (qty 2)
12. Washer (qty 2)
13. Jam Nut (qty 2)

Fig. 2, Fuel Line Routing (dual-tank installation)

Removal

If there is any damage to the fuel tank, replace it.

IMPORTANT: U.S. Federal Motor Carrier Safety Regulation 393.67 establishes standards relating to fuel tank strength, leakage, and venting. *Replacement fuel tanks must meet these same standards.*

⚠ WARNING

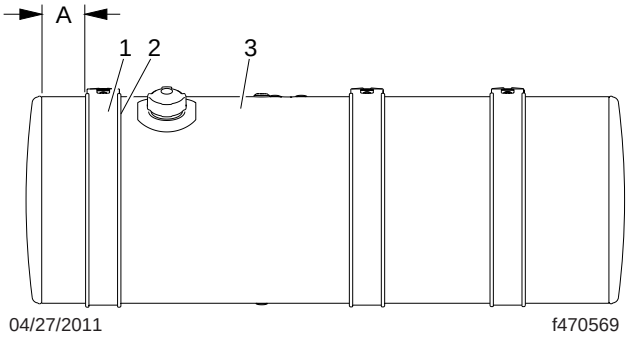
Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Remove the cab access steps.

IMPORTANT: On vehicles with dual-tank installations, close the fuel shutoff valves before draining the tank.

2. Drain the fuel from the tank.
   - 2.1 Remove the drain plug from the fuel tank that is to be replaced.
   - 2.2 Drain the fuel into a suitable container, big enough to hold the amount of fuel in the tank.
   - 2.3 If the fuel is to be re-used, store it in a clean container and keep it covered, clean, and free from contaminants.
3. Disconnect the fuel lines from the tank, then cap the lines.
4. Remove and clean all of the pipe plugs, then save them for installation on the new tank.
5. Before removing the fuel tank bands, measure and record the distance from the forward edge of the fuel tank to the edge of the forwardmost band isolator. See **Fig. 1**.
6. To prevent the fuel tank from rolling during and after removal, nail 2-by-4 or 4-by-4 wooden blocks to the top of a pallet about 18 inches (46 mm) apart, then place the pallet on the forks of a fork lift. See **Fig. 2**.

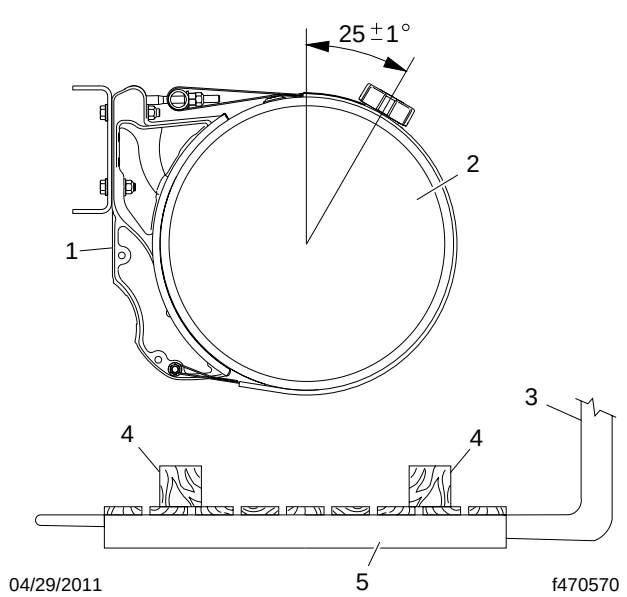
   Move the fork lift and pallet into place to support the fuel tank.



A. Measure this distance.

1. Tank Band
2. Tank Band Isolator
3. Fuel Tank

Fig. 1, Distance From Forward Edge of Fuel Tank to Isolator



NOTE: The fuel filler neck should be rotated 25 degrees outboard of the vertical on standard tanks.

1. Fuel Tank Bracket
2. Fuel Tank
3. Fork Lift
4. Wooden Blocks
5. Wooden Pallet

Fig. 2, Fuel Tank Orientation and Support

7. Loosen the jam nut on each tank band eye bolt. Remove the jam nut, inner hexnut, and washer. See **Fig. 3**.

Fuel Tank Removal and Installation

Drop the tank bands and isolators. Leave the tensioner lug inside the band.

8. Remove the fuel tank.
9. After removing the tank, inspect the tank bands, isolators, and brackets for damage. Replace worn or damaged parts with new parts. Refer to **Subject 110** for band replacement, and **Subject 120** for bracket replacement.

Installation

Note: The fuel filler neck should be oriented as follows:

- standard tanks under the cab: 25 degrees outboard of vertical
- auxiliary fuel tanks: 15 degrees outboard of vertical

1. Using the fork lift and pallet, put the fuel tank in its approximate installed position. Ensure the tank is rotated so the vent is located on top of the tank. See **Fig. 2**.

   Install the forward tank band and band isolator loosely.

   1.1 Holding the tank on the forklift, attach the band and isolator to the eye bolt.

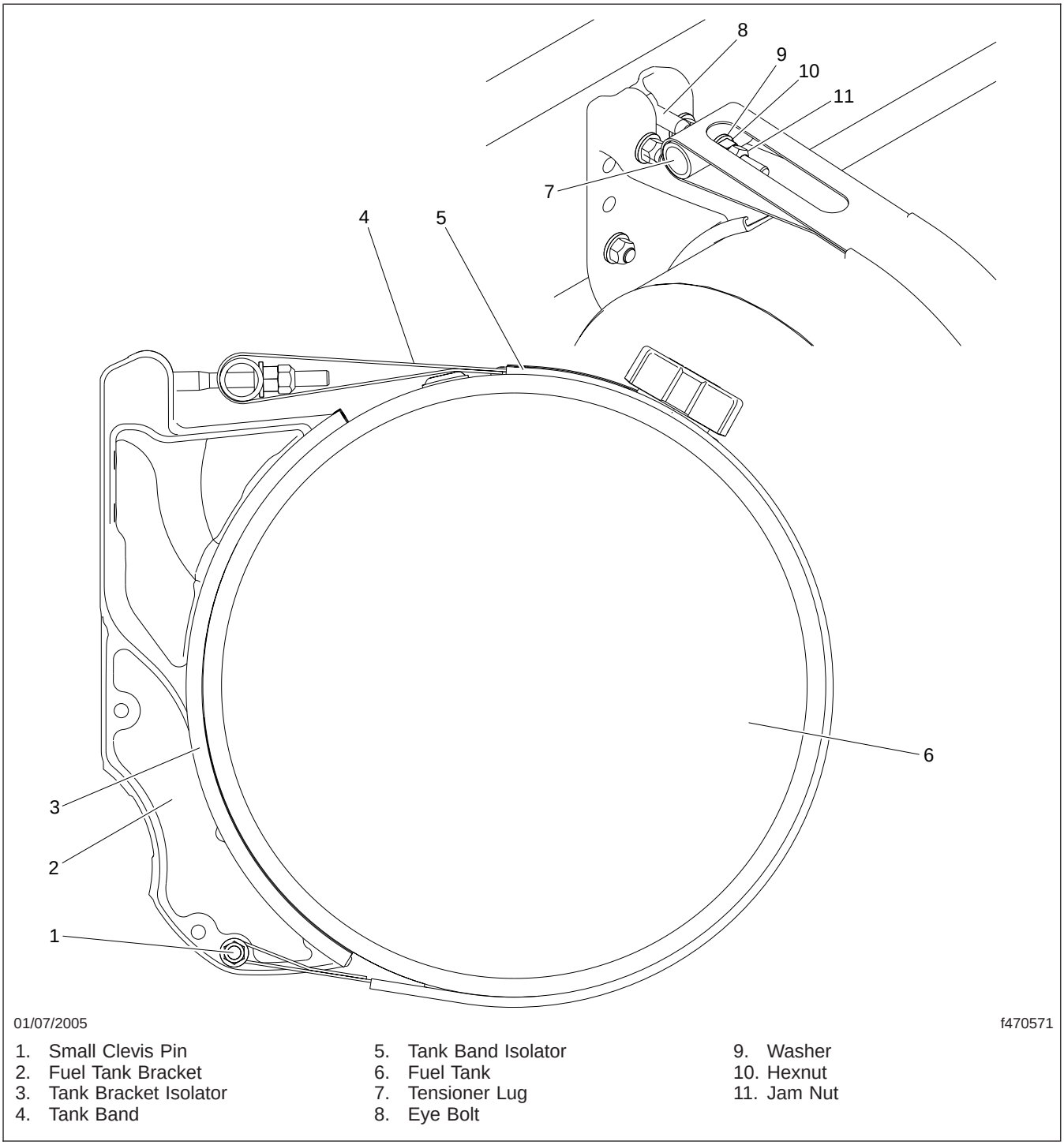
   1.2 Install a hardened flatwasher and the inner 5/8–11 hexnut, but do not tighten it yet.

2. Adjust the tank position until the distance between the forward edge of the tank and the tank band is equal to the distance measured in **Fig. 1**.

NOTICE

Fuel tanks can be damaged by direct isolator pressure on the tank weld seam, and by overtightening the fuel tank bands. Be sure the weld seam aligns with reliefs in the isolators and that the bands are tightened to specification.

3. Install the other tank band around the tank. Insert the isolators under the brackets so that the relief in each isolator aligns with the tank longitudinal weld seam.
4. Tighten the inner hexnuts alternately in stages, until each is tightened 32 lbf·ft (44 N·m).
5. Install a jam nut on each hexnut, then tighten each jam nut 32 lbf·ft (44 N·m).
6. Make certain the fuel lines are clean, then install them on the fuel tank fittings.
7. Coat the pipe plug threads with Loctite® 592, or an equivalent. Install pipe plugs in any remaining open threaded holes.
8. Install the cab access steps.
9. Fill the fuel tank with clean fuel. Prime the engine fuel pump. See the engine manufacturer's operation and maintenance manual for instructions.
10. On vehicles with dual-tank installations, open the fuel shutoff valves.



1. Small Clevis Pin
2. Fuel Tank Bracket
3. Tank Bracket Isolator
4. Tank Band
5. Tank Band Isolator
6. Fuel Tank
7. Tensioner Lug
8. Eye Bolt
9. Washer
10. Hexnut
11. Jam Nut

Fig. 3, Fuel Tank Band Assembly

Replacement

1. Remove the cab access steps.
2. Using a floor jack or fork lift and protective padding, support the fuel tank.
3. Remove the nuts and washer from the tank band eye bolt, at the outboard end of the tank bracket. See **Fig. 1**.
4. Drop the tank band. Inspect both the band and bracket isolators for wear or damage, and replace if needed.
5. Remove the small clevis pin from the bottom end of the fuel tank bracket, freeing the band.
6. Remove the band from the fuel tank.
7. Install the new band.
   - 7.1 Position the small end of the new band on the bottom edge of the fuel tank bracket.
   - 7.2 Install the small clevis pin with two hardened flatwashers onto the fuel tank bracket and band, and fasten it in place with a cotter pin.

NOTICE

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other could lead to corrosion of the metals, resulting in damage to the components.

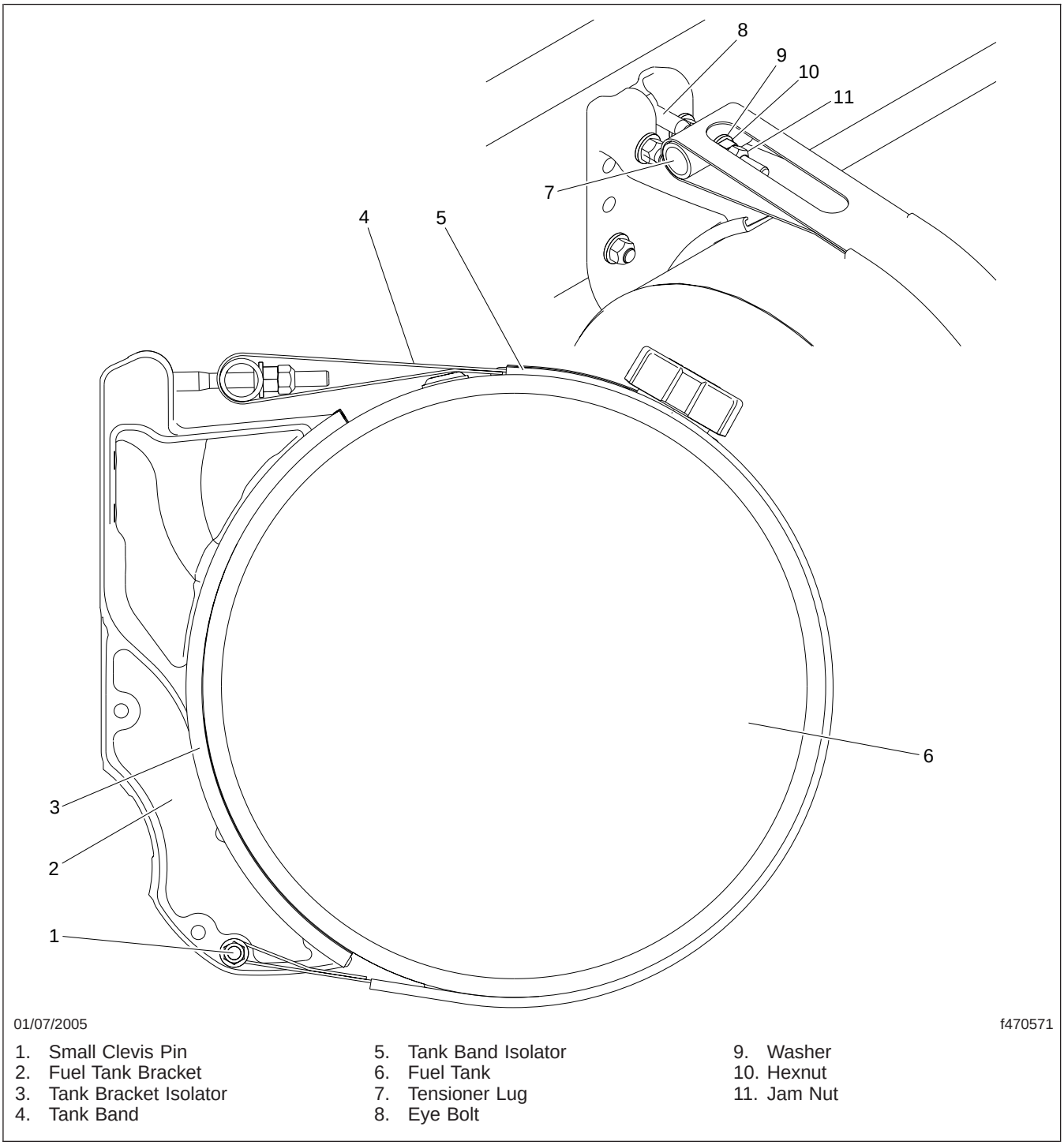
8. Apply Alumilastic®, or an equivalent, to the bracket where it contacts the band.

NOTICE

Fuel tanks can be damaged by direct isolator pressure on the tank weld seam, and by overtightening the fuel tank bands. Be sure the weld seam aligns with reliefs in the isolators and that the bands are tightened to specification.

9. Position the new tank band, with the band isolator, around the tank. Insert the bracket isolator under the bracket, so that the relief in the isolator aligns with the tank longitudinal weld seam.
10. Attach the upper end of the band and tighten the band nuts, as follows:
    - 10.1 Position the large end of the band, with tensioner lug in place, on the end of the eye bolt.
    - 10.2 Install a hardened flatwasher and the inner hexnut. Tighten the inner hexnut 32 lbf·ft (44 N·m).
    - 10.3 Install a jam nut on the hexnut and tighten the jam nut 32 lbf·ft (44 N·m).
11. Repeat this procedure to replace the other bands, as needed. When the bands have been replaced, check the inner hexnuts and jam nuts for tightness.
12. Install the cab access steps.

Fuel Tank Band Replacement



1. Small Clevis Pin
2. Fuel Tank Bracket
3. Tank Bracket Isolator
4. Tank Band
5. Tank Band Isolator
6. Fuel Tank
7. Tensioner Lug
8. Eye Bolt
9. Washer
10. Hexnut
11. Jam Nut

Fig. 1, Fuel Tank Band Assembly

Fuel Tank Bracket Replacement

Replacement

1. Support the tank and remove the fuel tank band from the bracket that is being replaced. See **Subject 110** for instructions.
2. Remove the fasteners that attach the bracket to the frame rail and remove the bracket. See **Fig. 1**.

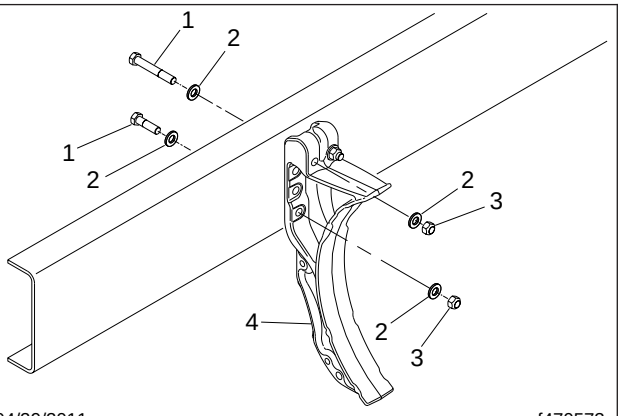


Fig. 1, Fuel Tank Bracket Installation

3. Install the new tank bracket.

NOTICE

Failure to apply Alumilastic compound, or an equivalent, to areas where aluminum and steel parts contact each other, could lead to corrosion of the metals, resulting in damage to the components.

3.1 Apply Alumilastic® compound, or equivalent, between the fuel tank bracket and the frame rail.

3.2 Position the new tank bracket against the outside of the frame rail. See **Fig. 1**.

3.3 Insert two 5/8–11 x 4-inch bolts with washers through the top holes in the frame rail and bracket.

3.4 Insert two 5/8–11 x 2-1/4 inch bolts with washers through the bottom holes in the frame rail and bracket.

3.5 Install hardened washers and hexnuts on all four bolts. Tighten the hexnuts 136 lbf·ft (184 N·m).

3.6 Install the fuel tank band. See **Subject 110** for instructions.

Fuel Shutoff Valve Replacement

Replacement

NOTE: Fuel shutoff valves are only installed on vehicles with dual tanks.

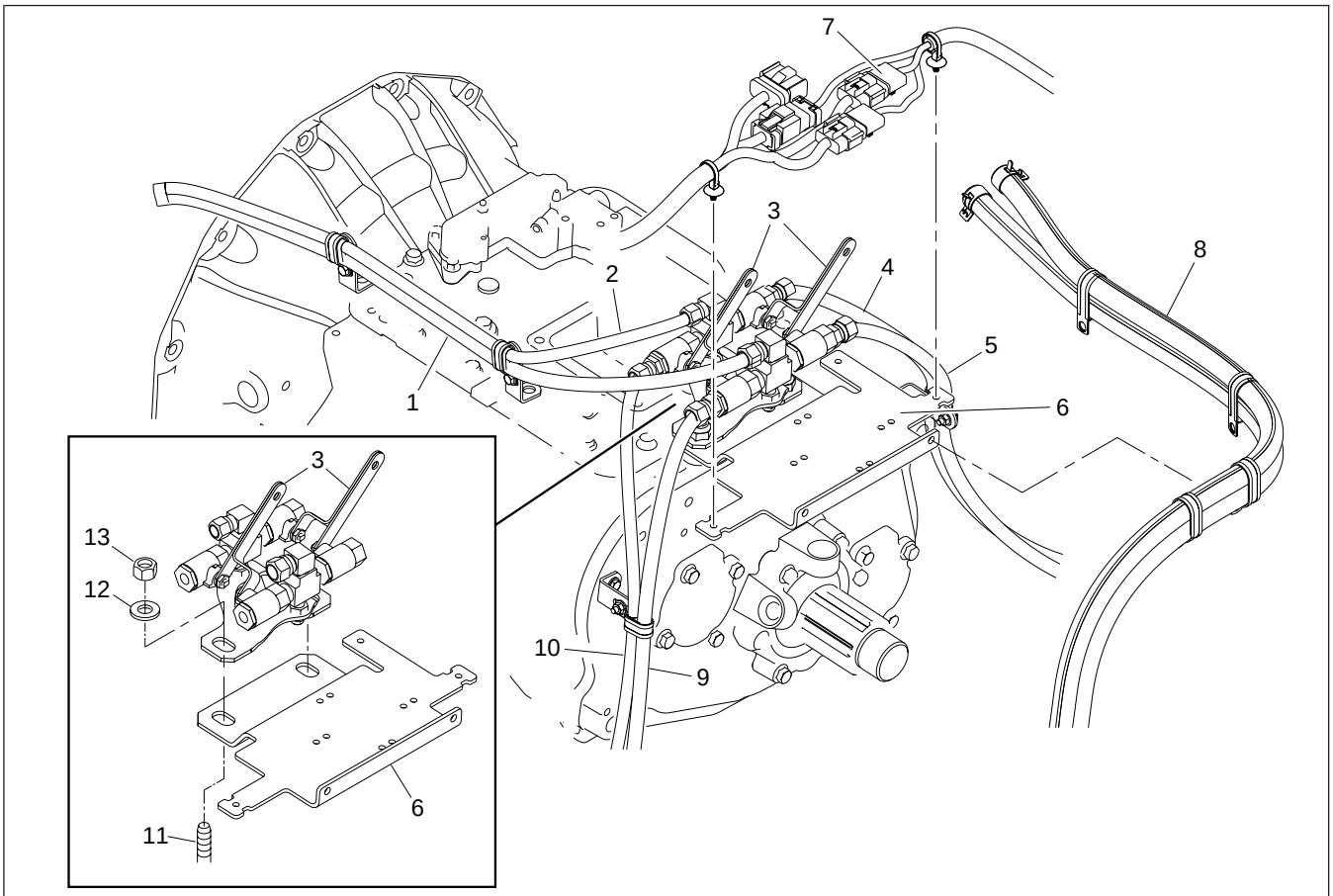
1. Apply the parking brakes, chock the tires, put the transmission into high gear, and open the hood.

⚠ WARNING

Aftertreatment device (ATD) internal temperatures can remain hot enough to cause personal injury or ignite combustible materials for hours after the engine is shut down, causing potentially serious burns or material damage. Wear appropriate protective gear when working around the ATD. Do not to let diesel from the fuel lines come into contact with the ATD.

2. Disconnect the driveline from the transmission output yoke. For instructions, see **Section 41.00, Subject 100** for uncoupling from a *half-round* end-yoke, or **Section 41.00, Subject 110** for uncoupling from a *full-round* end-yoke.
3. Disconnect the driveline midship bearing from the midship bearing bracket, and set the driveline out of the way.
4. Disconnect the aftertreatment device (ATD) wiring harnesses located on the EquiFlo bracket.
5. Disconnect the diesel exhaust fluid (DEF) coolant lines located on the EquiFlo bracket.
6. Disconnect the fuel lines from the tee fittings, then cap the lines.
7. In order to gain access to the fuel shutoff valves, it may be necessary to remove the standoff brackets that secure the DEF lines to the EquiFlo bracket, then move the lines aside. See **Fig. 1**.
8. Remove any remaining cables and brackets as needed to access the fuel shutoff valves.
9. Loosen the two jam nuts that secure the fuel shutoff valves and tee fittings to the EquiFlo bracket. Remove the tee fittings and valves as an assembly.
10. Remove the shutoff valves from the tee fittings, then install new shutoff valves.
11. Using two jam nuts, install the tee fitting and shutoff valve assembly on the EquiFlo bracket.
12. Install the fuel lines on the tee fittings and tighten the fittings.
13. If any ATD wiring harness standoff brackets were previously removed, install them on the EquiFlo bracket, then connect the wiring harnesses.
14. If any DEF line standoff brackets were previously removed, install them on the EquiFlo bracket.
15. Connect the DEF coolant lines.
16. Connect the ATD wiring harnesses.
17. Install any remaining cables and brackets that were previously removed.
18. Connect the driveline to the transmission output yoke. For instructions, see **Section 41.00, Subject 100** for coupling to a *half-round* end-yoke, or **Section 41.00, Subject 110** for coupling to a *full-round* end-yoke.
19. Connect the midship bearing to the midship bearing bracket.
20. Start the engine and check for leaks.

Fuel Shutoff Valve Replacement



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1. Fuel Supply Line to Engine
2. Fuel Return Line from Engine
3. Fuel Shutoff Valves (qty 2)
4. Fuel Return Line to Right-Hand Fuel Tank
5. Fuel Supply Line from Right-Hand Tank
6. EquiFlo Bracket
7. ATD Wiring Harnesses
8. Coolant Lines (to and from DEF tank)
9. Fuel Supply Line from Left-Hand Tank
10. Fuel Return Line to Left-Hand Tank
11. EquiFlo Bracket Stud (qty 2)
12. Washer (qty 2)
13. Jam Nut (qty 2)

Fig. 1, Fuel Shutoff Valve Assembly, Dual-Tank Vehicle

Flushing

In the event of a catastrophic failure of the high-pressure fuel pump, it is necessary to clean the fuel tanks and all other system components between the tanks and the engine. For information about cleaning the engine components after a failure, refer to the engine manufacturer's service literature.

IMPORTANT: Always follow EPA and local regulations when disposing of contaminated fuel.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Drain all of the fuel from the tank(s) into a suitable container. Dispose of the contaminated fuel in an appropriate manner.
3. Remove the tank(s) from the vehicle. For instructions, refer to **Subject 100**.
4. Thoroughly steam clean the inside of the tank until all water leaving the drain hole looks clean.
5. Install the drain plug and cap any other open outlets.
6. Put two gallons of diesel fuel in the tank, and install the cap. Slosh the diesel around in the tank making sure it reaches all interior surfaces. This should collect most of any remaining contaminants in the tank.
7. Drain this fuel from the tank into a suitable container. Dispose of the contaminated fuel in an appropriate manner.
8. If equipped, remove the fuel/water separator(s) from the system. For instructions, refer to **Group 47**.
9. Remove and discard the filter element. Then thoroughly clean the unit.
10. Install a new filter element.
11. Remove all of the fuel lines from the system and replace them with new lines.
12. Install the fuel/water separator. For instructions, refer to **Group 47**.
13. Install the fuel tank(s) on the vehicle. For instructions, refer to **Subject 100**.

General Description

The fuel/water separator is mounted on the frame rail, between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and solid contaminants. The fuel/water separator includes a spin-on filter element and a sight bowl. See **Fig. 1**. The fuel/water separator may also be equipped with the following optional components:

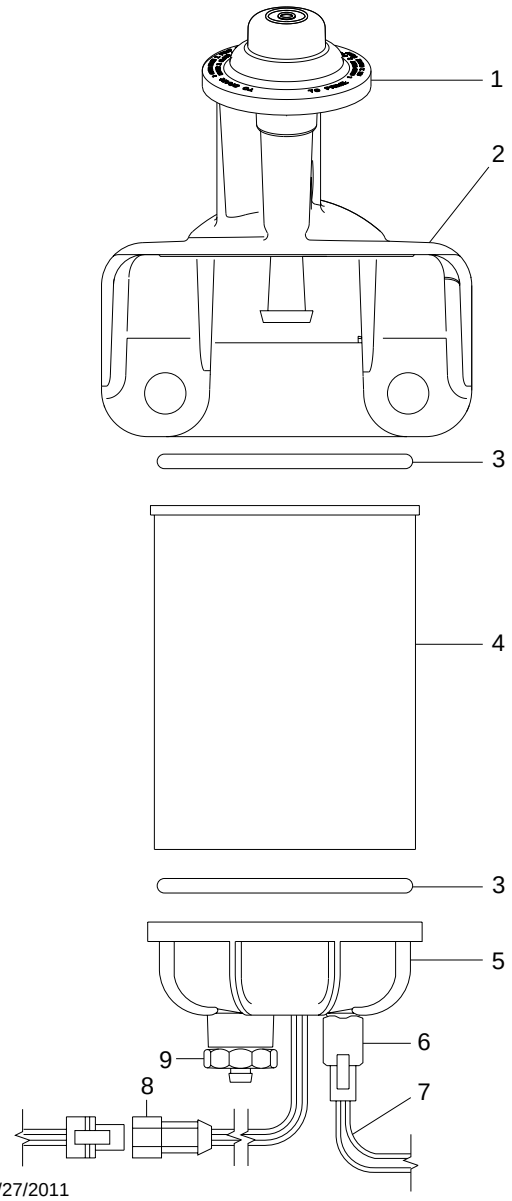
- Ignition-controlled heater to melt ice and wax in the fuel
- Water sensor probe to alert the operator to drain the sight bowl
- Manual priming pump to easily prime the fuel/water separator

Principles of Operation

Diesel fuel enters at the top of the separator and flows down past the heater element, if equipped, to the top of the filter element. As the fuel flows down the sides of the element, the heavier contaminants fall directly to the collection bowl. The filter element itself contains a resin that repels water and forces it to bead and fall to the collection bowl.

Filtered fuel is drawn out through the top of the separator, and the water and solid contaminants remain in the collection bowl. As water collects, it completes the circuit between the two prongs of the water sensor probe and a warning light on the dash alerts the operator to drain the bowl.

The heater is operated by turning on the ignition switch for 5 minutes before starting the engine.



1. Primer Pump
2. Mounting Head
3. O-Ring
4. Filter Element
5. Sight Bowl
6. Water-in-Fuel Sensor
7. Wiring Harness, Water-in-Fuel Sensor
8. Wiring Harness, Heater
9. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

Removal

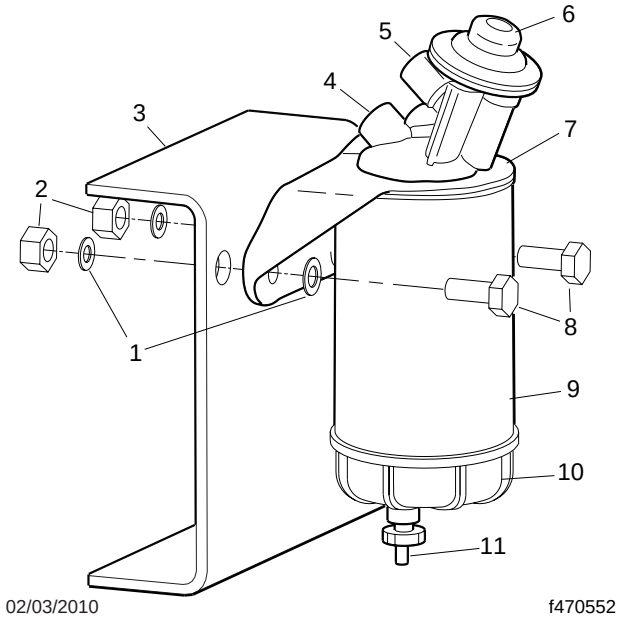
1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump. See **Fig. 1**.



1. Washers (qty 2)
2. Nuts (qty 2)
3. Frame Rail
4. Fuel Outlet Port
5. Fuel Inlet Port
6. Priming Pump
7. Mounting Head
8. Mounting Bolts (qty 2)
9. Filter Element
10. Sight Bowl
11. Drain Plug

Fig. 1, Fuel/Water Separator Assembly and Installation

4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the fuel lines from the fuel/water separator.
6. Disconnect the wiring harnesses from the water sensor probe and the heater element.
7. Remove the fuel/water separator mounting bolts, and remove the fuel/water separator from its mounting bracket.

Installation

1. Mount the fuel/water separator on the frame rail mounting bracket, and install the mounting bolts. Tighten the bolts 40 lbf·ft (55 N·m).
2. Remove the sight bowl and the filter element as a unit from the new fuel/water separator.
3. Using clean motor oil or diesel fuel, lubricate the gasket in the top of the filter element.
4. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
5. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
6. Connect the wiring harnesses to the water sensor probe and the heater.
7. Connect the fuel lines to the fuel/water separator. Tighten the fittings until one thread remains visible on the fitting body.
8. Prime the fuel/water separator.

   If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

   If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.
9. Start the engine and check for leaks.
10. Shut down the engine and repair any leaks.

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

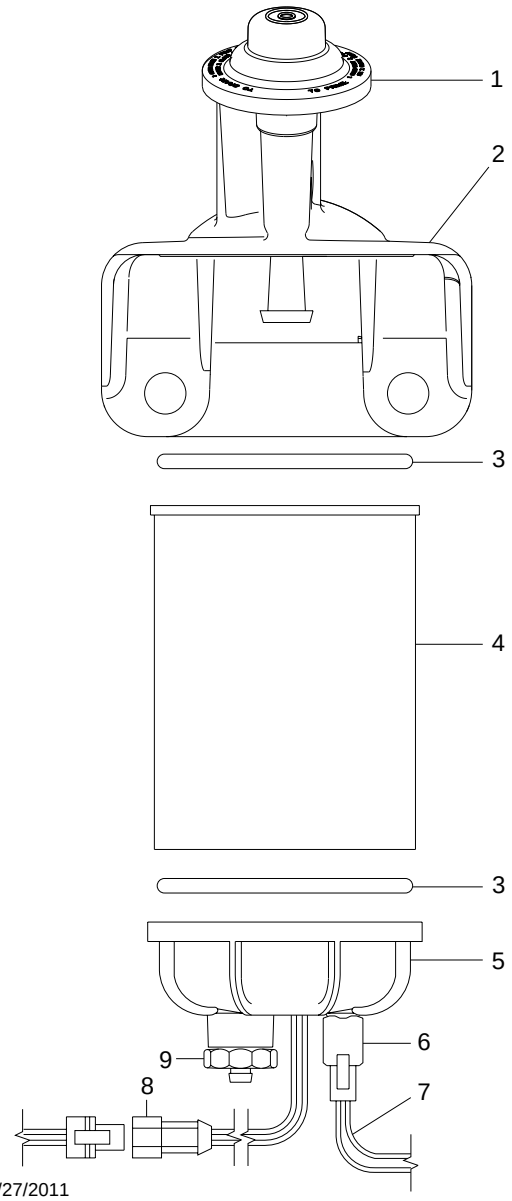
3. Turn the drain plug counterclockwise to open it. If equipped, operate the pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the wiring harnesses from the water sensor probe and the heater. See **Fig. 1**.
6. Spin off the sight bowl and the filter element as a unit. Remove the gasket from the top of the filter element.
7. Remove the sight bowl from the filter element. Clean the O-ring seating surface.
8. Apply a thin coating of clean diesel fuel or engine oil to the O-ring and the new gasket.
9. Spin the sight bowl onto the new filter element and then fill the filter element and sight bowl assembly with clean diesel fuel.
10. Spin the entire assembly onto the mounting head and tighten by hand until snug.
11. Connect the heater and water sensor wiring harnesses.
12. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.



1. Primer Pump
2. Mounting Head
3. O-Ring
4. Filter Element
5. Sight Bowl
6. Water-in-Fuel Sensor
7. Wiring Harness, Water-in-Fuel Sensor
8. Wiring Harness, Heater
9. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

Filter Element Replacement

If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

13. Start the engine and check for leaks.
14. Shut down the engine and repair any leaks.

Replacement

1. Shut down the engine, apply the parking brake, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

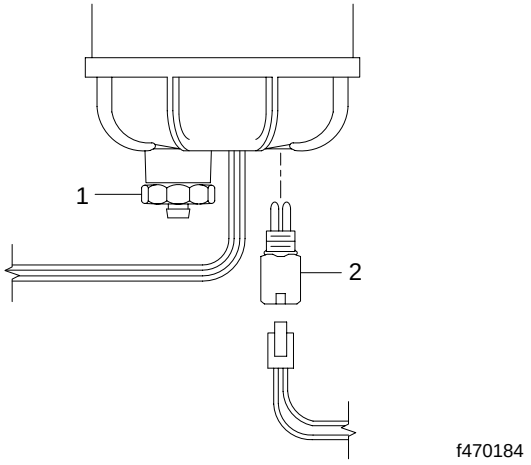
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

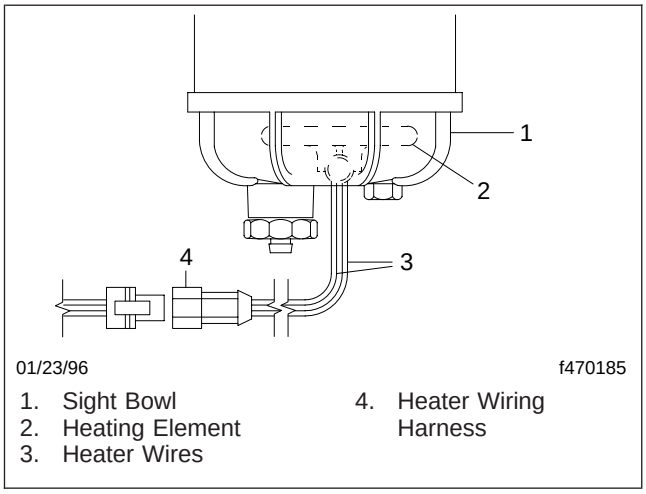
5. Disconnect the wiring harness from the water sensor probe. See **Fig. 1**.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe

6. Disconnect the heater wiring harness. See **Fig. 2**.



1. Sight Bowl
2. Heating Element
3. Heater Wires
4. Heater Wiring Harness

Fig. 2, In-Bowl Heater

7. Spin off the sight bowl and the filter element as a unit.
8. Remove the sight bowl from the filter element.
9. Remove the O-ring from the lip of the new sight bowl. Lubricate the O-ring with a thin film of clean engine oil or diesel fuel and put it back in the sight bowl.
10. Install the sight bowl on the bottom of the filter element and hand-tighten until it is snug.
11. Make sure the drain in the sight bowl is closed, then fill the filter element and bowl assembly with clean fuel.
12. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
13. Connect the heater wiring harness.

    Connect the water sensor wiring harness to the water sensor probe.

14. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

15. Start the engine and check for leaks.
16. Shut down the engine and repair any leaks.

Replacement

1. Apply the parking brakes, shut down the engine, and chock the tires.

   Open the hood.

2. Place a suitable container under the fuel/water separator.

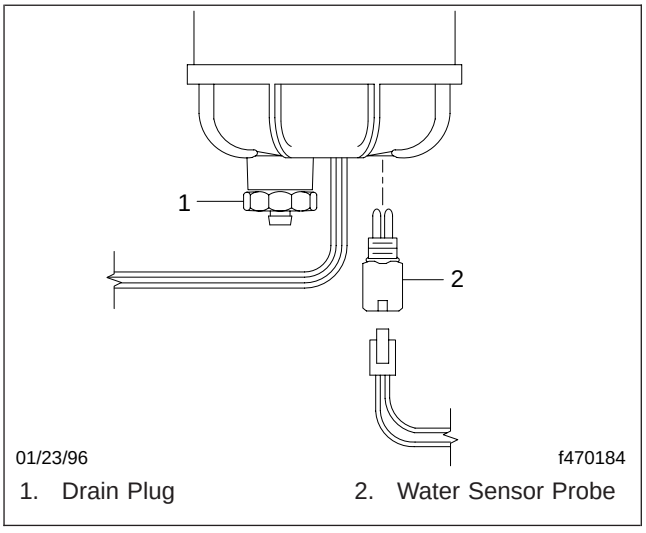
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

3. Turn the drain plug counterclockwise to open it. If equipped, operate the priming pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

5. Disconnect the water sensor wiring harness from the water sensor probe. See **Fig. 1**.



1. Drain Plug
2. Water Sensor Probe

Fig. 1, Water Sensor Probe

6. Spin off the sight bowl and filter element as a unit.
7. Unscrew the water sensor probe from the base of the sight bowl.
8. Install a new water sensor probe in the base of the sight bowl.
9. Make sure the drain plug in the base of the sight bowl is closed snugly.
10. Fill the filter element and sight bowl assembly with clean diesel fuel.
11. Install the element and bowl assembly on the mounting head and hand-tighten it until snug.
12. Connect the water sensor wiring harness to the water sensor probe.
13. Prime the fuel/water separator.

    If equipped with a priming pump, loosen the drain plug and operate the priming pump until fuel comes out at the drain.

    If not equipped with a priming pump, fill the filter element and sight bowl with clean fuel and crank the engine until it starts.

14. Start the engine and check for leaks.
15. Shut down the engine and repair any leaks..

Troubleshooting Tables

Problem—Air Leaking into the Fuel System

Problem—Air Leaking into the Fuel System	
Possible Cause	**Remedy**
The drain is not closed.	Tighten the drain valve.
The sight bowl or filter element is loose.	Hand-tighten the sight bowl or filter element until snug.
There are loose, broken, or clogged fuel fittings, valves, or filters.	Tighten, clean, or repair the fuel fittings, valves, or filters as needed.

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY

Problem—High Water Light Does Not Illuminate For 2 to 5 Seconds When Ignition is Turned to ACCESSORY	
Possible Cause	**Remedy**
Wiring connections are loose.	Tighten connections as needed.
Fuel/water separator is not grounded.	Check that power is on, and the fuel/water separator is grounded.
Wiring is damaged.	Check for damaged wiring and replace as needed. See EZWiring for a diagram of the sensor circuit.
Water sensor probe is damaged.	Replace the water sensor probe. See **Subject 130** for instructions.

General Information

Fuel/water separators are mounted between the fuel tank and the fuel pump. Fuel drawn to the engine travels through the fuel/water separator, which removes water and solid contaminants. See **Fig. 1**, **Fig. 2**, or **Fig. 3** for DAVCO fuel/water separator configurations.

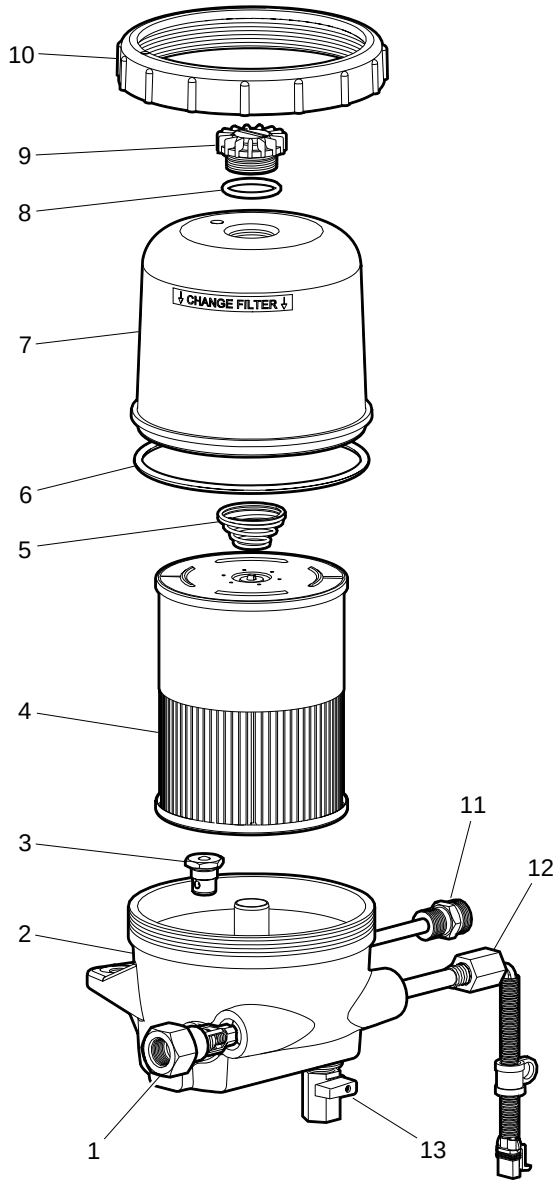
Heavier contaminants and water separate from the fuel in the lower housing of the fuel/water separator, and collect in the bottom to be drained out when the drain valve is opened. From the lower housing, the fuel level rises into the clear cover, which contains the replaceable filter element. The fuel passes through the filter element into the center of the filter, and on to the outlet port.

When the filter is new, fuel is able to pass through the lower part of the filter element. As the element's lower portion clogs, the fuel level rises in the clear cover in order to pass through the filter. This process continues until the filter element is clogged all the way to the top.

For efficiency, the filter should only be changed when the fuel level has reached the top of the filter element. There is no significant restriction to fuel flow until the element is completely clogged.

DAVCO fuel/water separators come in a number of different configurations. There may be an electric heating element installed in the lower housing (**Fig. 1**, items 11 and 12) or there may be a fluid heat exchanger in the lower housing (**Fig. 2**, item 3). If there is fluid heat, the warming fluid may be fuel returning from the engine or engine coolant. **Fig. 4** shows the patterns that fuel and heating fluids follow in fluid-heated units.

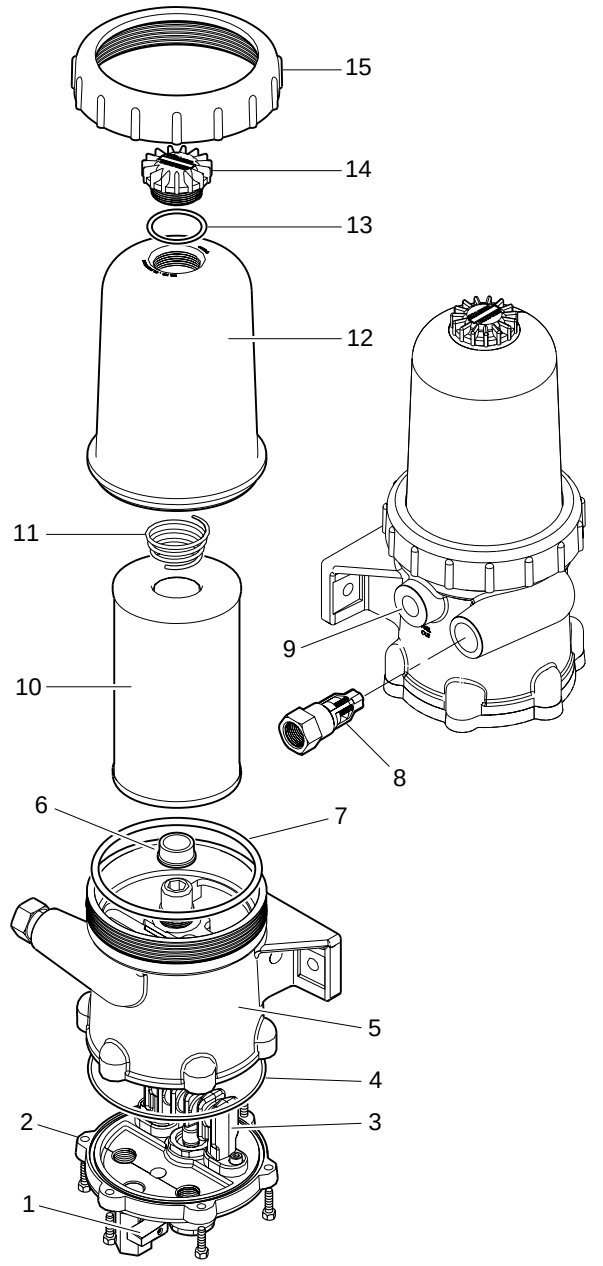
NOTE: The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.



1. Inlet Port/Check Valve
2. Lower Housing
3. Bypass Valve
4. Filter Element
5. Spring
6. Cover O-Ring
7. Clear Cover
8. Vent Cap O-Ring
9. Vent Cap
10. Collar
11. 120VAC Pre-Heater
12. 12VDC Pre-Heater
13. Drain Valve

Fig. 1, DAVCO Fuel Pro 482

General Information



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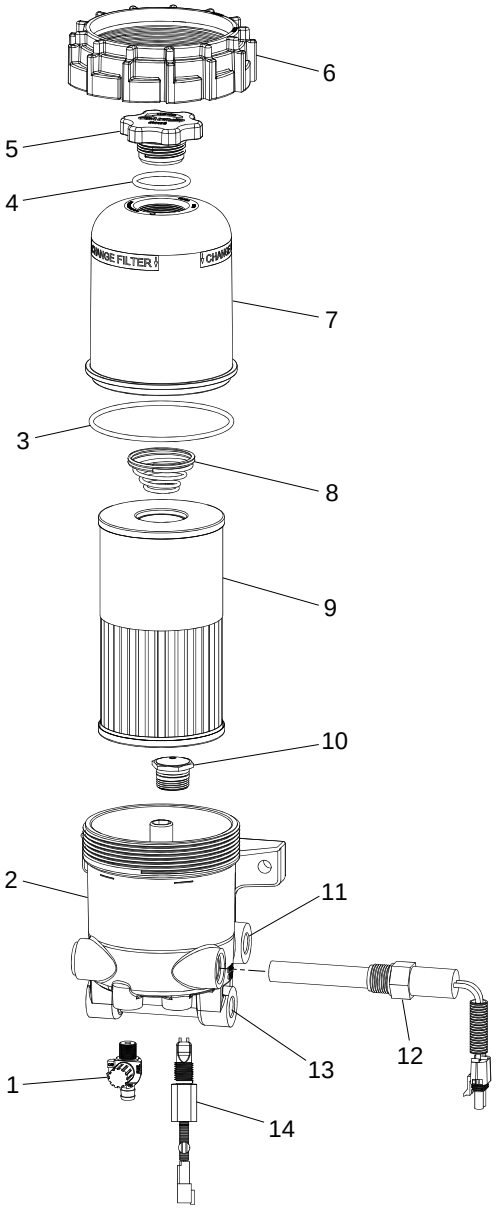
1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 2, DAVCO Fuel Pro 382



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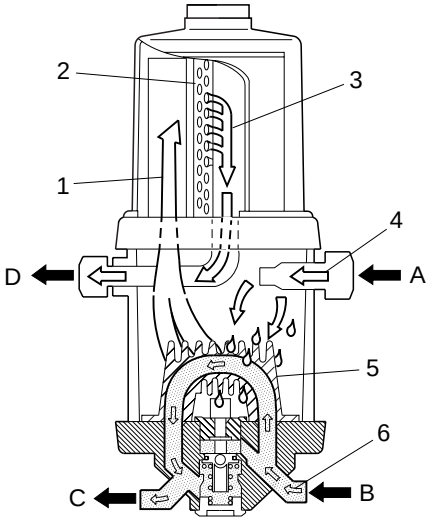
1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve Assembly
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 3, DAVCO Diesel Pro 243



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A. Fuel Inlet Flow
B. Heating Fluid Inlet Flow
C. Heating Fluid Outlet Flow
D. Fuel Outlet Flow

1. Unfiltered, Heated Fuel
2. Filter Element
3. Filtered Fuel
4. Fuel From Fuel Tank
5. Heat Exchanger
6. Heating Fluid From Engine

Fig. 4, Fluid Circulation, Fluid-Heated Units

Removal

WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Most service procedures are done with the fuel/water separator in place, but some procedures, such as pressure testing, require that the fuel/water separator be removed from the vehicle.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Unplug the electric heating element, if equipped, or disconnect the heating fluid lines.
5. Disconnect the fuel outlet line.
6. Disconnect the fuel inlet line. If the inlet line is difficult to reach, loosen the connection, then fully disconnect it after the fuel/water separator is removed from the frame rail.
7. Remove the fuel/water separator mounting fasteners and remove the fuel/water separator from the frame rail. If the fuel inlet line was not completely disconnected in the previous step, disconnect it.

Installation

IMPORTANT: All fittings must be very clean as they are installed. A piece of grit or a damaged surface on a sealing face or in threads can cause air leaks.

Use paste sealer to ensure that the tapered thread fuel line fittings will not leak. Do not use sealer on compression fittings and do not seal the fittings with tape, which will eventually leak.

1. If the inlet fuel line is inaccessible when the fuel/water separator is mounted on the vehicle, loosely connect the line before mounting the fuel/water separator on the frame rail.

   To minimize restrictions, keep fuel line routing as smooth as possible, with no low-hanging loops that could trap water. If the fuel line is being made to length on the job, be sure that the inner liner of the hose is not cut by the fitting. Be certain the interior of all fuel lines is clean and free of debris before connecting them, and confirm that all fittings are clean.
2. Mount the fuel/water separator on the frame rail and install the mounting fasteners.

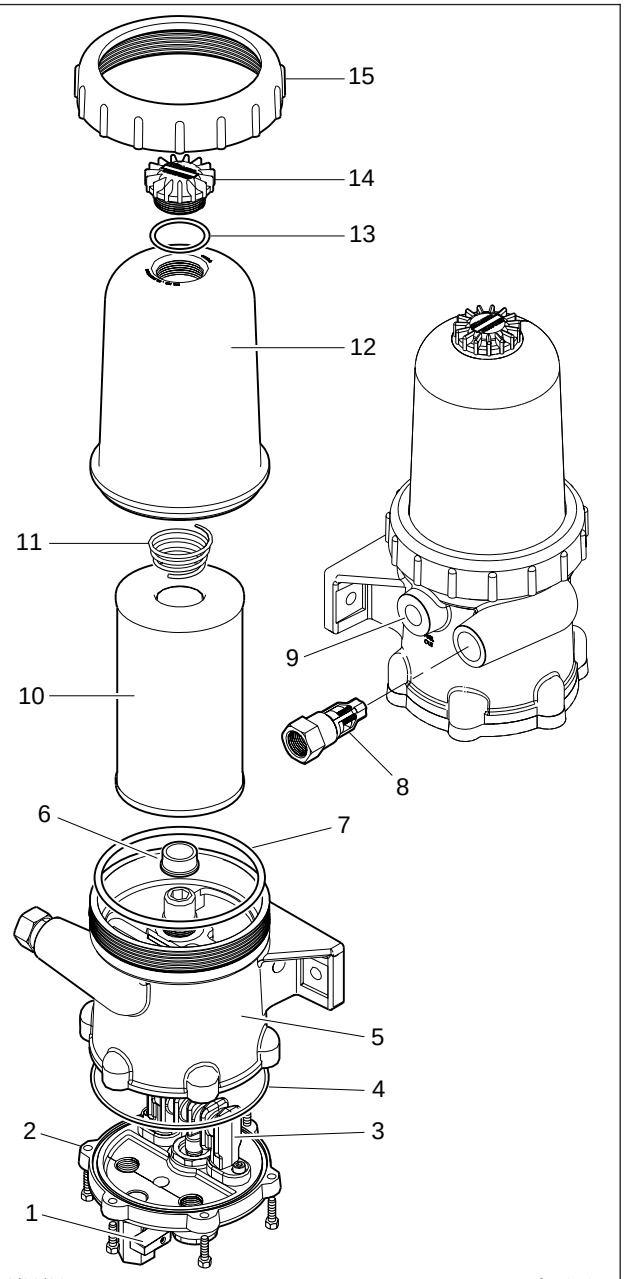
NOTICE

The lower housings on DAVCO fuel/water separators are made of aluminum. To avoid damaging threads, be careful not to overtighten fasteners or fittings on the fuel/water separator.

3. If the fuel inlet line was loosely connected previously, tighten it. If it was not connected, connect and tighten it.
4. Connect and tighten the fuel outlet line.
5. Install the electric heating element, if equipped, and connect the wiring harness, or connect the fluid heater lines. It does not matter which direction the heating fluid flows through the housing; the lines can be reversed.
6. Prime the system

   6.1 Ensure that the drain valve is closed.

Removal and Installation



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

6.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

6.3 Install and hand-tighten the vent cap.

6.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

6.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

6.6 Check for leaks and shut down the engine.

Filter Element Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO collar wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO collar wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and O-rings. Dispose of the filter and O-rings in an environmentally acceptable manner.
6. Remove the filter grommet from the filter stud, if equipped.
7. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
8. Install the grommet on the bottom of the new filter, if equipped.
9. Install the new filter and cover O-ring on the housing.
10. Install the clear cover and the collar. Hand-tighten the collar.
11. Prime the system
    - 11.1 Ensure that the drain valve is closed.
    - 11.2 Fill the housing to the top with clean diesel fuel.
    - 11.3 Install and hand-tighten the vent cap O-ring and vent cap.
    - 11.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 11.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 11.6 Check for leaks and shut down the engine.

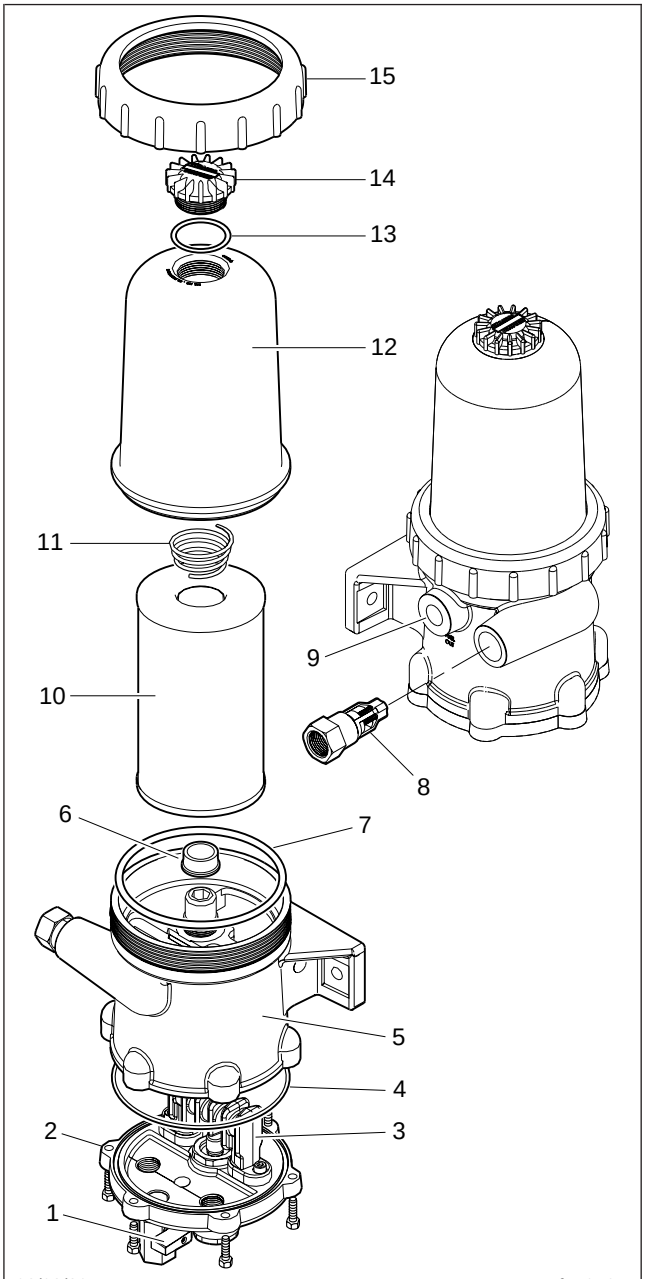
Emergency Temporary Filter Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense

Filter Element and Check Valve Replacement



1. Drain Valve
2. Bottom Plate
3. Heat Exchanger
4. Bottom Plate O-Ring
5. Lower Housing
6. Grommet
7. Cover O-Ring
8. Inlet Port/Check Valve
9. Fuel Outlet Port
10. Filter Element
11. Spring
12. Clear Cover
13. Vent Cap O-Ring
14. Vent Cap
15. Collar

Fig. 1, Fuel/Water Separator (Fuel Pro 382 shown)

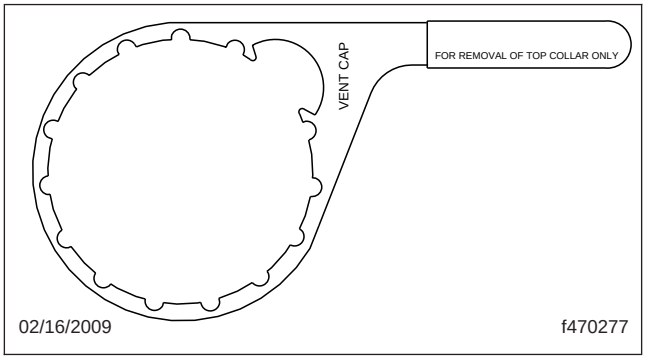


Fig. 2, DAVCO Collar Wrench

heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO collar wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO collar wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and dispose of it in an environmentally acceptable manner.
6. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.

7. Ensure that the drain valve is closed.
8. Remove the filter grommet from the filter stud, if equipped.
9. Fill the housing to the top with clean diesel fuel.
10. Install a standard engine spin-on filter (part number FF105 or equivalent) on the filter stud.
11. Install the cover O-ring, clear cover, and the collar. Hand-tighten the collar.
12. Install and hand-tighten the vent cap O-ring and vent cap.
13. Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
14. Check for leaks and shut down the engine.

Check Valve Replacement, Fuel Pro Configurations

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

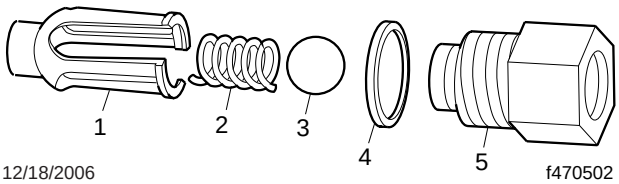
1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap (**Fig. 1**, Item 14) and open the drain valve (**Fig. 1**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing.
6. Remove and discard the check ball, spring, and plastic retainer. See **Fig. 3**.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly

7. Carefully clean the threads on the check valve body. Install the new check ball, spring, and plastic retainer on the check valve body.
8. Clean the threads on the fuel inlet fitting and fuel/water separator housing. Apply a soft-set pipe thread sealant to the check valve body threads.
9. Install the check valve body in the fuel/water separator housing and tighten per the specifications in **Table 1**. Do not use tape to seal the fuel fittings; it will eventually leak.

Check Valve Assembly Torque Values	
Fuel/Water Separator	**Torque Value: lbf·ft (N·m)**
Fuel Pro 382	44–60 (60–81)
Fuel Pro 482	45 (61)

Table 1, Check Valve Assembly Torque Values

Filter Element and Check Valve Replacement

10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap.
    - 10.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 10.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
    - 10.6 Check for leaks and shut down the engine.

Check Valve Replacement, Diesel Pro 243

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

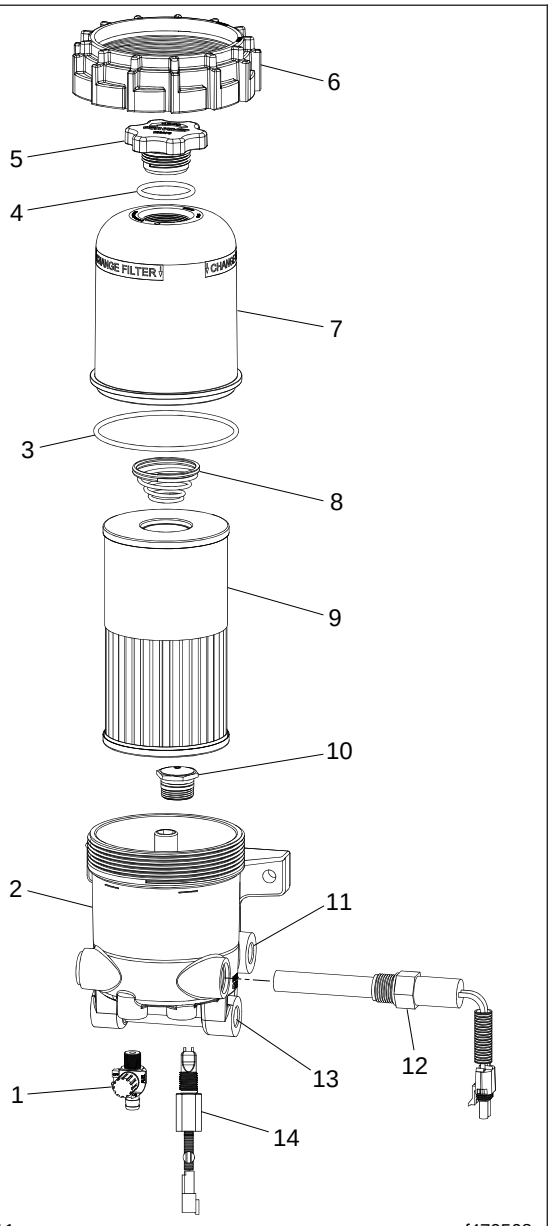
1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.
3. Remove the vent cap (**Fig. 4**, Item 5) and open the drain valve (**Fig. 4**, Item 1) to drain the fuel to just below the collar level, then close the drain valve.
4. Using a DAVCO collar wrench (**Fig. 2**), remove the clear cover and collar.

NOTE: Broken vent cap and collar warranty claims will not be accepted if any tool other than a DAVCO collar wrench, p/n 380134 or 382002, is used for removal. During installation, the vent cap and collar are to be **hand-tightened only**, not tightened with a wrench.

5. Remove the filter and O-rings. Dispose of the filter and O-rings in an environmentally acceptable manner.
6. Remove the check valve from the lower housing.
7. Clean all threads and sealing surfaces very thoroughly. Even a small amount of dirt will prevent the fuel/water separator from sealing, and an air leak will result.
8. Install the new check valve body in the lower housing. Tighten the check valve 12 to 14 lbf·ft (16 to 19N·m).
9. Install the new filter and cover O-ring on the housing.
10. Install the clear cover and the collar. Hand-tighten the collar.
11. Prime the system
    - 11.1 Ensure that the drain valve is closed.
    - 11.2 Fill the housing to the top with clean diesel fuel.
    - 11.3 Install and hand-tighten the vent cap O-ring and vent cap.
    - 11.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
    - 11.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just



1. Drain Valve
2. Lower Housing
3. Cover O-Ring
4. Vent Cap O-Ring
5. Vent Cap
6. Collar
7. Clear Cover
8. Spring
9. Filter Element
10. Check Valve
11. Fuel Inlet Port
12. Pre-Heater
13. Fuel Outlet Port
14. Water-In-Fuel Sensor

Fig. 4, DAVCO Diesel Pro 243

above the collar, then hand-tighten the vent cap.

11.6 Check for leaks and shut down the engine.

Electric Heater, Thermoswitch, and Fluid Heater Tests

Any one of several types of heaters and thermoswitches may be fitted to DAVCO fuel/water separators. They include 12 VDC heaters, 120 VAC heaters, combination heater thermoswitches, and fluid heaters. The voltage and wattage ratings are stamped on the hex or the sheath of each component.

Test procedures under these headings apply to the following heater types, as specified:

- Electric Heater
- 12 VDC Thermoswitch
- Combination Heater Thermoswitch
- Fluid Heat

The following equipment is recommended to test DAVCO heaters and thermoswitches:

- A precision low-resistance ohmmeter capable of measuring 0.1 ohm or less
- A clamp-on DC current-flow meter
- A means of chilling a thermoswitch, such as ice, dry ice, or compressed carbon dioxide
- A flameless source of heat, such as an infrared heat lamp
- A vortex tube to heat and cool a thermoswitch

Electric Heater

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the heater from the wiring harness.
3. Connect the ohmmeter leads to the pins of the heater (for heaters with one pin, connect to the pin and the bushing).
4. Read the resistance and use **Table 1** to determine whether the heater is within the acceptable resistance range.
5. Connect the heater wiring harness.

Electric Heater Test Parameters		
Electric Heater	**Watts**	**Resistance Range: Ohms**
12 VDC (two pin)	250	0.6–0.8
12 VDC (single pin)	250	0.4–0.5
12 VDC (single pin)	150	0.8–1.1
120 VAC	75	173–203
120 VAC	37	369–411

Table 1, Electric Heater Test Parameters

12 VDC Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the thermoswitch wiring harness, see **Fig. 1**. Remove the thermoswitch from the fuel/water separator.
5. Connect the ohmmeter leads to the pins of the thermoswitch.

Electric Heater, Thermoswitch, and Fluid Heater Tests

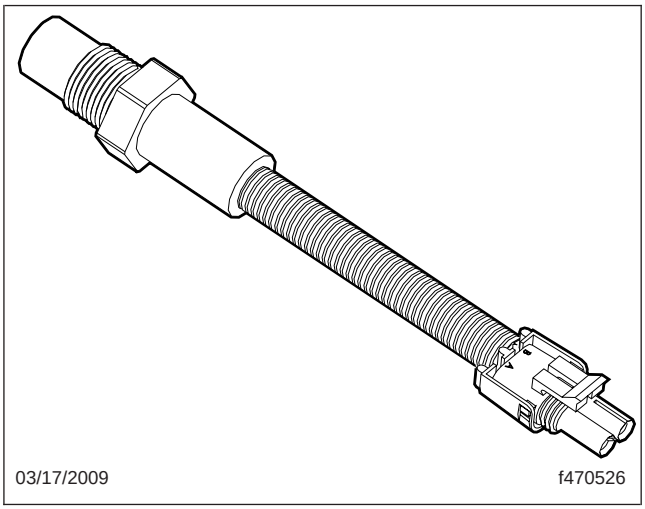


Fig. 1, 12 VDC Thermoswitch

6. Lower the thermoswitch temperature to below 40°F (4.4°C). The resistance shown on the ohmmeter should be less than 0.1 ohm.
7. Raise the thermoswitch temperature to above 60°F (15.5°C). The resistance should be more than 10 megohms.
8. Install the thermoswitch in the fuel/water separator. Connect the thermoswitch wiring harness.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Combination Heater Thermoswitch

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heater/thermoswitch unit from the wiring harness, see **Fig. 2**.
5. Connect the ohmmeter leads to the heater/thermoswitch pins.
6. Lower the heater/thermoswitch unit temperature to below 40°F (4.4°C).

   The resistance shown on the ohmmeter should be:

   - 0.8 to 1.1 ohms for a 12 VDC 150 W unit
   - 0.2 to 2.5 ohms for a 24 VDC 250 W unit

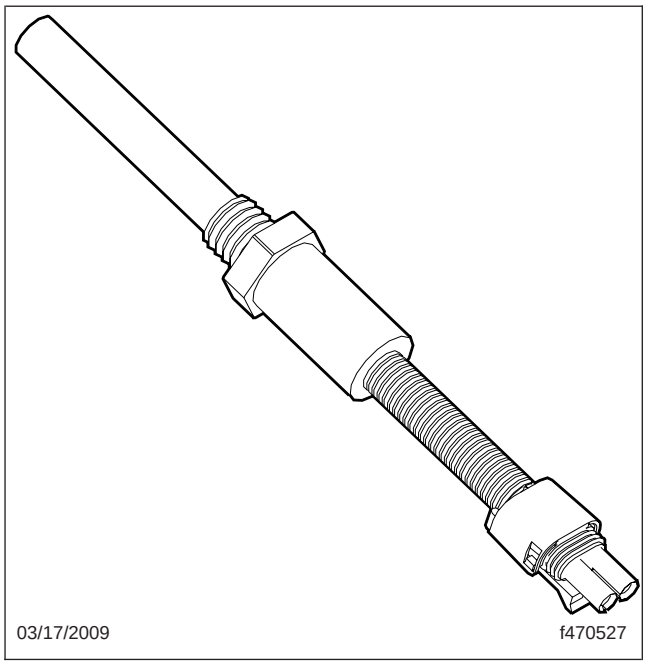


Fig. 2, Combination Heater Thermoswitch

7. Raise the heater/thermoswitch unit temperature to above 70°F (21°C). The heater/thermoswitch unit should show an open circuit.
8. Install the heater/thermoswitch in the fuel/water separator. Connect the heater/thermoswitch wiring harness.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Fluid Heat Exchanger

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

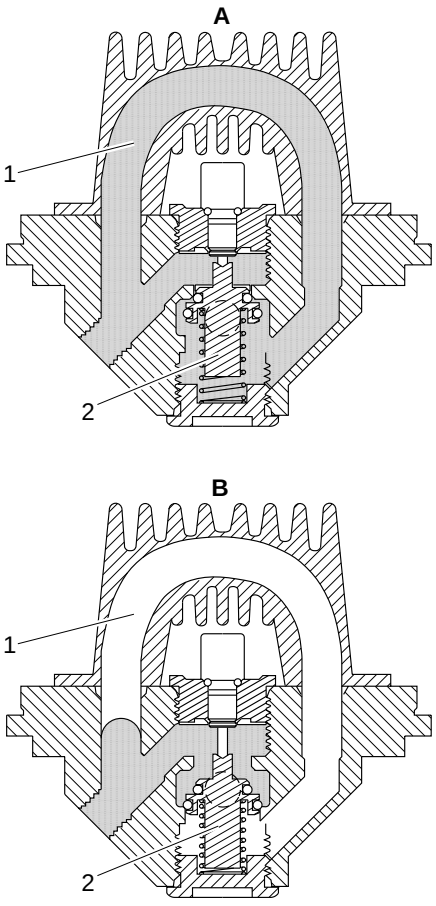
2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heating fluid lines from the bottom plate. These will be either engine coolant lines or return fuel lines. Plug engine coolant lines after removing them from the bottom plate of the housing.
5. Remove the bottom plate and lower housing O-ring.
6. When the fuel entering the fuel/water separator is cold, the thermovalve moves up, allowing warming fluid to enter the heater loop in the heat exchanger. When the fuel is warm, the thermovalve moves down, causing the warming fluid to bypass the heater loop and return directly to the tank. See **Fig. 3**.

Electric Heater, Thermoswitch, and Fluid Heater Tests

While looking into the fluid port of the bottom plate (**Fig. 4**), flow cold water over the thermovalve for 30 seconds, then run hot water over the thermovalve to determine whether the thermovalve spool is opening and closing.



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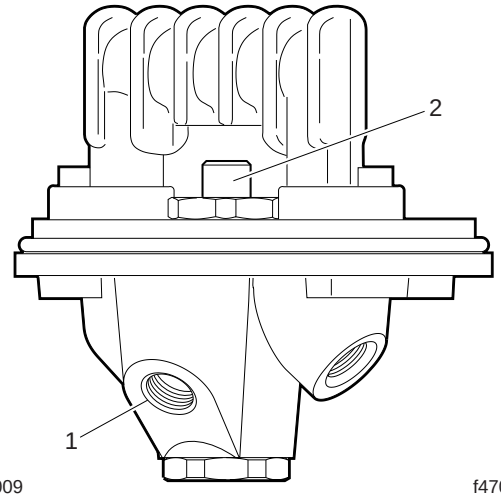
A. Fuel is Cold, Thermovalve Is Up
B. Fuel is Warm, Thermovalve is Down

1. Heater Loop
2. Thermovalve

Fig. 3, Heat Exchanger Fluid Flow

7. Replace the lower housing O-ring, and install the bottom plate on the fuel/water separator. Install the screws on the bottom plate and tighten them 8 to 10 lbf·ft (11 to 14 N·m).
8. Connect the heating fluid lines.
9. Prime the system



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1. Fluid Port
2. Top of Thermovalve Spool

Fig. 4, Fluid Heater Thermovalve Test

9.1 Ensure that the drain valve is closed.

9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.

9.3 Install and hand-tighten the vent cap.

9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.

9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

9.6 Check for leaks and shut down the engine.

The Daimler Trucks North America Learning Center (accessible through **www.AccessFreightliner.com**) and DAVCO (**www.DavcoTec.com**) offer excellent online resources for understanding, testing, and diagnosing fuel/water separator problems.

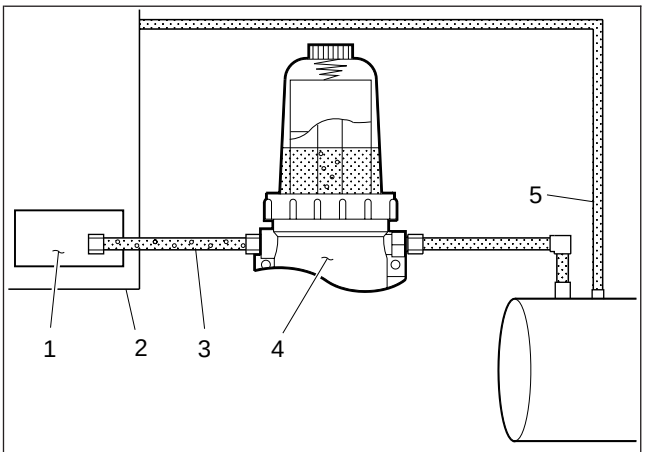
Identifying Bubble Types

Vapor Bubbles

Vapor bubbles are harmless and are present in all diesel fuel systems. Vapor bubbles are often mistaken for air bubbles, but *do not affect engine performance.*

Vapor bubbles (see **Fig. 1**) may be visible in a diagnostic sight tube installed between the fuel/water separator and the fuel pump. They consist of harmless fuel vapor and trapped air, may vary from champagne-size to 1/4-inch (6-mm) diameter, and may increase in volume or size as the engine rpm increases. The lower pressure inside a fuel/water separator filter, caused by the suction of the fuel pump pulling fuel through the fuel/water separator, creates vapor bubbles. These vapor bubbles are normal and harmless to engine operation. In the fuel pump, the fuel is pressurized and the vapor bubbles dissolve. Vapor bubbles do not appear on the fuel return side of the system.

There is no troubleshooting or repair procedure required for vapor bubbles. Vapor bubbles do not cause performance issues and will not be present downstream of the fuel pump.



1. Fuel Pump
2. Engine
3. Fuel Outlet Line, Vapor Bubbles Visible
4. Fuel/Water Separator, Vapor Bubbles Visible *Inside* Filter, *No* Bubbles Visible in Clear Cover
5. Fuel Return Line (no bubbles)

Fig. 1, Harmless Vapor Bubbles

Air and Gas Bubbles

Air or gas bubbles indicate harmful leaks, and can cause hard starting and impaired engine performance. All diesel fuel holds some trapped air, caused by the natural splashing that occurs in the fuel tank. But excessive air bubbles, severe enough to degrade engine performance, indicate an air leak on the suction side of the fuel system, from the fuel tank into the fuel pump.

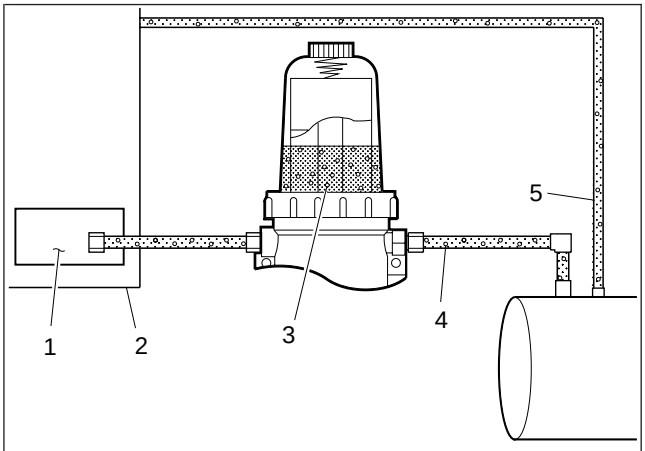
Air bubbles visible in the clear cover of a DAVCO fuel/water separator may indicate an air leak in the fuel system upstream of the bubbles, or in the fuel/water separator; see **Fig. 2**. If there are no bubbles visible in the clear cover but the engine runs rough, there may be an air leak at or between the fuel/water separator outlet port and the fuel pump inlet. These bubbles will be visible in a diagnostic sight tube installed between the fuel pump and the fuel/water separator, and in a diagnostic sight tube installed in the fuel return hose.

Exhaust gas bubbles may also be visible in the clear filter cover. They are the result of leaking fuel injector seals, which can allow combustion gases to enter the fuel system, pass through the fuel return line into the fuel tank, and be drawn into the fuel/water separator. They may be visible in a diagnostic sight tube installed in the fuel return line. To test for combustion gas in the fuel, disconnect the return line at the tank, submerge the end in a bucket of fuel, run the engine, and watch for bubbles. As they pop, these bubbles may smell like exhaust fumes.

In extreme cases, these combustion gas bubbles cause enough aeration in the fuel tank to create visible bubbles in the clear cover of the fuel/water separator and impair engine performance. See the engine manufacturer's documentation for diagnosis and repair of injector seal leakage.

Use the following procedures to determine which bubbles are present in the fuel system, and whether repair is necessary.

Troubleshooting



1. Fuel Pump
2. Engine
3. Fuel/Water Separator, Bubbles Visible in Clear Cover
4. Fuel Inlet Line, Bubbles Visible
5. Fuel Return Line, Bubbles Visible

Fig. 2, Air Bubbles Indicating a Leak

Initial Diagnostic Procedure

1. Apply the parking brake, chock the tires, and turn on the engine.
2. Check for air bubbles in the fuel/water separator clear cover.
3. If no bubbles are visible in the clear cover, but the engine continues to run rough, lopes, or has loss of power, there may be an air leak between the fuel/water separator outlet and the fuel pump inlet.

   If so, bubbles should be visible in a diagnostic sight tube installed at the fuel pump inlet. Air bubbles may also be visible in a diagnostic sight tube installed in the fuel return line to the fuel tank.
4. Replace fuel lines and tighten fittings as needed.

Testing Procedures

Air Leak in the Fuel System

Air leaks are sometimes caused by:

- loose fittings;
- a faulty inlet check valve;
- faulty O-rings;
- leakage elsewhere in the fuel system;
- or dirt on threads and sealing surfaces.

Air leaks originating between the fuel tank and the fuel/water separator cause air bubbles visible in the clear cover, as shown in **Fig. 2**.

If there are symptoms of sucking air and there are no bubbles in the clear cover, look for the air leak at:

- the outlet fitting;
- the fuel pump inlet connection;
- the fuel hose connections;
- or at the vent cap O-ring.

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

2. Remove the fuel hose from the fuel pump inlet port.
3. Install a jumper hose from the inlet port into the fuel tank through the fill cap, or into a container of fuel.
4. Start the engine and look for bubbles in the clear filter cover. If the air bubbles are eliminated, the air source (and the leak) is at either the fuel tank fittings, or the hose connections.

   If air bubbles persist after the tank fittings and hose connections are secured, the leak may be in the fuel/water separator.
5. If the leak is suspected to be in the fuel/water separator, disconnect all fuel connections, coat

the threads with liquid or paste sealer, and reconnect the fuel connections and tighten them securely.

Air Pressure Testing

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Remove the fuel/water separator from the chassis. For instructions, see **Subject 100**.

⚠ WARNING

Wear goggles and skin protection when pressure-testing a fuel/water separator, and be careful not to perform this test near a source of possible ignition, such as an open flame. Never exceed the maximum pressure stipulated for the test, and do not perform this test if the clear cover appears to be damaged.

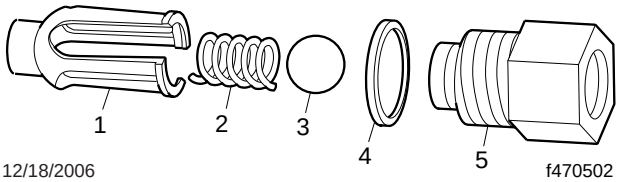
5. Plug the fuel outlet port. Do not remove the filter, filter cover, collar, vent cap, drain valve, or check valve. Do not remove the electric heating element (if equipped), and do not plug the fluid heat ports (if equipped).
6. Apply 15 psi (207 kPa) air pressure at the fuel inlet. Immerse the unit in a tank of water and look for air bubbles.
7. If no bubbles appear, the air leak is not in the fuel/water separator.
8. Install the fuel/water separator onto the chassis frame rail. For instructions, see **Subject 100**.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.

Filter Element Restriction Check

A properly assembled DAVCO fuel/water separator does not restrict fuel flow until the fuel level has risen to the top of the filter. If the fuel level has risen to the top of the filter, replace the filter.

Check Valve Operation Test, Fuel Pro Configurations

When air is introduced into the fuel system, (e.g. when draining fluid or when replacing the fuel filter), the check valve (**Fig. 3**) works to keep the fuel system primed from the fuel tank to the fuel/water separator.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 3, Check Valve Assembly, Fuel Pro Configurations

To test for proper check valve operation, remove the fuel inlet line, then open the vent cap. Fuel should not flow out of the check valve, although a slight seepage of fuel is normal. If fuel drains back out of the check valve, complete the following procedure.

Troubleshooting

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with, the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

2. Put a clean receptacle under the fuel/water separator and attach a piece of hose to the drain valve, to direct fuel into the receptacle.

NOTE: Use a hose with a ½-inch pipe thread to fit the drain valve on a Fuel Pro 382.

3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Place a shop towel under the fuel inlet fitting. Hold the check valve body in place with an open-end wrench and, using a flare-nut wrench, carefully remove the fuel inlet fitting. Drain any residual fuel into the container.
5. Remove the check valve assembly from the fuel/water separator housing, see **Fig. 3**.
6. Clean and inspect the check valve body. If the valve body is damaged, or if the ball seat is not smooth, replace the valve. For instructions, see **Subject 110**.
7. If the valve body and ball seat are not damaged, clean the threads on the check valve body, fuel inlet fitting, and the lower housing.
8. Apply a soft-set pipe thread sealant to the check valve body threads. Install the check valve body in the fuel/water separator housing. Do not use tape to seal the fuel fittings; it will eventually leak.

   Tighten the check valve body 44 to 60 lbf·ft (60 to 81 N·m) on a Fuel Pro 382, or 25 to 40 lbf·ft (34 to 54 N·m) on a Diesel Pro 232/233.
9. Prime the system
   - 9.1 Ensure that the drain valve is closed.
   - 9.2 Remove the vent cap from the clear cover, and fill the housing to the top with clean diesel fuel.
   - 9.3 Install and hand-tighten the vent cap O-ring and vent cap.
   - 9.4 Start the engine. When the lubricating oil reaches its normal operating pressure, increase engine speed to high idle for one to two minutes to purge air from the system.
   - 9.5 While the engine is running, and after the air is purged from the system, loosen the vent cap until the fuel level falls to just above the collar, then hand-tighten the vent cap.
   - 9.6 Check for leaks and shut down the engine.

Other Conditions Visible Inside the Cover

The clear filter covers fitted to DAVCO fuel/water separators provide the opportunity to monitor several aspects of fuel condition and engine status, as described in **Table 1**.

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Amber-colored fuel below the top of the filter element	Nothing, the filter is doing its job	Do not change the filter.

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
Amber-colored fuel with dark patches in places on the filter element	Dark patches indicate bacteria or algae may be present. Use Fleetguard Monitor Kit CC2650 to test for microbiological activity.	It may be necessary to use a microbicide, and suggest vehicle operator carry extra filters.
Extremely dark or cloudy fuel with thick black film or sludge collecting on the filter element	Black film or sludge on the filter media indicates the presence of asphaltenes. It may be necessary to use an asphaltene conditioner.	Do not assume this is oil from the engine. Monitor the vehicle for oil consumption. Refer to engine manufacturer's service literature for more information.
Bubbles inside the clear cover	Check for air leaks anywhere in the fuel system. Any leak in any fitting will cause bubbles to appear in the clear cover.	This problem will lead to power complaints; it must be remedied.
No bubbles in the cover, but the engine is running rough	Check for air leaks between the fuel/water separator outlet port and the fuel pump inlet. Check and tighten all fuel fittings in the area of the leak.	Do not replace the fuel/water separator.
Coolant in the fluid drained from the fuel/water separator	Check for leaks in the engine, where fuel and coolant are near each other. The most common problem place is the injector cup.	Do not allow the equipment to be operated until the problem is found and repaired.
Anything not listed here	Call DAVCO at 1-800-328-2611, or email: customerservice@DavcoTec.com.	—

Table 1, Conditions Visible Inside DAVCO Clear Filter Covers

Specifications

Torque Values					
Component	Fuel Pro 482	Fuel Pro 382		Diesel Pro 243	
	lbf·ft (N·m)	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)
Inlet Port/Check Valve	45 (61)	44–60 (60–81)	—	12–14 (16–19)*	—
Water in Fuel Sensor	—	—	20–24 (226–271)	—	20–24 (226–271)
Electric Heating Element	15–30 (20–41)	15–30 (20–41)	—	25–40 (34–54)	—

* Check valve assembly not connected to inlet port on Diesel Pro 243 configurations.

Table 1, Torque Values

General Description

IMPORTANT: The liquefied natural gas (LNG) fuel system should be routinely inspected for gas leakage. Always use a natural gas detector to check the fuel tank, fuel filtering and regulating mechanisms, and fuel lines. Repair or replace any lines, devices, or connections that are leaking.

LNG is created by condensing natural gas into a liquid by cooling it to approximately -259°F (-162°C). When vaporized at ambient temperatures, natural gas is less dense than air, and it will rise and disperse. Cold atmospheric conditions may prevent natural gas from disbursing quickly when released in large amounts.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

For natural gas to burn, it must first vaporize, then mix with air in the proper proportions (flammable range is 5 to 15% by volume in air), and then be ignited.

The LNG fuel system consists of the following components:

- fuel tank that stores LNG at an extremely low temperature
- pressure relief and manual fuel shutoff valves
- vaporizor or heat exchanging device that changes LNG to gaseous form
- filling connection with a check valve that prevents the gas from flowing back out of the fuel filling line
- pressure control regulator that reduces the high fuel tank pressure to the lower pressure needed for the engine
- gas-air mixer to produce a flammable mixture for the engine
- economizer, or pressure control regulator, that opens at pressures above 120 psi (827 kPa) to reduce pressure in the fuel tank
- dash-mounted fuel contents gauge that indicates the fuel supply in the tank

If a natural-gas-fueled vehicle is involved in an accident and the fuel tank is damaged, remove the tank from service and have it inspected and repaired by the tank manufacturer. Repair or replace any damaged or leaking fuel lines, fittings, or other components. Install parts and components in accordance with the manufacturer's instructions.

Related Information and Websites

Detailed LNG fuel system component repair, replacement, and troubleshooting information can be obtained from the fuel system manufacturer's website: **www.nexgenfueling.com**.

Chart Inc.
407 7th Street NW
New Prague, MN 56071
1-800-838-0856

The National Fire Protection Association website provides additional information about LNG and LNG fuel systems: **www.nfpa.org**.

Safety Precautions

⚠ WARNING

Natural gas vapors are highly flammable. Failure to observe the following safety precautions could lead to ignition of the natural gas, which could case severe bodily injury, death, or property damage.

Liquefied natural gas (LNG) vapors are highly flammable. Whenever a leak is suspected, immediately shut off all engines and ignition sources. Avoid causing sparks, and stay away from arcing switches and equipment. Extinguish cigarettes, pilot lights, flames, and other sources of ignition in the area and adjacent areas. Immediately provide extra ventilation to the area. Do not start any equipment until the gas leak is corrected and the area cleared of LNG.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

Periodic inspections of the LNG tank are required by law to ensure continued safety. Each fuel tank should be visually inspected at specified intervals for external damage and deterioration. See the *108SD and 114SD Maintenance Manual* for inspection schedule information.

If a tank receives an impact, or has deep scratches or gouges, it should be inspected before refilling. The inspection should be performed by a qualified person, in accordance with the tank manufacturer's established inspection criteria.

Always use a natural gas detector to test the system for leaks, whether an odor is present or not. A bubble solution can be used to pinpoint the exact location of leaks.

Servicing Precautions

Observe the following safety precautions when servicing LNG-powered vehicles.

- Always purge the fuel lines and tank before performing maintenance or repairs on the fuel system. This can be done by either transferring LNG in the fuel tank to an approved cryogenic-rated container, or by running the vehicle until the tank is empty and the engine stops.
- Close the fuel tank shutoff valves before performing maintenance and repairs. Open the valves only if LNG is needed to operate the engine or to check for leaks.
- Repair work on an LNG fuel system should be performed only by qualified technicians trained in automotive LNG system repair.
- Always tighten fasteners and fuel connections to the required torque specification. Overtightening or undertightening could cause leaks.
- Cover eyes and exposed skin with cryogenic-rated protective devices when working on the fuel system or fueling the vehicle.

Workshop Precautions

Do not store an LNG vehicle indoors for any extended period of time.

Observe the following safety precautions when LNG vehicles are inside a workshop.

- Use only safety fluorescent extension shop lights when working around LNG fuel systems.
- Ensure the shop ceiling is equipped with a vent system that will allow gas to escape and dissipate.
- Ensure the shop is equipped with an alarm system that activates when gas concentration in the air becomes dangerous.
- Have CO_2 fire extinguishers (ABC minimum) located in a highly visible and easily accessible location.
- Permit no smoking or other ignition sources within thirty feet of an LNG vehicle.
- Avoid open flames or sparks near an LNG vehicle.
- Check the fuel tank pressure gauge periodically to ensure that pressure is within the normal range of 120 to 150 psi (827 to 1034 kPa). In the unlikely event that tank pressure exceeds 230 psi (1586 kPa) and the pressure relief valve does not open automatically, vent the tank outdoors immediately.

Major Repair and Replacement of Parts

If a natural-gas-fueled vehicle is involved in an accident, remove the fuel tank from service and have

them inspected by a qualified technician. Replace any leaking or damaged fuel tanks and fuel lines; repair or replace leaking or damaged fittings. Install parts and components in accordance with the manufacturer's instructions.

Any and all replacement parts (valves, fittings, tubing, etc.) of the LNG fuel system must be designed specifically for LNG use, and must be approved for use by the fuel system manufacturer.

Install parts and components in accordance with the fuel system manufacturer's instructions.

Gas Detection System

A gas detection system is used in all Daimler Trucks LNG-fueled vehicles. The system has a sensor in the engine compartment and one in the cab, both situated in high areas to detect natural gas buildup as a result of leaks. The system is meant to serve as a supplemental warning only. It is not intended to replace standard safety practices that should be conducted around flammable gases.

IMPORTANT: To function properly, the gas detection system must be powered at all times. The gas detection system is directly powered by the batteries, and can only be powered off by disconnecting the batteries. When servicing a natural-gas-fueled vehicle, disconnect the batteries only when necessary, and do not leave the batteries disconnected for extended periods of time.

De-Fueling

⚠ WARNING

Liquefied natural gas (LNG) vapors are highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

IMPORTANT: Only vent liquefied natural gas (LNG) outdoors in a safe location. Follow all local, state, and federal guidelines regarding usage and venting of LNG.

Purging the fuel system and fuel tank can be done by either transferring LNG in the fuel tank to an approved cryogenic-rated container, or by running the vehicle until the tank is empty and the engine stops.

Detailed LNG tank de-fueling information and procedures can be obtained from the fuel system manufacturer: **www.nexgenfueling.com**.

Chart Inc.
1300 Airport Drive
Ball Ground, GA 30107
770-479-6531

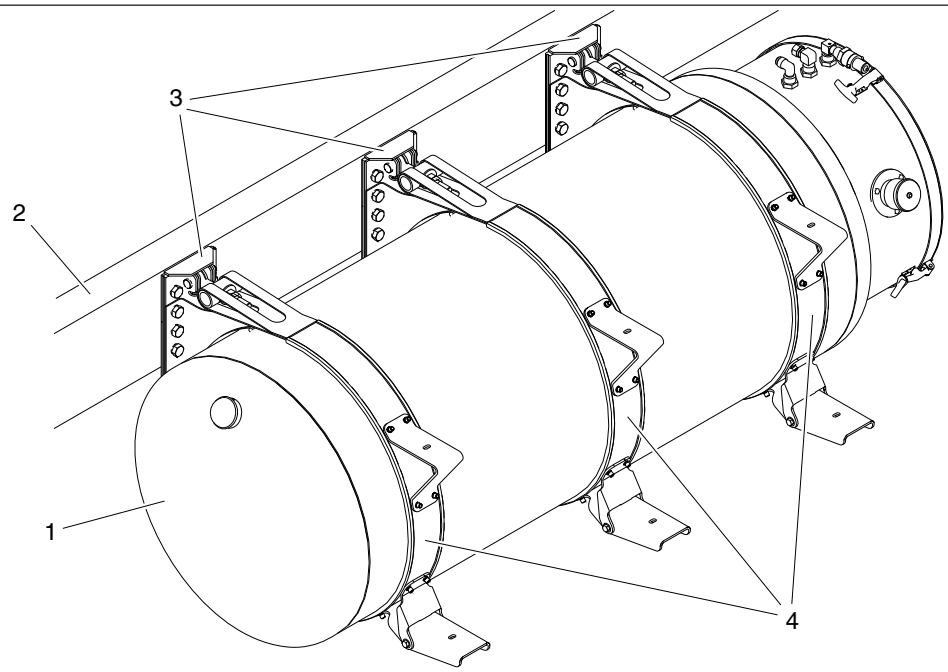
Removal

If there is any damage to the liquid natural gas (LNG) tank, replace it.

⚠ WARNING

Do not expose the fuel to open fire. Do not work with the fuel system near open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

Figure 1 shows a typical LNG tank installation.



1. LNG Tank
2. Frame Rail
3. Tank Mounting Bracket
4. Tank Straps

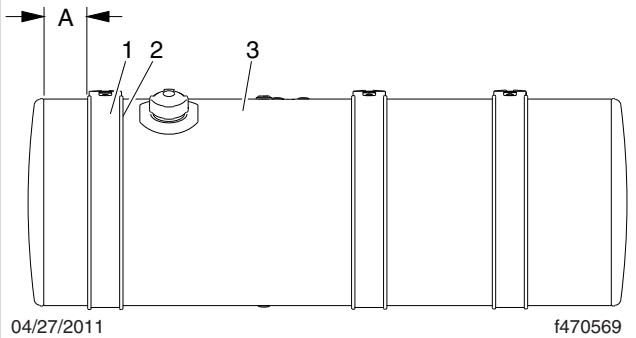
Fig. 1, LNG Tank Installation (left side shown)

1. Remove the access steps as needed.
2. Close the fuel shutoff valve on tanks that are not being removed.
3. De-fuel the tank to be removed. For more information, see **Subject 110**.
4. Disconnect the fuel lines from the tank. Cap or plug the open lines and fittings to prevent contamination.
5. Disconnect the electrical connectors from the tank.
6. Before removing the fuel tank bands, measure and record the distance from the forward edge of the fuel tank to the edge of the forwardmost band isolator. See **Fig. 2**.
7. To prevent the fuel tank from rolling during and after removal, nail 2-by-4 or 4-by-4 wooden blocks to the top of a pallet about 18 inches (46 mm) apart, then place the pallet on the forks of a fork lift. See **Fig. 3**.

   Move the fork lift and pallet into place to support the fuel tank.
8. Loosen the jam nut on each tank band eye bolt. Remove the jam nut, inner hexnut, and washer. See **Fig. 4**.

   Drop the tank bands and isolators. Leave the tensioner lug inside the band.
9. Remove the fuel tank.

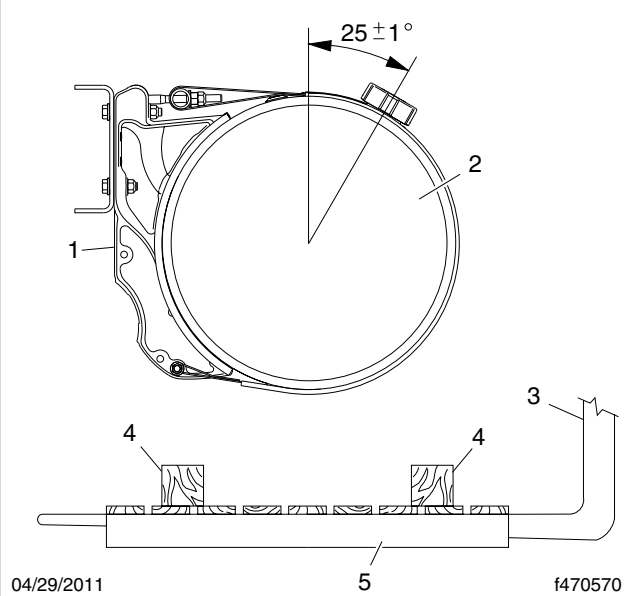
Tank Removal and Installation



A. Measure this distance.

1. Tank Band
2. Tank Band Isolator
3. Fuel Tank

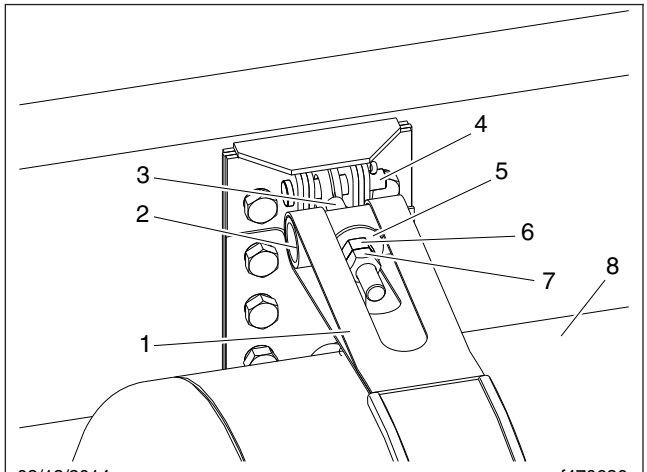
Fig. 2, Distance From Forward Edge of Fuel Tank to Isolator (diesel tank shown)



1. Fuel Tank Bracket
2. Fuel Tank
3. Fork Lift
4. Wooden Blocks
5. Wooden Pallet

Fig. 3, Fuel Tank Orientation and Support (diesel tank shown)

10. After removing the tank, inspect the tank bands, isolators, and brackets for damage. Replace worn or damaged parts with new parts.



1. Tank Strap
2. Tensioner Lug
3. Eye Bolt
4. Large Clevis Pin
5. Washer
6. Hexnut
7. Jam Nut
8. Fuel Tank

Fig. 4, Fuel Tank Band Assembly

Installation

1. Using the fork lift and pallet, put the fuel tank in its approximate installed position. See **Fig. 3**.
2. Install the forward tank band and band isolator loosely.
   - 2.1 Holding the tank on the forklift, attach the band and isolator to the eye bolt.
   - 2.2 Install a hardened flatwasher and the inner hexnut, but do not tighten it yet.
3. Adjust the tank position until the distance between the forward edge of the tank and the tank band is equal to the distance measured in **Fig. 2**.

NOTICE

Fuel tanks can be damaged by direct isolator pressure on the tank weld seam, and by overtightening the fuel tank bands. Be sure the weld seam aligns with reliefs in the isolators and that the bands are tightened to specification.

4. Install the other tank band around the tank. Insert the isolators under the brackets so that the relief in each isolator aligns with the tank longitudinal weld seam.

5. Tighten the inner hexnuts alternately in stages, until each is tightened 32 lbf·ft (44 N·m).
6. Install a jam nut on each hexnut, then tighten each jam nut 32 lbf·ft (44 N·m).
7. Make certain the fuel lines are clean, then install them on the fuel tank fittings.
8. Install the access steps.
9. Fill the fuel tank. For more information, see **Subject 110**.
10. Check for leaks. Repair as needed.

Welding

⚠ WARNING

Liquefied natural gas (LNG) vapors are highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

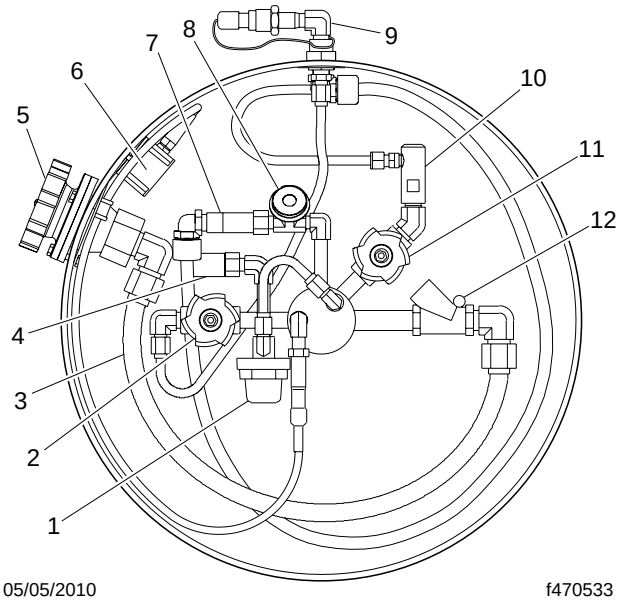
NOTICE

Welding an LNG fuel tank could damage the tank vacuum insulation and/or void the warranty. Consult the tank manufacturer (www.nexgenfueling-.com or 770-479-6531) before welding an LNG tank.

IMPORTANT: Follow all local, state, and federal guidelines regarding usage and venting of LNG.

1. Park the vehicle on a level surface, shut down the engine and set the parking brake. Chock the tires.
2. Ensure the vehicle is parked in a well-ventilated area. Do not park the vehicle in an area where natural gas can accumulate.
3. De-fuel the LNG tank. See **Subject 110** for more information.
4. Close the fuel shutoff and vapor shutoff valves. See **Fig. 1**.
5. Use a natural gas detector to test the area around the vehicle for natural gas.
6. Shut down all vehicle electrical systems.
7. Cover the LNG tank and fuel lines with a metal shield or welding blankets to prevent sparks or residue from falling on LNG equipment.
8. Complete all necessary welding, then remove the protective welding blankets or metal shield.
9. Start up the vehicle electrical systems.
10. Fill the LNG tank with fuel.

    IMPORTANT: Close all windows and doors during the fueling process. Keeping windows and doors closed allows for easier leak detection inside the cab after fueling.



1. Economizer
2. Vapor Shutoff Valve
3. Fuel Fill Hose
4. Secondary Relief Valve (red cap)
5. Fuel Fill Fitting
6. Fuel Level Sender Box
7. Primary Relief Valve
8. Tank Pressure Gauge
9. Fill Vent Fitting
10. Excess Flow Valve
11. Fuel Shutoff Valve (liquid)
12. Fill Check Valve

Fig. 1, Fuel Tank Plumbing Components

10.1 Remove the fuel fill fitting dust cap. See **Fig. 2**.

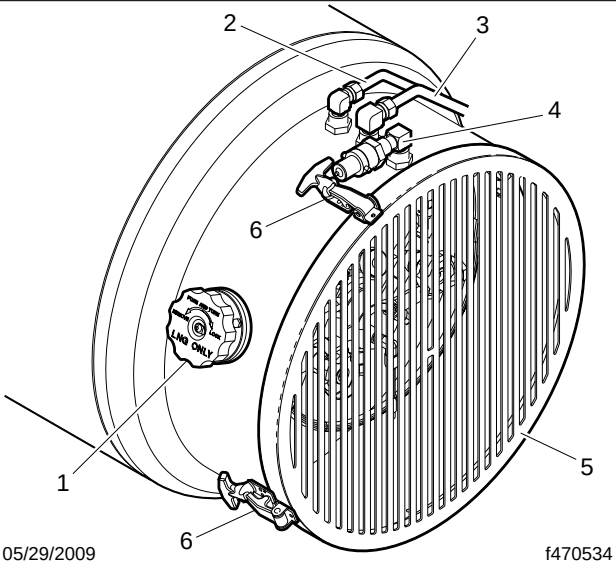
10.2 Using compressed nitrogen or a wire brush, remove any dirt, debris, or water that may have collected in the fuel fill fitting and the station dispensing nozzle.

10.3 Connect the station fueling nozzle to the tank fuel fill fitting.

10.4 Connect an electrical ground clamp and cable to the fuel tank.

IMPORTANT: An LNG tank on a vehicle that has not been operated in approximately ten days is considered to be a hot tank. When fueling a hot tank, LNG entering the tank will immediately vaporize, causing tank pressure to spike above 250 psi (1724 kPa) and automatically shutting down the station fuel pump. To prevent the pump from shutting

Welding an LNG Vehicle



1. Fuel Fill Fitting
2. Fuel Outlet Line
3. Primary Relief Vent Line
4. Fill Vent Fitting
5. Shroud Cover
6. Shroud Cover Latches

Fig. 2, LNG Fuel Tank

down, connect a vent line to the fill vent fitting to capture escaping vapor, then open the shroud cover and open the vapor shutoff valve.

10.5 Open the station's fill valve, if equipped, and start fueling. Monitor the flow or line pressure as filling progresses.

IMPORTANT: When fueling a hot tank, initially put 5 to 10 gallons (19 to 37 liters) of LNG in the tank and manually stop the fueling process. Drive the vehicle for 15 to 20 minutes to cool the tank and reduce tank pressure, then continue fueling the tank to full.

10.6 When a rapid pressure rise or flow rate drop is observed, close the station's fill valve, if equipped.

10.7 Disconnect the station hose from the tank fuel fill fitting.

10.8 Disconnect the electrical ground clamp and cable from the fuel tank.

10.9 Install the dust cap on the tank fuel fill fitting.

11. Open the fuel shutoff and vapor shutoff valves. See **Fig. 1**.

LNG System

Refer to the system manufacturer's service literature for system troubleshooting information.

If a natural-gas-fueled vehicle is involved in an accident and the fuel tank is damaged, remove the tank from service and have it inspected and repaired by the tank manufacturer. Repair or replace any damaged or leaking fuel lines, fittings, or other components. Install parts and components in accordance with the manufacturer's instructions.

Methane Detection System

⚠ WARNING

Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

The 108SD/114SD is equipped with a two-zone natural gas detection system. One sensor is located in the cab overhead panel in the control panel, the other sensor is located on the frontwall in the engine compartment. The system is powered directly from the vehicle batteries and is active at all times, unless the batteries are disconnected. When the system has power, and is operating normally with all sensors confirmed operational, and no leaks detected, the green "Power" LED, and the large green light are on. When the presence of gas is detected in any zone, an indicator LED will illuminate depending on the level of gas detected. If a problem with a sensor or wiring occurs, a "Fault" LED will illuminate for the zone that is affected. When a fault is present, no detection is operational in that zone. The following troubleshooting tables show all the different possible light combinations, what they indicate, the troubleshooting procedures, and the suggested remedy. For vehicle-specific wiring diagrams, refer to G06-89262 in EZWiring™.

IMPORTANT: Before performing any troubleshooting, allow the system 60 seconds to complete the initialization process.

Green "Power" Light On

03/20/2014 f470621

Front Panel Indication	Troubleshoot	Remedy
The green "Power" LED on the main panel and the large green LED are on. The system has power and is operating normally. In this state the panel and all sensors are confirmed operational.	System is operating normally.	No repair needed.

Troubleshooting

No Lights on Front Panel

03/06/2014 f470622

Front Panel Indication	Troubleshoot	Result	Remedy
No lights are illuminated on the panel. The panel has no power. No gas detection or warning is possible.	Are all of the connectors plugged in at the back of the panel?	Yes	Go to next the step.
		No	Plug in the connector. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Is there power (9-14 vdc) and ground at the panel?	Yes	Replace the panel.
		No	Go to the next step.
	Check the terminal on the back of the panel for loose or improperly installed pins. Were there any bad pins?	Yes	Repair and Go to next the step. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Is the fuse blown or missing at the power-net distribution box (PNDB)?	Yes	Replace the fuse. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Does the circuit have continuity or high resistance?	Yes	If it has continuity, and still has no power go to PNDB troubleshooting.
		No	If there is no continuity, or high resistance Go to next the step.
	Check connectors at the fire wall and PNDB. Have any of the cables been pinched, cut, or damaged?	Yes	Replace the damaged cable(s).
		No	Contact the vendor.

Amber "Sensor Fault" Light On

03/20/2014 f470623

Front Panel Indication	Troubleshoot	Result	Remedy
The amber "Sensor Fault" light indicates that there is a problem in the zone specified. In this case zone 1 and 2. When a fault light is on, detection is not possible in any zones where a fault is present.	Check the sensor connections at the back of the panel and at the sensors. Are the connectors loose or damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Check the pins in the connectors on the panel and in the sensors. Are the pins loose or damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	If both "Sensor Fault" lights are on, skip this step and proceed to the next step. Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step.
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check for continuity in the harness. Is there high resistance in the sensor harness?	Yes	Replace the harness.
		No	Replace the sensor, unless it is both, then replace the panel.

Troubleshooting

Amber "Trace" Light Flashing

03/20/2014 f470624

Front Panel Indication	Troubleshoot	Result	Remedy
The flashing amber "Trace" light indicates that a trace amount of gas (greater than 20% and less than 50%) has been detected in the specified zone, in this case zone 2.	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step.
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed.
	check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

⚠ WARNING

The following tests should only be performed after determining that it is safe to do so.

Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.).

Have the problem repaired by qualified personnel before further operation of the vehicle.

Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.

Red "SIGNIFICANT" Light, Amber "Trace" Lights, and Buzzer 1

03/20/2014 f470625

Front Panel Indication	Troubleshoot	Result	Remedy
The red "SIGNIFICANT" light and amber "Trace" lights and buzzer 1 indicate that a significant level of combustible gas (greater than 50% lower explosive limit (LEL)) has been detected in the applicable zone. In this case zone 2. Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.). Have the problem repaired by qualified personnel before further operation of the vehicle. Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.	Is the "Amerex Push to Test" button being held?	Yes	Let go.
		No	Go to next the step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to next the step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step.
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

Troubleshooting

Red "SIGNIFICANT" Light, Amber "Trace" Lights, and Buzzers 1 and 2

03/20/2014 f470626

Front Panel Indication	Troubleshoot	Result	Remedy
The red "Significant" light and amber "Trace" lights along with buzzers 1 and 2 indicate that a significant level of combustible gas (greater than 50% LEL) has been detected in the applicable zone, in this case zone 2. Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.). Have the problem repaired by qualified personnel before further operation of the vehicle. The large red LED and buzzer 2 indicates the significant gas detection has been present for over 15 seconds and the relay has engaged. Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.	Is the "Amerex Push to Test" button being held and has it been held continuously for 15 seconds causing the relay to trip?	Yes	Release the button, and press the "Shutdown/Reset" button to reset the relay. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to next the step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable proceed to the next step.
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

Red "Relay Engaged" LED, Large Red LED, and Buzzer 2

03/20/2014 f470627

Front Panel Indication	Troubleshoot	Result	Remedy
The red "Relay Engaged" LED and the large red LED along with buzzer 2 indicates that a significant level of gas (greater than 50%) was detected at some point. The significant gas level is no longer present, as the "SIGNIFICANT" LED and "Trace" LED are no longer illuminated. The panel relay has engaged and must be reset by pressing the "Shutdown/ Reset" button. Do not troubleshoot the system until the reason for the significant alarm is understood.	Has the "Amerex Push to Test" button been pressed and held for 15 seconds causing the relay to trip?	Yes	Press the "Shutdown/Reset" button. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to next the step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to next the step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step.
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

General Description

IMPORTANT: The compressed natural gas (CNG) fuel system should be routinely inspected for gas leakage. Use a natural gas detector to check fuel cylinders, fuel filtering and regulating mechanisms, and fuel lines. Replace leaking fuel cylinders; repair or replace any lines, devices, or connections that are leaking.

CNG is made by compressing natural gas to less than 1% of its volume at standard atmospheric pressure. When vaporized at ambient temperatures, natural gas is less dense than air, and it will rise and disperse. Cold atmospheric conditions may prevent natural gas from disbursing quickly when released in large amounts.

Natural gas is nontoxic, but can cause asphyxiation at high enough concentrations simply by excluding adequate oxygen to sustain life.

Commercial CNG normally contains an odor-producing chemical. However, a natural gas detector is recommended for leak checking.

For natural gas to burn, it must first vaporize, then mix with air in the proper proportions (flammable range is 5 to 15% by volume in air), and then be ignited.

The CNG fuel system consists of the following components:

- fuel cylinders that store CNG at high pressure
- pressure relief and manual fuel shutoff valves
- filling connection with a check valve that prevents the gas from flowing back out of the fuel filling line
- high-pressure fuel filter
- pressure control regulator that reduces the high fuel cylinder pressure to the lower pressure needed for the engine
- gas-air mixer to produce a flammable mixture for the engine
- dash-mounted fuel contents gauge that indicates the available fuel supply in the cylinders

Related Information and Websites

Detailed CNG fuel system repair, replacement, and troubleshooting information can be obtained from the fuel system manufacturer.

Agility Fuel Systems
1815 E Carnegie Avenue
Santa Ana, CA 92705
949-267-7738

www.agilityfuelsystems.com

Agility Customer Support, 949-267-7745.

The following documents and websites provide additional information about CNG and CNG fuel systems:

- NFPA 52 *Vehicular Gaseous Fuel Systems Code, 2010*: **www.nfpa.org**
- Society of Automotive Engineers *Recommended Practice for Compressed Natural Gas Vehicle Fuel*: **standards.sae.org/j1616_199402/**
- Compressed Gas Association: **www.cganet-.com**

Safety Precautions

⚠ WARNING

Compressed natural gas is highly flammable. Failure to observe the following precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

Whenever gas is smelled, immediately shut off all engines and ignition sources. Avoid causing sparks, and stay away from arcing switches and equipment. Extinguish cigarettes, pilot lights, flames, and other sources of ignition in the area and adjacent areas. Immediately provide extra ventilation to the area. Do not start any equipment until the gas leak is corrected and the area cleared of natural gas.

Periodic inspections of the compressed natural gas (CNG) fuel cylinders are required by law to ensure continued safety. Each fuel cylinder should be visually inspected at specified intervals for external damage and deterioration. See the *108SD and 114SD Maintenance Manual* for inspection schedule information.

If a cylinder receives an impact or has deep scratches or gouges, it should be inspected before refilling. The inspection should be performed by a qualified person, in accordance with the manufacturer's established inspection criteria and Compressed Gas Association procedures.

Always use a natural gas detector to check for leaks.

Servicing Precautions

Observe the following safety precautions when servicing CNG-powered vehicles.

- Always purge the fuel lines before performing maintenance or repairs on a CNG fuel system. Do not transfer CNG from one vehicle to another, as a buildup of static electricity could cause a spark and ignite the fuel.
- Only vent CNG outdoors in a safe location.
- Close the fuel cylinder shutoff valves before performing maintenance and repairs. Open the valves only if CNG is needed to operate the engine or to check for leaks.
- Repair work on a CNG fuel system should be performed only by qualified technicians trained in automotive CNG system repair.
- Always tighten fasteners and fuel connections to the required torque specification. Overtightening or undertightening could cause leaks.
- Cover eyes and exposed skin when working on a CNG fuel system or fueling a CNG vehicle.

Workshop Precautions

Do not store a CNG vehicle indoors for any extended period of time.

Observe the following safety precautions when CNG vehicles are inside a workshop.

- Use only safety fluorescent extension shop lights.
- Ensure the shop ceiling is equipped with a vent system that will allow gas to escape and dissipate.
- Ensure the shop is equipped with an alarm system that activates when gas concentration in the air becomes dangerous.
- Have CO_2 fire extinguishers (ABC minimum) located in a highly visible and easily accessible location.
- Permit no smoking or other ignition sources within thirty feet of a CNG vehicle.
- Avoid open flames or sparks near a CNG vehicle.
- Close the fuel cylinder shutoff valves when storing the vehicle inside. Open the valves only if CNG is needed to operate the engine or to check for leaks.

Major Repair and Replacement of Parts

Replace any leaking or damaged fuel cylinders and fuel lines; repair or replace leaking or damaged fittings. Install parts and components in accordance with the manufacturer's instructions.

Any and all replacement parts (valves, fittings, hoses, etc.) of the CNG fuel system must be designed specifically for CNG automotive use, and must be offi-

cially approved and rated for the pressures and conditions that pertain.

Gas Detection System

A gas detection system is used in all Daimler Trucks CNG-fueled vehicles. The system has a sensor in the engine compartment and one in the cab, both situated in high areas to detect natural gas buildup as a result of leaks. The system is meant to serve as a supplemental warning only. It is not intended to replace standard safety practices that should be conducted around flammable gases.

IMPORTANT: To function properly, the gas detection system must be powered at all times. The gas detection system is directly powered by the batteries, and can only be powered off by disconnecting the batteries. When servicing a natural-gas-fueled vehicle, disconnect the batteries only when necessary, and do not leave the batteries disconnected for extended periods of time.

Venting

⚠ WARNING

Compressed natural gas is highly flammable. Do not attempt to transfer compressed natural gas (CNG) from one vehicle to another, as a buildup of static electricity could cause a spark and ignite the fuel, which could cause severe bodily injury, death, or property damage.

IMPORTANT: Only vent compressed natural gas (CNG) outdoors in a safe location. Follow all local, state, and federal guidelines regarding usage and venting of CNG.

The fuel cylinder shutoff valves are installed in line from top to bottom. Closing a fuel cylinder shutoff valve will cut off the flow of CNG from that cylinder and all of the fuel cylinders positioned above it in the storage box.

Compressed natural gas can be vented from the fuel cylinders in two ways.

- Run the engine until it stops.
- Open the CNG bleed valve on the manifold.

If only one cylinder needs to be purged, close the fuel shutoff valves on the fuel cylinders positioned above it. Then, either run the engine until the cylinders are empty and the engine stops, or open the bleed valve and allow the CNG to vent. At this time, all CNG in the venting cylinder and the cylinders in line below it will have vented.

CNG Fuel Tank Removal and Installation

⚠ WARNING

Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

NOTE: The tanks can be removed with CNG present in the tanks. Tanks must be stored outdoors, or in an approved facility with proper ventilation, and a natural gas safety monitoring system.

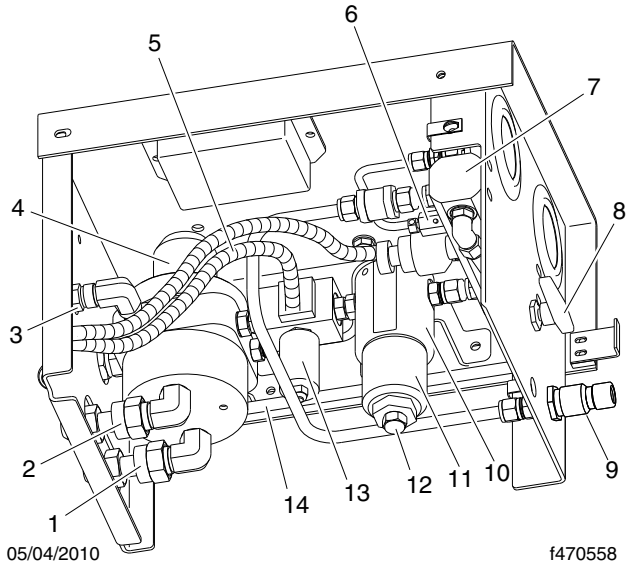
Back-of-Cab-Mounted Tank Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brakes. Chock the tires.
2. Depressurize the CNG system. Follow the instructions in **Subject 110**.

IMPORTANT: Some residual pressure and gas from the low-pressure side of the system may escape when loosening the fittings. Be prepared for this, and observe all safety precautions.

NOTE: The fuel management module (FMM), coolant hoses, natural gas fuel lines, and wire harnesses are located in the lower area of the cabinet on vehicles with only a back-of-cab installation. See **Fig. 1**.

3. Disconnect CNG fuel lines.
4. Cap or plug all open fuel lines and fittings to prevent system contamination.
5. Position the lifting device as needed and connect the chain or sling to the eyelets on the top of the cabinet. Apply enough pressure to prevent the cabinet from tipping when loosened.
6. Remove the mounting bracket bolts. See **Fig. 2**.
7. Using safe lifting procedures with a forklift or hoist, lift the tank up off the frame rails and out or backwards to clear the chassis.



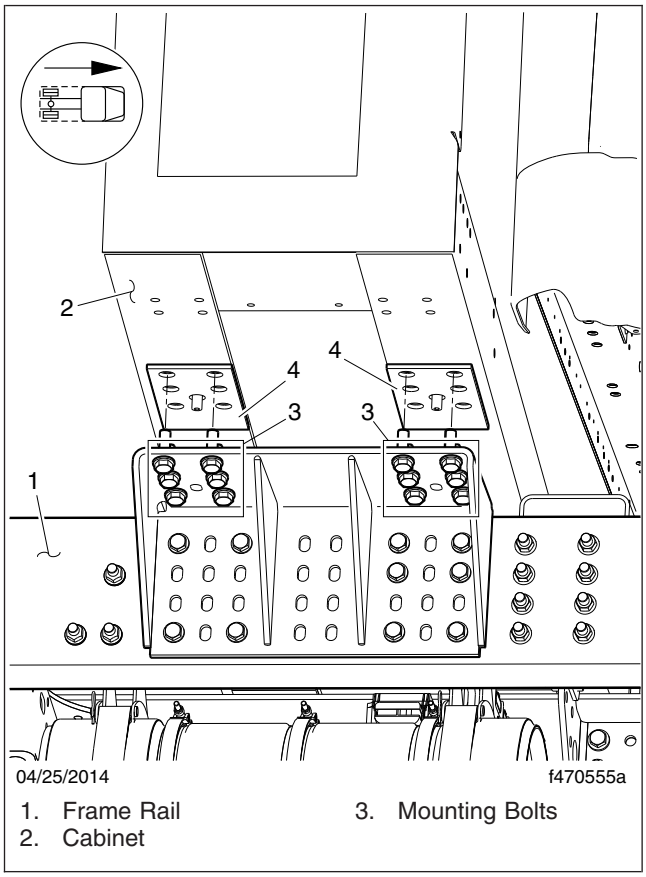
1. Coolant Inlet Port
2. Coolant Outlet Port
3. Pressure Relief Valve
4. Pressure Regulator
5. Wiring Harness
6. Manifold Bleed Valve
7. Manifold
8. Manual Fuel Shut-Off Valve
9. Fuel Fill Port
10. Filter Housing
11. Filter Bowl
12. Filter Drain Plug
13. Solenoid Valve
14. Fuel Line To Cylinders

Fig. 1, Back-of-Cab Plumbing and Wiring

Back-of-Cab Mounted Tank Installation

1. Using an appropriate lifting device, position the cabinet on the frame rails and align the mounting bracket holes on the cabinet with the holes in the mounting brackets on the frame rails.
2. While still supported with the lifting device, install the mounting bolts with washers from the bottom of the cabinet. See **Fig. 2**. Tighten the nuts 160 lbf·ft (217 N·m).
3. Remove lifting device.
4. Connect the coolant hoses.
5. Connect the CNG fuel lines. Tighten the fittings to the specifications shown in **Table 2**.
6. Connect the wiring harnesses.
7. Secure any mounting that was removed.

CNG Fuel Tank Removal and Installation



1. Frame Rail
2. Cabinet
3. Mounting Bolts

Fig. 2, Back-of-Cab Cabinet Installation

8. Pressurize the system.
9. Check for leaks per the manufactures specifications. Repair any leaks as needed.

⚠ WARNING

Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

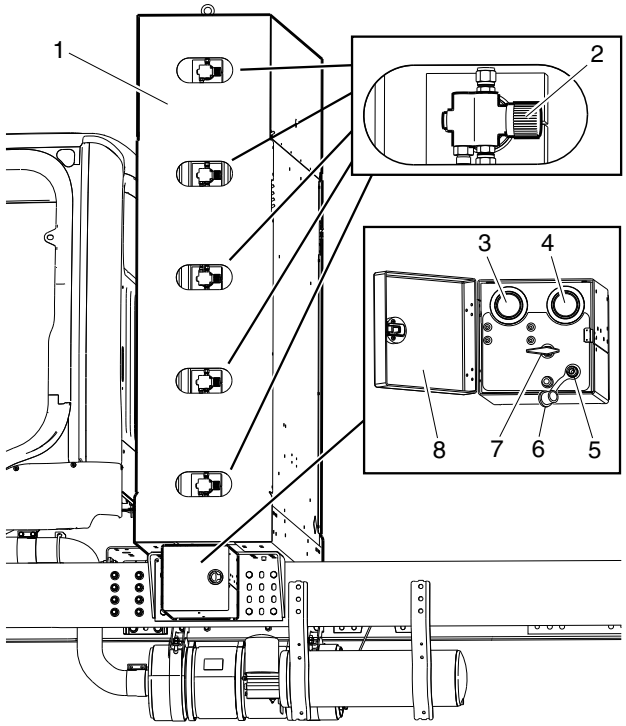
Welding

IMPORTANT: Follow all local, state, and federal guidelines regarding usage and venting of compressed natural gas (CNG).

1. Park the vehicle on a level surface, shut down the engine and set the parking brake. Chock the tires.
2. Close the CNG fuel cylinder shutoff valves. See **Fig. 1**.
3. Start the engine and let it idle until the fuel lines are empty and the engine stops. The gauges on the fuel panel should now read at or near 0 psi (0 kPa).
4. Close the manual fuel shutoff valve on the fuel panel.
5. Remove and save the two capscrews that secure the access cover to the fill panel, then remove the access cover. See **Fig. 2**.
6. Slowly open the bleed valve on the manifold to relieve remaining fuel pressure within the system. See **Fig. 3**.

IMPORTANT: Some pressure may remain in the fuel system between the solenoid valve and the engine. Use caution when loosening fittings, as a small amount of gas may leak out.

7. Disconnect the wiring harness from the solenoid valve.
8. Use a remote 12-volt power source to activate the solenoid valve to drain any compressed natural gas remaining in the fuel system between the solenoid valve and the engine.



1. Fuel Cylinder Storage Box
2. Fuel Cylinder Shutoff Valves (5 valves on a 5-tank system)
3. High-Pressure Gauge
4. Low-Pressure Gauge
5. Fuel Fill Port
6. Dust Cap
7. Manual Shutoff Valve
8. Fuel Panel Access Door

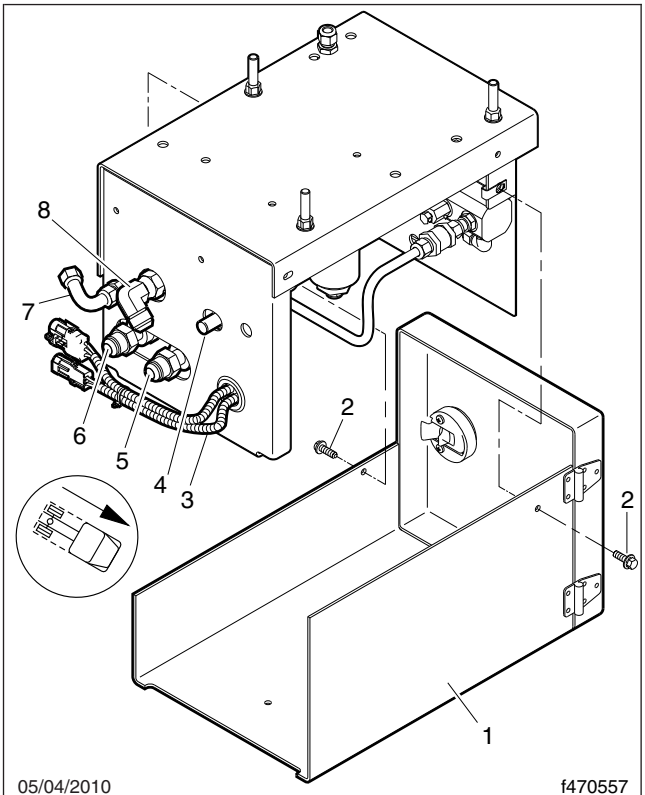
Fig. 1, CNG Fuel Cylinder Storage Box (5-cylinder system shown)

NOTICE

Disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs. Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from

Welding a CNG Vehicle



NOTE: CNG fuel panel may be located on the right side of the vehicle.

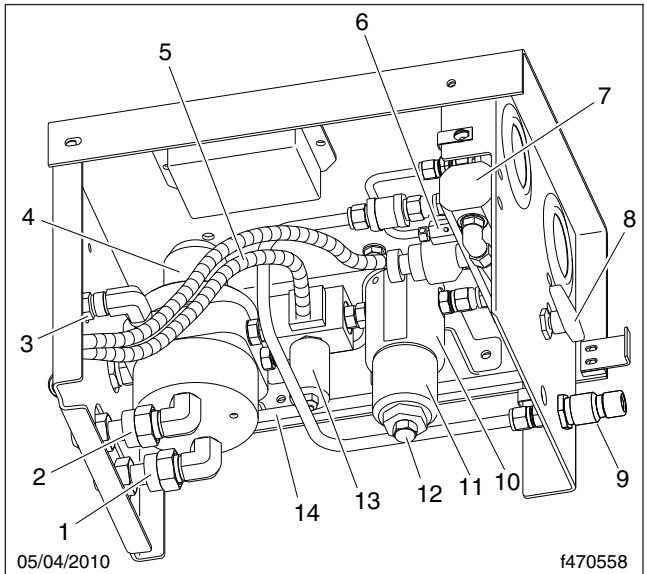
1. Fuel Panel Access Cover
2. Capscrews (qty 2)
3. Wiring Harness
4. Pressure Relief Valve and Cap
5. Coolant Outlet Line
6. Coolant Inlet Line
7. Fuel Inlet Line (from fuel cylinders)
8. Fuel Outlet Line (to engine)

Fig. 2, CNG Fuel Panel Assembly

the battery positive post, or disconnect the main connection at the ECU.

9. Shut down all vehicle electrical systems and disconnect the battery.
10. Let the vehicle sit in a well-ventilated area for at least 10 minutes.

IMPORTANT: Do not weld in areas directly adjacent to CNG tanks. Avoid direct heat exposure on tanks.



1. Coolant Inlet Port
2. Coolant Outlet Port
3. Pressure Relief Valve
4. Pressure Regulator
5. Wiring Harness
6. Manifold Bleed Valve
7. Manifold
8. Manual Fuel Shutoff Valve
9. Fuel Fill Port
10. Filter Housing
11. Filter Bowl
12. Filter Drain Plug
13. Solenoid Valve
14. Fuel Line to Cylinders

Fig. 3, CNG Fuel Panel Components

11. Cover the CNG tanks and fuel lines with a metal shield or welding blankets to prevent sparks or residue from contacting CNG equipment.
12. Complete all necessary welding, then remove the protective welding blankets or metal shield.
13. Start up the vehicle electrical system and connect the battery.
14. Connect the electrical harness to the solenoid valve.
15. Close the bleed valve on the manifold and open the manual fuel shutoff valve on the fuel panel.
16. Open the fuel cylinder shutoff valves.
17. Start the engine and check for gas leaks in the fuel system.

Using a methane detector, leak test all fuel system components. A bubble solution can be used to pinpoint the exact location of leaks.

Repair or replace any leaking components.

18. Using the two capscrews removed previously, install the access cover on the fill panel.

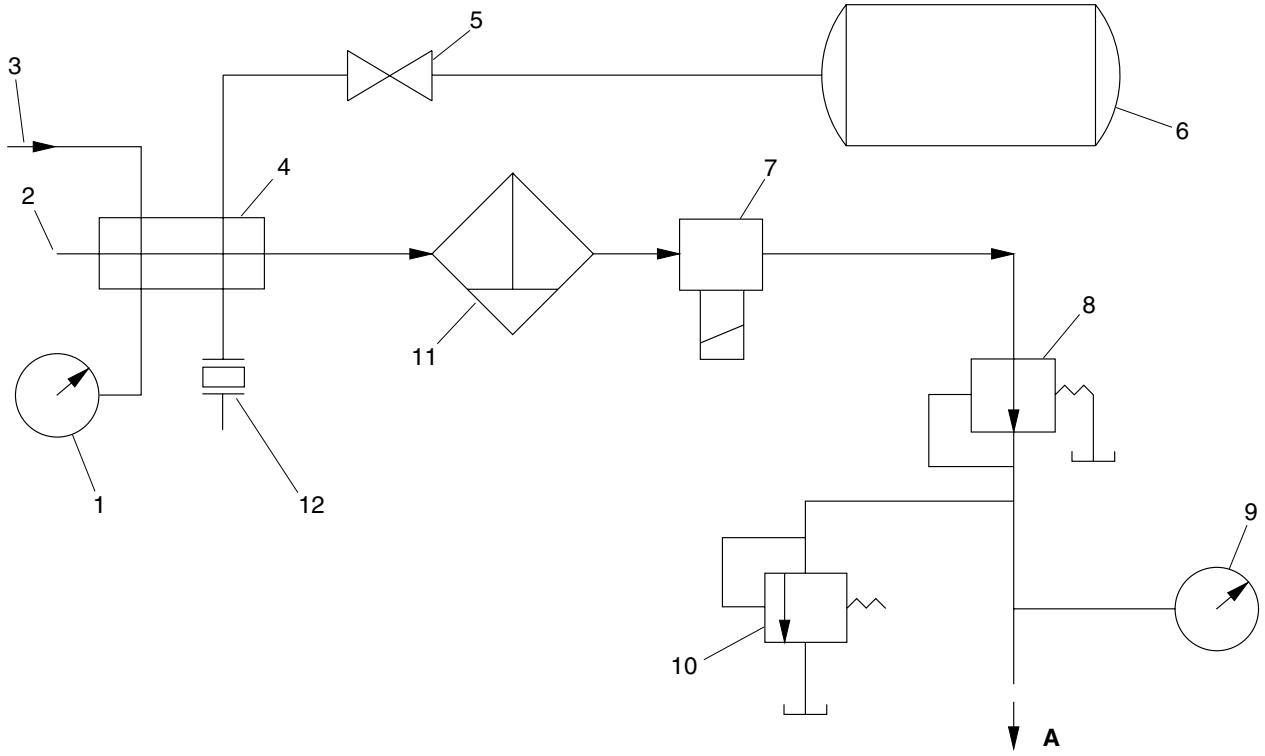
CNG System

See **Fig. 1** for a schematic of CNG fuel system components.

See **Fig. 2** for a flow chart to troubleshoot problems with an engine running lean.

See **Fig. 3** for a flow chart to troubleshoot a faulty dash-mounted fuel gauge reading.

See **Fig. 4** for a flow chart to troubleshoot a compressed natural gas leak in the fuel system.



A. Fuel flow to engine.

1. High-Pressure Gauge
2. Bleed Port
3. Fuel Fill Port
4. Manifold
5. Shutoff Valve
6. CNG Fuel Cylinder(s)
7. High-Pressure Solenoid Valve
8. Pressure Regulator
9. Low-Pressure Gauge
10. Pressure Relief Valve
11. High-Pressure Fuel Filter
12. Pressure Transducer

Fig. 1, CNG Fuel System Schematic (typical)

Troubleshooting

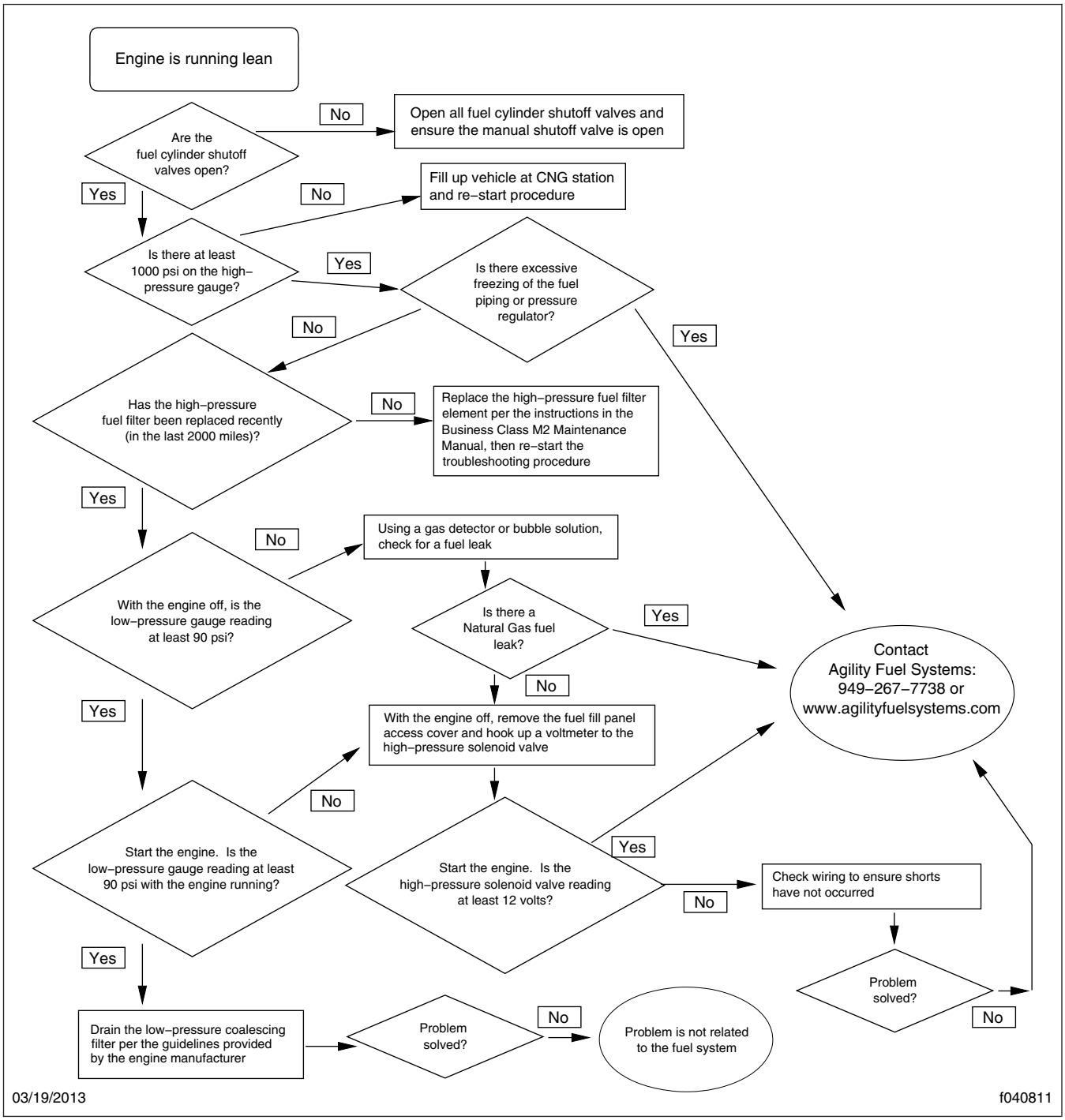


Fig. 2, Flow Chart: Engine Running Lean

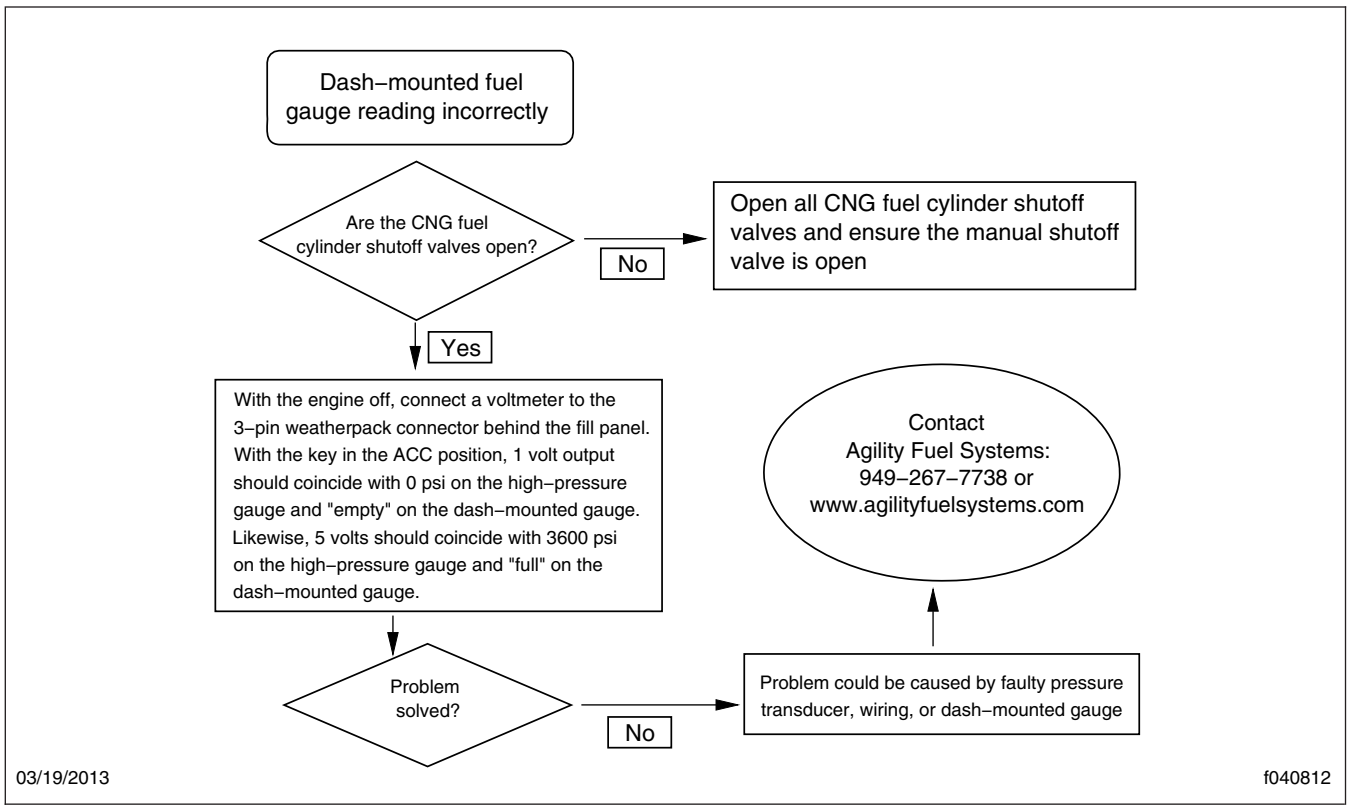


Fig. 3, Flow Chart: Faulty Dash Gauge

Troubleshooting

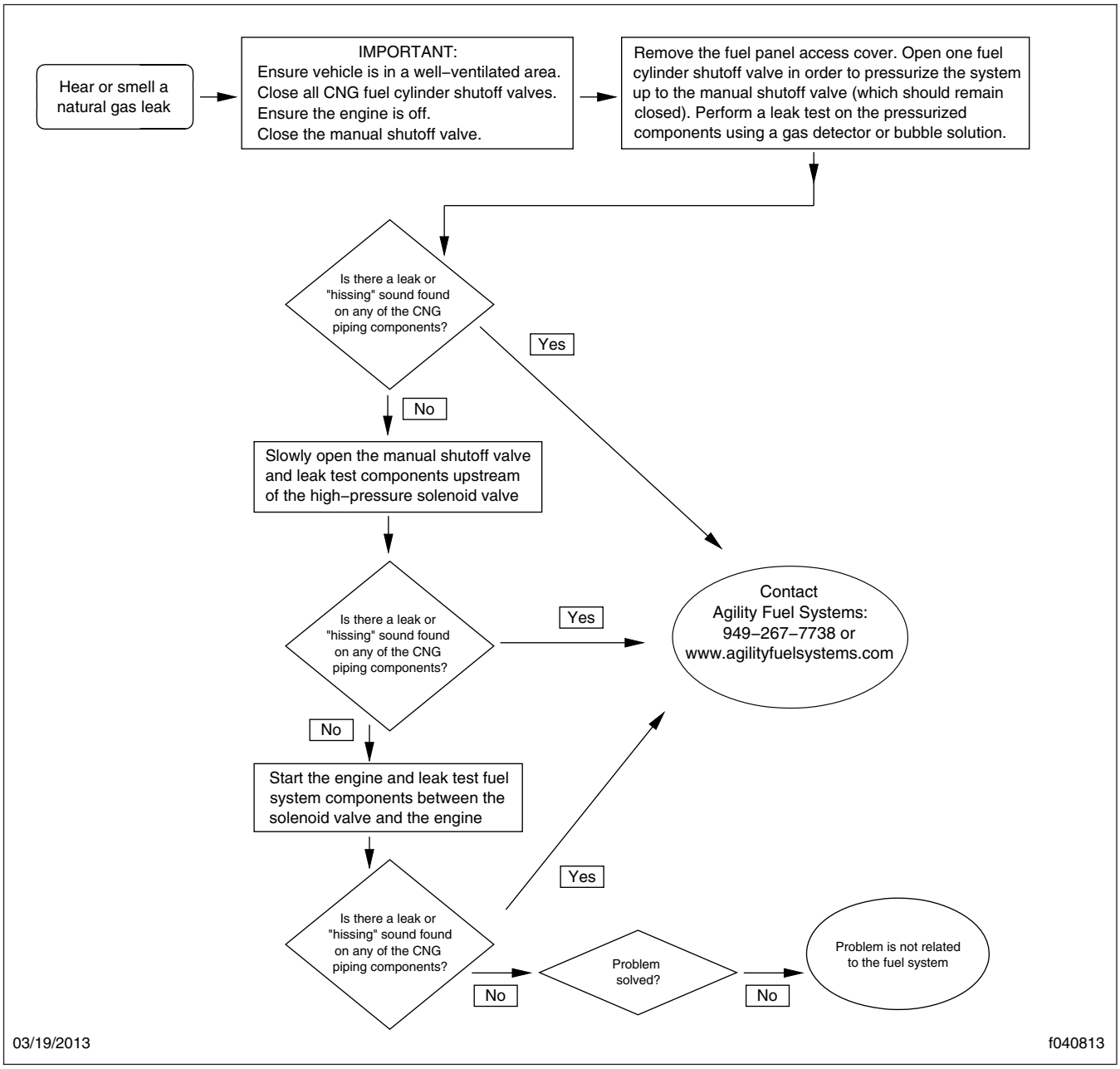


Fig. 4, Flow Chart: Gas Leak

Methane Detection System

⚠ WARNING

Compressed natural gas is highly flammable. Refer to the safety precautions listed in Subject 100 before servicing the vehicle. Failure to observe these precautions could lead to the ignition of the natural gas, which could cause severe bodily injury, death, or property damage.

The Business Class M2 is equipped with a two-zone natural gas detection system. One sensor is located in the cab overhead panel in the control panel, the other sensor is located on the frontwall in the engine compartment. The system is powered directly from the vehicle batteries and is active at all times, unless the batteries are disconnected. When the system has power, and is operating normally with all sensors confirmed operational, and no leaks detected, the green "Power" LED, and the large green light are on. When the presence of gas is detected in any zone, an indicator LED will illuminate depending on the level of gas detected. If a problem with a sensor or wiring occurs, a "Fault" LED will illuminate for the zone that is affected. When a fault is present, no detection is operational in that zone. The following troubleshooting tables show all the different possible light combinations, what they indicate, the troubleshooting procedures, and the suggested remedy. For vehicle-specific wiring diagrams, refer to G06-89262 in EZWiring™.

IMPORTANT: Before performing any troubleshooting, allow the system 60 seconds to complete the initialization process.

Green "Power" Light On

03/20/2014 f470621

Front Panel Indication	Troubleshoot	Remedy
The green "Power" LED on the main panel and the large green LED are on. The system has power and is operating normally. In this state the panel and all sensors are confirmed operational.	System is operating normally.	No repair needed.

Troubleshooting

No Lights on Front Panel

03/06/2014 f470622

Front Panel Indication	Troubleshoot	Result	Remedy
No lights are illuminated on the panel. The panel has no power. No gas detection or warning is possible.	Are all of the connectors plugged in at the back of the panel?	Yes	Go to the next step.
		No	Plug in the connector. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Is there power (9-14 vdc) and ground at the panel?	Yes	Replace the panel.
		No	Go to the next step.
	Check the terminal on the back of the panel for loose or improperly installed pins. Were there any bad pins?	Yes	Repair and Go to the next step. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Is the fuse blown or missing at the power-net distribution box (PNDB)?	Yes	Replace the fuse. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Does the circuit have continuity or high resistance?	Yes	If it has continuity, and still has no power go to PNDB troubleshooting.
		No	If there is no continuity, or high resistance Go to the next step.
	Check connectors at the fire wall and PNDB. Have any of the cables been pinched, cut, or damaged?	Yes	Replace the damaged cable(s).
		No	Contact the vendor.

Amber "Sensor Fault" Light On

03/20/2014 f470623

Front Panel Indication	Troubleshoot	Result	Remedy
The amber "Sensor Fault" light indicates that there is a problem in the zone specified. In this case zone 1 and 2. When a fault light is on, detection is not possible in any zones where a fault is present.	Check the sensor connections at the back of the panel and at the sensors. Are the connectors loose or damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Check the pins in the connectors on the panel and in the sensors. Are the pins loose or damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	If both "Sensor Fault" lights are on, skip this step and proceed to the next step.. Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step..
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check for continuity in the harness. Is there high resistance in the sensor harness?	Yes	Replace the harness.
		No	Replace the sensor, unless it is both, then replace the panel.

Troubleshooting

Amber "Trace" Light Flashing

03/20/2014 f470624

Front Panel Indication	Troubleshoot	Result	Remedy
The flashing amber "Trace" light indicates that a trace amount of gas (greater than 20% and less than 50%) has been detected in the specified zone, in this case zone 2.	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step..
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed.
	check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

⚠ WARNING

The following tests should only be performed after determining that it is safe to do so.

Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.).

Have the problem repaired by qualified personnel before further operation of the vehicle.

Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.

Red "SIGNIFICANT" Light, Amber "Trace" Lights, and Buzzer 1

03/20/2014 f470625

Front Panel Indication	Troubleshoot	Result	Remedy
The red "SIGNIFICANT" light and amber "Trace" lights and buzzer 1 indicate that a significant level of combustible gas (greater than 50% lower explosive limit (LEL)) has been detected in the applicable zone. In this case zone 2. Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.). Have the problem repaired by qualified personnel before further operation of the vehicle. Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.	Is the "Amerex Push to Test" button being held?	Yes	Let go.
		No	Go to the next step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to the next step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step..
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

Troubleshooting

Red "SIGNIFICANT" Light, Amber "Trace" Lights, and Buzzers 1 and 2

03/20/2014 f470626

Front Panel Indication	Troubleshoot	Result	Remedy
The red "Significant" light and amber "Trace" lights along with buzzers 1 and 2 indicate that a significant level of combustible gas (greater than 50% LEL) has been detected in the applicable zone, in this case zone 2. Remove all personnel from the area. Ventilate the area. Manually shut off the source of gas (propane/CNG/LNG, etc.). Have the problem repaired by qualified personnel before further operation of the vehicle. The large red LED and buzzer 2 indicates the significant gas detection has been present for over 15 seconds and the relay has engaged. Do not perform "SIGNIFICANT" and "Trace" diagnosis, until the non-presence of gas is confirmed and the panel has had constant power for 60 seconds of calibration.	Is the "Amerex Push to Test" button being held and has it been held continuously for 15 seconds causing the relay to trip?	Yes	Release the button, and press the "Shutdown/Reset" button to reset the relay. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to the next step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable proceed to the next step..
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

Red "Relay Engaged" LED, Large Red LED, and Buzzer 2

03/20/2014 f470627

Front Panel Indication	Troubleshoot	Result	Remedy
The red "Relay Engaged" LED and the large red LED along with buzzer 2 indicates that a significant level of gas (greater than 50%) was detected at some point. The significant gas level is no longer present, as the "SIGNIFICANT" LED and "Trace" LED are no longer illuminated. The panel relay has engaged and must be reset by pressing the "Shutdown/ Reset" button. Do not troubleshoot the system until the reason for the significant alarm is understood.	Has the "Amerex Push to Test" button been pressed and held for 15 seconds causing the relay to trip?	Yes	Press the "Shutdown/Reset" button. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Using an approved NG testing method, check all fuel fittings and fuel lines for leaks. Verify that pressure relief devices are not venting or leaking. Is there a gas leak?	Yes	Repair as needed. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Are any nuisance gases present? Nuisance gases can be caused by cleaners, paint, polish, lacquer, gasoline, strong adhesives, fiberglass repair, etc.	Yes	Clear the area of contaminants and check again. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
		No	Go to the next step.
	Check the connectors and pins on the panel and sensors. Are they damaged?	Yes	Repair as needed. If the problem is resolved, no further work is needed.
		No	Go to the next step.
	Swap the zone that is reporting a sensor fault by switching the connectors at the rear of the panel. Did the other light illuminate?	Yes	If the fault moves with the cable, proceed to the next step..
		No	If it stays, replace the panel. If the problem is resolved, no further work is needed. If the problem still exists, go to the next step.
	Check continuity and resistance in the sensor harness. Is the harness good?	Yes	Replace the sensor.
		No	Replace the harness.

General Information

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable.

IMPORTANT: The ATS is part of an integrated engine and emissions management system, controlled by the ACM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

The ATS is always chassis-mounted, but there are several different installation options available to fit any needed vehicle configuration. ATS exhaust piping is stainless steel. The EPA10 aftertreatment system (ATS) includes all the piping and equipment between the turbocharger outlet and the tip of the exhaust pipe. It includes an aftertreatment device (ATD), an SCR catalyst, a DEF tank, tank header unit, pump, metering unit, DEF, aftertreatment control module (ACM), coolant, and air lines that run between each component. See **Fig. 1** for system components and function. Monitoring and operation of the ATS is controlled by an electronic control module (ACM).

EPA10 engines require ultralow sulfur diesel (ULSD) fuel, for low emissions and long life of the diesel particulate filter (DPF), a honeycomb soot filter inside the ATD. Inside the ATD, the exhaust first passes through the diesel oxidation catalyst (DOC) where combustion gasses are chemically broken down to water and carbon dioxide, then through the DPF, where solid particles are trapped. The soot is reduced to ash during regeneration, and the ash is collected in the DPF until the DPF is full, at which time the DPF must be removed and cleaned. The DPF needs to be removed and cleaned of ash at specific cleaning intervals. For DPF maintenance and repair information, see the specific engine manufacturer's service literature.

If the exhaust temperature is high enough, the trapped soot is reduced to ash in a process called passive regen, which occurs as the vehicle is driven normally. Passive regen, however, cannot always keep the DPF clean, so the ATD must also periodically undergo active regen. During active regen, extra fuel is injected into the exhaust stream to superheat and reduce the soot trapped in the DPF to ash. Active regen happens only when the vehicle is moving above a certain speed, as determined by the engine manufacturer.

Both active and passive regen happen automatically, without driver input. When operating conditions do not allow for active or passive regen, the vehicle may require a driver-activated parked regen which takes 20 to 60 minutes, depending on ambient conditions.

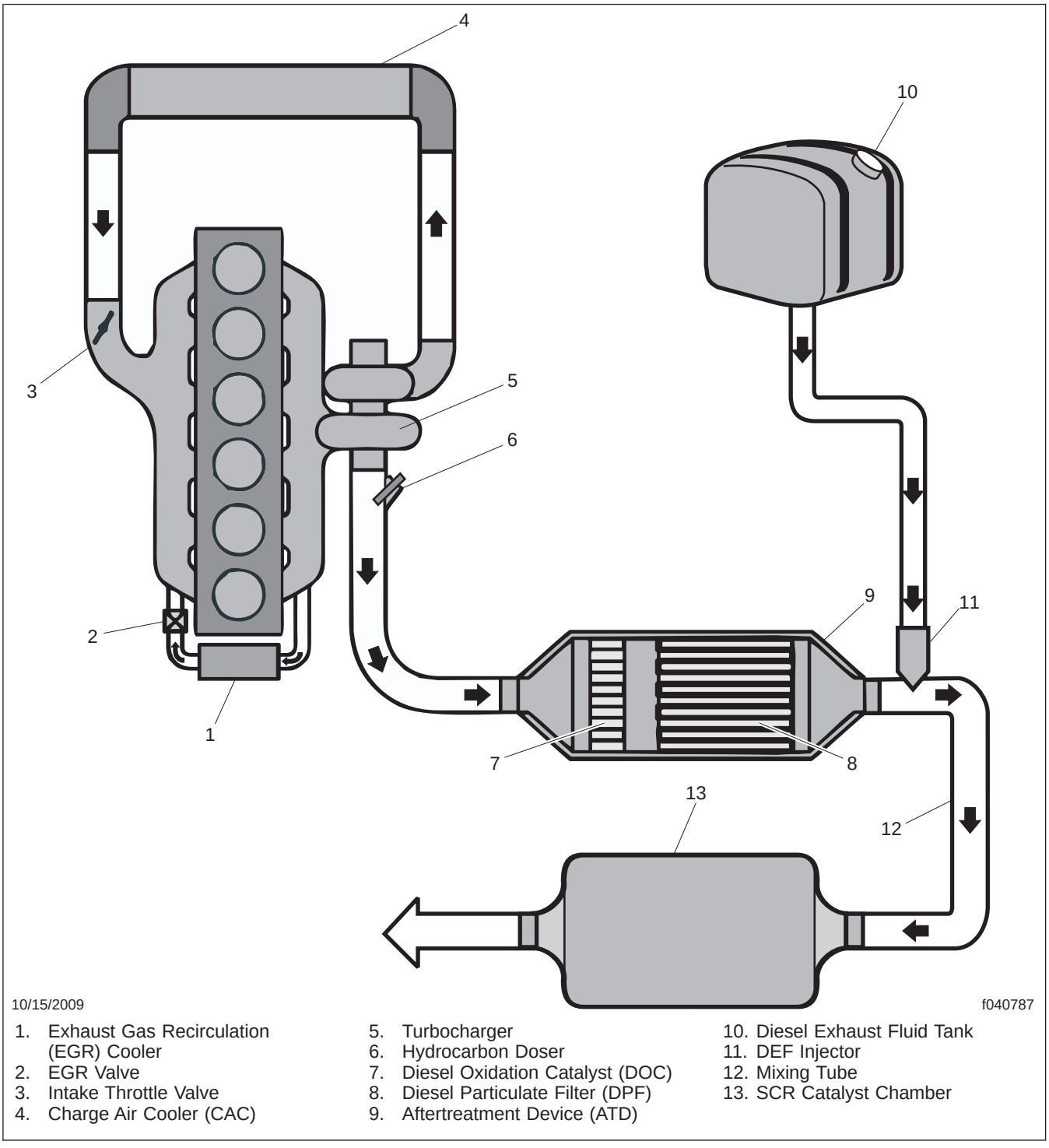
After exhaust gases leave the ATD, a controlled quantity of diesel exhaust fluid (DEF) is injected into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the SCR chamber to yield nitrogen and water vapor, which exit through the tailpipe.

EPA10 compliant DTNA vehicles are equipped with an additional tank to carry the DEF necessary for the SCR process. The DEF tank will require filling a minimum of every second diesel refuel, dependant on the DEF tank capacity. DEF consumption will vary depending on ambient conditions and vehicle application.

IMPORTANT: All EPA10 compliant DTNA vehicles require the use of ULSD fuel with a maximum sulfur content of 15 parts per million (PPM). In addition, DTNA vehicles require the use of CJ-4 engine oils with less than 1% ash. See the specific engine manufacturer's literature for additional information.

NOTE: Freightliner documentation deals only with removal and installation of the components of the ATS. Refer to the engine manufacturer's service literature for all testing, disassembly, cleaning, and repair of the ATS components.

General Information

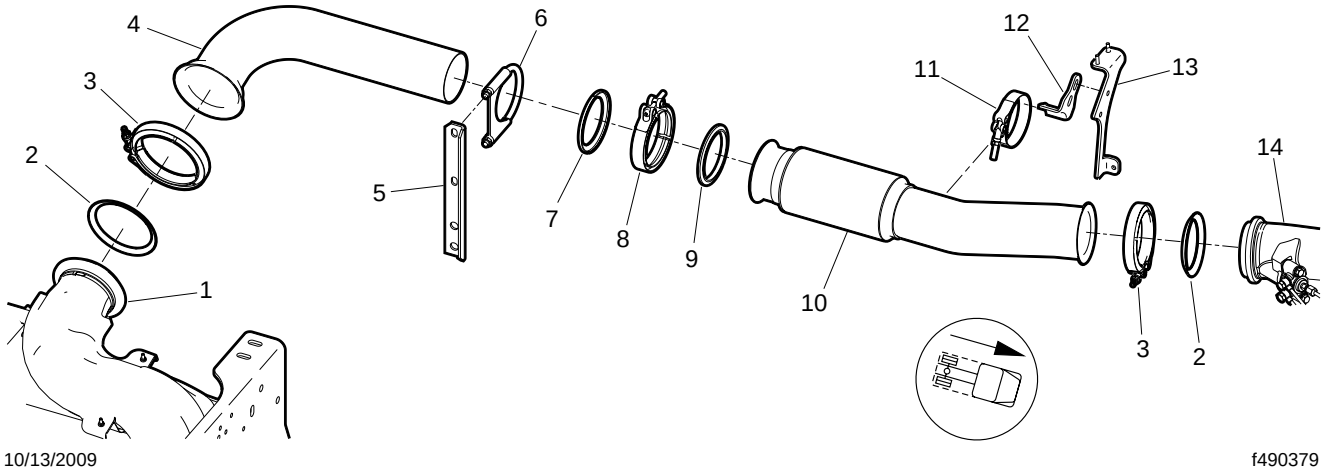


1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. Diesel Exhaust Fluid Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 1, Aftertreatment System (typical)

Bellows Replacement

Refer to **Fig. 1** for bellows replacement.



1. ATD Inlet
2. Spherical Clamp Gasket
3. Spherical Clamp
4. ATD Inlet Pipe
5. Bracket
6. Clamp
7. Compression Gasket
8. Slip-Joint Clamp
9. Conical Gasket
10. Bellows
11. Bellows Pipe Support Clamp
12. L-Bracket
13. Bellows Pipe Support Bracket
14. Turbocharger Outlet Pipe

Fig. 1, Exhaust Bellows Installation (DD13 engine shown)

NOTE: Always use new exhaust pipe clamps and gaskets when installing exhaust system components.

1. Shut down the engine and chock the tires.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the exhaust system to cool before working on it.
3. Remove the inner fender/splash shield.
4. Remove the spherical clamp at the turbocharger outlet pipe. Discard the clamp and gasket.
5. Remove the spherical clamp at the ATD inlet. Discard the clamp and gasket.
6. Remove the turbocharger-outlet-pipe support bracket clamp. Save the clamp for reuse.
7. Remove the ATD-inlet-pipe support bracket clamp. Save the clamp for reuse.
8. If needed to make clearance, remove the ATD-inlet-pipe support bracket form the framerail.
9. Remove the bellows and ATD inlet pipe as an assembly.
10. On the workbench, replace the bellows as follows.
    - 10.1 Remove the bellows-to-ATD inlet-pipe slip-joint clamp and gaskets. Discard the clamp and gaskets.
    - 10.2 Slide the new slip-joint clamp, then the two new gaskets onto the ATD inlet pipe in the order shown in **Fig. 1**.

Bellows Replacement

10.3 Slide the new bellows onto the ATD inlet pipe.

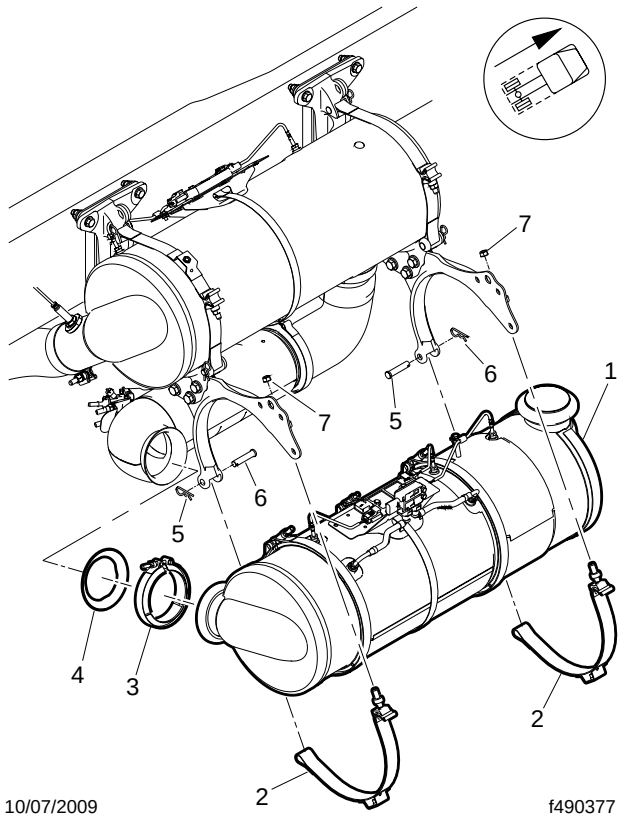
10.4 Position the slip-joint clamp over the gaskets. Do not tighten at this time.

11. Position the bellows and ATD inlet pipe assembly on the vehicle.
12. Slide the ATD inlet pipe in or out of the bellows to align it with the ATD inlet.
13. Install the new spherical clamp and gasket at the ATD inlet. Do not tighten at this time.
14. Install the new spherical clamp and gasket at the bellows-to-the turbocharger outlet-pipe connection. Do not tighten at this time.
15. If removed, install the ATD-inlet-pipe support bracket on the framerail.
16. Install the turbocharger-outlet-pipe support bracket clamp. Do not tighten at this time.
17. Install ATD-inlet-pipe support bracket clamp. Do not tighten at this time.
18. Using a straight edge, align the bellows, the ATD inlet pipe, and the turbocharger outlet pipe. Check from at least two positions about 90 degrees apart. All three components should form a straight line through the connections.
19. Tighten the spherical clamp at the turbocharger outlet pipe connection 126 to 138 lbf·in (1425 to 1560 N·cm).
20. Tighten the spherical clamp at the ATD inlet connection 126 to 138 lbf·in (1425 to 1560 N·cm).
21. Tighten the slip-joint clamp at the ATD inlet to bellows connection 13 lbf·ft (18 N·m).
22. Tighten the turbocharger-outlet-pipe support bracket clamp 24 lbf·ft (30 N·m).
23. Tighten the ATD-inlet-pipe support bracket clamp 24 lbf·ft (30 N·m).
24. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.
25. Install the inner fender/splash shield.

Cummins ISB/ISC Under-Step Switchback ATD Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the ATD components.



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1. ATD
2. Clamping Straps
3. Spherical Clamp
4. Gasket
5. Retaining Pin
6. Clamping Strap Pin
7. Clamping Strap Nut

Fig. 1, Cummins ISB/ISC Under-Step Switchback ATS

NOTE: The ATD can be removed and installed without disturbing the SCR catalyst.

1. Set the parking brakes and chock the tires.

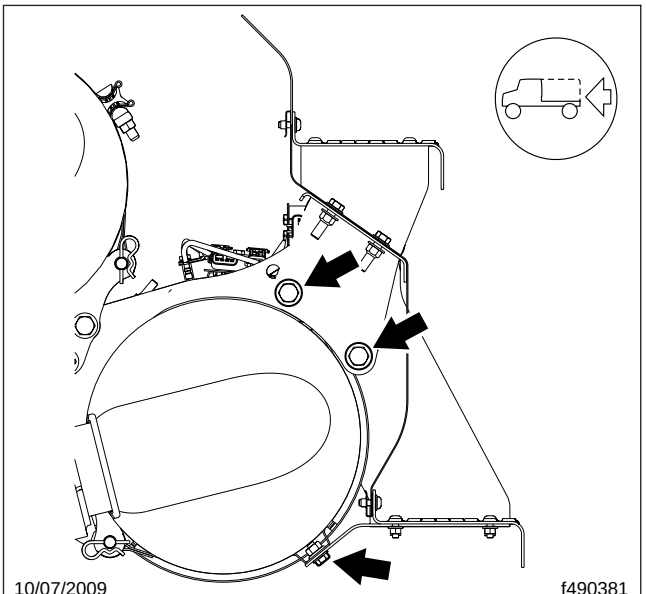
⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before attempting to work on it.
3. Remove the right side inner fender. See **Group 60**.
4. Remove the upper step plate. See **Fig. 2**.



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Remove these bolts.

Fig. 2, Step Removal

5. Remove the step unit from the ATS brackets.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during as-

Cummins ISB/ISC Under-Step Switchback ATD Removal and Installation

sembly. Failure to accurately align all of the components of the ATS may result in component damage.

6. Make alignment marks on all of the components to be removed.
7. Disconnect the wiring harness at the control box on the ATD.

NOTICE

It is not necessary to disconnect the lines from the DEF metering unit to the DEF injector on the mixer tube unless one of these components is being replaced. However, it should be handled carefully to prevent damaging the hose connections.

8. Remove the mixer-tube clamp at the ATD and support the mixer tube as needed. Discard the clamp.
9. Remove the clamp, and disconnect the exhaust pipe from the engine at the ATD. Discard the clamp.
10. Position the ATD jack under the ATD.
11. Remove the nuts from the ATD clamping straps. Remove the straps, and discard the straps and hardware.

NOTICE

Be careful not to bump any of the sensors while removing the ATD. The sensors are easily damaged.

12. Carefully lower the ATD.
13. If replacing the ATD, transfer the control box from the old ATD to the new one.

Installation

IMPORTANT: Always use new gaskets when installing exhaust system components.

1. Using the jack, raise the ATD into position.

NOTICE

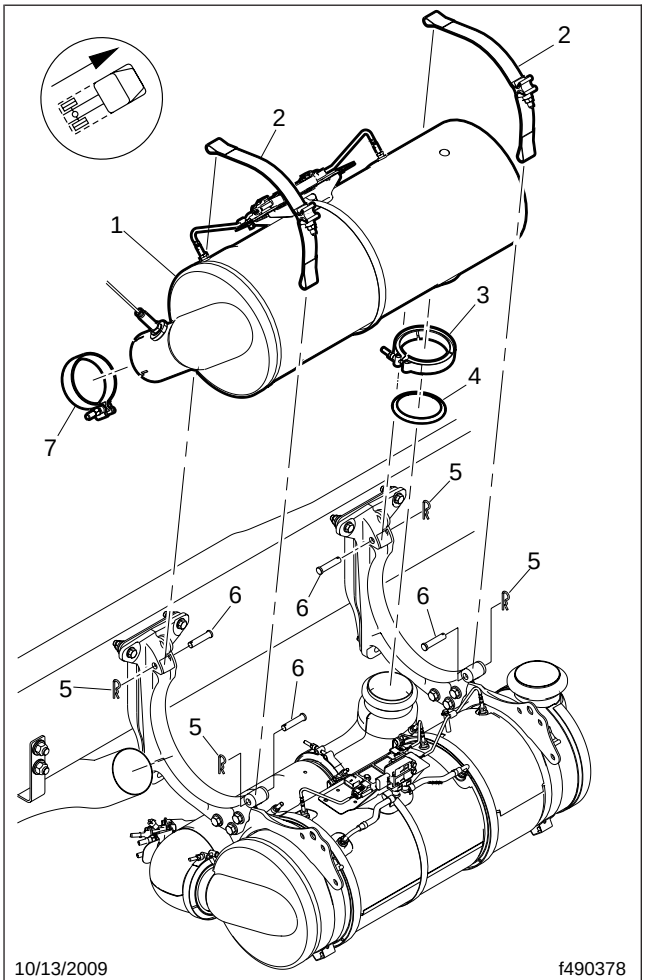
The ATD may rotate while tightening the clamps. It is important that this is prevented. Check the alignment during and after the clamping procedure and make adjustments as needed. Improper installation may lead to component failure.

2. Align the ATD, and install the new clamping straps. Do not tighten at this time.
3. Connect the exhaust pipe from the engine and install the new spherical clamp and gasket. Do not tighten at this time.
4. Position the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
5. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).
6. Check all alignment marks again. If not correct, loosen the clamp and repeat the previous step. Check the alignment on all connections. Make adjustments as needed.
7. Tighten the spherical clamps at the ATD inlet and the mixer tube connections 126 to 138 lbf·in (1425 to 1560 N·cm).
8. Connect the wiring harness to the control box on the ATD.
9. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.
10. Install the steps.
11. Install the inner fender.

Cummins ISB/ISC Under-Step Switchback SCR Catalyst Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the SCR catalyst components.



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1. SCR Catalyst
2. Clamping Strap
3. Spherical Clamp
4. Gasket
5. Retaining Pin
6. Clamping Strap Pin
7. Clamp, Exhaust Pipe

Fig. 1, Cummins ISB/ISC Under-Step Switchback SCR Catalyst Installation

NOTE: The SCR catalyst can be removed and installed without disturbing the ATD.

1. Set the parking brakes and chock the tires.

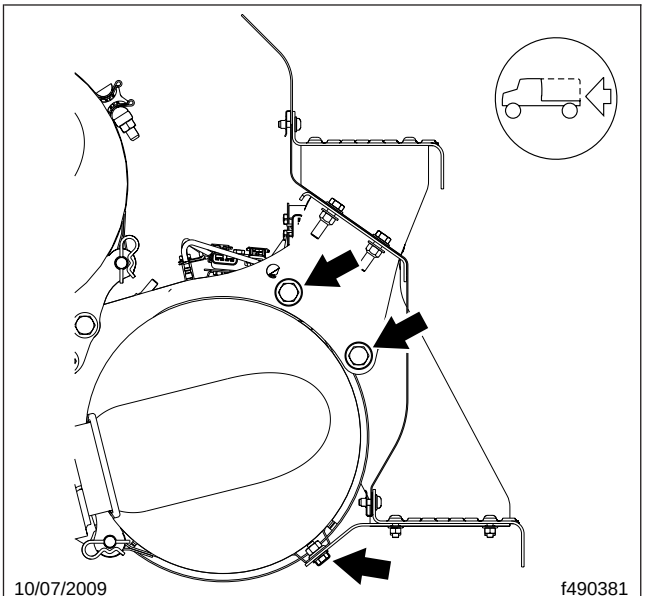
WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before attempting to work on it.
3. Remove the right side inner fender. See **Group 60**.
4. Remove the upper step plate. See **Fig. 2**.



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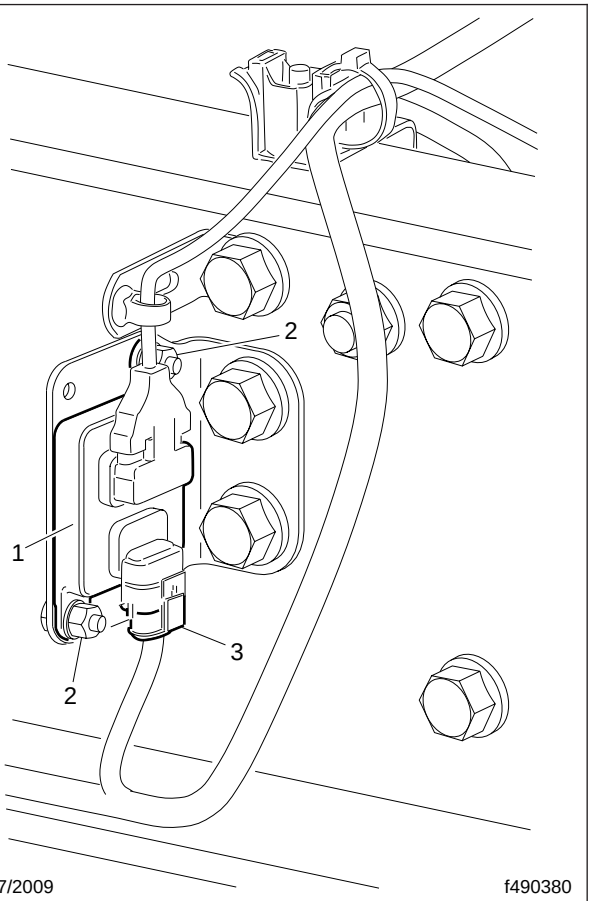
Remove these bolts.

Fig. 2, Upper Step Removal

5. Remove the step unit from the ATS brackets.
6. Disconnect the NOx sensor module from the main harness, and remove it from the frame rail bracket. See **Fig. 3**.

Cummins ISB/ISC Under-Step Switchback SCR Catalyst Removal and Installation



1. NOx Sensor Module
2. Mounting Bolts and Nuts
3. Chassis Harness Connector

Fig. 3, NOx Sensor Module Installation

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

7. Make alignment marks on all of the ATS components that will be removed.
8. Disconnect the exhaust outlet pipe at the SCR catalyst as needed.
9. Remove the clamp on the mixer tube. Discard the clamps.
10. Carefully let the mixer tube swing down, and support it as needed.

NOTICE

Do not bump any of the sensors while removing the SCR catalyst. The sensors are easily damaged.

11. Remove the nuts from the SCR catalyst clamping straps. Discard the straps and hardware.
12. With help from an assistant, lift the SCR catalyst out.

Installation

IMPORTANT: Always use new clamps and gaskets when installing exhaust system components.

1. With help from an assistant, position the SCR catalyst in the bracket, and align the alignment marks.
2. Install the new clamping straps. Do not tighten at this time.
3. Position the mixer tube and install the clamp. Do not tighten at this time.
4. If removed, connect the exhaust pipe to the SCR catalyst and install the clamp. Do not tighten at this time.

NOTICE

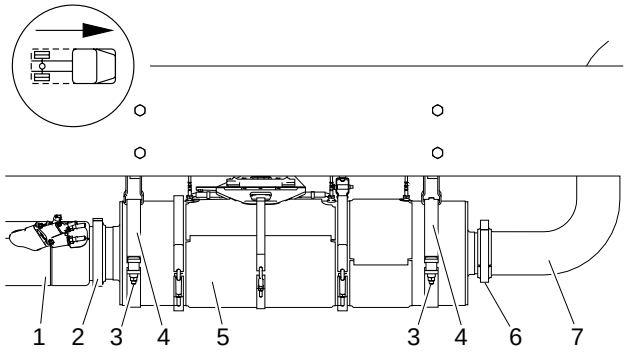
The SCR catalyst may rotate while tightening the clamps. It is important that this is prevented. Check the alignment during and after the clamping procedure and make adjustments as needed. Improper alignment may lead to component failure.

5. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m) then 30 lbf·ft (41 N·m).
6. Check all alignment marks again. If not correct, loosen the clamp and repeat the previous step.

7. Tighten the spherical clamps at the SCR catalyst inlet and the mixer tube 126 to 138 lbf·in (1425 to 1560 N·cm).
8. Tighten the exhaust pipe clamp at the outlet of the SCR catalyst 45 to 60 lbf·ft (60 to 80 N·m).
9. Install the NOx sensor module on the bracket on the frame rail, then connect it to the chassis harness.
10. Connect the wiring harness to the control box on the SCR catalyst.
11. Start the engine and check for exhaust leaks. Further tighten the clamps on any leaking connections as needed.
12. Install the steps.
13. Install the inner fender.

Removal

Refer to **Fig. 1** for removal and installation of the ATS components.



1. Mixer Tube
2. Spherical Clamp
3. Mounting-Strap Bolt and Nut
4. Mounting Strap
5. Aftertreatmment Device (ATD)
6. Spherical Clamp
7. ATD Inlet Pipe

Fig. 1, Cummins ISB/ISC 2HH ATD Installation

1. Shut down the engine and chock the tires.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all of the components to be removed.
4. Disconnect the wire harness to the control module on the ATD.
5. Remove the spherical clamp and gasket that connects the ATD inlet pipe to the ATD. Discard the clamp and gasket.
6. Remove the spherical clamp and gasket that connects the ATD to the mix-tube. Discard the clamp and gasket.
7. Position the jack and cradle under the assembly and secure it with straps.
8. Remove the bolts and nuts from the four mounting straps.
9. Lower the unit.
10. Remove and discard the mounting straps and hardware.

Installation

1. Position the assembly in the jack cradle and secure it with straps.
2. Slide the unit under the vehicle and raise it into position.
3. Install the new mounting straps.
4. Position the assembly in the mounting straps, then install the clamp bolts and nuts. Do not tighten at this time.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the ATD to the ATD inlet pipe and install the new spherical clamp and gasket. Do not tighten at this time.

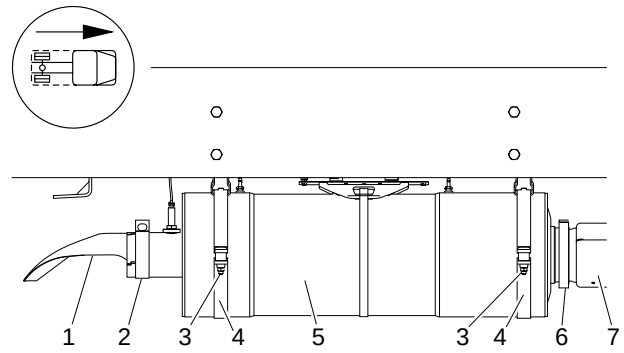
Cummins 2HH ATD Removal and Installation

6. Connect the ATD outlet to the mix tube and install the new spherical clamp and gasket. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then incrementally tighten the bolts 15 lbf·ft (20 N·m), them 30 lbf·ft (41 N·m).
8. Tighten the spherical clamps at the connections to the ATD inlet pipe and the mix tube 126 to 138 lbf·in (1425 to 1560 N·cm).
9. Connect the wiring harnesses to the control module on the ATD.
10. Remove the jack and cradle.
11. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Cummins 2HH SCR Catalyst Removal and Installation

Removal

Refer to **Fig. 1** for removal and installation of the ATS components.



1. Exhaust Pipe Tip
2. Wide-Band Clamp
3. Mounting-Strap Bolt and Nut
4. Mounting Strap
5. SCR Catalyst
6. Spherical Clamp
7. Mixer Tube

Fig. 1, Aftertreatment System Installation

1. Shut down the engine and chock the tires.

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

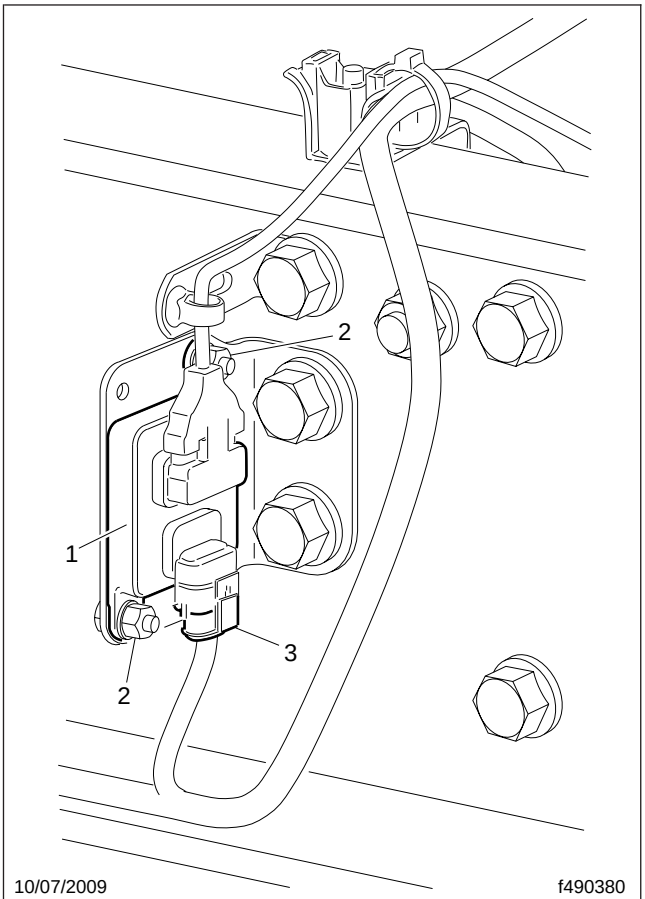
- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the ATS to completely cool before working on it.

NOTICE

Component alignment is critical to proper installation of ATS components. Before removing any components, put alignment marks (use both clocking and longitudinal marks where applicable) on all ATS components. This will aid in faster and more accurate alignment during assembly. Failure to accurately align all of the components of the ATS may result in component damage.

3. Make alignment marks on all components to be removed.
4. Disconnect the wire harness to the NOx sensor.
5. Remove the NOx sensor module from the frame rail bracket and secure it to the SCR catalyst. See **Fig. 2**.



1. NOx Sensor Module
2. Mounting Bolts and Nuts
3. Chassis Harness Connector

Fig. 2, NOx Sensor Module Installation

6. Disconnect the wire harness to the control module on the SCR catalyst.

Cummins 2HH SCR Catalyst Removal and Installation

7. Remove the spherical clamp that connects the SCR catalyst to the mixer tube. Discard the clamp.
8. Remove the wide-band clamp that connects the SCR catalyst to the exhaust pipe. Discard the clamp.
9. Position the jack and cradle under the assembly and secure it with straps.
10. Remove the bolts and nuts from the four mounting straps.
11. Remove and discard the mounting straps and hardware.
12. Lower the unit.

Installation

1. Position the assembly in the jack cradle and secure it with straps.
2. Install the new clamp straps.
3. Slide the unit under the vehicle and raise it into position.
4. Position the assembly in the mounting straps, and install the clamp bolts and nuts. Do not tighten at this time.

IMPORTANT: Always use new gaskets when installing exhaust system components.

5. Connect the SCR catalyst to the mixer tube and install the new spherical clamp and gasket. Do not tighten at this time.
6. Connect the SCR catalyst to the exhaust outlet pipe and install the new wide-band clamp. Do not tighten at this time.
7. Recheck the alignment of all components. Make adjustments to the mounting straps (and brackets) as needed then tighten the bolts 15 lbf·ft (20 N·m), then 30 lbf·ft (41 N·m).
8. Tighten the spherical clamp at the connection of the SCR catalyst and the mixer tube 126 to 138 lbf·in (1425 to 1560 N·cm).
9. Install the NOx sensor module on the bracket on the frame rail, then connect it to the chassis harness.
10. Connect the wiring harness to the control box on the SCR catalyst.
11. Remove the jack and cradle.
12. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

DDC Understep 1-Box ATD and SCR Catalyst Removal and Installation

Removal

NOTICE

Under normal circumstances, the two top, and the forward ATD mounting brackets, should not be removed during one-box understep ATD removal. If the brackets must be removed for any reason, mark their exact location with spray paint or with some other method before removing the brackets. Improper alignment of the ATD during installation can lead to unnecessary component failure. Warranty does not cover parts that are damaged due to improper installation.

1. Shut down the engine, set the parking brakes, and chock the tires.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

2. Allow the exhaust system to completely cool before working on the aftertreatment system.
3. Remove the eight bolts that mount the steps to the mounting brackets on the ATD housing, and remove the steps.
4. Remove the inner splash shield.

NOTE: The exhaust piping from the turbocharger outlet to the ATD inlet will vary depending on vehicle configuration and engine installation.

5. Remove the clamp at the ATD inlet. See **Fig. 1**.
6. Remove the cover from the DEF metering unit. Disconnect the DEF supply and return lines, and the control wiring connectors, from the metering unit. See **Fig. 2**.
7. Disconnect the wiring harness from the sensor box.

NOTE: Exhaust piping downstream from the ATD will vary depending on vehicle configuration.

8. Disconnect the exhaust pipe from the SCR catalyst outlet pipe as needed.
9. Position the ATD jack, with the one-box understep attachment, under the ATD and strap the ATD to the jack. **Figure 3** shows the jack and attachment.
10. Remove the four nuts and bolts that attach the ATD to the upper mounting brackets. See **Fig. 4**.
11. On the forward ATD mounting bracket, remove the four bolts that fasten the ATD to the frame rail mounting bracket. Leave the mounting bracket attached to the frame rail. See **Fig. 5**.
12. On the rear ATD mounting bracket remove the three bolts that fasten the ATD mounting bracket to the frame rail. See **Fig. 6**.
13. Move the ATD away from the frame rail a few inches, then lower it to the floor.

Installation

NOTICE

Be careful not to bump the probe on the back side of the ATD when positioning the ATD on the frame rail. The probe could be damaged.

1. Using the ATD jack, lift the ATD and position it on top of the upper ATD mounting brackets.
2. Install the four bolts into the forward frame rail mounting bracket and tighten the bolts 10 lbf·ft (14 N·m).
3. Install the four bolts (two on each bracket) into the upper ATD mounting brackets and tighten the bolts 10 lbf·ft (14 N·m).
4. Align the rear frame rail mounting bracket to the frame rail, install the three bolts and tighten the bolts 10 lbf·ft (14 N·m).
5. Loosen the four bolts on the rear ATD mounting bracket.

DDC Understep 1-Box ATD and SCR Catalyst Removal and Installation

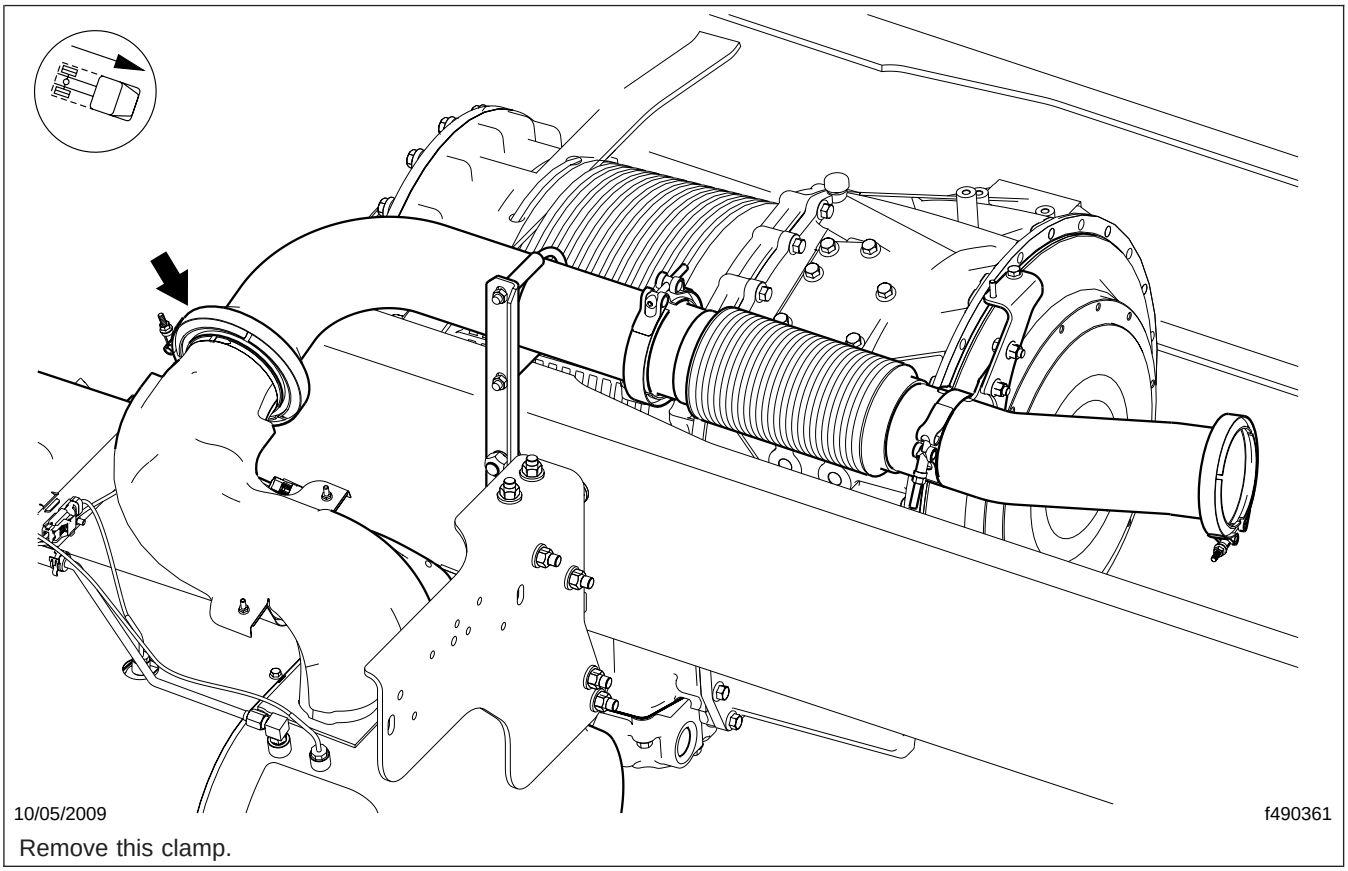


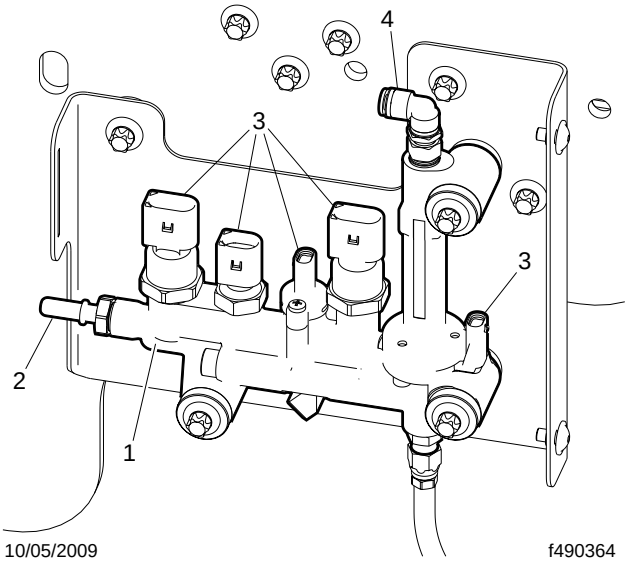
Fig. 1, Disconnecting the ATD from the Exhaust Piping, DD13

NOTICE

Follow the tightening sequence shown in Fig. 7 for the following steps. Improper tightening will put potentially damaging stresses on the installation.

6. Tighten the four bolts on the forward ATD mounting bracket 50 lbf·ft (68 N·m).
7. Tighten the four bolts (two on each bracket) on the upper ATD mounting brackets 50 lbf·ft (68 N·m).
8. Tighten the four bolts on the rear ATD mounting bracket 50 lbf·ft (68 N·m).
9. Tighten the three bolts on the rear frame rail mounting bracket 50 lbf·ft (68 N·m).
10. Remove the ATD jack.
11. Connect the wiring harness to the sensor box.
12. Connect the DEF supply and return lines, and the control wiring connectors, to the metering unit. Install the cover.
13. Install the spherical clamp and gasket at the ATD inlet. See Fig. 1. Tighten 126 to 138 lbf·in (1425 to 1560 N·cm).
14. If disconnected, connect the exhaust pipe to the SCR catalyst outlet pipe. Tighten 45 to 60 lbf·ft (60 to 80 N·m).
15. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.
16. Install the inner splash shield.
17. Install the steps.

DDC Understep 1-Box ATD and SCR Catalyst Removal and Installation



1. Metering Unit
2. Metering Unit Air Line
3. Wiring (controls, sensors, and heaters)
4. Metering Unit DEF Supply Line

Fig. 2, DEF Metering Unit Installation (cover removed for clarity)

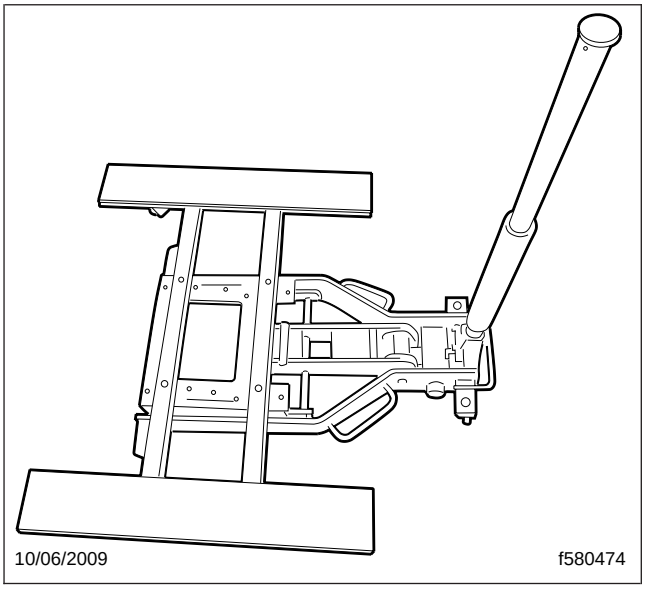


Fig. 3, ATD Jack (with "one-box" attachment)

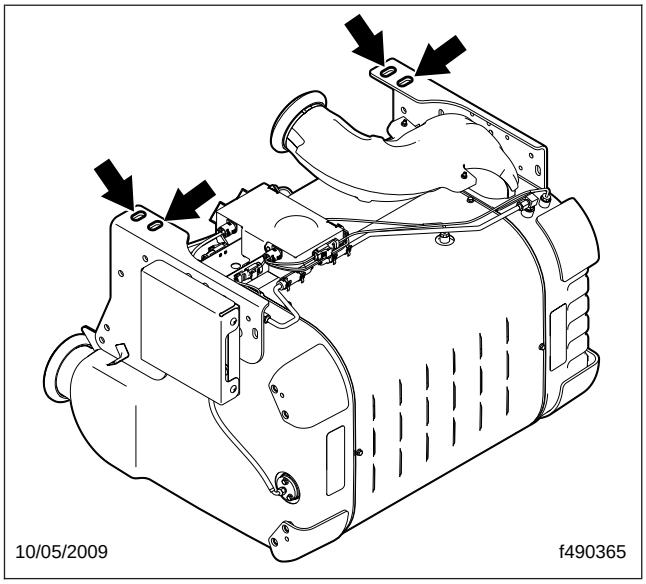


Fig. 4, Upper ATD Mounting Brackets

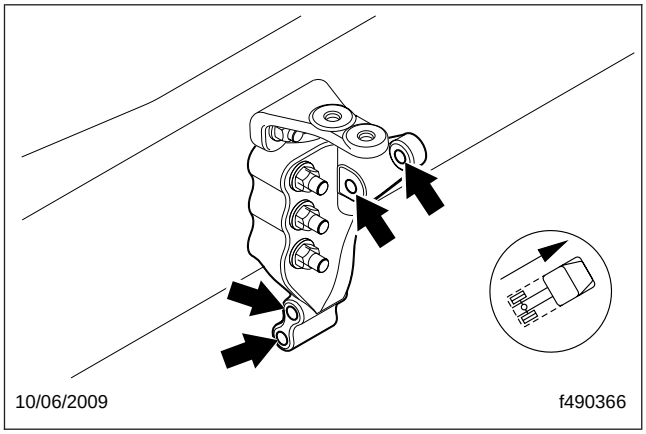


Fig. 5, Forward ATD Mounting Bracket

DDC Understep 1-Box ATD and SCR Catalyst Removal and Installation

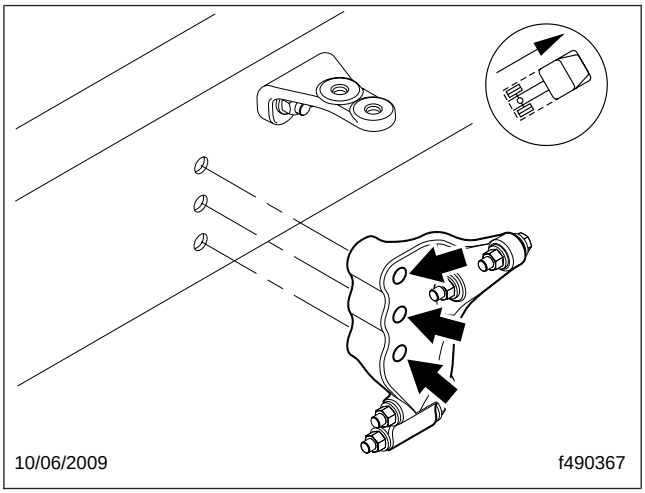


Fig. 6, Rear ATD Mounting Bracket

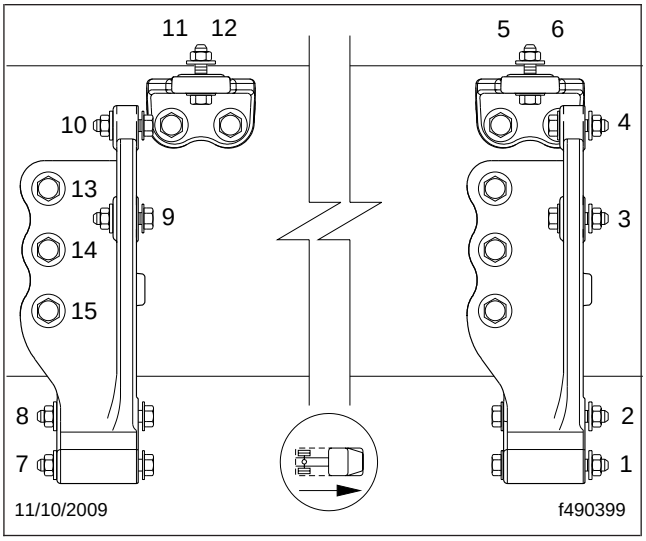


Fig. 7, Mounting Bolt Tightening Sequence

DDC 2V2 ATD and SCR Catalyst Removal and Installation

General Information

Removing the DDC 2V2 ATD and SCR catalyst as a unit is the quickest, and easiest, way to remove it from the vehicle. The ATD or the SCR catalyst can be removed separately. When removing the components separately, mark all parts to assist in proper assembly. Daimler Trucks North America LLC does not recommend disassembling the ATD on the vehicle. Remove the component following the instructions below, and then disassemble it on a workbench following the instructions in the engine manufacturer's service literature.

⚠ WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

ATD and SCR Catalyst Removal and Installation

Removal

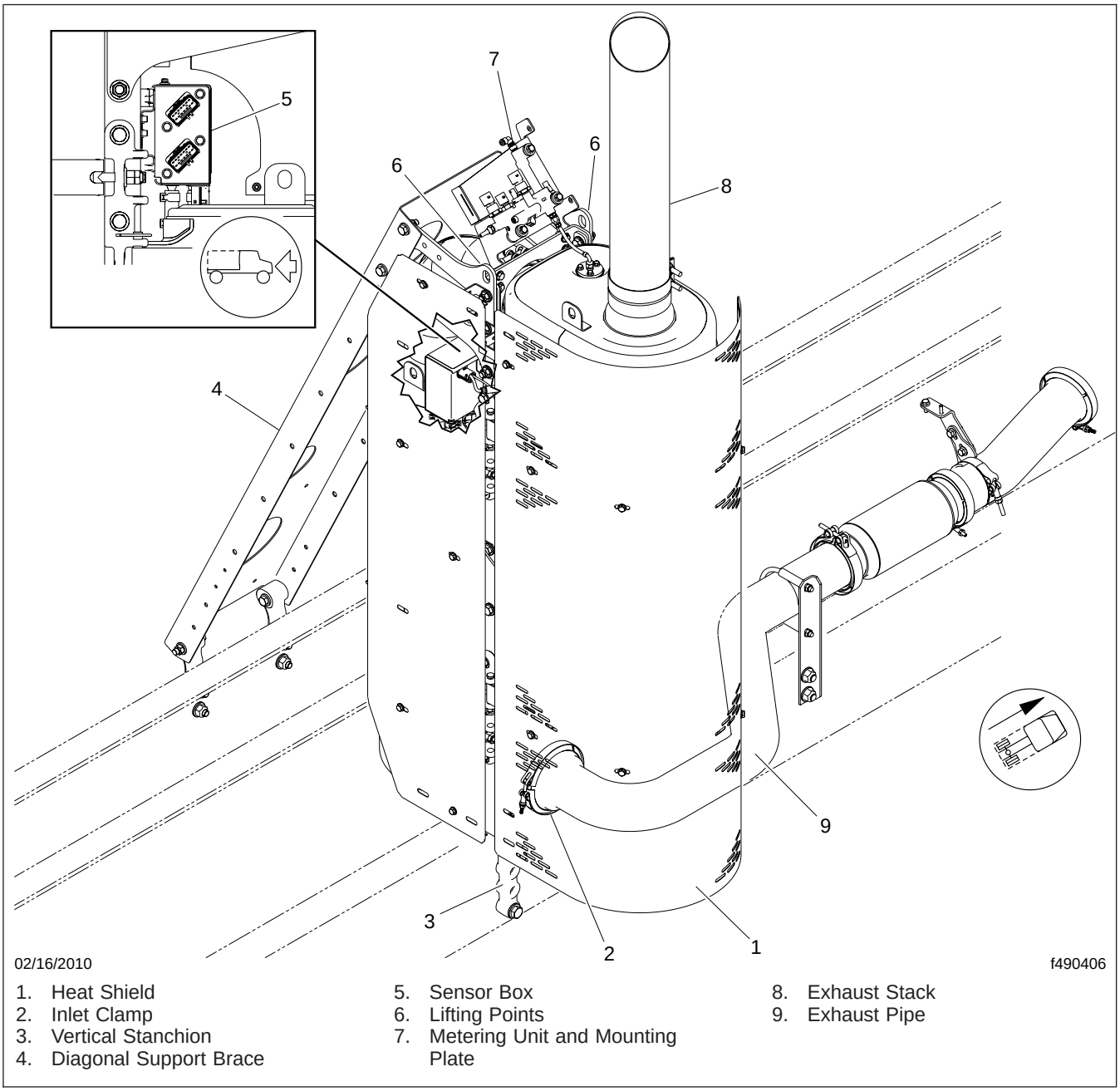
Refer to **Fig. 1** for the following procedure.

1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Remove the exhaust stack from the SCR catalyst.
5. Disconnect the two 14-pin connectors at the sensor box.
6. Disconnect the wiring connectors from the metering unit.
7. Disconnect the air lines from the metering unit.
8. Disconnect and cap/plug the DEF lines from the metering unit.
9. Remove the metering unit mounting plate with the metering unit attached.
10. Loosen the lower fasteners on the diagonal support brace. Disconnect the diagonal support brace from the lifting bracket that attaches to the vertical stanchion and swing it out of the way. Secure it as needed.
11. Disconnect the exhaust pipe at the intake to the ATD. Support it as needed so there is no stress on the bellows.
12. Position the overhead lifting device over the vertical stanchion and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
13. Remove the four mounting fasteners that attach the vertical stanchion to the frame rail.
14. Lower the unit away from the vehicle.

Installation

1. Using the overhead lifting device, position the unit at the frame rail, and install the mounting fasteners. Tighten 159 to 201 lbf·ft (212 to 268 N·m).
2. Position the diagonal support brace and install the mounting fasteners. Tighten the upper and lower fasteners 49 to 63 lbf·ft (66 to 86 N·m).
3. Connect the two 14-pin connectors at the sensor box.
4. Install the metering unit and mounting plate.
5. Connect the wiring connectors to the metering unit.
6. Connect the air lines to the metering unit.
7. Connect the DEF lines to the metering unit.
8. Using a new seal, connect the exhaust pipe to the ATD. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
9. Install the exhaust stack. Tighten the clamp 27 to 37 lbf·ft (37 to 50 N·m).
10. Install the heat shield. Tighten 13 to 17 lbf·ft (18 to 22 N·m).

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Inlet Clamp
3. Vertical Stanchion
4. Diagonal Support Brace
5. Sensor Box
6. Lifting Points
7. Metering Unit and Mounting Plate
8. Exhaust Stack
9. Exhaust Pipe

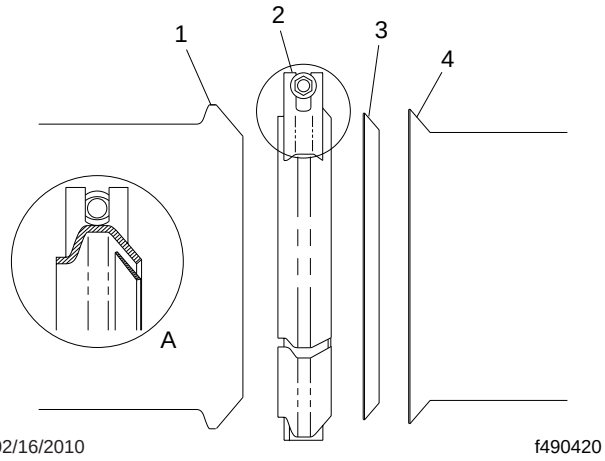
Fig. 1, 2V2 ATD and SCR Catalyst Installation

11. Start the engine and check for leaks. Tighten any connections as needed.

ATD Removal and Installation

Refer to **Fig. 3** for the following procedure.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



NOTE: Clamp and seal are directional.

A. Correct Clamp and Seal Installation

1. ATD
2. Clamp
3. Gasket
4. Exhaust Pipe

Fig. 2, Spherical Clamp Installation

NOTICE

Alignment is essential. Mark every component's position prior to disassembling it on the truck. Improper assembly may result in leaks or damage to the ATS.

Removal

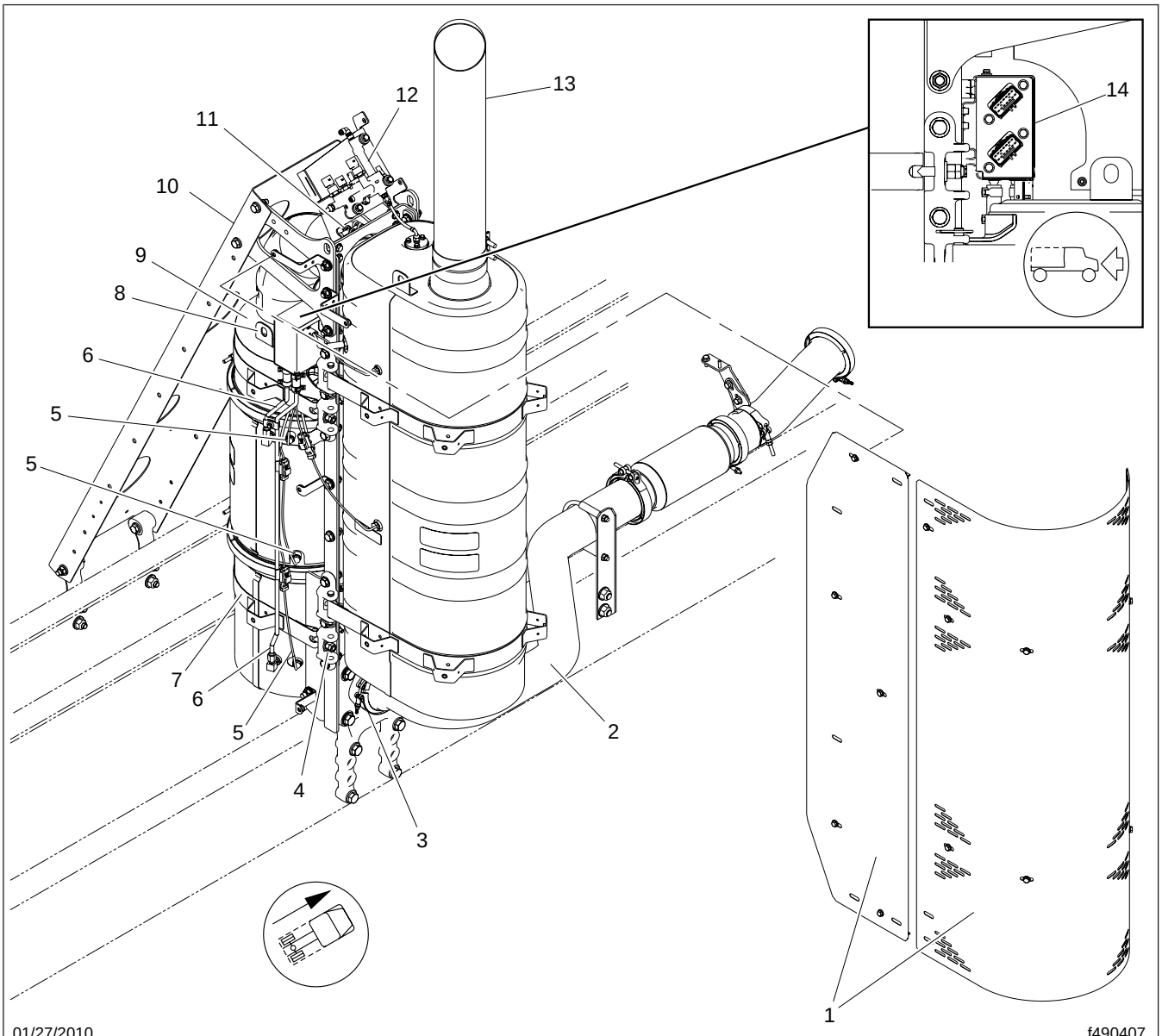
1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Disconnect the two pressure tubes at the connection to the ATD.
5. Disconnect the three temperature sensors on the ATD.
6. Disconnect the two 14-pin connectors at the sensor box.
7. Disconnect the wiring connectors from the metering unit.
8. Disconnect the air lines from the metering unit.
9. Disconnect and cap/plug the DEF lines from the metering unit.
10. Remove the metering unit mounting plate with the metering unit attached.
11. Loosen the lower fasteners on the diagonal support brace. Disconnect the diagonal support brace from the vertical stanchion, and swing it out of the way. Secure it as needed.
12. Remove the intake and outlet clamps from the ATD. Support the turbo outlet pipe as needed so there is no stress on the bellows.
13. Position the overhead lifting device over the ATD and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
14. Remove the mounting clamps.
15. Lift the ATD away from the vehicle.

Installation

1. Using the overhead lifting device, position the ATD on the vertical stanchion, and secure it in position with the mounting clamps. Do not tighten the straps at this time.
2. Align the connection with the SCR catalyst, and using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
3. Align the connection with the exhaust pipe from the turbocharger, and, using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
4. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).

   Install the jam nuts. Using a back-up wrench, tighten 30 lbf·ft (40 N·m).
5. Connect the two pressure tubes.
6. Connect the three temperature sensors.
7. Position the diagonal support brace and install the mounting fasteners. Tighten the upper and lower fasteners 49 to 63 lbf·ft (66 to 86 N·m).
8. Connect the two 14-pin connectors at the sensor box.
9. Install the metering unit and mounting plate.
10. Connect the wiring connectors to the metering unit.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Exhaust Pipe
3. Intake Clamp
4. Clamping Strap Nuts
5. Temperature Sensor
6. Pressure Tube
7. Clamping Strap
8. Lifting Points
9. ATD
10. Diagonal Support Brace
11. Outlet Clamp
12. Metering Unit and Mounting Plate
13. Exhaust Stack
14. Sensor Box

Fig. 3, 2V2 ATD Installation

11. Connect the air lines to the metering unit.
12. Connect the DEF lines to the metering unit.
13. Install the heat shield.
14. Start the engine and check for leaks. Tighten any connections as needed.

SCR Catalyst Removal and Installation

Refer to **Fig. 4** for the following procedure.

Removal

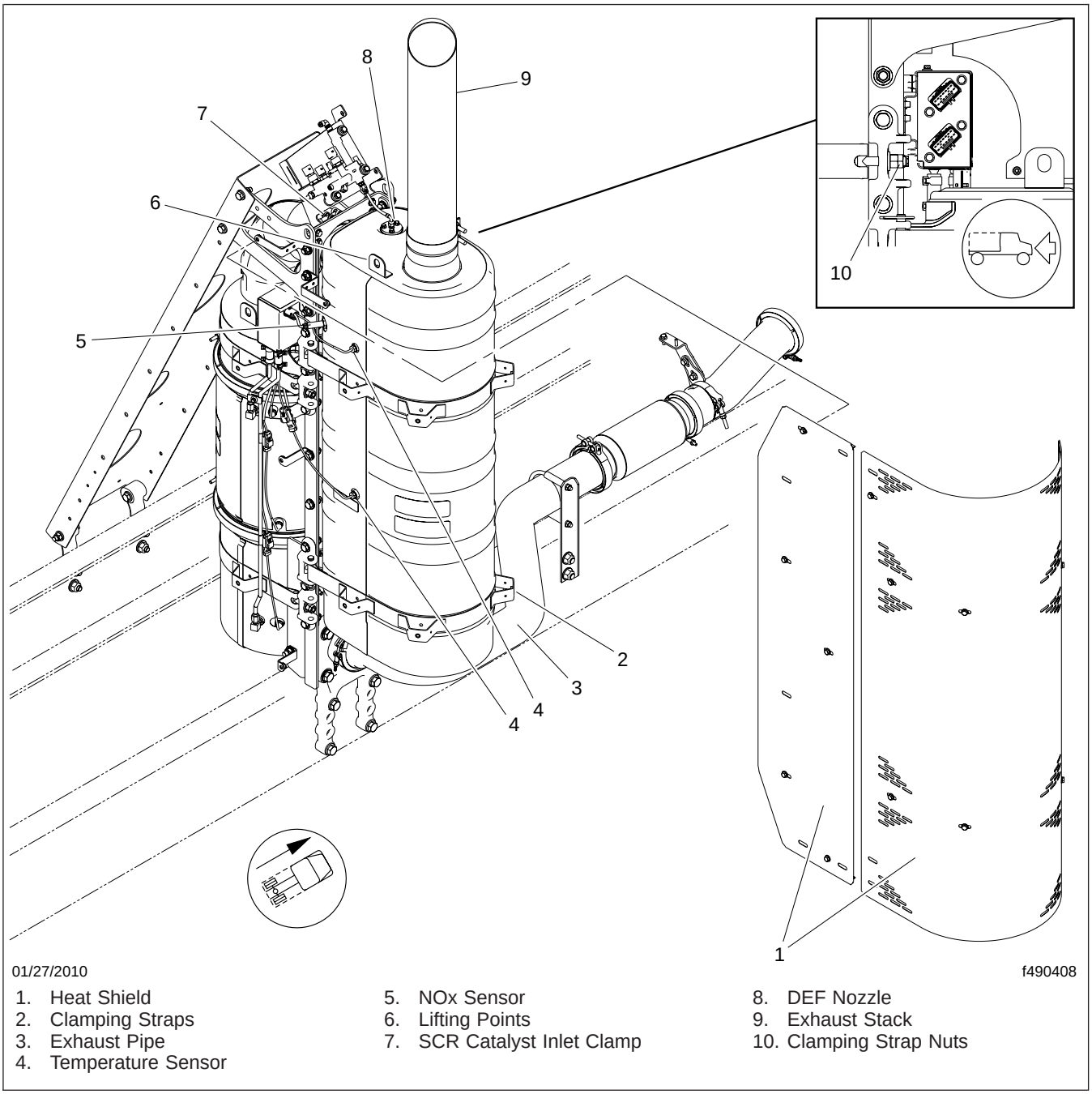
1. Shut down the engine and chock the tries.
2. Allow the ATS time to cool.
3. Remove the heat shield.
4. Remove the exhaust stack from the SCR catalyst.
5. Remove the SCR catalyst inlet clamp.
6. Disconnect the two temperature sensors and the NOx sensor.
7. Disconnect the DEF nozzle.
8. Position the overhead lifting device over the SCR catalyst and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
9. Remove the clamping strap nuts.
10. Lift the SCR catalyst away from the vehicle.

Installation

1. Using the overhead lifting device, position the SCR catalyst on the vertical stanchion, and secure it in position with the mounting clamps. Do not tighten the straps at this time.
2. Align the connection with the ATD, and using a new seal, install the clamp. See **Fig. 2** for proper installation. Tighten the clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
3. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).

   Install the jam nuts. Using a back-up wrench, tighten 30 lbf·ft (40 N·m).
4. Connect the two temperature sensors and the NOx sensor.
5. Connect the DEF nozzle.
6. Install the exhaust stack. Tighten the clamp 27 to 37 lbf·ft (37 to 50 N·m).
7. Install the heat shield. Tighten 13 to 17 lbf·ft (18 to 22 N·m).
8. Start the engine and check for leaks. Tighten any connections as needed.

DDC 2V2 ATD and SCR Catalyst Removal and Installation



1. Heat Shield
2. Clamping Straps
3. Exhaust Pipe
4. Temperature Sensor
5. NOx Sensor
6. Lifting Points
7. SCR Catalyst Inlet Clamp
8. DEF Nozzle
9. Exhaust Stack
10. Clamping Strap Nuts

Fig. 4, 2V2 SCR Catalyst Installation

DDC 2HV ATD and SCR Catalyst Removal and Installation

WARNING

Aftertreatment Device (ATD) internal temperatures can remain hot enough to cause personal injury, or ignite combustible materials, for hours after the engine is shut down.

To avoid potentially serious burns or material damage:

- Let the ATD cool before handling it; be especially careful when opening it to expose the DPF.
- Wear appropriate protective gear.
- Be careful not to place the ATD where flammable gases or other combustible materials may come into contact with hot interior parts.

NOTICE

Alignment is essential. Mark every component's position prior to disassembling it on the truck. Improper assembly may result in leaks or damage to the ATS.

ATD Removal and Installation

Daimler Trucks North America LLC does not recommend disassembling the ATD on the vehicle. Remove the component following the instructions below, and then disassemble it on a workbench following the instructions in the engine manufacturer's service literature.

Removal

Refer to **Fig. 1** for this procedure.

1. Shut down the engine, set the parking brakes, and chock the tires.
2. Remove the spherical clamps connecting the ATD inlet and outlet pipes to the ATD.
3. Disconnect the electrical harnesses going to the ATD sensor box.
4. Make alignment marks on the ATD and the mounting brackets to assist in proper assembly.
5. Position the ATD jack under the ATD and secure it to the jack with a strap.
6. Remove the clamping strap nuts from the two clamping straps holding the ATD to the mounting brackets. Remove and discard the clamping straps and hardware.
7. Lower the ATD from the truck.

Installation

1. Using the ATD jack, raise ATD into mounting brackets.
2. Install the new clamping straps, and tighten the clamping strap nuts just enough to hold the ATD in place.
3. Align the ATD fore and aft to match the ATD inlet and outlet pipes, then install the two spherical clamps. Do not tighten at this time. See **Fig. 2** for proper installation.

NOTICE

Do not allow the clamping strap to twist while tightening it. A twisted strap could lead to a strap failure and possible damage to the ATS.

4. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).
5. Tighten the spherical clamps 114 to 126 lbf·in (1290 to 1425 N·cm).
6. Connect the electrical harnesses to the ATD sensor box.
7. Start the engine and check for leaks. Tighten any connections as needed.

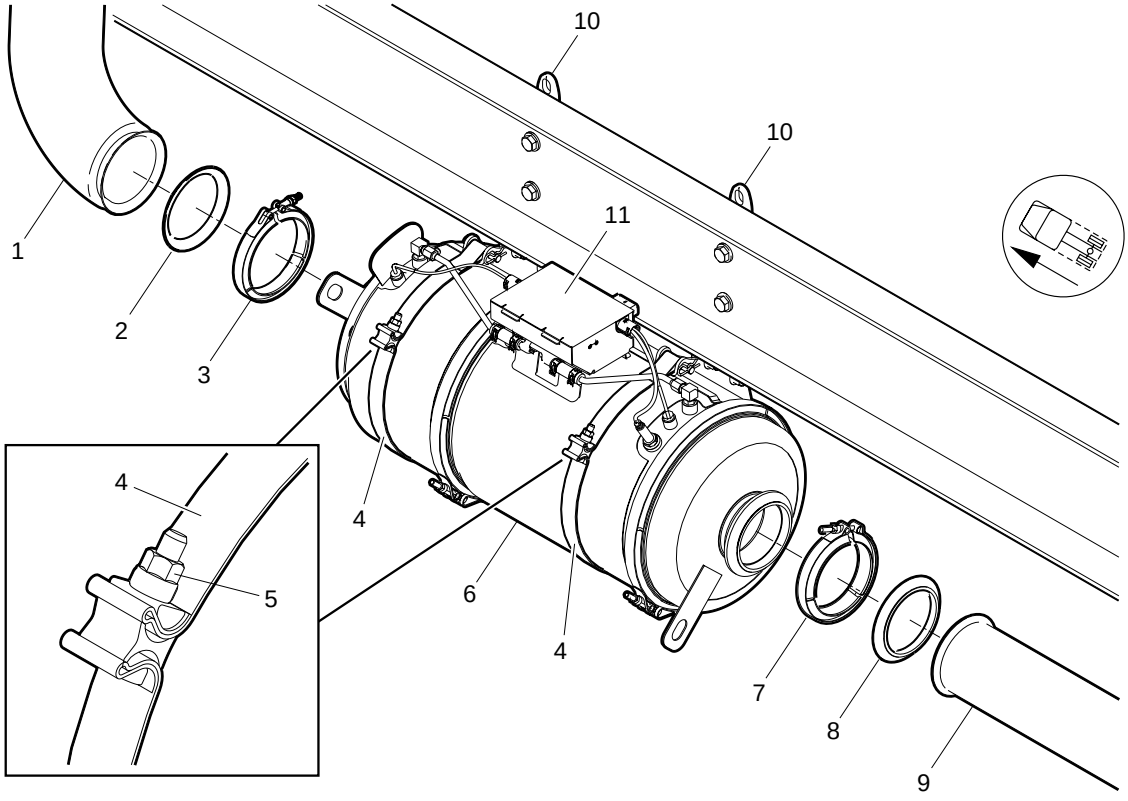
SCR Catalyst Removal and Installation

Refer to **Fig. 3** for this procedure.

Removal

1. Shut down the engine, set the parking brakes, and chock the tires.
2. Remove the six fasteners holding the SCR catalyst heat shield in place.
3. Remove the stack.
4. Disconnect the two temperature sensors and the NOx sensor.
5. Disconnect the DEF nozzle supply line.

DDC 2HV ATD and SCR Catalyst Removal and Installation



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1. ATD Inlet Pipe
2. Gasket
3. Spherical Clamp
4. Clamping Strap
5. Clamping Strap Nut
6. ATD
7. Spherical Clamp
8. Gasket
9. ATD Outlet Pipe
10. ATD Mounting Brackets
11. Sensor Box

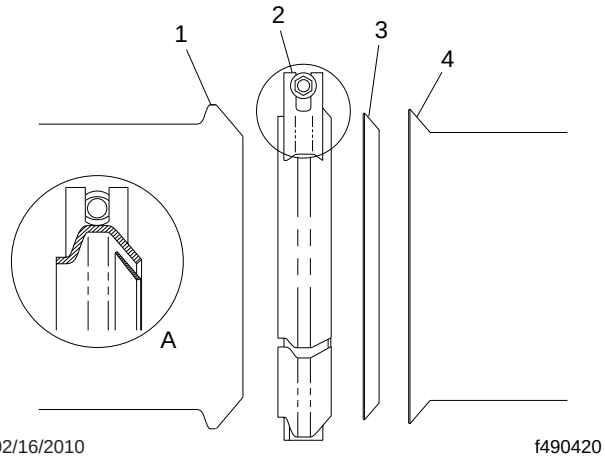
Fig. 1, ATD Installation

6. Remove the spherical clamp at the SCR catalyst inlet.
7. Disconnect the electrical harness from the SCR catalyst.
8. Make alignment marks on all parts to assist in proper assembly.
9. Position the overhead lifting device over the SCR catalyst and connect the hooks at the lifting points. Apply enough pressure to the lift points to prevent the unit from dropping when loosened.
10. Remove the two mounting straps from the SCR catalyst.
11. Move the SCR catalyst outboard away from the truck horizontally until the inlet clears the vertical mounting bracket. Then lift the SCR catalyst away from the truck.

Installation

1. Using the overhead lifting device, lower the SCR catalyst vertically until the inlet aligns vertically with the hole in the mounting bracket. Then move the SCR catalyst horizontally until the SCR catalyst is up against the mounting bracket and the inlet is through the mounting bracket hole.
2. Install the two mounting straps. Do not tighten at this time.
3. Align the SCR catalyst inlet to the exhaust pipe, and install the spherical clamp. Do not tighten at this time. See **Fig. 2** for proper installation.

DDC 2HV ATD and SCR Catalyst Removal and Installation



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NOTE: Clamp and seal are directional.

A. Correct Clamp and Seal Installation

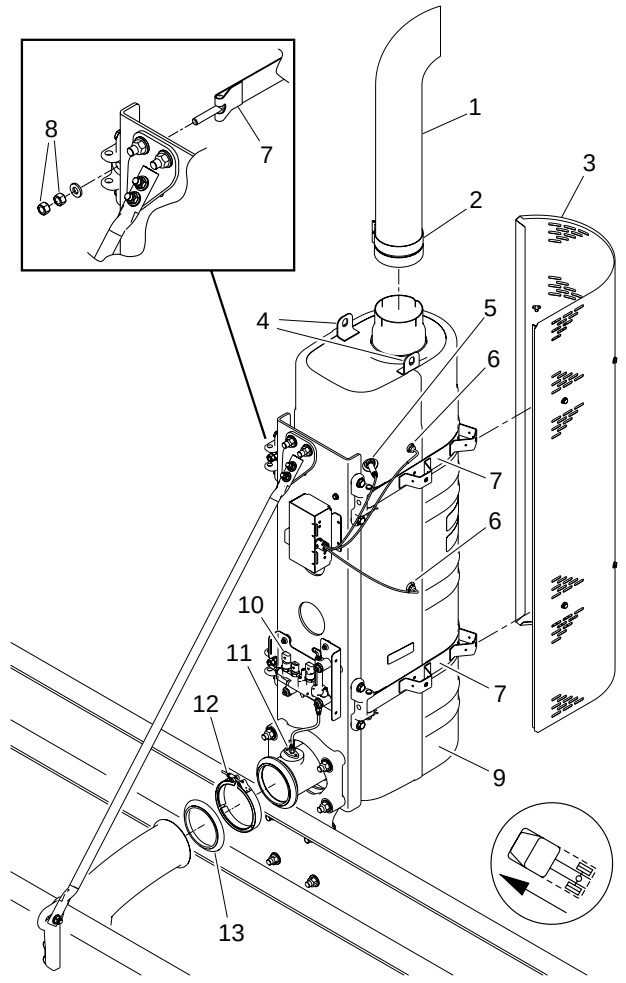
1. ATD
2. Clamp
3. Gasket
4. Exhaust Pipe

Fig. 2, Spherical Clamp Installation

NOTICE

Do not allow the clamping strap to twist while tightening it. A twisted strap could lead to a strap failure and possible damage to the ATS.

4. Check all alignment marks, and tighten the clamping strap nuts incrementally, first 15 lbf·ft (20 N·m), then 30 lbf·ft (40 N·m).
5. Tighten the spherical clamp 114 to 126 lbf·in (1290 to 1425 N·cm).
6. Connect the two temperature sensors and the NOx sensor.
7. Connect and tighten the DEF nozzle supply line.
8. Install the stack. Align the outlet 45 degrees out from the back of the cab. Tighten the clamp 27 to 37 lbf·ft (37 to 50 N·m).
9. Install the six bolts that attach the heat shield to the SCR catalyst. Tighten 13 to 17 lbf·ft (18 to 22 N·m).
10. Start the engine and check for leaks. Tighten any connections as needed.



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1. Stack
2. Clamp
3. Heat Shield
4. Lifting Points
5. NOx Sensor
6. Temperature Sensor
7. Clamping Strap
8. Clamping Clamp Nuts
9. SCR Catalyst
10. DEF Metering Unit
11. DEF Nozzle
12. Spherical Clamp
13. Gasket

Fig. 3, SCR Catalyst Installation

General Description

The Environmental Protection Agency (EPA) mandated that all engines built after December 31, 2009 must reduce the level of emissions exhausted by the engine to 0.2 grams per brake horsepower hour (g/bhp-hr) of nitrogen oxides (NOx).

To meet the EPA10 requirements, Daimler Trucks North America is using technology known as Selective Catalytic Reduction (SCR) in the exhaust aftertreatment system (ATS). See **Fig. 1**.

The SCR process requires the introduction of diesel exhaust fluid (DEF) into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the ATS, the exhaust gases pass through the ATD, then are treated with precisely-controlled quantities of DEF, and then pass into the SCR catalyst. DEF consumption is dependent on ambient conditions and vehicle operation.

DEF is drawn from the tank by the DEF pump. The DEF is then filtered and, from the pump, transported through the DEF lines to the metering unit. The metering unit measures the correct amount of DEF, which is then injected into the hot exhaust flow after exhaust gases have passed through the ATD. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the selective catalyst chamber to yield harmless nitrogen and water vapor, which exit out the tailpipe.

DEF causes mild discoloration to aluminum, but will not affect its strength or structure. White crystals may be noticeable around components that come into contact with DEF. The crystals can be easily removed using water.

DEF freezes to a slush consistency at 12°F (-11°C). Because DEF can freeze, the DEF lines and metering unit are designed to purge whenever the engine is shut down to prevent damage. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

DEF in the tank is allowed to freeze while the vehicle is non-operational. The DEF temperature sensor detects when the temperature of the DEF in the tank is approaching its freezing point. After the engine has been started and the engine coolant reaches a certain temperature, the coolant valve opens, allowing the coolant to flow through the coolant lines inside the DEF tank. The lines transfer heat, causing any frozen DEF in the tank to thaw and preventing liquid DEF from freezing during operation in cold weather. After flowing through the tank, the coolant is redirected back to the engine.

DEF will degrade over an extended period of time; shelf life is between twelve and eighteen months in standard operating conditions and temperatures. As DEF begins to degrade, it is usable but may be consumed at a slightly higher rate than normal.

A minor engine derate (approximately 25%) will occur when the DEF level registers below 5% on vehicles with Detroit Diesel engines, or 2.5% on vehicles with Cummins engines. If the DEF tank is empty, a major engine derate (vehicle speed is limited to 5 mph) will occur after an engine shut down and restart if the diesel tank has been refueled and the DEF tank is not refilled.

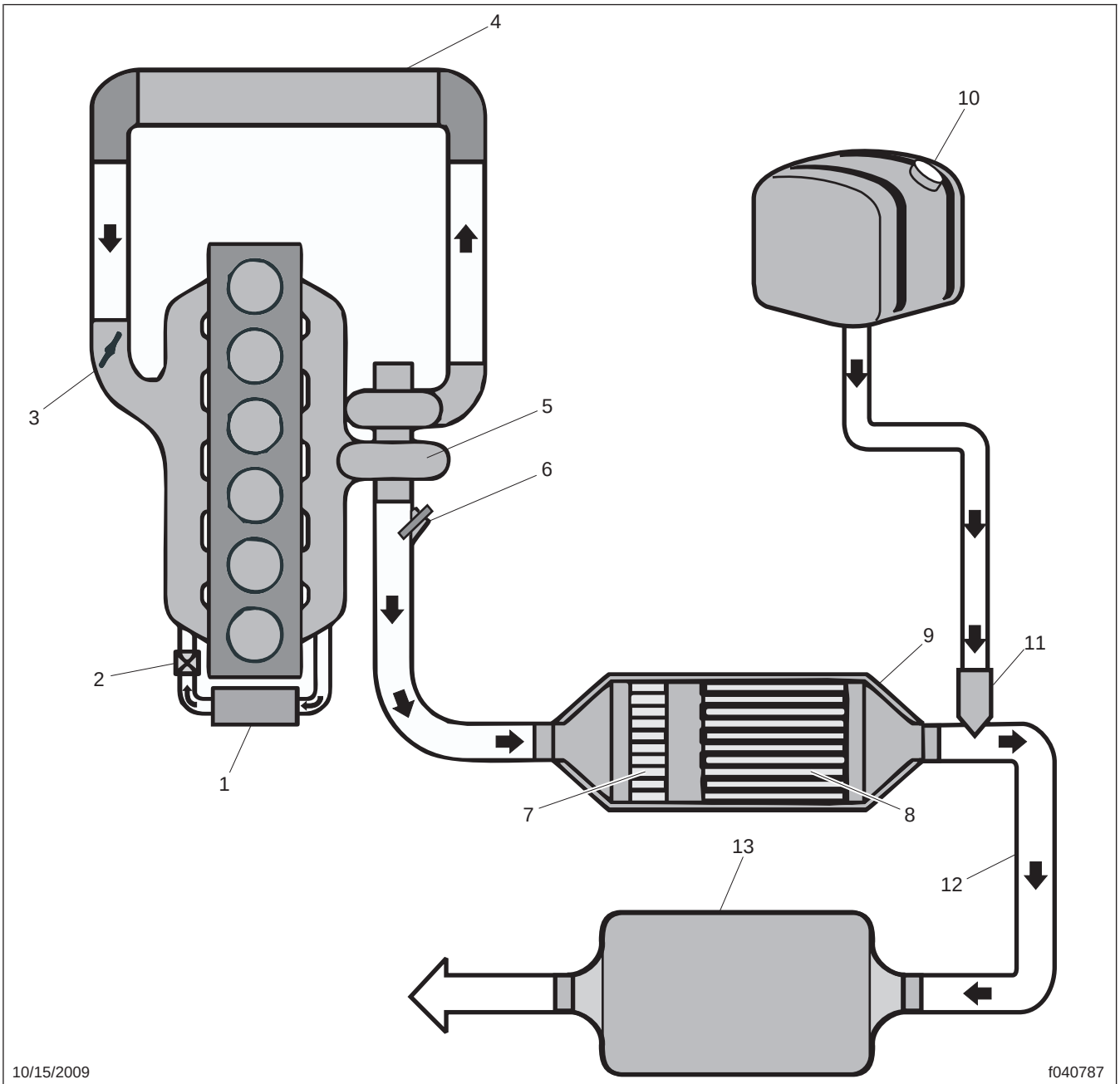
There are also safety controls that derate the engine if a contaminant has been introduced into the DEF tank. When a contaminant is detected, a minor engine derate will occur. When the vehicle has operated for 20 hours or 1000 miles with a contaminated tank, the vehicle will experience a major engine derate once the system determines that the vehicle is in a safe situation. Once the DEF tank has been filled with clean DEF, engine performance will return to normal.

DTNA-covered components of the DEF system include the DEF tank, tank header unit, pump, and coolant, DEF, and air lines between these components. See the engine manufacturer's service literature for information regarding other DEF system components such as the metering unit and injector, and DEF system maintenance instructions and intervals.

For additional operating information, see the *108SD and 114SD Driver's Manual*.

For additional information on and definitions for EPA10-compliant systems and components, see **Section 01.02**, EPA10 Engine Information.

For additional information on the ATS, see **Section 49.00**, Aftertreatment System, EPA10.



1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7 Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. DEF Tank
11. DEF Injector
12. Mixing Tube
13. SCR Catalyst Chamber

Fig. 1, EPA10 Aftertreatment System

Daimler Trucks North America vehicles carry diesel exhaust fluid (DEF) tanks in three sizes: 6 gallons, 13 gallons, or 23 gallons.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

6-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the coolant from the cooling system. For instructions, see **Group 20**.
4. Place a clean drain pan underneath the tank to catch draining DEF. Uncontaminated DEF may be reused.

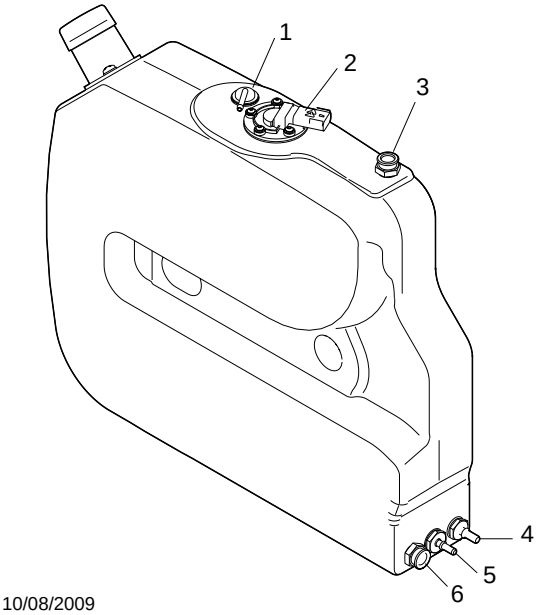
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

5. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

6. Disconnect the DEF lines from the supply and return ports and let the DEF drain into the drain pan. See **Fig. 1** or **Fig. 2**.
7. Disconnect the wiring harness from the tank header unit.



1. Vent
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Inlet
4. DEF Outlet
5. DEF Inlet
6. Coolant Outlet

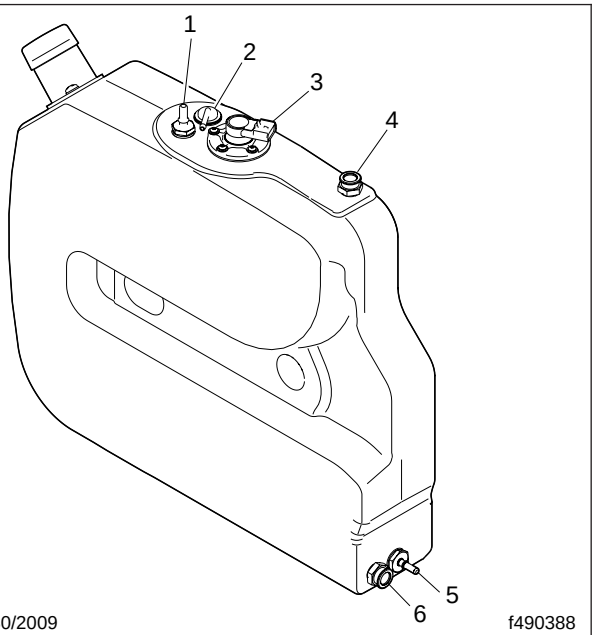
Fig. 1, 6-Gallon Tank Ports (Detroit Diesel shown)

8. Disconnect the coolant lines from the supply and return ports.
9. Disconnect the vent line.
10. If another chassis-mounted component is located directly aft of the DEF tank, check to see if the component is mounted close enough to prevent the tank from sliding off the mounting studs. If so, remove the nuts, bolts, and washers that secure the tank assembly to the frame casting, and remove the assembly from the frame casting.
11. Remove the two capscrews that secure the tank and retaining washers on the mounting studs. See **Fig. 3**.
12. Remove the two tank retaining washers from the tank mounting studs.
13. Slide the tank off of the mounting studs.

Installation

1. Slide the tank onto the mounting studs.

Tank Removal and Installation

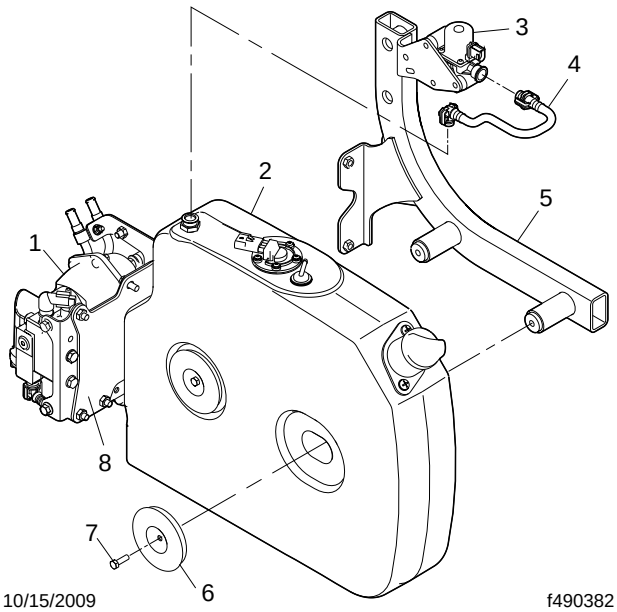


1. DEF Inlet
2. Vent
3. DEF Level and Temperature Sensor Wiring Harness
4. Coolant Inlet
5. DEF Outlet
6. Coolant Outlet

Fig. 2, 6-Gallon Tank Ports (Cummins shown)

2. Install two tank retaining washers on the tank mounting studs.
3. Install two capscrews onto the mounting studs, securing the tank and retaining washers on the tank mounting studs. Tighten the capscrews 11 to 18 lbf·ft (15 to 25 N·m).
4. If the tank assembly was previously removed from the frame casting, install the tank assembly on the frame casting. Tighten the four tank assembly mounting bolts 112 lbf·ft (152 N·m).
5. Connect the vent line.
6. Connect the coolant supply and return lines to the coolant ports on the tank.
7. Remove any white DEF crystals from the DEF ports on the tank and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.



1. DEF Pump
2. DEF Tank
3. Coolant Valve
4. Coolant Supply Line
5. Tank Mounting Bracket
6. Tank Retaining Washer (Qty 2)
7. Capscrew (Qty 2)
8. Pump Mounting Bracket

Fig. 3, 6-Gallon Tank Mounting Assembly

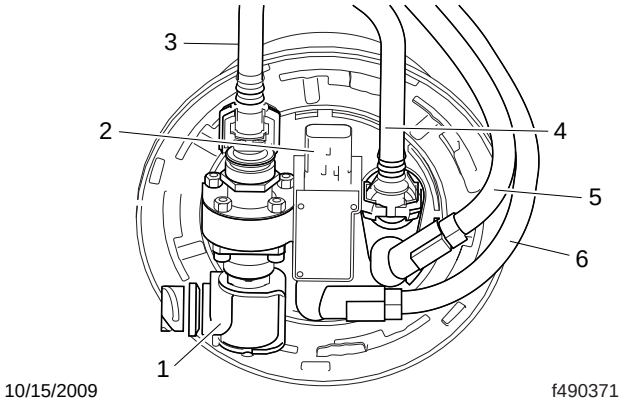
8. Connect the DEF supply and return lines to the DEF ports on the back of the tank.
9. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
10. Connect the wiring harness to the tank header unit.
11. Fill the DEF tank.
12. Fill the cooling system and check for leaks. For instructions, see **Group 20**.
13. Close the hood.

13- or 23-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the coolant from the cooling system. For instructions, see **Group 20**.
4. Remove the beauty cover, if equipped.
5. Using a siphon, empty the DEF from the tank into a clean container. Uncontaminated DEF may be reused.
6. Place a drain pan underneath the tank to catch any remaining DEF or coolant that drains out.
7. Disconnect the coolant valve and DEF level and temperature sensor wiring harnesses from the tank header unit. See **Fig. 4**.



1. Coolant Valve Wiring Harness
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Return Line
4. Coolant Supply Line
5. DEF Return Line
6. DEF Supply Line

Fig. 4, DEF Tank Header Unit (Detroit Diesel shown)

8. Disconnect the coolant lines from the tank header unit.

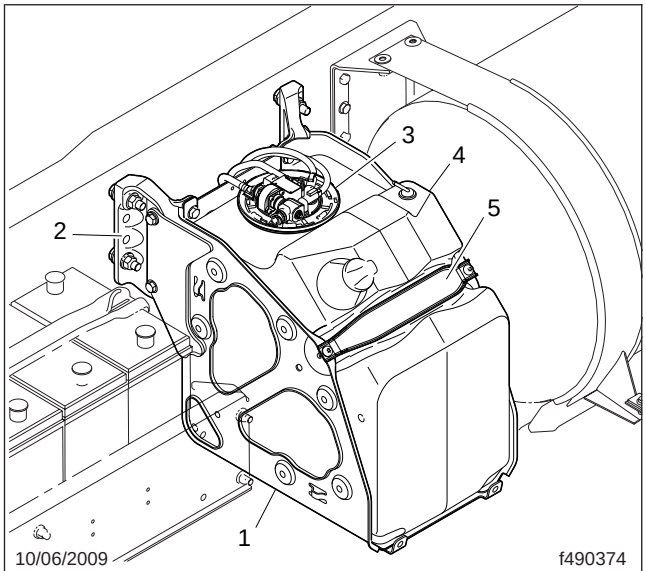
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

9. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

10. Disconnect the DEF lines from the tank header unit.
11. Disconnect the vent line.
12. Remove the two nuts that secure the tank retaining bracket to the tank mounting cage and remove the retaining bracket. See **Fig. 5**.



1. Mounting Cage
2. Mounting Support Bracket
3. Tank Header Unit
4. Tank
5. Tank Retaining Bracket

Fig. 5, 13- or 23-Gallon DEF Tank Mounting Assembly

13. Remove the tank from the mounting cage.

Installation

1. Install the tank into the mounting cage.

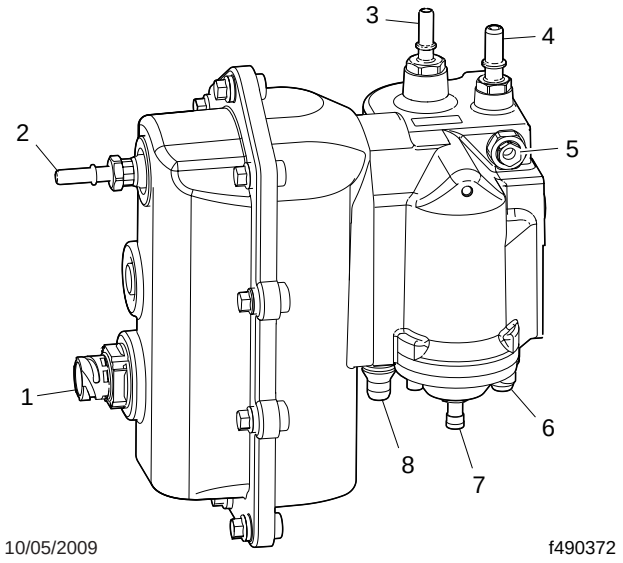
Tank Removal and Installation

2. Install the tank retaining bracket on the tank mounting cage studs. Install two nuts on the tank retaining bracket and tighten the nuts 12 lbf·ft (16 N·m).
3. Connect the vent line.
4. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

5. Connect the DEF supply and return lines to the tank header unit.
6. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
7. Connect the coolant lines to the tank header unit.
8. Connect the coolant valve and DEF level and temperature sensor wiring harnesses to the tank header unit.
9. Fill the DEF tank.
10. Install the beauty cover, if equipped.
11. Fill the cooling system and check for leaks. For instructions, see **Group 20**.
12. Close the hood.

EPA10-compliant vehicles have a diesel exhaust fluid (DEF) pump module (**Fig. 1**) mounted in a protective box to the back of the DEF tank.



1. Wiring Harness Connector
2. DEF Inlet Port
3. DEF Outlet Port (to metering unit)
4. DEF Outlet Port (to tank)
5. Compressed Air Port
6. Coolant Outlet Port
7. Air Bladder Fill Valve
8. Coolant Inlet Port

Fig. 1, DEF Pump (Detroit Diesel shown)

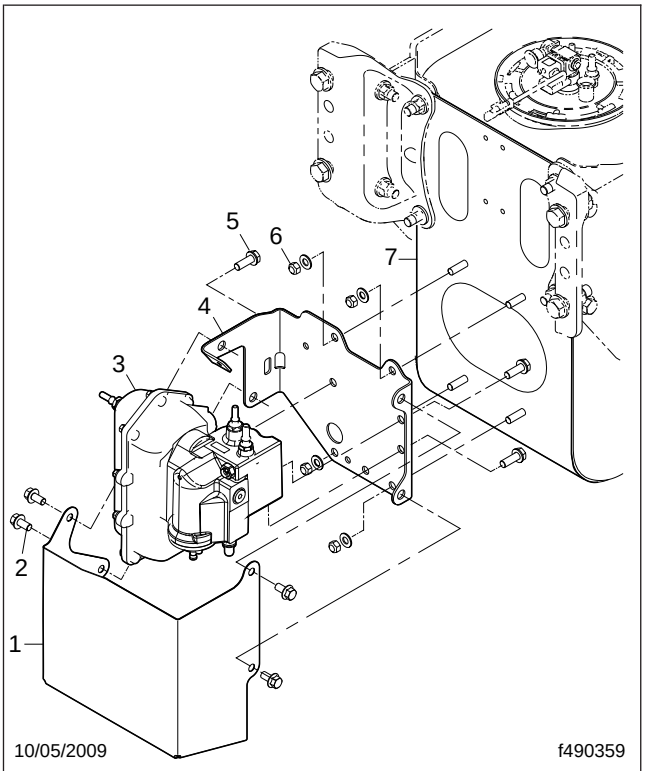
The DEF pump module filters and supplies DEF to the metering unit. The only serviceable components of the pump module are the air bladder and the filter. See the engine manufacturer's service literature for maintenance instructions and intervals.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Removal

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Open the hood.
3. Drain the air system.
4. On a vehicle equipped with a Detroit Diesel engine, drain the coolant from the cooling system. For instructions, see **Group 20**.
5. Place a drain pan underneath the pump to catch any DEF or remaining coolant that drains out.
6. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. See **Fig. 2**.
7. Disconnect the wiring harness from the pump.



1. Protective Cover
2. Protective Cover Mounting Fasteners
3. DEF Pump
4. Pump Mounting Bracket
5. Pump Mounting Fasteners
6. Mounting Bracket Fasteners
7. DEF Tank Mounting Cage

Fig. 2, DEF Pump Removal and Installation

Pump Removal and Installation

8. Disconnect the coolant lines and air line, if equipped, from the pump.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

9. Disconnect the DEF line heater wiring harnesses from the DEF lines at the pump.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

10. Disconnect the DEF lines from the pump.
11. Loosen and remove the four nuts that secure the pump mounting bracket to the tank mounting cage.
12. Remove the DEF pump and mounting bracket.
13. Remove the three fasteners that secure the pump to the mounting bracket, and remove the pump from the bracket.

Installation

1. Using the three pump mounting fasteners, secure the pump to the pump mounting bracket. Tighten the fasteners 26 lbf·ft (35 N·m).
2. Install the four nuts that secure the pump mounting bracket to the DEF tank mounting bracket. Tighten the nuts 23 lbf·ft (31 N·m).
3. Remove any white DEF crystals from the DEF ports on the pump and the DEF line couplings.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

4. Connect the DEF supply and return lines to the three DEF ports on the pump.
5. Connect the DEF line heater wiring harnesses to the DEF lines at the pump.
6. Connect the air line and coolant lines, if equipped, to the pump.
7. Connect the wiring harness to the pump.
8. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).
9. On a vehicle equipped with a Detroit Diesel engine, fill the cooling system and check for leaks. For instructions, see **Group 20**.
10. Fill the air system.
11. Close the hood.

NOTE: Diesel exhaust fluid (DEF) creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Replacement

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

2. Disconnect the batteries.
3. Place drain pans underneath the DEF pump and the DEF metering unit to catch any draining DEF.
4. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank, pump, and metering unit.

NOTICE

To disconnect a DEF line, push the line coupling in towards the male connector to move the holding clip to the unlocked position, then compress the prongs of the holding clip and pull the line off of the male connector. Failure to properly remove a DEF line can result in damage to a line coupling or DEF fitting.

5. Disconnect the DEF lines between the DEF pump and the tank. See **Fig. 1**.
6. Disconnect the DEF lines between the pump and the metering unit.
7. Discard the lines.
8. Ensure the new DEF lines are undamaged and free of dirt or debris.
9. Remove any white DEF crystals from the DEF ports on the tank, pump, and metering unit.

IMPORTANT: To connect a DEF line, push the line coupling onto the DEF port male connector, then pull back gently on the coupling to engage the holding clip in the locked position.

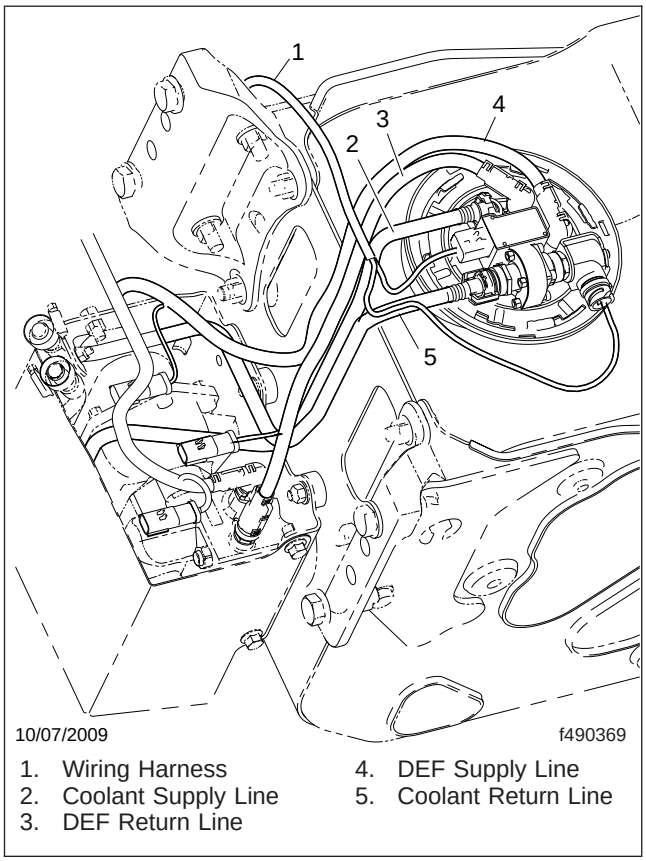


Fig. 1, DEF Pump Line Connections

10. Install new DEF lines between the DEF pump and the tank.
11. Install new DEF lines between the DEF pump and the metering unit.
12. Connect the DEF line heater wiring harnesses to the DEF lines at the tank, pump, and metering unit.
13. Connect the batteries.

NOTE: DEF creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Replacement, 6-Gallon Tank

The DEF header unit on vehicles with a 6-gallon DEF tank is secured to the top of the tank, and contains the DEF level sensor and the DEF temperature sensor.

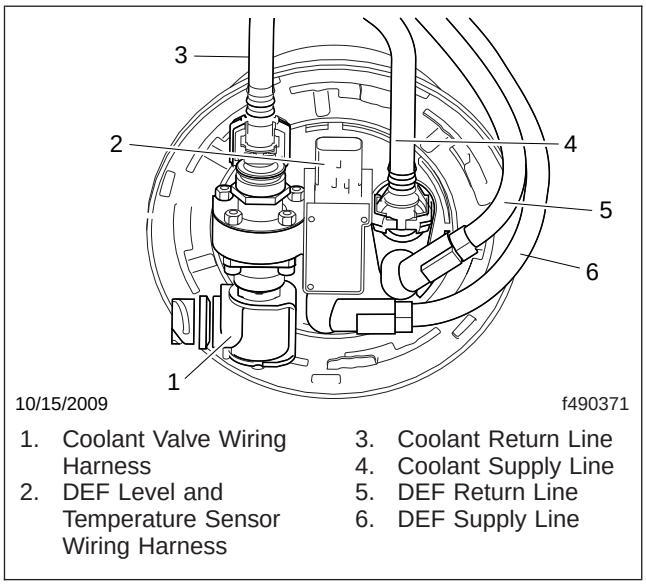
IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the tank from the vehicle. See **Subject 100** for instructions.
3. Remove the header unit mounting capscrews and washers that secure the header to the tank.
4. Remove the header unit from the tank.
5. Install a new header unit into the tank.
6. Ensure that the header unit is situated securely on the raised lip of the tank, and is not tilted to the side.
7. Install the mounting capscrews and washers to secure the header unit to the tank. Tighten the capscrews 5 lbf·ft (7 N·m).
8. Connect the DEF level and temperature sensor wiring harness.
9. Install the DEF tank on the vehicle. See **Subject 100** for instructions.

Replacement, 13- or 23-Gallon Tank

The DEF header unit on vehicles with a 13- or 23-gallon DEF tank is secured to the top of the tank, and contains the engine coolant lines that run through the tank, the coolant valve, the DEF level sensor, and the DEF temperature sensor. See **Fig. 1**.

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.



1. Coolant Valve Wiring Harness
2. DEF Level and Temperature Sensor Wiring Harness
3. Coolant Return Line
4. Coolant Supply Line
5. DEF Return Line
6. DEF Supply Line

Fig. 1, DEF Tank Header Unit (Detroit Diesel shown)

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Remove the tank from the vehicle. See **Subject 100** for instructions.
3. Rotate the header lockring counter-clockwise to loosen it, then remove the lockring.
4. Remove the header unit from the tank by pulling the assembly straight up, then tilting it to pull the horizontal end clear of the tank; see **Fig. 2**.
5. Install a new header unit by tilting it to insert the horizontal end into the tank. Once the horizontal segment is inside the tank, tilt the header unit back to vertical to settle the bracket on top of the tank.
6. Ensure that the header unit is situated securely on the raised lip of the tank, and is not tilted to the side.
7. Install the header lockring and rotate it clockwise to secure it to the tank.
8. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line couplings.
9. Install the DEF tank on the vehicle. See **Subject 100** for instructions.

Tank Header Unit Replacement

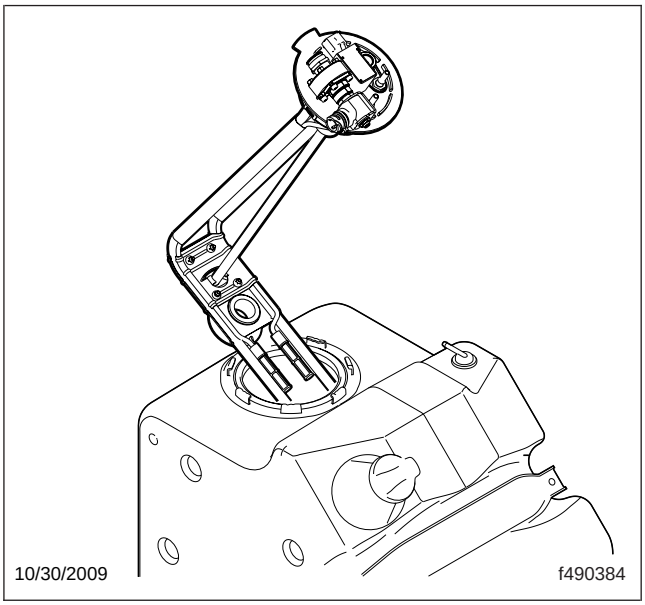


Fig. 2, Header Unit Tilt

NOTE: Diesel exhaust fluid (DEF) creeps, causing white crystals to form around the line fittings. The presence of crystals does not mean the system has a leak. Replacing fittings or components is not necessary unless there is a system failure or a fault code.

Periodic maintenance of the DEF pump filter is required. For instructions and intervals, see the engine manufacturer's service literature.

Replacement

Detroit Diesel

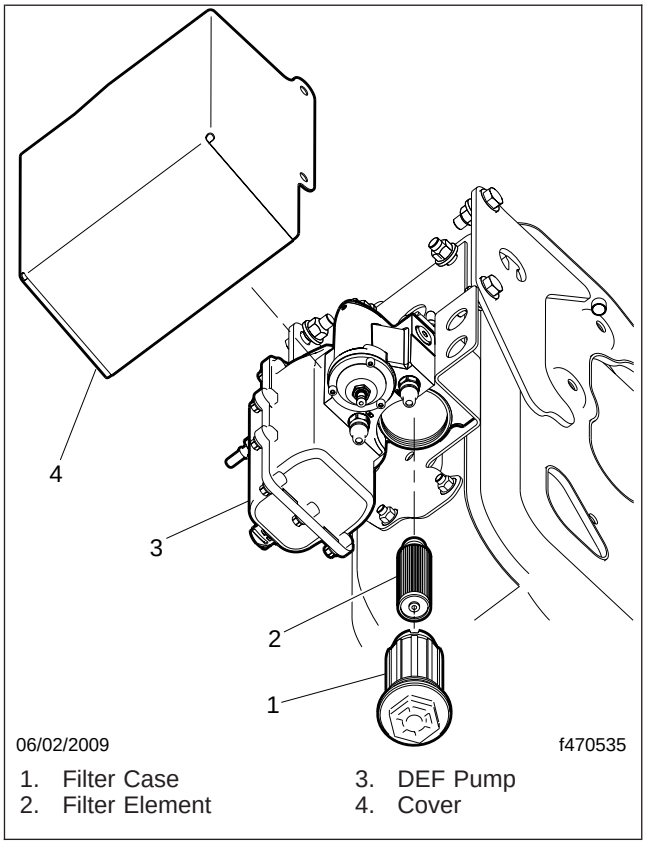
IMPORTANT: Discard contaminated DEF in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

2. Disconnect the batteries.
3. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. The pump is located next to, or inboard of, the DEF tank.
4. Unscrew the filter cartridge; see **Fig. 1**. The cartridge includes both the filter case and the filter element, which are replaced as a unit. Verify that the filter element was removed with the case. If the filter element was not removed, use a suitable tool to remove it from the pump.

   Discard the filter element and case.
5. Lubricate the O-rings with clean DEF.
6. Check the new filter cartridge to ensure that the O-ring end of the filter element is facing out of the cartridge. Install the cartridge into the DEF pump. Tighten the filter cartridge 22 to 25 lbf·ft (30 to 34 N·m).
7. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).



1. Filter Case
2. Filter Element
3. DEF Pump
4. Cover

Fig. 1, DEF Filter Replacement, Detroit Diesel Engine

8. Connect the batteries.

Cummins

IMPORTANT: Discard contaminated DEF in accordance with EPA regulations.

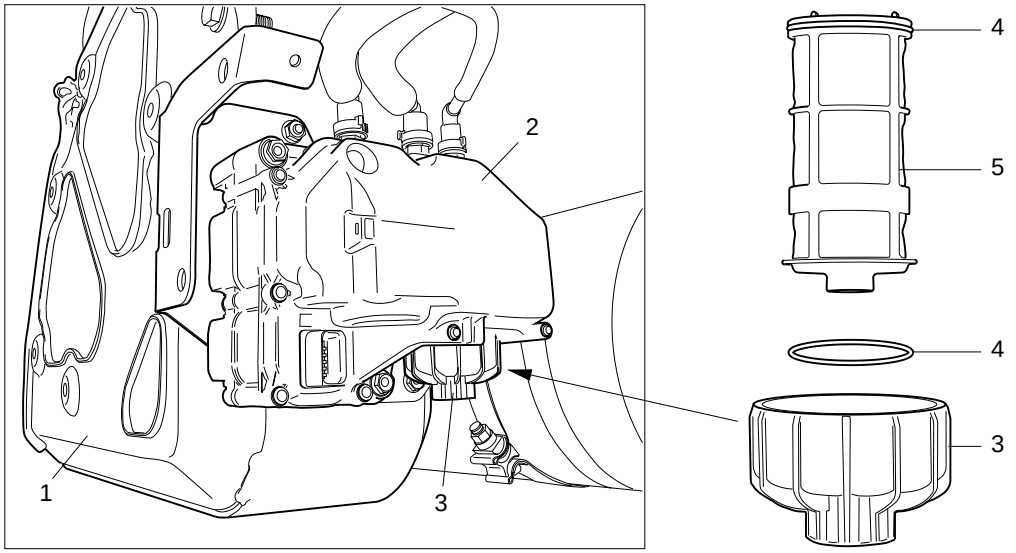
1. Shut down the engine, apply the parking brake, and chock the tires.

IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the battery ground cable. Disconnecting the battery ground cable too soon will prevent purging of the DEF lines after the engine is shut down.

2. Disconnect the batteries.
3. Remove the four mounting bolts that secure the protective cover over the pump. Remove the cover. The pump is located inboard of the DEF tank.

Pump Filter Replacement

4. Unscrew the filter cap, then remove and discard the filter element. See **Fig. 2**.
5. Install the new filter element into the DEF pump with the O-ring end facing into the pump.
6. Install the filter cap. Tighten the cap 15 to 18 lbf·ft (20 to 25 N·m).
7. Place the protective cover over the pump and install the four mounting bolts that secure the protective cover to the pump mounting bracket. Tighten the bolts 37 lbf·ft (50 N·m).
8. Connect the batteries.



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1. DEF Tank
2. DEF Pump
3. Filter Cap
4. O-Ring
5. Filter Element

Fig. 2, DEF Filter Replacement, Cummins Engine

If a contaminant has been introduced into the diesel exhaust fluid (DEF) system and the engine has been started, the following DEF components must be replaced:

- Tank
- Pump
- Header unit
- Metering unit
- Injector

See the other subjects in this section for tank, pump, and header unit replacement.

See the engine manufacturer's service literature for other component replacement instructions.

Flushing

If a contaminant has been introduced to the DEF tank, but the engine has not been started, complete the following steps.

1. Apply the parking brake and chock the tires.
2. Place a suitable container underneath the DEF tank to catch any draining DEF.

IMPORTANT: Discard contaminated DEF or coolant in accordance with EPA regulations.

3. Remove the DEF and contaminant from the tank.

   On vehicles with a 6-gallon DEF tank, disconnect the DEF line from the DEF outlet port and let the DEF drain into the drain pan.

   On vehicles with a 13- or 23-gallon DEF tank, use a siphon to empty the DEF from the tank.
4. Remove the DEF tank. See **Subject 100** for instructions.
5. Thoroughly flush the tank with water until the tank is free of all contaminants.
6. Install the DEF tank. See **Subject 100** for instructions.

General Information

The on-highway environment places severe demands on a vehicles electrical system. The following material describes the methods for repairing and sealing electrical connections that will provide the durability necessary for the automotive environment.

There are four distinct components for making a wire repair that will withstand:

- the mechanical demands of vibration, strain, and thermal cycling
- the electrical requirement of oxidation free conductivity
- the insulating properties to resist shorting to adjacent objects
- the ability to seal for corrosion protection

When troubleshooting electrical systems, consider body height and suspension travel. Interference and strain may be caused by normal frame flexing and body accessories that are not apparent when a vehicle is stationary.

Wire Repair and Splicing

Disconnect the batteries at the negative terminals before performing any repairs to the electrical system.

IMPORTANT: Before repairing or replacing any damaged electrical system components impacted by a failure, locate and correct the component/condition that caused the failure before proceeding with the repair.

Wire that is discolored or melted due to an external heat source may need to be re-routed or installation of a heat shield may be necessary. If wire length permits, a splice may be made with a single connector. Often a length of wire will need to be added and two splices are made. Carefully check damaged wire for signs of corrosion that has wicked up into the insulation and through the wire. If the wire conductor has become green or black, cut off the discolored wire and replace it with a new section.

Corrosion on battery cable terminals may be cleaned with a mild solution of baking soda and water, and scrubbed with a wire brush.

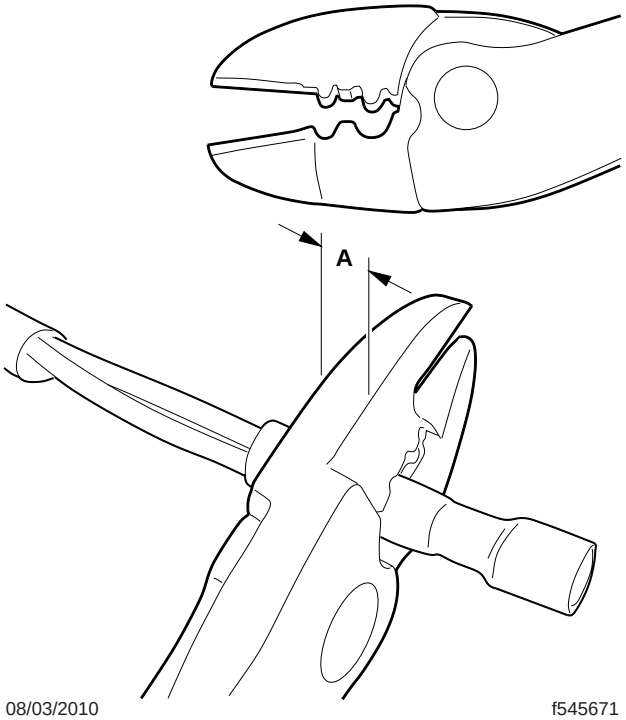
Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in packages of 25 connectors. Use the connectors and adhesive lined shrinkable tubing shown in **Table 1** when making a wiring splice.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 1000°F (538°C).



A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a 3-inch section of adhesive coated shrink tubing onto one of the wires.
2. Crimp the splice connector onto the wires. Use the type of crimp tool that makes a dimple in the connector. The dimple must be at least 3/16 inch wide or there will be too much space inside the connector and the solder will not flow into the wire. This crimp provides the mechanical retention needed. See **Fig. 2**.

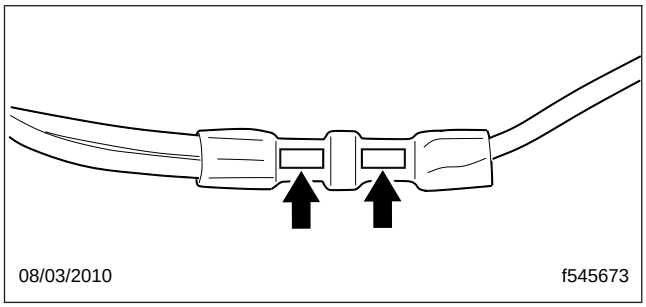


Fig. 2, Properly Crimped Splice

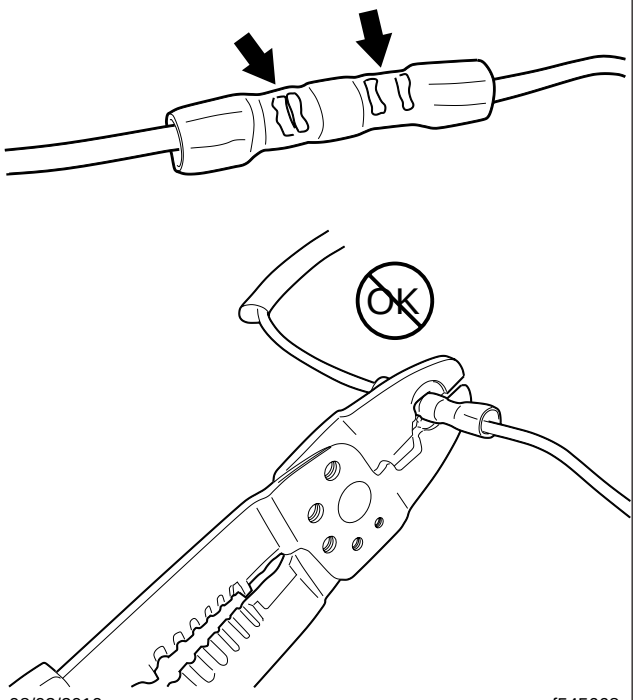
3. Pull test the wires by hand to ensure the crimp is mechanically solid.
4. A crimp tool that is too narrow will leave excessive air gaps in the crimp. The connection will not have the required amount of mechanical strength and the solder will not bond the wire to the connector. **Figure 3** shows an example of a bad crimp when the wrong tool is used.
5. Heat the properly crimped splice connector with the heat gun while slowly rotating the wire. The solder will take longer to flow than it will for the shrinkable insulation to contract. Heat until the solder band has completely melted into the connector. If the shrinkable insulation ruptures and a small amount of solder bubbles out, gently shake the splice to remove the solder. See **Fig. 4**.
6. When the connector has cooled, center the shrinkable tubing over the splice and heat the tubing until it has completely sealed the splice and a small fillet of adhesive is visible at the ends of the shrink tube. See **Fig. 4**.
7. A three-wire tap splice can be made following the same procedure. Use a connector that is large enough to fit all the strands of the wires. See **Fig. 5** for an example of the completed splice.

Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Solderless Connector Parts		
Wire Size: gauge (mm)	**Connector Part Number***	**Shrinkable Tubing (Daimler Part Number)**
20 to 18 (0.5 to 0.8)	PHM 1 1863	1/4 inch with internal adhesive coating (48-02461-025)
16 10 14 (1 to 2)	PHM 1 1862	1/4 inch with internal adhesive coating (48-02461-025)
12 to 10 (3 to 5)	PHM 1 1861	3/8 inch with internal adhesive coating–4 foot length (48-02461-038)
8 or larger (5 or larger)	Replace the terminal or the entire cable	Use adhesive lined red for positive cables and black for negative cables.

* Twenty-five connectors per pack.

Table 1, Solderless Connector Parts



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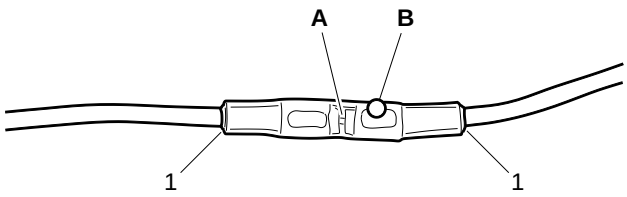
NOTE: Even with two crimps, there is too much air gap; the solder will not bond.

Fig. 3, Wrong Tool Being Used and a Crimp That Will Fail



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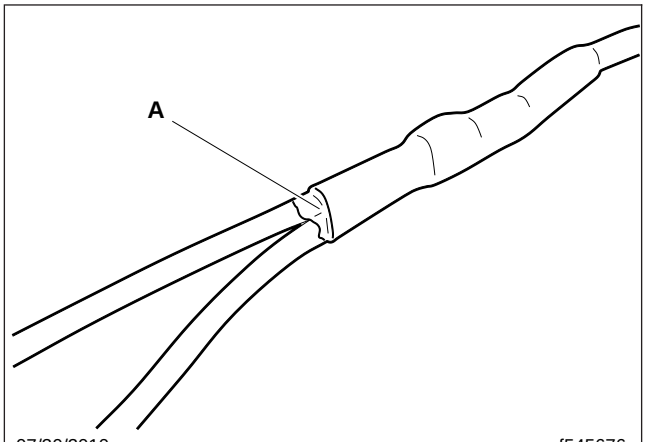
A. The solder band is completely melted.
B. Insulation rupture; gently shake off the solder bead.

1. Adhesive Fillet

Fig. 4, Solder Bead Rupture



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A. The fillet of adhesive at the ends of the shrink tube indicate a complete seal.

Fig. 5, Completed Three-Wire Tap Splice

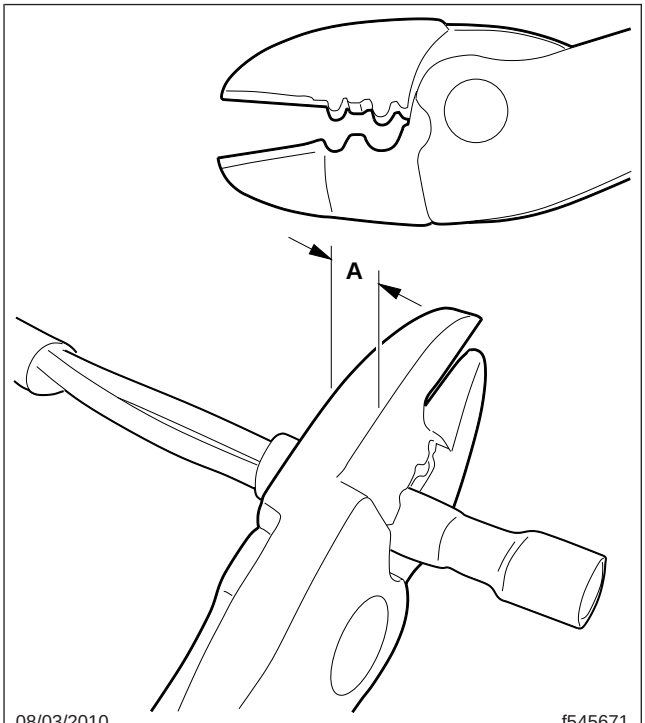
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in kits with material for 50 splices. This kit may be used on 16 to 14 gauge (1 to 2 mm) wire.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 250°F (121°C).



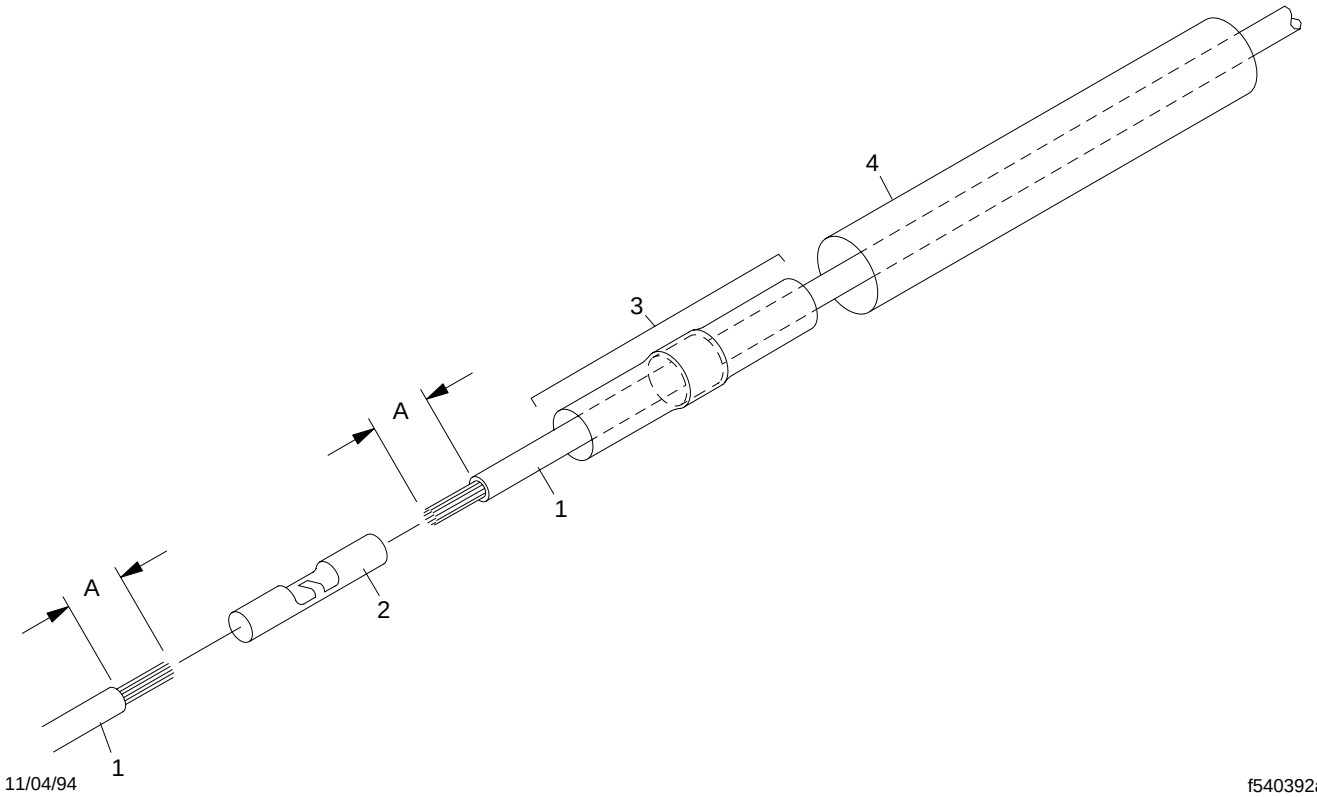
A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a piece of the shrink tubing from the kit onto one of the wires.
2. Slide a shrinkable solder sleeve from the kit onto one of the wires.
3. Place the wires that will be spliced into each end of the barrel connector. See **Fig. 2** for an example of the splice.
4. Crimp each end of the barrel using a dimple-type crimp tool to secure the wires. See **Fig. 1** for an example of a proper crimp tool.
5. Pull test the wires by hand to ensure the crimp is mechanically solid.
6. Slide the shrinkable solder sleeve onto the barrel connector so the solder band is at the center of the barrel connector.
7. Heat the splice using a heat gun rated at 250°F (121°C) until the sleeve has completely shrunk against the wire and the solder flows into the barrel connector. A small fillet of adhesive may be visible at the ends of the connector. See **Fig. 3**.
8. Slide the shrinkable tubing over the splice and apply heat with a heat gun rated at 250°F (121°C) until it has completely shrunk against the wire insulation. A small fillet of adhesive should be visible at the ends of the shrinkable tubing.

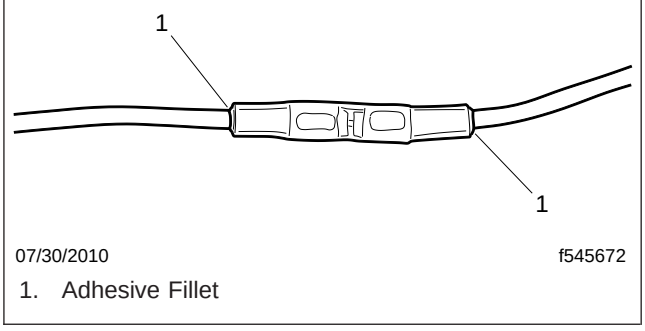
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404



A. 1/4 inch (6.4 mm)

1. Wire End
2. Barrel Connector
3. Solder Sleeve
4. Shrink Tube

Fig. 2, Splice Prepared with Parts in Kit ESY ES66 404



1. Adhesive Fillet

Fig. 3, Heated Solder Sleeve with Solder Band Melted into the Splice

Parts

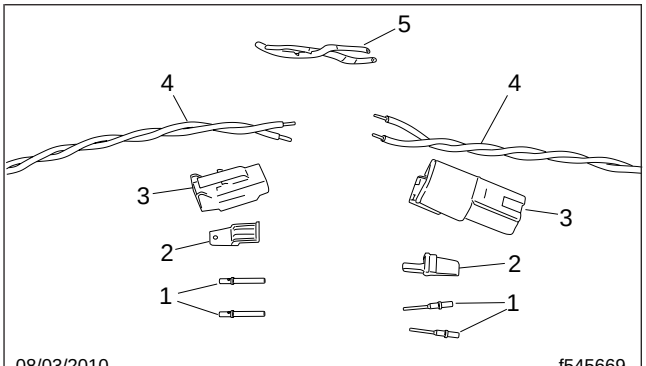
Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of Datalink Wires

Fig. 1, Datalink Splice Parts

2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.

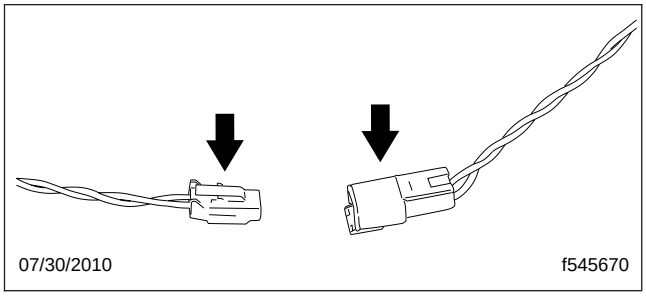


Fig. 2, Datalink Connectors

Connection Protection

Use the dielectric protectants and procedures provided here to protect electrical connections from corrosion. A list of approved dielectric protectants is shown in **Table 1**.

The components listed in **Table 2** have electrical connections that need to be protected.

When disconnecting any of these circuits, clean the connection and remove the old dielectric material. Completely cover the exposed area after assembly using the product and procedure in this bulletin. Always follow the product manufacturers recommendations for work area ventilation.

Approved Dielectric Protectants			
Material	**Type**	**Manufacturer**	**Product**
Dielectric Red Enamel	Spray On	3M®	1602 IVI
		Glyptal	1201A
	Brush On	Glyptal	1201E 2100
Dielectric Grease	Lithium Base	Fiske Brothers Lubriplate® (FLP)	DS-ES
	Synthetic	Nye	Nyogel 760G

Table 1, Approved Dielectric Protectants

Electrical Component Protection and Procedure		
Protection	**Component**	**Procedure**
Dielectric Red Enamel	Starter - All Exposed Connections	Protect connections and cable terminals.
	Magnetic Switch	Protect connections and cable terminals.
	Alternator	Protect all connections. Do not allow dielectric material to enter the alternator.
	Bolt and Stud Ground Connections (outside cab)	Cover all terminals, studs, and nuts with dielectric enamel.
	Battery Cut-Off Switch Connections	Protect connections and cable terminals.
	Exposed Battery Cable Connections (located outside of the battery box)	Protect connections and cable terminals.
	Power Distribution Modules	Protect battery power studs on chassis mounted PDMs.
	Mega Fuses (when located outside of the battery box)	Place tape across the part of the fuse with the labeling, then apply the dielectric material. Remove the tape.

Electrical Connection Protection

Electrical Component Protection and Procedure		
Protection	**Component**	**Procedure**
Dielectric Grease, Lithium Base	Tail Lamp Bulb Sockets (non LED)	Remove the bulb, apply grease to the inside of socket. Replace the bulb.
	Battery Terminals	Apply grease to battery terminals before connecting interconnect cables.
	Battery Interconnect Cable Connections	Apply grease to connection studs and pads before connecting battery cables.
	Parked HVAC Power Connections	Disconnect the two power and one ground cable where they enter the basket on the underside of the cab. Apply grease, then connect.
	Inverter Power Connections	Disconnect the power and ground feeds at the cab pass through. Apply grease, then connect.
	Mega Fuses (if located in the battery box)	Apply grease to protect exposed terminals and connections.
Dielectric Grease, Synthetic	Connections with serial data circuits or with very low voltage signals.	Apply synthetic grease to the terminals inside the connector.

Table 2, Electrical Component Protection and Procedure

General Specifications

See **Table 1** for standard wiring color-coding.

See **Table 2** for standard wiring circuit numbers and descriptions.

Standard Wiring Color-Coding		
Color	**Abbr**	**Typical Usage**
Black	BK	Ground, General
Black-White	BK-W	Ground, Clean or Isolated
Blue DK	DKBL	Backup/Windshield Wiper/Trailer Auxiliary
Blue LT	LTBL	HVAC/Circulation Fans/1922+
Blue LT-White	LTBL-W	Water, Oil Gauge and Indicator (Engine and Transmission)
Brown	BR	Marker, Tail and Panel Lamps
Gray	GY	Electronic Engine (or TXL Insulation)
Green DK	DKG	Turn Signal, RH/Driver's Display/Data Record/1587+/1939–
Green DK-White	DKG-W	Starting Aids/Fuel Heaters/Material Control/Winch/Tailgate
Green LT	LTG	Headlamp/Roadlamp/DRL
Green LT-White	LTG-W	Axle Controls and Indicators/Suspension/Fifth Wheel
Orange	O	ABS/EBS/1587–
Pink	PK	Start Control/Ignition/Charging/Volt and Ammeter/1922–
Pink-White	PK-W	Fuel Control and Indicators/Shutdown/Speed Limiter
Purple	PRP	Engine Fan/PTO/Auto Lube and Oil
Purple-White	PRP-W	Utility/Spot/Ad/Interior/Emergency Lighting
Red	R	Power Distribution, Constant
Red-White	R-W	Brake/Pneumatic/Hydraulic/Retarder/Stop
Tan	T	MPH, RPM Signals/Horn/Flasher/Pyro/Turbo
Tan-White	T-W	Audio/Video/Security/Window/Computer/Seat/Mirror
White	W	Transmission (or SXL Insulation)
Yellow	Y	Turn Signal, LH/1939+ (or GXL Insulation)
Yellow-White	Y-W	Air Bag and SPACE

Table 1, Standard Wiring Color-Coding

Circuit Numbers		
Circuit Number	**Description**	**Modules**
1	Battery Cable, Ground	156 286 291
6	Battery Cable, Positive	224 281 291 292 293 295
14	Cab Power, Main	156 224 277 281 285 286 291 292 293 295 306 320 321
15	Starter, Crank Circuit	146 155 156 157 158 286 291 320 895
16	Alternator, Main Power	124 125 286 320 836 846

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
18	Air Pressure Warning	320 486 838 840 877 880 882
19	Voltmeter	286 320 836 846
20	Headlamp, Left	27D 288 304 312 320 659
21	Headlamp, Right	27D 288 304 312 320 659
22	Headlamp, Low and High Beam	27D 288 304 312 320 659
23	Tail Lamps	288 294 296 301 302 304 30A 320 335
24	Horn, Electric	288 320 321 726
25	Horn, Air	288 320 321 726
27	Road Lamp	288 313 314 320
28	Fog Lamp	288 313 314 320
29	Instrument Panel Lamps	27D 288 296 302 304 30A 312 320 335 659 732 811 81B
30	Transmission Temperature and Filter	286 320 343 345 34B 34C 353 355 863 864
31	Transmission Aux Controls and Temp	286 320 343 345 34B 34C 353 355 863 864
34	Engine Oil Pressure	165 286 320 852
35	Engine Oil Temperature	286 320 854
36	Stop Lamps	288 294 296 301 320 335 486 838 840 877 880 882
38	Turn Signal	288 294 296 298 299 300 301 320 335 811
39	Stop/Turn Combination Lamp	288 294 296 301 320 335 880
41	Dome/Interior Lamp	271 287 294 300 302 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 320 322 324 325 327 328 32B 32C 469 470
42	Axle Oil Temperature, Forward	288 320 865 866
43	Axle Oil Temperature, Rear	288 320 865 866
44	Axle Oil Temperature, Center	288 320 865 866
45	Receptacle, Trailer	173 285 296 297 303 306 307 308 309 310 320 321 331 334 335
46	Marker Lamps	288 296 302 304 30A 320 335
47	Fuel Level	288 320 844 847
48	Fuel Control and Level, Natural Gas	148 150 152 162 164 283 286 288 320 811 814 844 847 860
52	Ignition Switch	156 285 306 320 321
55	Data Recorder	283 286 320 343 810 817
57	12V Power Outlet/Lighter	284 287 320 785
58	Heater, Auxiliary	130 287 320 700 703 70A 70C 723
73	Utility Lamps	287 288 318 31J 320 327 329 57W
74	Starter Mag Switch, Solenoid	155 156 157 158 286 320 895
75	Starter Mag Switch, Ground	146 155 156 157 158 286 895

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
76	Mirror Heat	320 656 744 74E
78	Spot Lamp	316 320 57V
81	Ignition Switch Control Devices	156 285 304 306 320 811 814 860
82	Starter Mag Switch Power	155 156 157 158 286 320 895
86	Axle Lock Solenoid	288 320 452 874 878 87A 87B 87F 896 900
87	Axle Lock	288 320 452 865 866 874 878 87A 87B 87F 896 900
88	Lubrication System, Automatic	288 594
90	Sander, Road	288 320 329
91	Heater, Diesel Fired Auxiliary	130 132 138 140 141 154 166 286 287 288 320 467 700 703 70A 70C 723
94	Air Dryer, Heated	288 480 48A 880
95	Speaker, Radio	287 320 746 74D 750 751 753 75B 75C 79F 79G
97	Air Conditioner	130 287 320 700 703 70A 70B 723
98	Heater – A/C Motor, Blower	130 156 283 285 286 287 320 321 700 703 70A 70B 70C 723
99	Fuel Solenoid, Engine Run	148 150 152 162 164 283 286 320
102	Parking Lamps	288 296 302 304 30A 320 335
108	Door Activated Lamps Courtesy/ Footwell/Door	320 324 325 32B 675 676 677 67E 67F 811 814 860
117	Speed Sensor +	283 286 320 343 810 817
118	Speed Sensor –	283 286 320 343 810 817
119	Coolant Temperature, Engine	198 199 286 320 732 810 812 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
120	Back-Up Lamps	288 294 320 471 721
121	Brake, Engine	128 129 164 283 286
122	Back-Up Alarm	288 294 320 471 721
123	Alternator, Voltage Regulation/ Rectifier	124 125 156 286 836
125	Park Brake Indicator/Warning	288 294 296 301 320 335 486 838 840 877 880 882
132	Alternator Charge Monitor	124 125 156 286 836
137	Alternator Indicator/Relay	124 125 156 286 836
140	Oil Pressure, Engine	286 320 852
149	Fan Manual Controls, Engine	273 276 286 320
154	Auxiliary Air Pressure	288 320 486 838 840 865 866 877 880 882
155	Axle Lift Controls	288 320 452 874 878 87A 87B 87F 896 900
157	Power Mirror Controls	320 656 744 74E
162	Tachometer Sensor +	283 286 320 812 819
163	Tachometer Sensor –	283 286 320 812 819

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
166	Engine Starting Aid, Ether	132 154 286 320 467
168	Hour Meter, Engine	286 320 812 813 81A 837 852
170	Fifth Wheel Slide Lock and Controls	173 296 297 303 307 308 309 310 331 334 581 87E
172	Clock	287 320 687 738
173	Coolant Level, Engine	152 286 320 856
182	Fuel Pressure	320 841 843 845
183	Air Cleaner Restriction, Engine	329 472
196	Fuel Water Separator Heater	110 127 220 288
200	PTO Controls	148 283 286 288 320 372
203	Exhaust Brake	128 129 164 283 286
204	Seat Belt Indicator/Warning	320 74F 756 760 763
208	Axle Control, Tri Axle, Steer Lock	288 320 376 452 865 866 874 876 878 87A 87B 87C 87F 896 898 900
209	Axle, Two Speed Shift Control	283 286 288 320 343 376 810 817 876 87C 898
210	Power Distribution Module, Outside Cab	224 281 285 286 291 292 293 295 306 320 321
214	Generator, Auxiliary	124 125 286 599
218	Pyrometer	286 320 858
219	Turbo Pressure	286 320 842
221	Suspension Dump Controls	288 320 87D 888 910
222	Headlamp Dimmer Controls	27D 288 304 312 320 659
223	Transmission Controls, Auto Shift	160 283 285 286 288 320 330 343 345 34B 34C 355 376 732 736 810 811 813 814 817 876 87C 898
224	Transmission Controls	286 288 320 343 345 34B 34C 353 355 376 876 87C 898
225	Air Pressure Gauge, Primary	320 486 838 840 877 880 882
226	Air Pressure Gauge, Secondary	320 486 838 840 877 880 882
227	Air Pressure Gauge, Application	320 486 838 840 877 880 882
232	Transmission Controls Power Supply	160 283 285 286 320 330 343 345 34B 34C 353 355 732 736 811 813 814
234	Engine Fan Controls	273 276 286 320
236	Transmission Neutral Indicator	286 320 343 345 34B 34C 353 355
242	Seat Controls	320 74F 756 760 763
243	Shore Power, Power Inverter	274 277 284 287 307 320 336 337 33C 785
244	Speed Limiter, Vehicle, Hewitt	150 164 283 286
246	Electric Fuel Pump	148 150 152 162 164 283 286 320
254	Roof Mounted Emergency Lamp/ Strobe	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
255	Advertising/Identification Lamp	288 296 302 304 30A 319 320 335
256	Optional Power Wire	285 286 306 320 321
261	Axle Lock, Controlled Differential	288 320 865 866
262	Retarder, Allison Transmission	128 129 286 343 34B 34C 34W 353
281	Oil Filter Change Indicator	165 286 320 852
285	Suspension Electric and Air Controls	288 320 87D 888 910
286	Fuel Water Separator Indicator	122 127 288 320 80F 844 845 847
294	Air Tank Auto Drain Valve	288 480 48A 880
295	Radio, AM/FM/CB/Disc	287 320 746 748 74D 750 751 752 753 75B 75C 79F 79G
299	Air Temperature, Exterior	320 860 867
300	Radio, Audio Signal	287 320 746 74D 750 751 753 75B 75C 79F 79G
303	Low Air Pressure	322 486 838 840 877 880 882
315	Windshield Wipers and Controls	320 321 660 66B
320	Windshield Washer	320 321 660 66B
331	Diagnostic Connector Power/Tach Ext Test	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
338	HVAC Controls	130 287 320 700 703 70A 70B 70C 723
339	LBCU/ICU/Gauge Power/Data	320 732 811 814 860
347	Shutter, Engine Fan	273 276 286 320
359	Headlamp On Signal, LBCU/ICU	27D 288 304 312 320 659
363	Power Windows	320 654 656 66A
364	Power Windows, Rear	320 654 656 66A
372	Receptacle # 2, Trailer 7-Way, ISO 3731	173 296 297 303 307 308 309 310 331 334 335
376	Antilock Brake Controls	160 283 285 286 296 308 320 330 331 332 333 335 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814
377	Antilock Brake Sensors	308 330 331 332 333 414 447 44G 44H 454 490 493
378	Antilock Brake Valves	160 283 285 286 308 320 330 331 332 333 343 34B 414 447 44G 44H 454 490 493 732 736 811 813 814
379	Daytime Running Lamps (DRL)	271 27D 288 294 300 302 304 305 311 312 314 316 318 319 31A 31B 31C 31D 31E 31F 320 322 324 325 327 328 469 470 659
388	Hydraulic Brake Power/Controls	288 320 486 49A 880
399	Optional Circuit, Cab/Chassis, Customer Specified	160 283 285 286 306 320 321 329 330 343 34B 472 732 736 811 813 814 860
400	Optional Circuit, Cab/Chassis, Customer Specified	329 472
402	Engine Start/Stop System, TAS	152 156 162 283 285 286 287 320 321

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
406	Emergency Lamp, Alternating, Access	264 271 275 27A 27B 27C 27E 287 288 318 31A 31B 31C 31D 31G 31J 320 327 33A 57W
407	—	—
408	Emergency Vehicle Accessory and Warning Lights	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
410	Emergency Siren and Bells	288 320 321 726
416	Refrigerator/Video Power	284 287 320 737 75B 785
417	Mobile Phone Power	320 789 79C
424	Headlamp Wiper/Washer	288 304 312 320
425	PNDB/CLDS Controls	224 277 281 285 291 292 293 295 306
427	Satellite Tracking System	287 320 786 78A 79H 80D
428	Battery Isolator Protection System	124 125 156 224 277 281 285 286 291 292 293 295 306 836
430	Windshield Wiper Heater	320 321 660 66B
431	Starting Aid, Engine Preheater	132 154 286 320 467
432	Seat Controls	320 74F 756 760 763
433	Data Recorder	160 286 320 813
434	Suspension Controls, ECAS	283 286 288 320 343 810 817 87D 888 910
435	Seat Belt Indicator/Warning	320 74F 756 760 763
436	Camera, Rear and Side View	160 288 320 736
437	Instrument Control Unit/LBCU	320 486 732 811 814 838 840 860 877 880 882
439	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 372
440	Engine ECU and Controls	106 128 129 148 149 152 156 160 162 164 273 276 283 285 286 301 320 330 343 34B 732 736 811 813 814 856 880
441	Engine ECU and Controls	106 148 164 165 283 286 320 852
442	Data Recorder/Data Logger	160 286 320 813
443	Door Locks	320 655 656 787
445	Body Controls/Dump Lock	288 320 329
446	Tire Pressure Monitor System	288 320 489
447	Battery Cutoff Protection System	130 156 224 277 281 285 287 291 292 293 295 306 320 700 703 70A 70B 723
448	Tail Gate Controls	288 320 329
449	Fueling Data Recording and Transmitter	198 199 283 286 288 320 343 732 810 812 817 830 836 838 83A 840 841 842 843 844 845 846 847 852 854 856 858 862 864 865 866 867 868 869
450	Mirror Dimming Controls	320 656 744 74E
453	Optional Customer Specified Wiring	164 283 285 286 306 320 321 329 343 345 34B 34C 353 355 472
454	Inflatable Restraint and Seat Pretension	160 283 285 286 320 330 343 34B 725 732 736 811 813 814

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
455	Instrument Left/Right Side Selection	320
457	Dash Controls, Datalink, (BPU)	164 283 286
459	Steering Pump Controls	539
460	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
461	Transmission-Automatic, Controls	286 320 343 345 34B 34C 353 355
462	Headlamps, Auxiliary	27D 288 304 312 313 314 320 659
463	Headlamps, Auxiliary Right	27D 288 304 312 313 314 320 659
464	Transmission, Smart Shift Control	286 320 343 345 34B 34C 353 355
465	Headlamp, Flashing Control	27D 288 304 312 320 659
467	Engine Coolant Flow Systems	152 286 320 856
469	Level Control, Body/Chassis	288 320 329
470	Datalink Transmit	287 320 786 78A 79H 80D
471	Datalink Receive	287 320 786 78A 79H 80D
472	Engine ECU and Controls	106 128 129 148 152 156 162 164 283 286 320 343 34B 34C 34W 353 856
473	Multifunction Stalk Switch	329 472
474	Smart Switch, Resistance Identified, MUX	329 472
475	Engine Idler Controls	152 156 162 283 286
476	Adjustable Pedal Controls	288 320 486 49A 880
478	E-Stroke Brake Monitoring System	320 486 838 840 877 880 882
479	CB Radio Antenna Coaxial	320 748 751 752
480	Switched Auxiliary Air Pressure	288 320 486 49A 880
481	Chassis Expansion Module	160 283 285 286 320 329 330 343 34B 472 732 736 811 813 814
482	Firetruck Pump Controls	148 283 286 372
483	Engine ECU and Controls	106 148 152 156 160 162 164 283 285 286 320 330 343 34B 372 732 736 811 812 813 814 819
484	Tire Chains	288 320 452 874 878 87A 87B 87F 896 900
485	Public Address System	287 320 746 74D 750 751 753 75B 75C 79F 79G
486	Vehicle Information Center	283 286 288 320 732 74F 756 760 763 811 812 814 819 860 867 877 882
487	Engine Emissions Detection and Monitor	148 150 152 162 164 283 286 320 811 814 860
488	Brake Wear Indicator	320 486 838 840 877 880 882
491	Engine Compartment Lights/Buzzer	287 320 327 329 656 787 811 814 860
492	Engine ECU and Controls	148 150 152 162 164 283 286 320 372

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
493	All Wheel Drive Controls	288 320 452 874 878 87A 87B 87F 896 900
494	Transmission Shift Controls	286 320 343 345 34B 34C 353 355
495	Emergency Medical Service Accessories	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
496	Steering Wheel Controls	329 472
497	Transmission Controls	286 320 343 345 34B 34C 353 355
498	Transmission Controls	286 320 343 345 34B 34C 353 355
499	Engine ECU and Controls	164 283 286
504	Dome/Interior Lamp	287 320 322 324 325 32C
506	Aerial Equipment Systems	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
508	CAN Datalink	287 320 786 78A 79H 80D
509	Firetruck Pump And Hose Controls	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
510	Firetruck Pump And Hose Controls	265 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
512	Emergency Vehicle Auxilixry Switches	—
513	Emergency Vehicle Door Switches	—
514	Emergency Vehicle Lights and Alarm	288 294 320 471 721
515	Emergency Vehicle Tank Level Systems	—
518	Emergency Vehicle Ladder and Rack Systems	—
519	Emergency Vehicle Body Lighting	—
520	Emergency Vehicle Body Lighting	—
521	Emergency Vehicle Body Lighting	—
522	Emergency Vehicle Body Lighting	—
523	Emergency Vehicle Body Lighting	—
524	Emergency Vehicle Power Source	—
525	Emergency Vehicle Warning Lights	—
526	Emergency Vehicle Body Lighting	—
527	Firetruck Pump And Hose Controls	—
528	Emergency Vehicle AC Power System	—
529	Windshield Defroster Grid	287 320 716 718
532	Aftertreatment Systems, Exhaust	160 164 283 285 286 320 330 343 34B 732 736 811 813 814

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
533	Engine ECU and Controls, Alternative Fuel	106 148 152 164 283 286 320 856
1939	J1939 CAN Datalink	160 283 286 320 330 343 725 732 736 811 813 888

Table 2, Circuit Numbers

General Information

Powernet Distribution Box (PNDB)

The powernet distribution box (PNDB) distributes and fuses battery power to many of the vehicle loads. An optional cab load disconnect switch (CLDS) is available to disconnect selected circuits. The CLDS may be located on the chassis near the battery box or mounted so that it is operated from inside the cab. There is an LED in the CLDS that will illuminate when power is on. The LED will flash when certain faults are detected.

Some vehicles have an auxiliary PNDB in addition to the primary PNDB. If the vehicle is equipped with a CLDS, it controls both. An additional LED status indicator is in the CLDS on dual PNDB systems.

The primary PNDB is located on the engine side of the front wall near the steering shaft. See **Fig. 1** for the primary PNDB and other power distribution modules.

NOTE: See **Fig. 2** for the auxiliary PNDB.

Main Power Distribution Module

The main PDM is located on the driver side inner fender in the engine compartment. Power for most cab and many chassis functions are protected by fuses in the main PDM. Most vehicles have spare fuse circuits in the main PDM that can be used for customer installed options. A map of fuses to output connectors for the circuits in the main PDM is shown in **Subject 130**.

Powertrain Power Distribution Module

The vehicle uses a powertrain PDM to protect circuits to the engine, transmission, and exhaust after treatment systems. The powertrain PDM is located inside the engine compartment on a bracket near the main PDM on the drivers side inner fender.

Trailer Power Distribution Module

The trailer PDM fuses and supplies power for trailer lighting. The chassis module controls the inputs to this PDM. The trailer PDM is located inside the cab on the drivers side behind the seat. See **Fig. 2** for a typical in-cab trailer PDM.

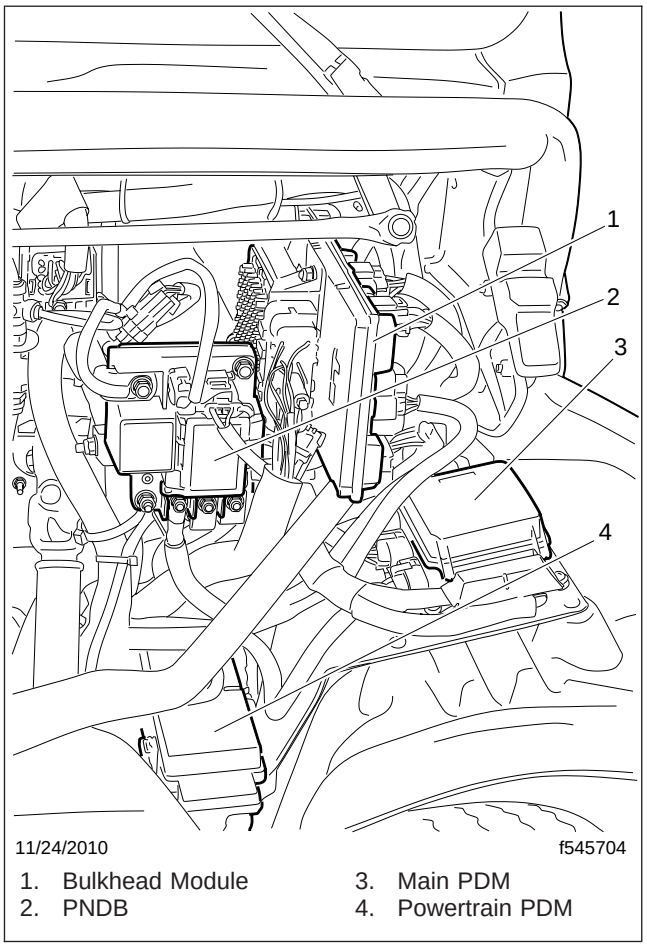
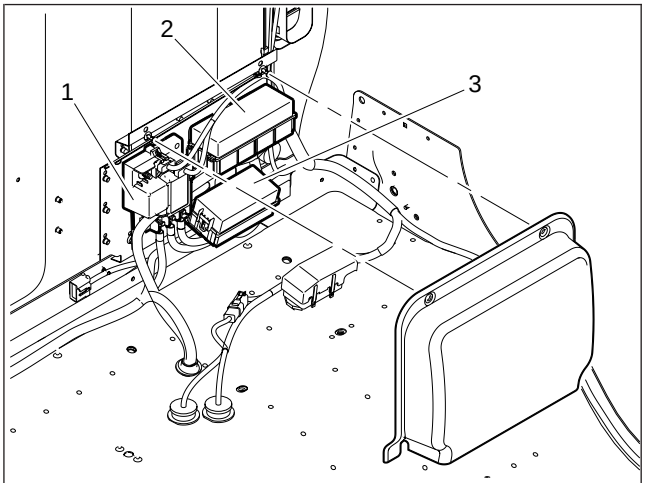


Fig. 1, Power Distribution Modules

Body Lighting Power Distribution Module

The body lighting PDM supplies higher amperage power for exterior lighting in addition to ignition and battery power for options installed by the truck equipment manufacturer. The body lighting PDM is located inside the cab on the drivers side behind the seat on the back wall or the floor. See **Fig. 2** for a typical in-cab body lighting PDM installation.

General Information



1. PNDB
2. Trailer PDM
3. Body Lighting PDM

Fig. 2, In-Cab PDM Installation

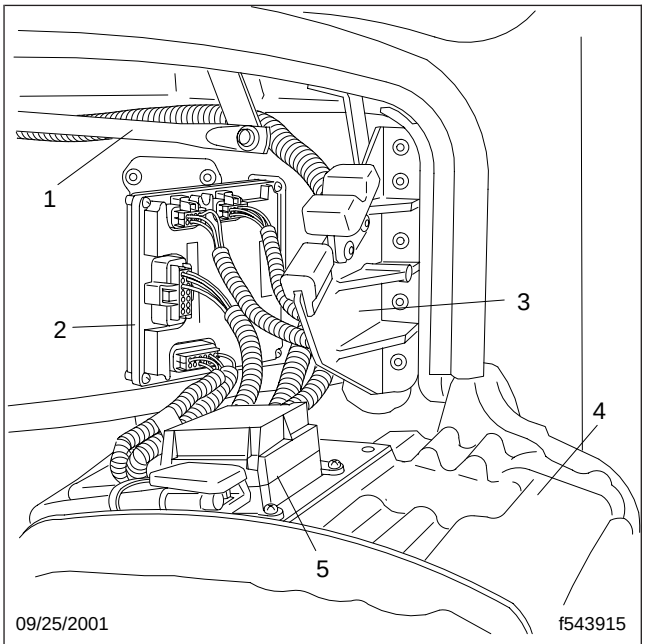
Main Power Distribution Module Removal and Installation

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The main power distribution module (PDM) is mounted in the engine compartment on the left front inner fender. See **Fig. 1**.

2. Remove the nuts and washers that attach the battery power cables to the power studs, then remove the battery power cables from the PDM. See **Fig. 2**.



1. Wiper Linkage
2. Bulkhead Module
3. Hood Support Bracket
4. Quarter Fender
5. Main Power Distribution Module

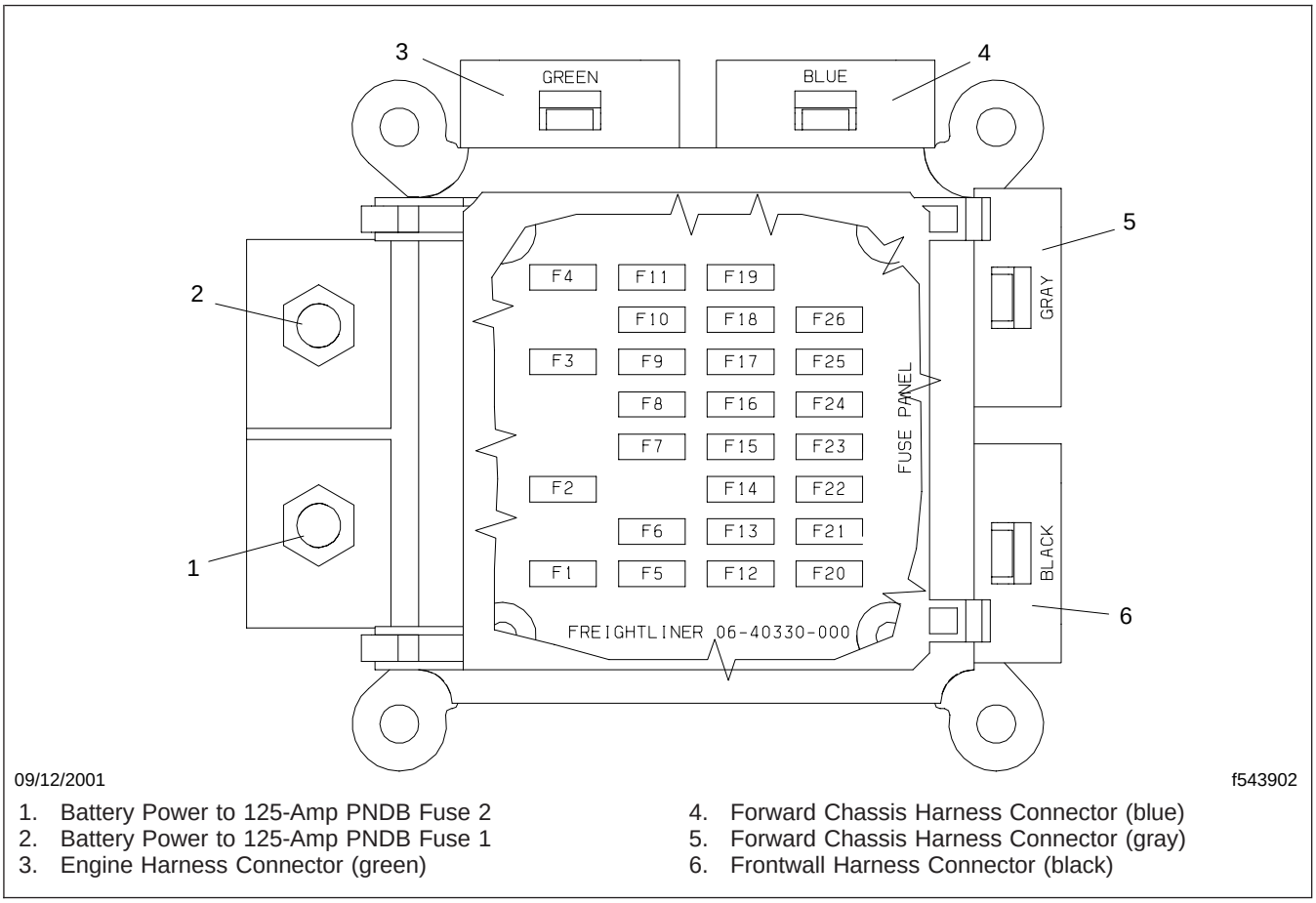
Fig. 1, Main Power Distribution Module Installation

3. Remove the four harness connectors (green, blue, gray, and black) from the PDM.
4. Remove the four Torx® capscrews that attach the PDM to the inner fender, then remove the PDM.

Installation

1. Properly orient the PDM and attach it to the quarter fender using four Torx capscrews.
2. Connect the four harness connectors to the PDM.
3. Using nuts and washers, attach the battery power ring connectors to the power studs. Apply dielectric red enamel to the power connections.
4. Connect the batteries.
5. Verify operation of electrical components.

Main Power Distribution Module Removal and Installation



1. Battery Power to 125-Amp PNDB Fuse 2
2. Battery Power to 125-Amp PNDB Fuse 1
3. Engine Harness Connector (green)
4. Forward Chassis Harness Connector (blue)
5. Forward Chassis Harness Connector (gray)
6. Frontwall Harness Connector (black)

Fig. 2, Main PDM Fuse Panel Layout and Connections

Powertrain Power Distribution Module Removal and Installation

Removal

1. Disconnect the batteries at the negative terminals.
2. Insert a small flat screwdriver into the openings between the mounting bracket and the side of the PDM, then release the tabs. See **Fig. 1**.

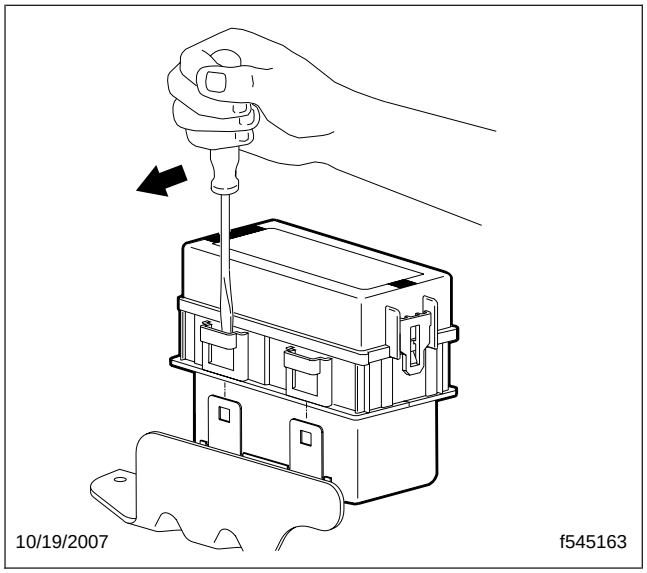


Fig. 1, PDM Removal

3. Open the cover and remove the two retaining clips. See **Fig. 2**.
4. Lift the PDM block assembly out from the housing. The power feed circuits can be disconnected from the bus when the block assembly is about half way out of the housing.
5. Identify the positions and values of the fuses and relays, then remove them.
6. Lift the terminal locks up and out of the PDM.
7. Label all the wires before removing them from the PDM. Remove the wires.
8. Use a Delphi pick tool to release the tab on the terminal then remove it from the bottom side.
9. Remove the PDM from the vehicle.

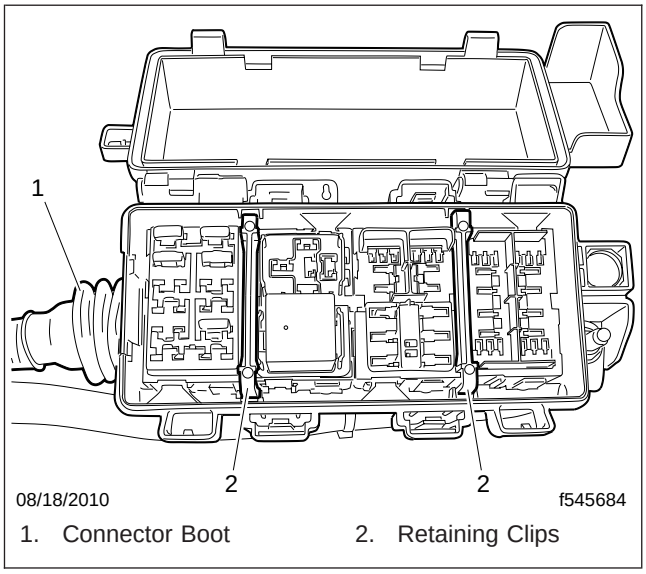


Fig. 2, PDM Retaining Clips

Installation

1. Insert each circuit into the bottom of the PDM block assembly. If the terminal is backward, the lock will not seat into place. See **Fig. 3**.
2. Install the terminal locks and the fuses and relays, as previously noted.

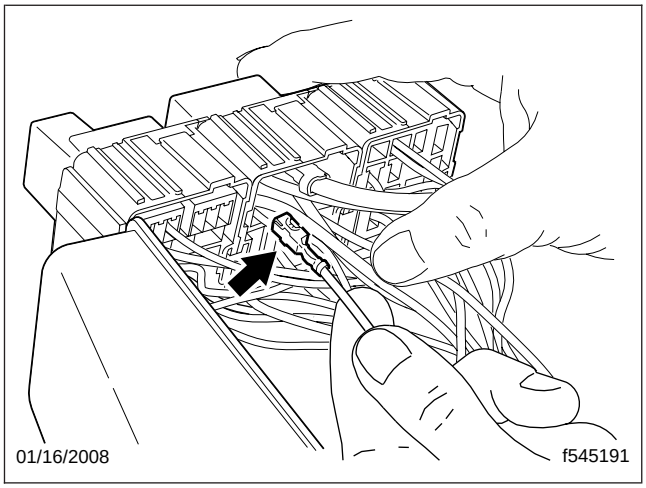
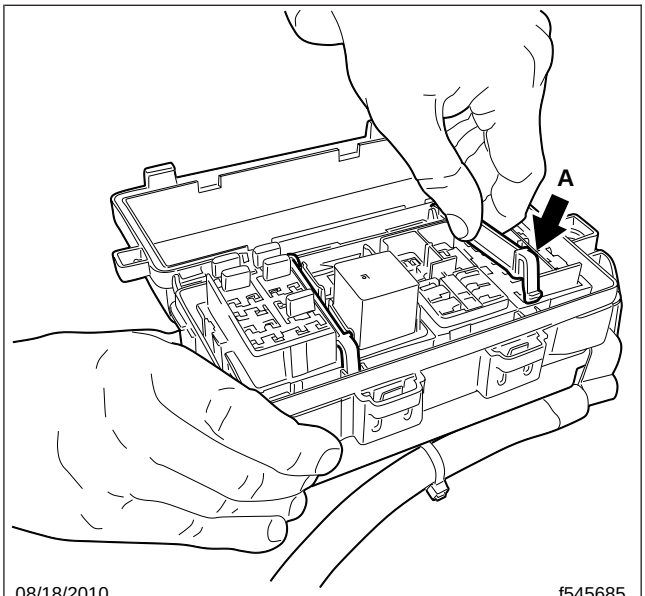


Fig. 3, Inserting Circuits in to the PDM

3. Place the PDM block assembly into the housing, and connect the power feed circuits to the buss bar.

Powertrain Power Distribution Module Removal and Installation

4. Gently squeeze the PDM housing and install the two retaining clips. See **Fig. 4**.
5. Close the PDM cover.



A. Squeeze the housing of the PDM when installing the retaining clips.

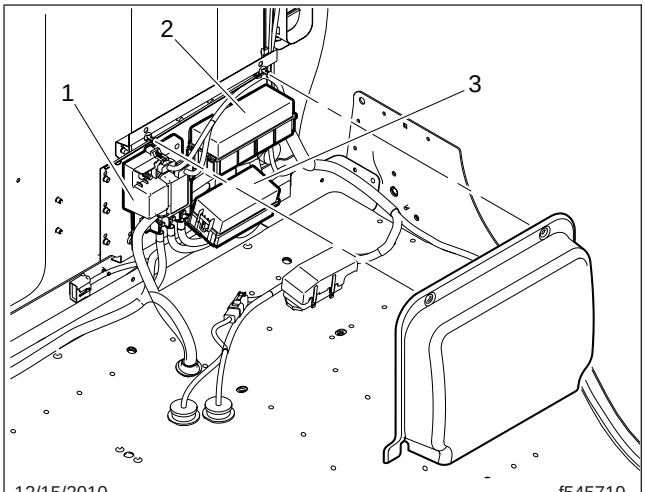
Fig. 4, Installing the Retaining Clips

6. Install the PDM housing onto the bracket, if it was removed.
7. Connect the batteries and close the hood.

Body Lighting PDM Removal and Installation

Removal

1. Disconnect the batteries at the negative terminals.
2. Open the cover and remove the two retaining clips. See **Fig. 1**.



1. Body Builder PNDB
2. Trailer PDM
3. Body Lighting PDM

Fig. 1, Power Distribution Modules

3. Lift the PDM block assembly out from the housing. The power feed circuits can be disconnected from the bus when the block assembly is about half way out of the housing.
4. Identify the positions and values of the fuses and relays, then remove them.
5. Lift the terminal locks up and out of the PDM.
6. Label all the wires before removing them from the PDM. Remove the wires.
7. Remove the PDM from the vehicle.

Installation

1. Insert each circuit into the bottom of the PDM block assembly. If the terminal is backward, the lock will not seat into place.
2. Install the terminal locks and the fuses and relays, as previously noted.
3. Place the PDM block assembly into the housing, and connect the power feed circuits to the buss bar.
4. Gently squeeze the PDM housing and install the two retaining clips.
5. Close the PDM cover.
6. Install the PDM housing onto the bracket, if it was removed.
7. Connect the batteries and close the hood.

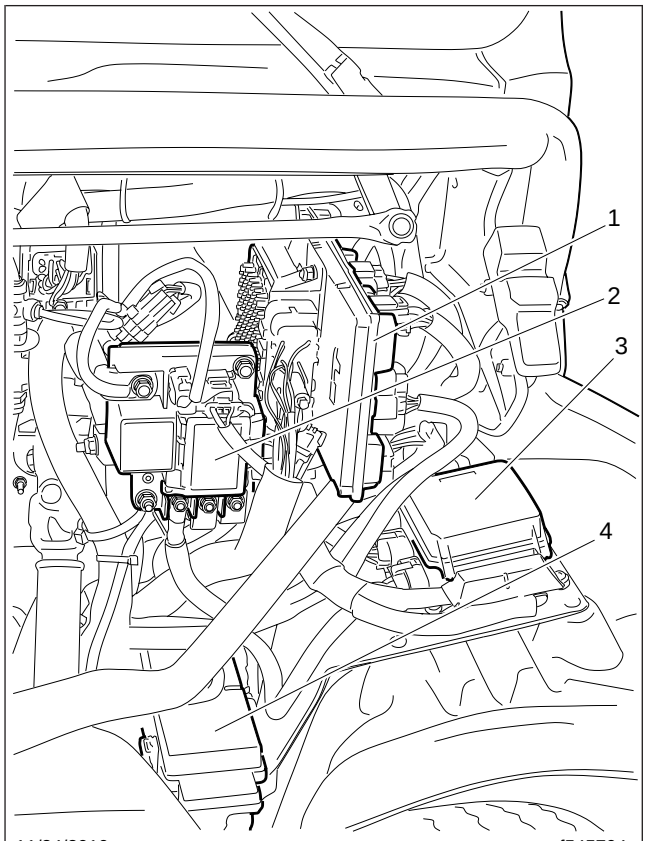
Removal

1. Disconnect the batteries.
2. Open the hood.

NOTE: The powernet distribution box (PNDB) is located on the cab frontwall, next to the bulkhead module. See **Fig. 1**.

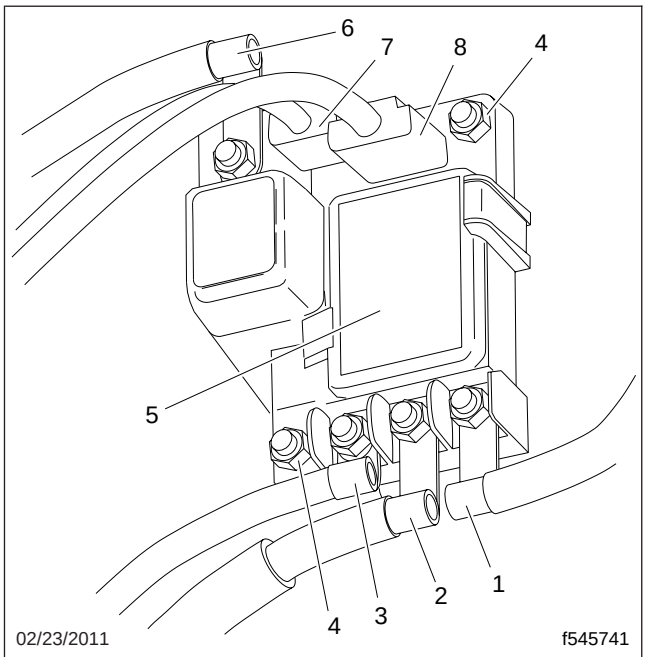
3. Disconnect the battery and power cables from the PNDB. See **Fig. 2**.
4. Disconnect the cab load disconnect switch (CLDS) connecter, if equipped.
5. Disconnect the keep-alive circuit connector from the PNDB.

   5.1 Using a flat-head screwdriver, push the red locking tab up.



1. Bulkhead Module
2. PNDB
3. Main PDM
4. Powertrain PDM

Fig. 1, Power Distribution Modules (EPA10 shown)



1. Main PDM Power (circuit 1)
2. Main PDM Power (circuit 2)
3. Powertrain PDM Power
4. Mounting Nut
5. Fuse Cover
6. Power (B+)
7. Disconnect Switch (CLDS) Connector
8. Keep-Alive Circuit Connector

Fig. 2, Powernet Distribution Box

   5.2 Press and release the tab, then remove the connector.

6. Remove the two mounting nuts.
7. Remove the PNDB from the vehicle.

Installation

1. Position the PNDB on the frontwall, and attach the two mounting nuts.
2. Connect the battery and power cables.
3. Attach the keep-alive circuit connector and the CLDS connector.
4. Connect the keep-alive circuit.
5. Connect the batteries.
6. Close the hood.

Troubleshooting

MEGA Fuses

MEGA fuses must be measured using a voltmeter when in the circuit or with an ohm meter when out of the circuit to determine if they are open. There is no visual method of determining continuity.

Powernet Distribution Box (PNDB)

Each powernet distribution box (PNDB) on the vehicle provides up to 4 low amperage circuits (30 amp and less), and up to three high amperage circuits through midi fuses. The fuses are located behind a cover on the face of the PNDB. On vehicles equipped with a cab load disconnect switch (CLDS), the high amperage circuits are switched on and off with the CLDS. The low amperage circuits are always live. Vehicles may have one or two PNDBs and both are connected to the same CLDS.

When the CLDS is in the on position, an LED on the switch, and another on the PNDB, will be illuminated. When there is an error condition with the PNDB system, the LED on the PNDB and CLDS may flash. A flashing LED indicates an error as well as an LED that remains on when the switch is off or no LED when the switch is on.

To test for open fuses, use conventional troubleshooting methods. The LED's in the PNDB and switch are not affected by open fuses or the circuits they connect.

NOTE: See **Table 1** to troubleshoot a switched PNDB system.

PNDB and CLDS Troubleshooting

Step	Test Procedure	Test Result	Action
1	Check the power cables on the PNDB for proper torque. Open the cover and inspect the MIDI fuse fastener torque and for discoloration caused by excessive heat.	Loose fasteners or heat discoloration	Determine if the fasteners can be properly torqued or if the PNDB needs replacement. Repair or replace as required.
		All OK	Go to step 2.
2	Does the LED on the PNDB flash in a constant pattern when the CLDS is switched to the OFF or ON position or does the LED on the PNDB just randomly flicker?	Constant Repeating Flashing Pattern	Troubleshoot and repair any wiring faults on circuits 425D, 425F, or circuit 425G between the CLDS and the PNDB. If there is no wiring fault, replace the CLDS.
		Random flickering	Replace the PNDB.
		No	Go to step 3.

Troubleshooting

PNDB and CLDS Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
3	Measure for ground on PNDB connector 1, pins 1 and 6. If either of these pins are not populated with a wire disregard measuring the unpopulated pin. Is ground present in the wiring harness supplying these pins?	Yes	Measure the voltage on PNDB connector X1, pin 4. If pin 4 is at about 11 volts then troubleshoot and repair for a wiring fault in circuits 425D, 425F, 425G between the CLDS and the PNDB and for a open or short circuit in the CLDS. If there is no wiring or switch fault, replace the PNDB.
		No	Repair an open ground circuit to the PNDB.

Table 1, PNDB and CLDS Troubleshooting

See **Fig. 1**, **Fig. 2**, **Fig. 3**, and **Fig. 4** for illustrations of the connectors with pin identification.

NOTE: PNDB connector X2 is not part of the switching and control system. See **Table 3** for information on the function of PNDB connector X2.

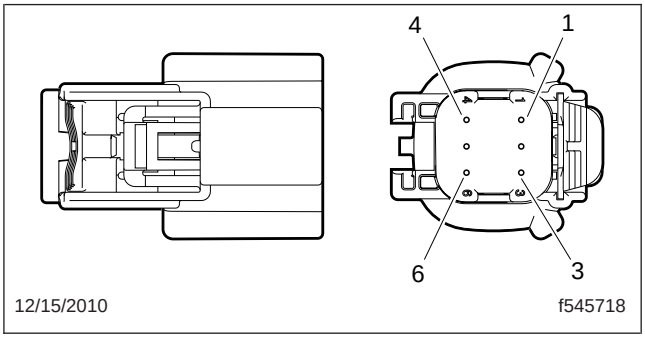


Fig. 1, Wire Insertion View of PNDB Connector X1

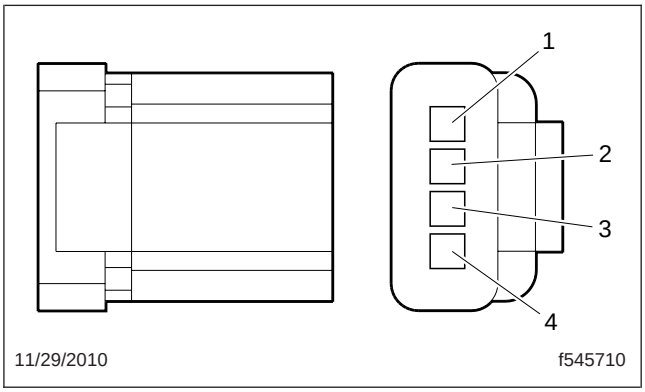


Fig. 2, Wire Insertion View of PNDB Connector X2

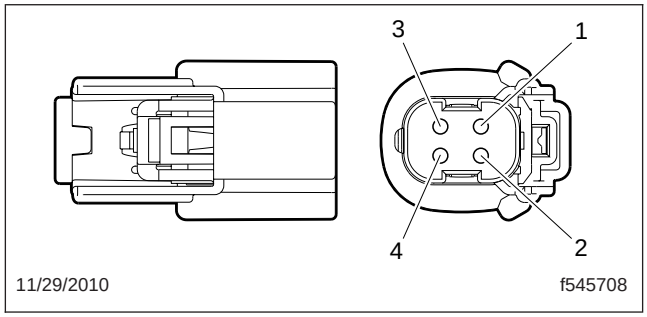


Fig. 3, Wire Insertion View of CLDS Connector X1

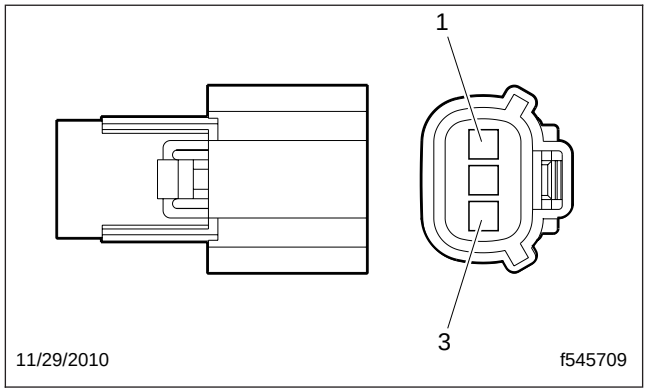


Fig. 4, Wire Insertion View of CLDS Connector X2

Primary PNDB and CLDS Connector and Pin Functions			
Device	**Connector, Pin**	**Voltage**	**Function**
Primary PNDB	X1, 1	0	Ground
	X1, 2	0	Off Signal – Always at ground.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
	X1, 4	11	On Signal – Approximately 11 volts.
	X1, 5	11 – ON 0 – OFF	Control Signal – Approximately 11 volts when CLDS is on. At ground when off.
	X1, 6	0	Not used or ground circuit connecting to aux PNDB.
CLDS	X1, 1	11	On Signal – Always at battery voltage.
	X1, 2	11 – ON 0 – OFF	Control Signal – Approximately 11 volts. when CLDS is on. At ground when off.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when switch is on.
	X1, 4	0	Off Signal – Always at ground.
	X2, 1	11 – ON 0 – OFF	Control Signal - Approximately 11 volts when CLDS is on. At ground when off.
	X2, 2	0	Off Signal – Always at ground.
	X2, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
Auxiliary PNDB	X1, 1	0	Ground
	X1, 2	0	Off Signal – Always at ground.
	X1, 3	0 – ON	LED Indicator – PNDB drives this low when the switch is on.
	X1, 4	X	Not used.
	X1, 5	11 – ON 0 – OFF	Control Signal – At approximately 11 volts when CLDS is on. At ground when off.
	X1, 6	0	Not used, or ground.

Table 2, PNDB and CLDS Connector and Pin Functions

See **Fig. 5** for a schematic of the dual PNDB system with the cab load disconnect switch option.

Troubleshooting

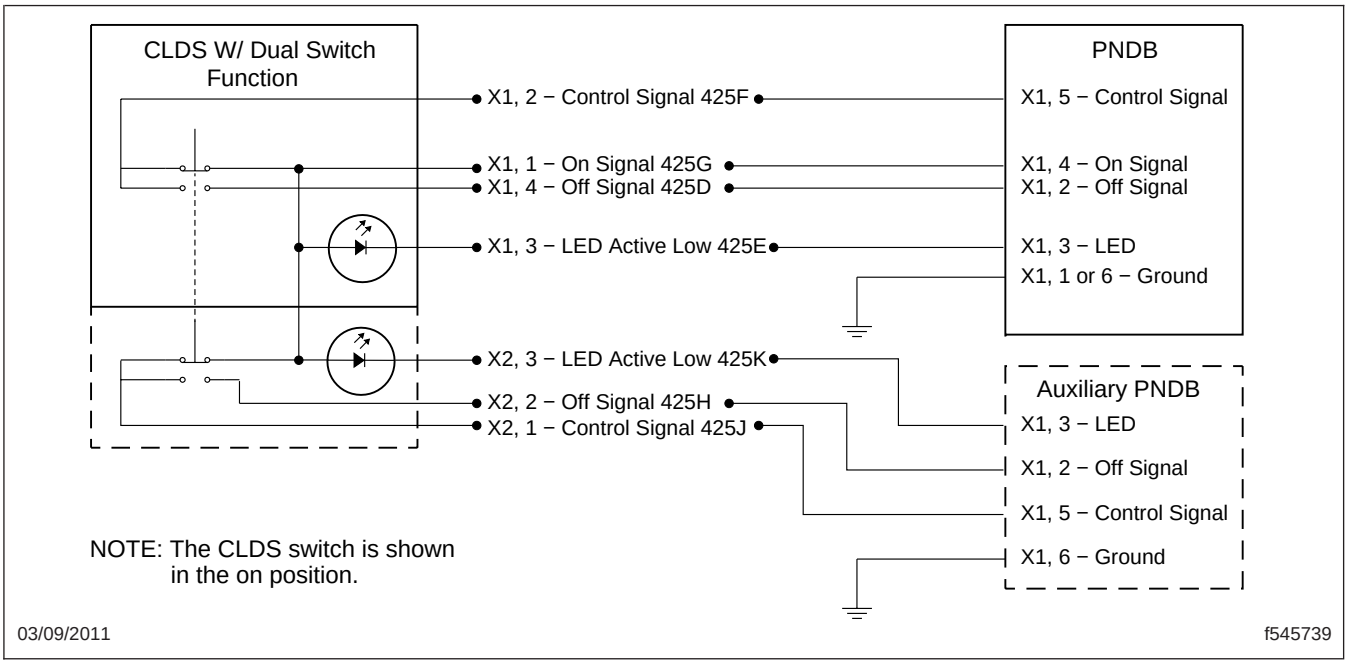


Fig. 5, Primary and Auxiliary PNDB with CLDS Option

Primary PNDB Fuses and Functions					
Fuse	**Amperage**	**Function**	**Circuit**	**Connector/Pin**	**Module**
ATC – A	30	ACM (After Treatment Module)	439	X2/1	28F
ATC – B	—	—	—	X2/2	—
ATC – C	5	Radio and Clock	295B	X2/3	74D
ATC – D	5	Alternator Remote Sense	125E	X2/4	12C
MIDI – 1	175	Powertrain PDM	439	1	283
MIDI – 2	125	Main PDM 1	14E	2	285
MIDI – 3	125	Main PDM 2	14E	3	285

Table 3, Primary PNDB Fuses and Functions

Main PDM

Main PDM Circuit Mapping		
Fuse	**Connector, Pin**	**Power Source**
F1	Green, A	1
F2	Green, B	1
F3	Green, H	2
F4	Green, G	2
F5	Black, D	1

Main PDM Circuit Mapping		
Fuse	**Connector, Pin**	**Power Source**
F6	Black, C	1
F7	Gray, F	1
F8	Green, C	2
F9	Green, D	2
F10	Blue, G Green, F	2
F11	Blue, H	2
F12	Black, H	1
F13	Gray, E	1
F14	Black, B	1
F15	Black, A	2
F16	Blue, A	2
F17	Blue, C	2
F18	Blue, B	2
F19	Gray, G	2
F20	Black, E	1
F21	Black, F	1
F22	Black, G	1
F23	Gray, H Blue, E	1
F24	Gray, D	1
F25	Gray, C	2
F26	Gray, A Gray, B Blue, D	2

Table 4, Main PDM Circuit Mapping

Powertrain PDM

Engine, transmission, and exhaust after treatment systems are powered through the powertrain PDM.

The circuits that populate this PDM will vary depending on vehicle option content.

Powertrain PDM			
Position	**Rating**	**Description**	**Module**
F1	30A	ECM/MCM, BAT	283
F2	10A	CPC, BAT	283
F3	10A or 30A	TCU, BAT	34B

Troubleshooting

Powertrain PDM			
Position	**Rating**	**Description**	**Module**
F4	25A	COOLANT PUMP BAT	34B
F5	30A	BATTERY FAN, BAT	34B
F6	20A	DEF LINE HEATERS, BAT	28F
F7	10A	TCU/IGN or COOLANT PUMP, IGN	34B
F8	—	SPARE	—
F9	20A	ENG/SCR NOX SENSOR, IGN	28F
F10	5A or 15A	ECM, CPC, MCM, ACM – IGN	283
F11	10A	ELECTRIC FAN, IGN	276
F12	5A	DCU, IGN	28F
F13	50A	ECA/BAT	34B
F14	30A	HCM, BAT	34B
F15	25A	HEAT EXCHANGER FAN,BAT	34B
R1	MINI	PTO #2 or BATTERY FAN	885/34B
R2	75A	IGN	283
R3	MICRO	AUTO NEUTRAL or COOLANT PUMP	877/34B
R4	MICRO	DEF LINE HEAT	28328F
R5	MICRO	PTO/MEIIR OR 12V CRANK	885/34B
R6	MICRO	ELECTRIC FAN	276
R7	MICRO	NEUTRAL INTERLOCK	87K
R8	MICRO	START ENABLE (TRANS)	34B

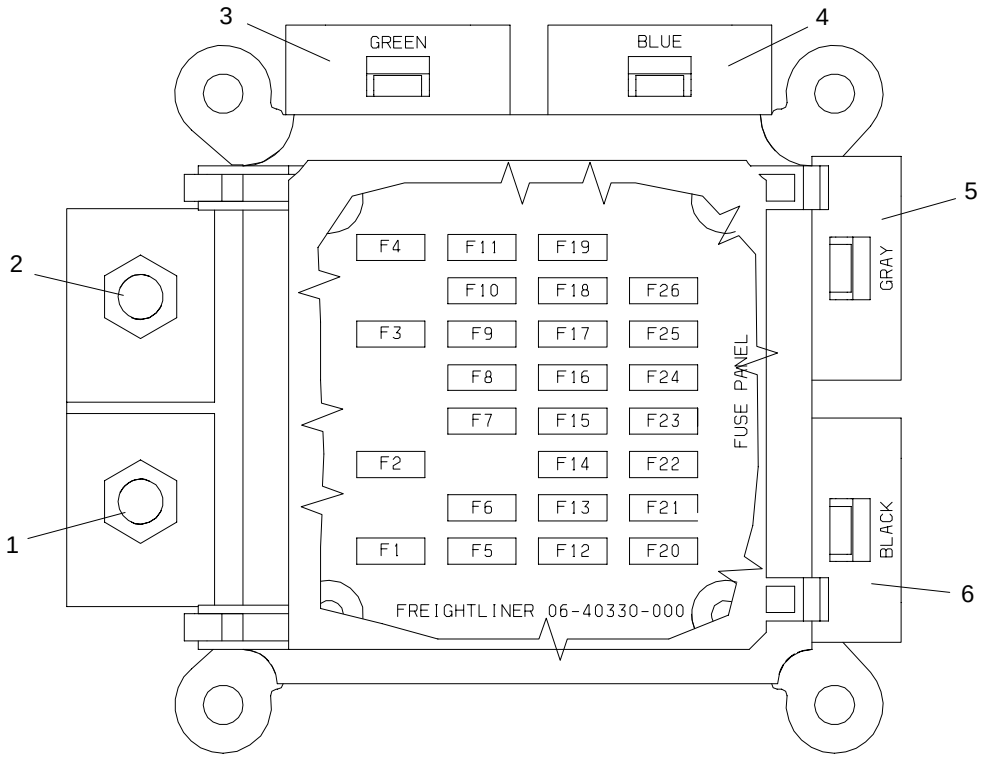
Table 5, Powertrain PDM

Main PDM Specifications

See **Fig. 1** for an illustration of the main PDM fuse panel layout and connections.

See **Table 1** for PNDB fuses and the PDM fuses it protects.

See **Table 2** for PDM fuses and the corresponding PDM output pins.



1. Battery Power to 125-Amp PNDB Fuse 2
2. Battery Power to 125-Amp PNDB Fuse 1
3. Engine Harness Connector (green)
4. Forward Chassis Harness Connector (blue)
5. Forward Chassis Harness Connector (gray)
6. Frontwall Harness Connector (black)

Fig. 1, Main PDM Fuse Panel Layout and Connections

Specifications

PNDB Fuse and the Corresponding PDM Fuses It Protects	
PNDB Fuse	**PDM Fuse**
1	F1
	F2
	F5
	F6
	F7
	F12
	F13
	F14
	F20
	F21
	F22
	F23
	F24
2	F3
	F4
	F8
	F9
	F10
	F11
	F15
	F16
	F17
	F18
	F19
	F25
	F26

Table 1, PNDB Fuse and the Corresponding PDM Fuses It Protects

PDM Fuses and the Corresponding PDM Output Pins	
PDM Fuse	**Output Connector and Terminal**
F1	Green A
F2	Green B
F3	Green H
F4	Green G
F5	Black D
F6	Black C
F7	Gray F
F8	Green C
F9	Green D
F10	Blue G
	Green F
F11	Blue H
F12	Black H
F13	Gray E
F14	Black B
F15	Black A
F16	Blue A
F17	Blue C
F18	Blue B
F19	Gray G
F20	Gray E
F21	Black F
F22	Black G
F23	Gray H
	Blue E
F24	Gray D
F25	Gray C
F26	Gray A
	Gray B
	Blue D

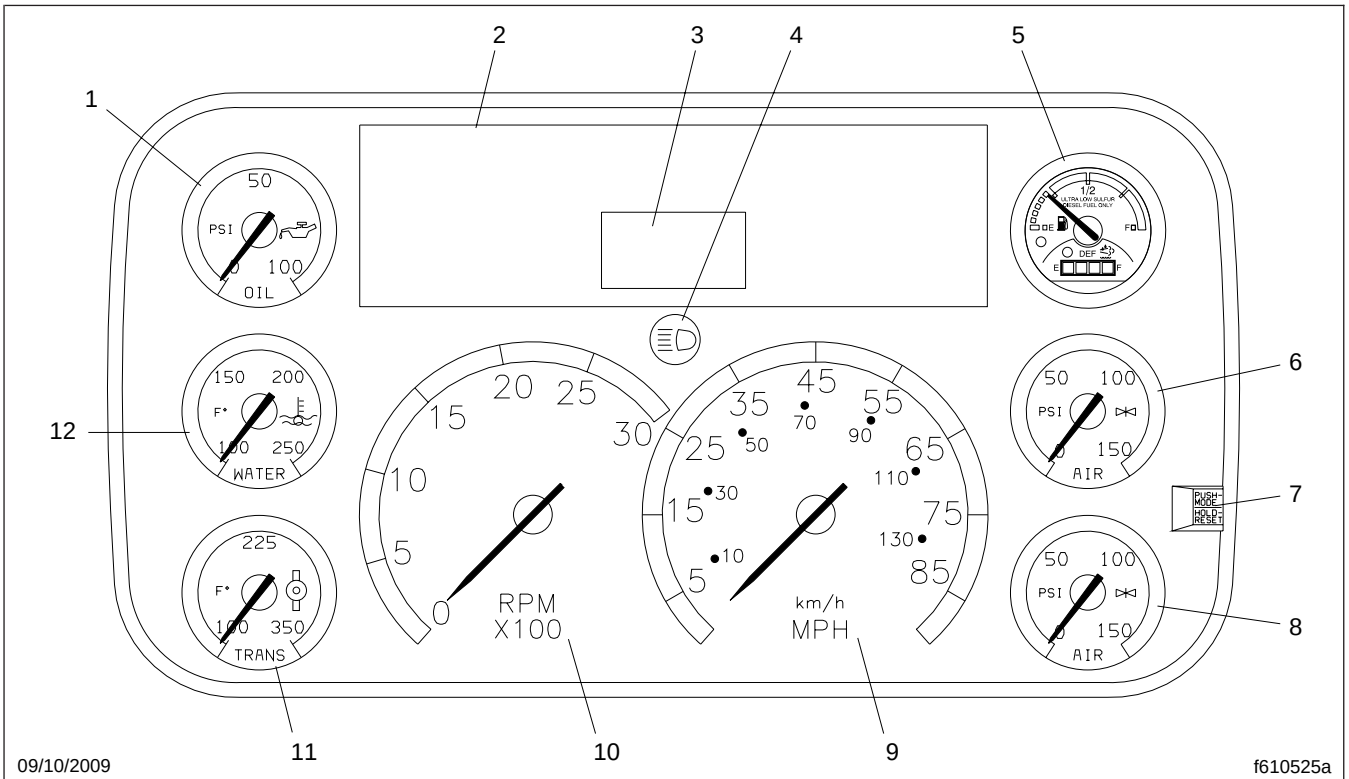
Table 2, PDM Fuses and the Corresponding PDM Output Pins

ICU3

The ICU3 instrument cluster is comprised of gauges, warning lights, indicator lights, a buzzer, and a driver display screen built into a single unit to provide the driver with engine and vehicle information. The ICU3 receives data through datalink messages, hard wire inputs, and air pressure inputs. The ICU3 contains up to 8 individual gauges, and up to 6 additional satellite gauges. See **Fig. 1**. The ICU3 contains a message center with a liquid crystal display (LCD), driver display, and up to 28 warning and indicator lamps. The ICU3 has no field changeable parameters, with the exception of those functions that can be set using the Mode/Reset button, and the display menus such as service intervals and odometer units.

Main ICU Gauges

The speedometer, fuel level, engine coolant temperature, tachometer, primary and secondary air pressure, and engine oil pressure gauges are standard on all ICU3 configurations. Vehicles may have additional optional gauges depending on the configuration. The ICU3 receives data to drive most of the gauges. Data is received from the engine controller or transmission controller, or from sensors wired directly to the ICU3. Air pressure gauges are connected directly to the air system they monitor. They are not controlled by the ICU directly, except for backlighting. The ICU3 gauges sweep 270 degrees, except for the tachometer, which sweeps 180 degrees. ICU3 gauge pointers and backlighting are lit



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1. Engine Oil Pressure Gauge
2. Dash Message Center
3. Dash Driver Display Screen
4. Headlight High-Beam Indicator
5. Fuel Level Gauge
6. Primary Air Pressure Gauge
7. Mode/Reset Button
8. Secondary Air Pressure Gauge (optional)
9. Speedometer (U.S. version)
10. Tachometer
11. Transmission Fluid Temperature Gauge
12. Coolant Temperature Gauge

Fig. 1, ICU3 Gauge Layout (typical U.S.)

by light emitting diodes (LEDs). The only serviceable parts on the ICU3 are the air pressure gauge module, the nine top center indicator lamps and lenses, and the Mode/Reset button.

Remote-Mounted (Satellite) Gauges

The ICU3 can drive external satellite gauges connected to the proprietary datalink between the ICU3 and the satellite gauges. Four pins are used for this function: gauge power, gauge ground, data, and backlighting. Optional satellite gauges include engine oil temperature, turbo boost, pyrometer, forward-rear axle temperature, rear-rear axle temperature, application air, axle lift, and suspension air pressure.

Awake State and Sleep State

The Bulkhead Module (BHM), Chassis Module (CHM), and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awakened, the remaining components wake up if they are not already awake. When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door
- turning on the hazard switch
- turning the ignition switch to any position other than off
- turning on the headlight/parking light switch
- depressing the service brake

The BHM, CHM, and ICU will enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs and all other power down requirements are met.

To check whether or not the electrical system is going into a sleep state:

1. Enter the vehicle.
2. Shut the doors.
3. Remove your foot from the service brake.
4. Make sure the ignition switch and hazard switch are in the off position.

NOTE: One minute after these conditions are met, and provided that one of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Dash Message Center

The dash message center has two parts; an array of standard and optional warning and indicator lights, and a driver display screen. The driver display screen is a one-line by seven-character liquid crystal display (LCD) that normally shows odometer readings. Below that is a one-line by three-character LCD that shows voltmeter readings along with several other messages coded into the display that are activated by the CPU.

Information provided by the dash driver display screen includes:

- odometer readings (in miles or kilometers)
- trip and total engine distance
- trip and total engine hours
- service screens
- fault code display

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 1, Parameters

Mode/Reset Button

Functions

The Mode/Reset button, located on the right side of the instrument cluster, is used to scroll through the displays on the dash driver display screen, to reset the trip distance and trip hours values to zero, and to read fault codes.

When the odometer reading is displayed and the parking brake is not applied:

- Press the Mode/Reset button once to display trip distance.
- Press the Mode/Reset button a second time to display trip hours (engine hours).
- Press the Mode/Reset button again to display outside temperature.
- Press the Mode/Reset button a fourth time to return to the odometer reading.

When the parking brake is applied, pressing the Mode/Reset button will scroll through the following screens:

A. Trip distance

B. Trip hours

C. Temperature

D. Select screen

E. Temp alert screen

F. Diagnostic screen

G. Clear screen (with less than 254 miles)

H. Engine miles

I. Engine hours

J. Set Up

K. Back to odometer

Trip Miles

To reset trip miles and/or trip hours to zero, press the Mode/Reset button for 1 second or longer.

Miles or Kilometers

To toggle between MI (miles) or KM (kilometers), press the Mode/Reset button while in the SELECT screen.

Fault Codes

When a fault code exists and the parking brake is applied, the display shows the source address (SA), of the ECU (electronic control unit) with the fault. If more than one ECU is reporting an active fault, the display cycles through the SAs for each ECU.

Use the following instructions to display the active fault codes.

1. Press the mode/reset button until **dIAG n** displays. The letter "n" represents the number of active faults.
2. Press and hold the mode/reset button once to display the SA of the fault.
3. Press the mode/reset button again to display the SPN (suspect parameter number) of the fault.
4. Press the mode/reset button again to display the failure mode indicator (FMI) of the fault.
5. Press the mode/reset button again to return to the first fault display.
6. If more than one fault code is active, press and hold the mode/reset button to proceed to the next fault, then follow the previous four steps to display the additional faults.

Warning and Indicator Lights

The ICU3 has spaces for 28 warning and indicator lights. See **Fig. 2**

There are four rows of warning and indicator lights. The lights, or telltales, in the top row are optional. The light in position 8 (counting left to right across the top row) is a permanently mounted amber LED. The remaining top row indicators use replaceable incandescent lamps.

NOTE: Positions 1 through 8 are ground and databus-activated circuits. Position 9 is power activated and databus activated.

The lights on the other three rows are installed at fixed positions that do not vary. Some lights are optional. If an optional light is not requested, the position is blank (does not light up).

The following fixed-position lights are standard:

- cruise indicator (green)
- malfunction indicator lamp (amber)
- high exhaust temperature indicator (amber)

General Information

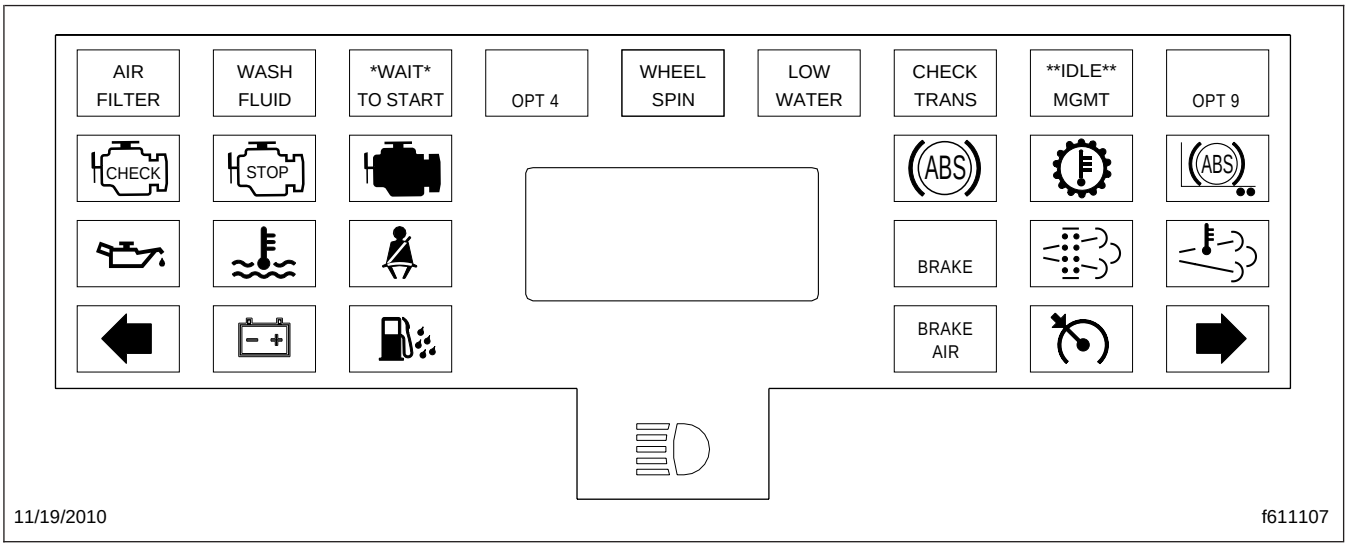


Fig. 2, Dash Message Center, ICU3

- diesel particulate filter status indicator (amber)
- stop engine warning (red)
- check engine indicator (amber)
- low air pressure warning (red)
- low engine oil pressure warning (red)
- high coolant temperature warning (red)
- fasten seat belt warning (red)
- low battery voltage warning (red)
- parking brake on warning (red)
- tractor ABS indicator (amber)
- left-turn signal (green)
- right-turn signal (green)
- high beams on indicator (blue)
- water in fuel indicator (amber)

The following fixed-position lights are optional:

- high transmission temperature warning (amber)–installed on vehicles with automatic transmissions
- trailer ABS indicator (amber)–installed on vehicles designed to be used with a trailer

The following lights are optional:

- low coolant level warning (red)
- air filter restriction indicator (amber)
- EBS (electronic braking system) warning (red)
- check transmission indicator (amber)
- intake heater indicator (amber)
- low washer fluid indicator (amber)
- alternator no charge indicator (amber)
- optimized idle indicator (amber)
- wait to start indicator (amber)
- wheel spin indicator (amber)

Other optional lights may be specified.

Principles of Operation

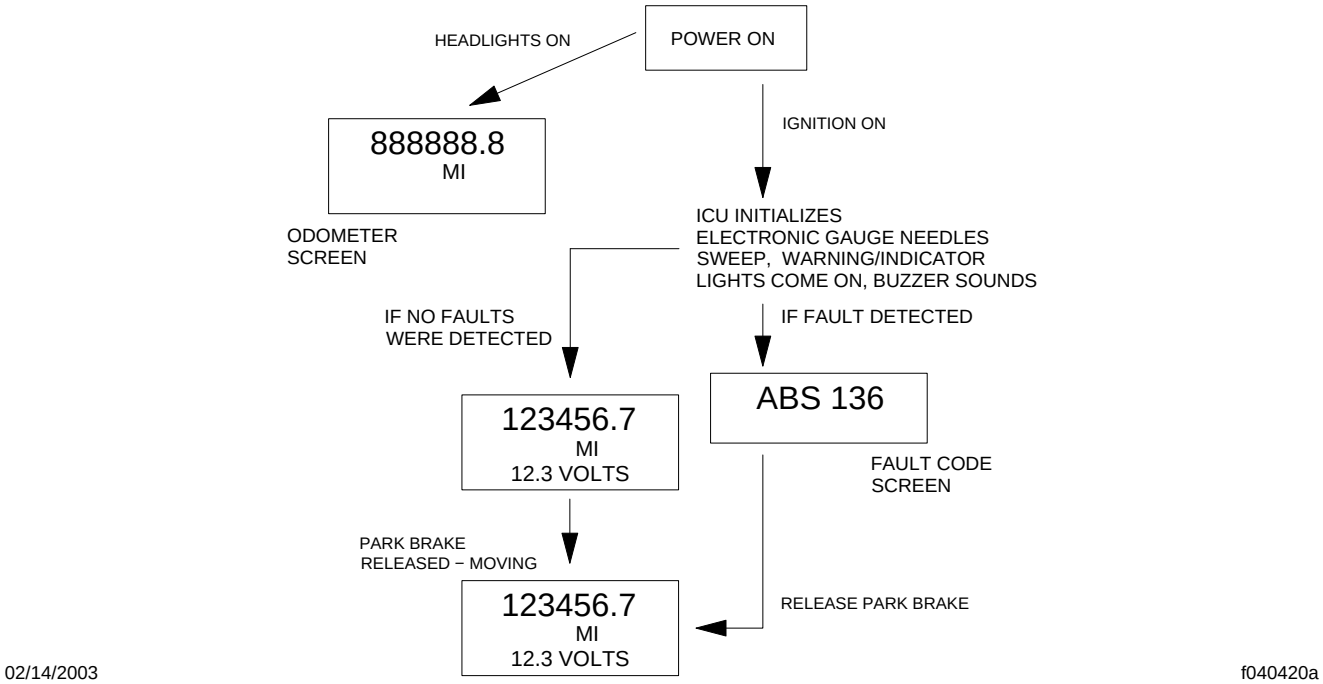
Ignition Sequence

When the ignition is turned on, the ICU3 runs through the ignition sequence. See **Fig. 3**.

If only the headlights are turned on, the dash driver display screen displays the odometer.

IMPORTANT: When the ignition is first turned on, all the electronic gauges complete a full sweep of their dials, the warning and indicator lights light up, and the buzzer sounds for 3 seconds.

The following warning and indicator lights go on during the ignition sequence:



NOTES:

- During the first half of the self-test, all segments of the display illuminate. During the second half of the self-test, the software revision level is displayed.
- If there is more than one fault, the ICU3 displays them, one after another, changing every 3 seconds, until the park brake is released.

Fig. 3, ICU3 Ignition Sequence

- low engine oil pressure warning
- high coolant temperature warning
- low air pressure warning
- parking brake on warning
- low battery voltage indicator
- fasten seat belt warning illuminates for 15 seconds unless pin D10 is hardwired. If pin D10 is hardwired, the light will remain on for only 3 seconds.
- all engine warning lights, including, check engine, and stop engine
- high exhaust temperature and diesel particulate filter status
- cruise indicator
- check transmission and high transmission temperature (learned feature)
- all ABS warning lights, including wheel spin, tractor ABS, and trailer ABS (if installed)
- the DEF level indicator illuminates all segments green, then turn them off one at a time before turning the left most segment amber then red.

NOTE: While the engine and ABS warning lights go on during the ignition sequence, they are not controlled by the ICU3, but by their own system ECU.

Once the ignition has been turned on, the ICU performs a self-test, and polls the databus for faults. During the first half of the self-test, all segments of the dash driver display screen illuminate as follows: "888888.8." During the second half of the self-test, the software revision level is displayed.

If there are no active faults, the screen displays the odometer.

If, however, the ICU3 has received active fault codes from other devices, it displays the three-letter acro-

nym for the device broadcasting the fault. It also displays the SA number for each for 3 seconds, one after the other, until the parking brake is released or the ignition is turned off.

The screen displays a code, called the source address (SA). These identify the ECU or system that is broadcasting the fault code.

NOTE: If the ICU3 receives a message from an ECU that has not been preprogrammed into the memory of the ICU, it displays "SYS ###" instead, where ### is replaced by the SA of the broadcasting device.

Once the parking brake is released, the ICU3 displays the odometer again.

Odometer

The odometer is set to display in either miles or kilometers, depending on the primary scale of the speedometer. The legend, either **MI** or **KM**, illuminates between the odometer and the volts display when the engine is running or the headlights are turned on.

To toggle between MI (miles) or KM (kilometers), press the Mode/Reset button while in the SELECT screen.

The odometer is a seven-digit display with a decimal point until the vehicle has traveled 999,999.9 miles or kilometers (km). At one million miles (km), the odometer rolls over to "1000000" without the decimal point, and can continue up to 9,999,999. The odometer only displays significant figures (no leading zeros).

The ICU compares odometer data received from the engine controller to its own stored value. It will only alter its stored value if the difference is less than 2 miles. When the ICU is replaced, the odometer display will start from zero even though the engine controller odometer may be a much larger value.

IMPORTANT: Although the odometer uses data supplied by the engine control module (ECM) to update its count, it keeps its own mileage starting from zero, when it was first installed. The ICU odometer may not match the engine ECU odometer. This may occur if the engine has been operated with the ICU disconnected, as may occur during factory break-in or engine service, or if the ICU has been replaced.

Buzzer/Chime

The buzzer sounds during the ignition sequence and whenever one of the following conditions exist:

- The engine oil pressure falls below the preset level, which is 5 to 9 psi (35 to 60 kPa) on most engines.
- The coolant temperature rises above the preset level, which is 215°F (101°C) on Detroit Diesel engines and 225 to 230°F (107 to 110°C) on Cummins engines.
- The air pressure falls below the preset level of approximately 70 psi (483 kPa).
- The parking brake is set with the vehicle moving at a speed greater than 2 miles per hour.
- The J1939 brake failure message is received from the ABS.
- The system voltage falls below 12 volts.
- An optional circuit connected to pin B12 will activate the buzzer when it is connected to ground.
- The door is open and the parking brake is not set.

Removal

The instrumentation control unit, ICU3, is a one-piece unit, including housing, fixed gauges, a removable air gauge module, and the dash message center. See **Fig. 1**.

1. Disconnect all negative leads from the batteries.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

2. Discharge the air pressure from the primary and secondary air tanks.
3. Remove the dash trim piece by removing the 11 screws that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.

NOTICE

Do not forcibly pull the ICU3 from the dash. This may dislodge electrical connections or air lines from the back of the ICU3, causing damage to connections, lines, or the dash.

4. Remove the four screws that secure the ICU. See **Fig. 3**.
5. Disconnect the two electrical connectors from the back of the ICU. See **Fig. 4**.
6. Remove the air lines by pressing the push-lock connectors, then pulling the air lines away from the gauges. The lines are color-coded for ease of installation. The primary air line is green and is connected to the upper gauge. The secondary air line is red and is connected to the lower gauge.
7. Remove the ICU from the dash.

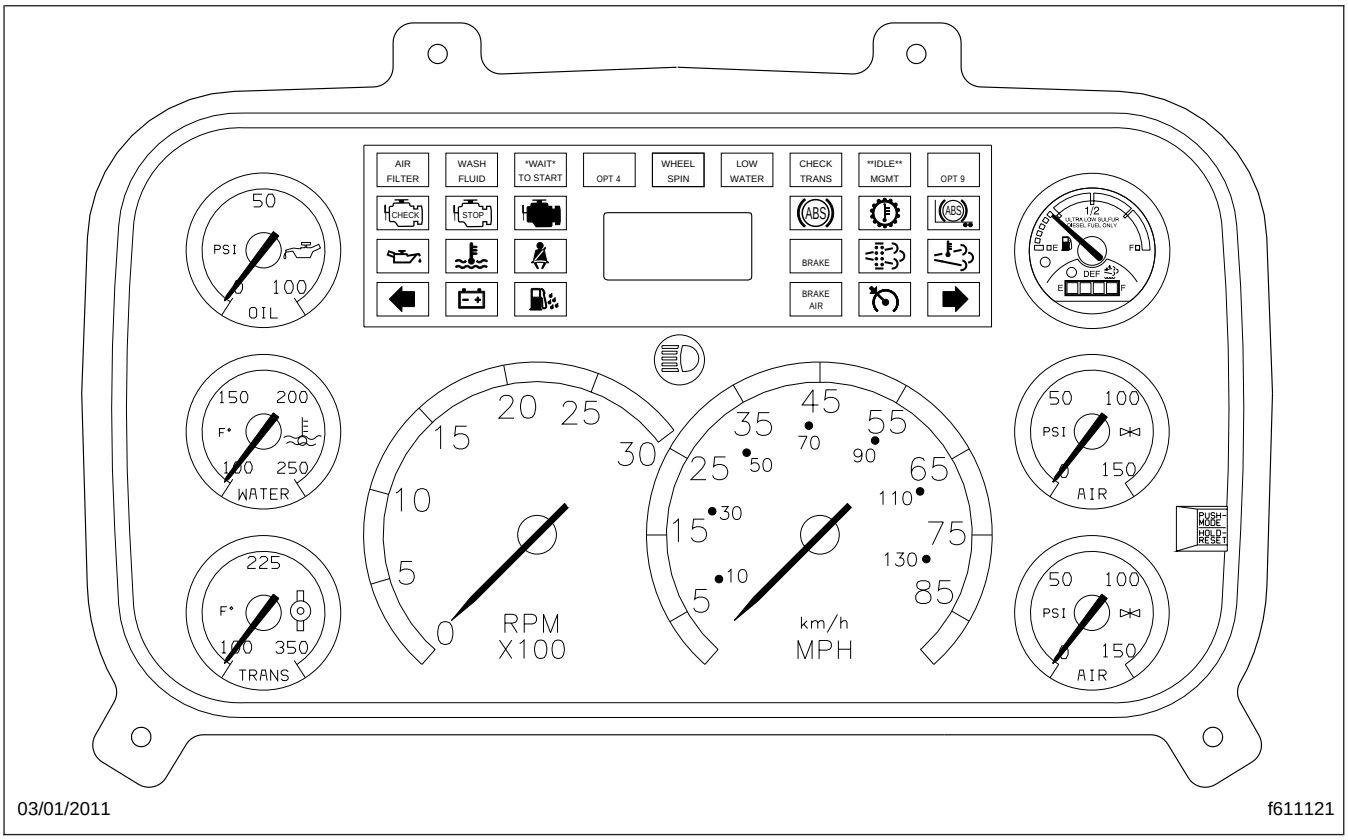


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Fig. 1, ICU3, Front View

Removal and Installation

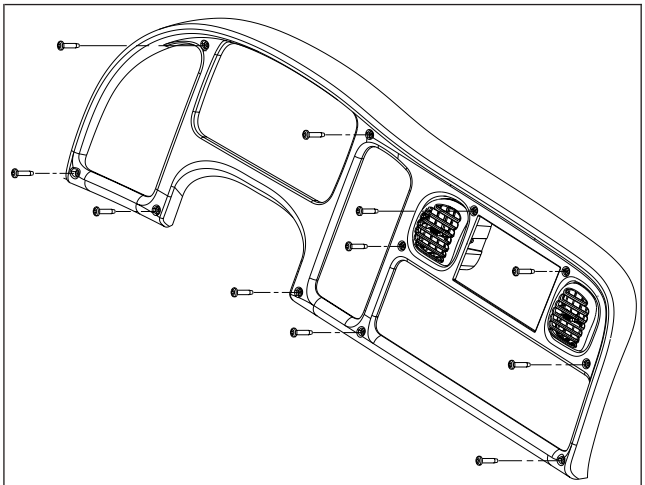

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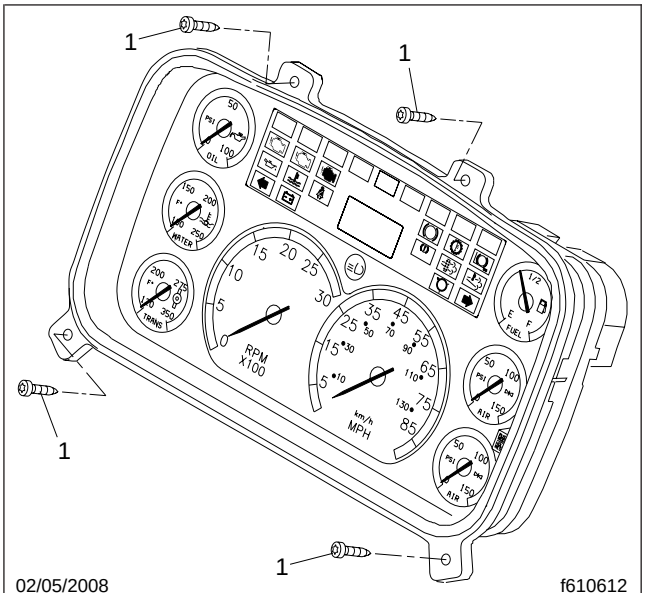
Fig. 2, Dash Trim Piece



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1. 10–16 Torx Capscrew

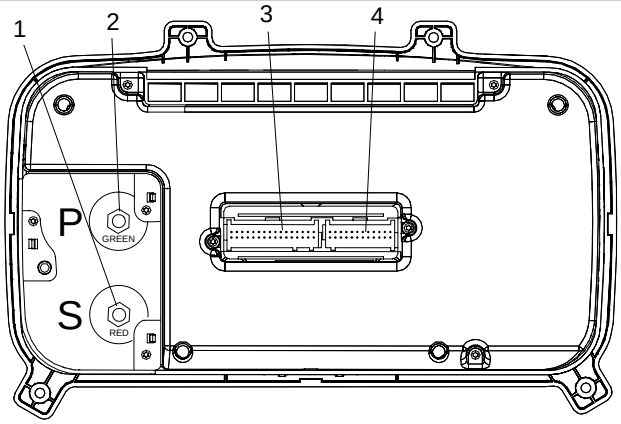
Fig. 3, ICU3 Installation

Installation

1. Connect the air lines to the air gauges by pressing them firmly into the push-lock connector on the back of the gauge. The green air line connects to the primary (upper) gauge. The red air line connects to the secondary (lower) gauge. See **Fig. 4**.
2. Connect the electrical connectors to the back of the ICU3.
3. Place the ICU3 in the dash opening and secure it with the four capscrews. Tighten the capscrews 30 lbf·in (340 N·cm).
4. Install the dash trim piece and secure it with 11 capscrews. Tighten the capscrews 30 lbf·in (340 N·cm).
5. Connect the batteries.

NOTE: Mechanical (air) gauges do not make a sweep.

6. Turn on the ignition and test the operation of the cluster. All electronic gauges should make one complete sweep and return to their normal indicating positions. The warning and indicator lights should turn on, then off, as described is **Subject 050**.
7. Start the engine and verify proper operation of the air gauge module as the air pressure builds.



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1. Secondary Air Pressure Gauge
2. Primary Air Pressure Gauge
3. 32-Pin Electrical Connector
4. 24-Pin Electrical Connector

Fig. 4, ICU3, Rear View

The instrumentation control unit, ICU3, is a one-piece unit, including housing, fixed gauges, a removable air gauge module, and the dash message center. See **Fig. 1**.

NOTICE

Do not forcibly pull the ICU3 from the dash. This

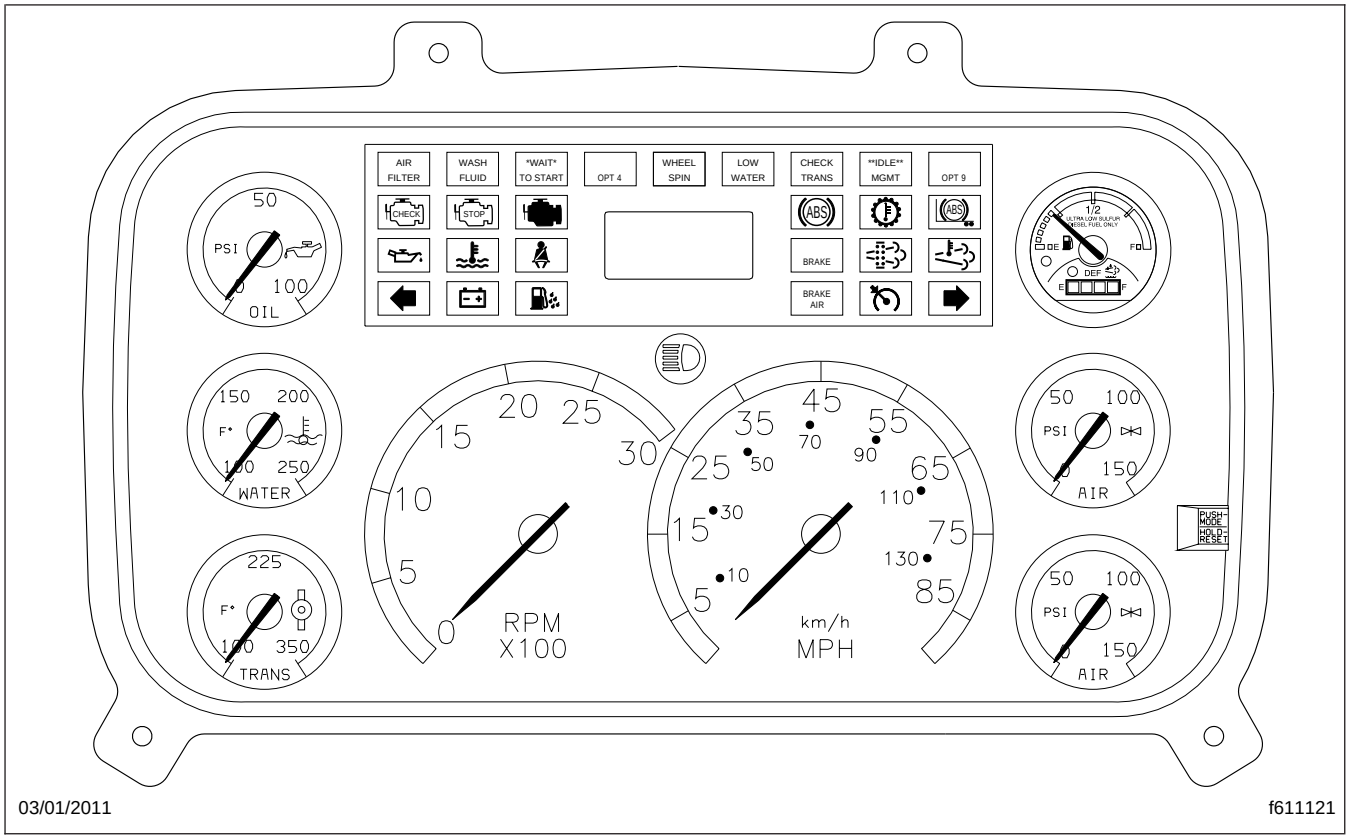

Fig. 1, ICU3, Fron View

NOTE: Since the top-row warning and indicator lamps are optional, some positions in the row may not have a lamp and telltale.

The nine top-row warning and indicator lamps are all replaceable except for the lamp in position 8, counting left to right. The lamp in that position is a permanent LED.

The term "telltale" refers to the small plastic bezel in the top row with a warning or indicator message printed on it. Telltales are replaceable.

may dislodge electrical connections or air hoses from the back of the ICU3, causing damage to the connections, the air hoses, or the dash.

Lamp Replacement

1. Disconnect the negative leads from the batteries and discharge the pressure from the air tanks.
2. Remove the dash trim piece by removing the 11 capscrews that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.
3. Remove the four capscrews that secure the ICU3. See **Fig. 3**.

Lamp and Telltale Replacement

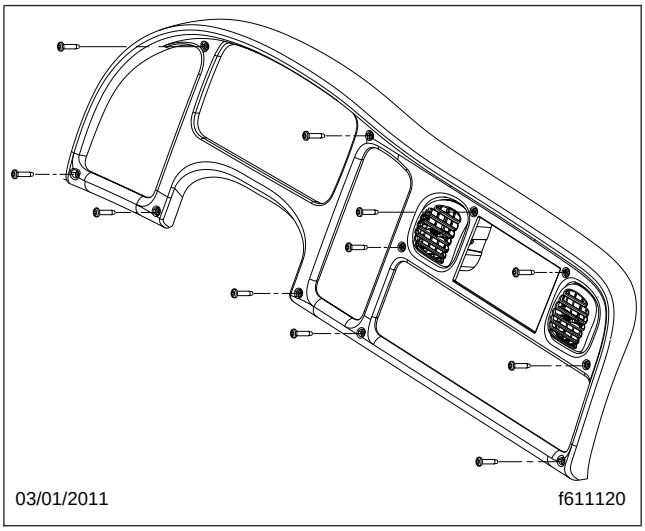

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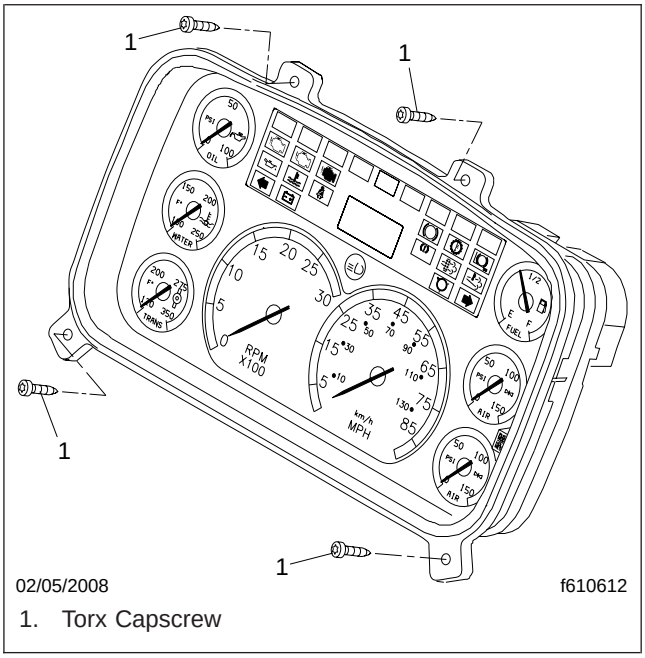
Fig. 2, Dash Trim Piece

4. Place a clean towel over the front of the ICU3 before pulling it forward to prevent scratches. Carefully pull the ICU3 forward to access the top row of lamps and telltales.
5. Use a small screwdriver or flat blade to twist out the lamp by its base behind the telltale. Turn the lamp one-quarter turn and remove. See **Fig. 4**.



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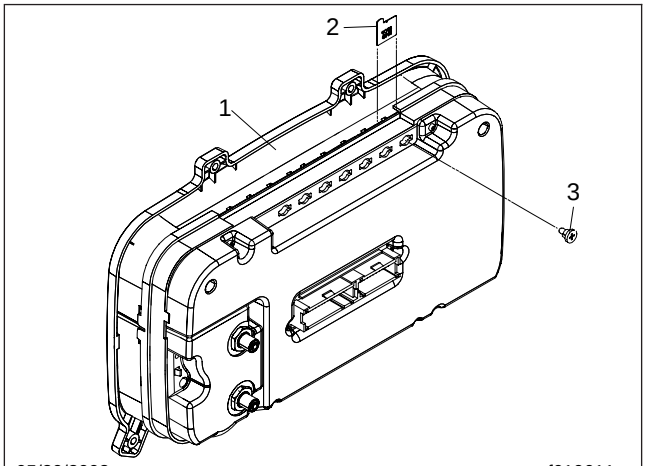
1. Torx Capscrew

Fig. 3, ICU3 Installation



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NOTE: Air gauge and electrical connections are shown removed for clarity.

1. ICU3
2. Telltale
3. Lamp

Fig. 4, ICU3, Rear View

6. Place a new lamp in the opening and twist it one-quarter turn.
7. Using capscrews, install the ICU3.
8. Using capscrews, install the dash trim piece.
9. Connect the batteries.

Telltale Replacement

1. Disconnect the negative leads from the batteries and drain the air tanks.
2. Remove the dash trim piece by removing the 11 capscrews that secure it. All fasteners for this procedure are 10–16 Torx® capscrews. See **Fig. 2**.
3. Remove the four capscrews that secure the ICU3. See **Fig. 3**.
4. Place a clean towel over the front of the ICU3 before pulling it forward to prevent scratches. Carefully pull the ICU3 forward to access the top row of lamps and telltales.
5. Using a pair of needlenose pliers or a similar tool, grab the exposed tab at the top of the telltale slot and carefully pull the telltale out from the top of the ICU. See **Fig. 4**.

6. Place a new telltale in the slot the same way it was removed. Properly orient the telltale so the text is readable from the front, then grab the top tab of the telltale and slide it into the slot.
7. Using capscrews, install the ICU3.
8. Using capscrews, install the dash trim piece.
9. Connect the batteries.
10. Turn the ignition on. Check all lamps and telltales for correct operation.

Refer to **Subject 100** for instructions on removing the ICU3.

Air Pressure Gauge Replacement, ICU3

The only replaceable gauges on the ICU3 are the air pressure gauges. If any other gauge in the cluster fails, the cluster must be replaced.

1. Drain the primary and secondary air tanks.
2. Remove the ICU3 from the dash, including disconnecting the electrical connectors and the air lines. For detailed instructions, see **Subject 100**.

NOTE: Be careful not to damage the ribbon electrical connector or the air gauge needles when removing the air gauge module. The gauge needles are exposed once the module is removed. A thin-ribbon electrical connector connects the air gauge module and the ICU3 housing. Once the fasteners that secure the air gauge module are removed, take care in separating the module from the ribbon electrical connector.

3. Carefully place the ICU3 face down on a smooth surface and remove the three T-8 capscrews that secure the air gauge module to the ICU. Do not remove the air gauge module cover.
4. Separate the air gauge module slightly from the ICU to allow access to the electrical ribbon that connects the module to the ICU. See **Fig. 1**.
5. Remove the electrical connection ribbon from the ICU, not from the air gauge module. Grip the ribbon firmly and lift out, then remove the air gauge module. See **Fig. 2**.
6. Place the air gauge module close to the opening it belongs in and connect the electrical ribbon connector in its slot. Gripping the ribbon end firmly at the edge, place the ribbon end into the slot and push it straight in until it stops.
7. Place the air gauge module into its opening in the ICU3. Make sure the rubber cup for the mode/reset button lines up with the matching alignment receptacle in the air gauge module when placing the module in the ICU.

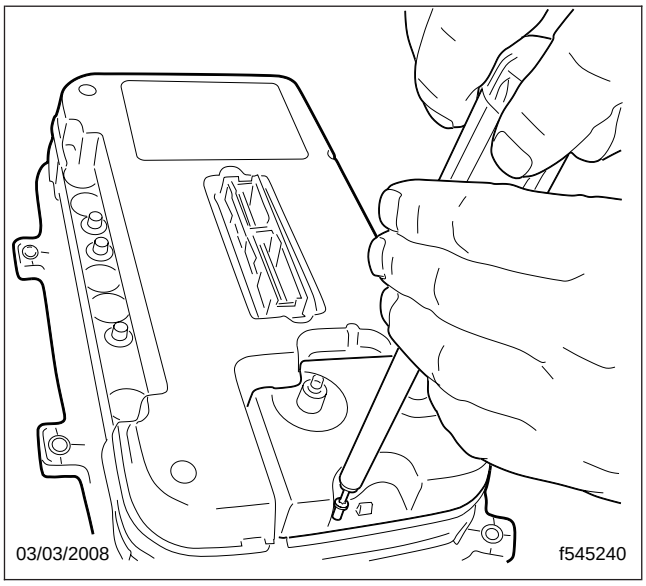


Fig. 1, Removing the Mounting Screws

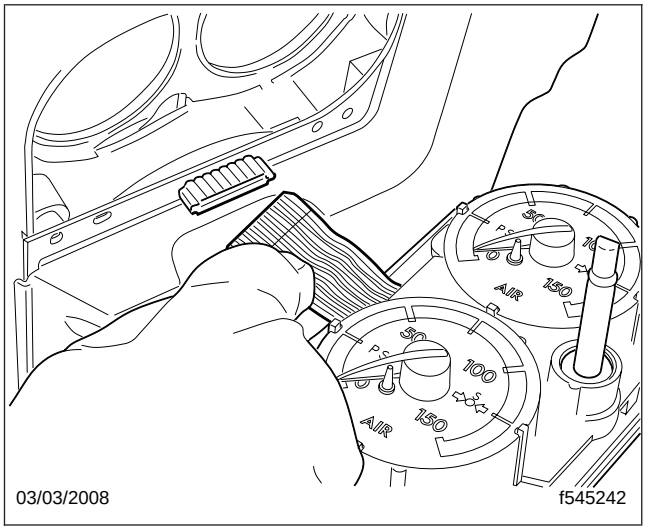


Fig. 2, Disconnecting the Ribbon Electrical Connector

NOTE: Insure the slack of the ribbon cable is folded and tucked inside the gauge module cover.

8. Install the three Torx capscrews and tighten them to secure the air gauge module.
9. Test the operation of the mode/reset button to insure it is not sticking or binding.
10. Install the ICU3. For detailed instructions, see **Subject 100**.

Gauge Replacement

11. After installing the ICU3, including the electrical connectors and the air lines, start the engine and verify the proper operation of the air gauge module as the air pressure builds.

IMPORTANT: Begin troubleshooting the ICU using **Table 1**.

ICU Instrumentation Troubleshooting – Start Here		
Problem Type	**Symptom**	**Procedure to Use**
Fault Code	A fault code is displayed on the ICU display	**Table 13**
	A Roll Call fault is present – Examples are "no ENG" or "no ABS"	**Table 13**
	"nO DATA" is displayed on the LCD	**Table 13**
	"nO J1939" is displayed on the LCD	**Table 13**
	"- - - - - - -" (seven dashes) is displayed on the LCD	**Table 13**
Gauges	Problem with a gauge in the ICU	**Table 2**
	Problem with a satellite gauge	**Table 4**
Backlighting	Problem with backlighting in the ICU	**Table 16**
	Problem with backlighting in a remote gauge	**Table 16**
Warning Indicators	Problem with an in-gauge indicator	**Table 20**
	Problem with the seat belt lamp	**Table 21**
	Problem with an indicator in the ICU	**Table 19**
	Problem with the DEF indicator	**Table 12**
LCD Display	A segment of the LCD does not work	**Table 17**
	The LCD is completely inoperative	**Table 17**
Mode/Reset Button	The mode/reset button is sticking or does not change the display	**Table 18**

Table 1, ICU Instrumentation Troubleshooting – Start Here

Gauge Diagnosis

ICU Gauge Diagnosis – Start Here			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition to ON without starting the engine. All the gauges, except air pressure gauges, should sweep full scale and back in unison. Do the gauges sweep correctly when the ignition is turned ON, and does the DEF indicator cycle?	Yes	Go to Step no. 3.
		No	Go to Step no. 2.
2	Is the ICU completely non-responsive?	Yes	Test for battery power on pin D14, ignition power on pin D15, and the ground on pin D13. Troubleshoot and repair any fault with these circuits as necessary. If these circuits are all working, replace the ICU.
		No	Replace the ICU.

Troubleshooting

ICU Gauge Diagnosis – Start Here			
Step	**Test Procedure**	**Test Result**	**Action**
3	Use **Table 3** to determine the gauge input source. Use the troubleshooting action based on the gauge input.	Fuel Level	Go to **Table 8**.
		DEF Level	Go to **Table 12**.
		Air Pressure	Go to **Table 7**.
		Sensor Driven	Go to **Table 9**.
		Data Driven	Go to **Table 10**.

Table 2, ICU Gauge Diagnosis – Start Here

Table 3 defines where each gauge, standard or optional, receives its input signal. Some gauges are datalink-driven, meaning the information is sent to the instrument cluster from some other ECU. Other gauges are controlled by a sensor wired directly to the instrument cluster or an air line connected directly to the gauge.

Standard and Optional Gauges: Input Source to ICU	
Gauge	**J1939 Input**
Ammeter*	Not part of the ICU
Application Air Pressure	Air line connected to gauge
DEF Level	J1939 from engine (SA 00 SPN 5245) or J1939 from aftertreatment control module (ACM) (SA 61 SPN 5245)
Engine Coolant Temperature	J1939 from engine (SA 00 SPN 110)
Engine Oil Pressure	J1939 from engine (SA 00 SPN 100)
Engine Oil Temperature	J1939 from engine (SA 00 SPN 175)
Forward Rear Axle Temp	Sensor connected to ICU
Fuel Level	Sensor connected to ICU
Low DEF Indicator	J1939 from engine (SA 00 SPN 5245)
Primary Air System Pressure	Air line connected to gauge
Pyrometer	J1939 from engine (SA 00 SPN 3241)
Rear Rear Axle Temp	Sensor connected to ICU
Secondary Air System Pressure	Air line connected to gauge
Speedometer	J1939 from engine (SA 00 SPN 84
Suspension Air Pressure	Air line connected to gauge
Tachometer	J1939 from engine (SA 00 SPN 190)
Transmission Oil Temperature	Manual, Eaton, and AGS - sensor connected to ICU Allison, and G transmissions - Data from transmission ECU SPN 177
Turbo Boost Pressure	J1939 from engine (SA 00 SPN 102)

* Ammeter is a stand-alone gauge that is not connected to the ICU.

Table 3, Standard and Optional Gauges: Input Source to ICU

Satellite Gauge Diagnosis

The ICU is capable of controlling up to eight additional gauges located in the dash panels. These gauges are controlled by a databus with backlighting, power, and ground sourced by the ICU. See **Table 4**.

Satellite gauges that are sensor or data driven will initialize at power on with the same sequence as the gauges in the main ICU3. The air pressure gauges only use the backlighting power from the ICU3. If there is a short circuit in any of the satellite gauges or the interconnecting wiring harness, it is possible that none of the gauges will work.

Satellite Gauge Daisy Chain Circuits		
Connector/Pin	**Name**	**Function**
C6	Gauge Power	12 volt source for satellite gauges
C7	Gauge Ground	Ground supply for satellite gauges
D6	Illumination	Backlighting voltage source for satellite gauges
D7	Gauge Data	Databus to satellite gauges

Table 4, Satellite Gauge Daisy Chain Circuits

Table 5 identifies the satellite gauges that may be used with the ICU.

ICU Satellite Gauges	
Gauge	**Input Source**
Engine Oil Temperature	Data from the Engine Controller
Turbo Boost Pressure	Data from the Engine Controller
Pyrometer	Data from the Engine Controller
Forward Rear Axle Temperature	Sensor Connected to ICU
Rear Rear Axle Temperature	Sensor Connected to ICU
Application Air Pressure	Air Line Connected to Gauge
Suspension Air Pressure	Air Line Connected to Gauge
Lift Axle Pressure (Up to 4)	Air Line Connected to Gauge

Table 5, ICU Satellite Gauges

Satellite Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition ON without starting the engine. All the satellite gauges, except air pressure gauges should sweep full scale and back in unison. Do the electrical satellite gauges sweep correctly when the ignition is turned ON?	Yes	Go to Step no. 3.
		No	Go to Step no. 2.

Troubleshooting

Satellite Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
2	Are all the electrical satellite gauges non responsive?	Yes	Troubleshoot for a short in the satellite gauge wiring by testing for ignition voltage on pin C6 and ground on pin C7. Disconnect the satellite gauges one at a time to troubleshoot for a short in a gauge that could be taking the databus down. Repair any wiring fault or replace any defective gauge. If no problem was found, replace the ICU.
		No	Troubleshoot for a fault in the connection to the inoperative gauge and repair as appropriate. Otherwise, replace the inoperative gauge.
3	Use **Table 5** to determine the gauge input source. Use the troubleshooting procedure based on the gauge input.	Air Pressure	Go to **Table 7**.
		Sensor Driven	Go to **Table 9**.
		Data Driven	Go to **Table 10**.

Table 6, Satellite Gauge Diagnosis

Air Pressure Gauge Diagnosis

Air Pressure Gauge Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
1	Which air pressure gauge is not functioning correctly?	Primary or secondary	Go to Test No. 2.
		Application	Go to Test No. 3.
		Suspension	Go to Test No. 4.
		Lift axle pressure	Go to Test No. 5.
2	Drain the air tanks. Connect an accurate pressure gauge to the primary or secondary air tank depending on which gauge has a problem. Start the engine and build air pressure until the compressor cuts out. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge module.

Air Pressure Gauge Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
3	Connect an accurate pressure gauge to a delivery port on the foot valve. Make a 90 psi (621 kPa) brake application while observing the application air pressure gauge in the cluster and the test gauge. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.
4	Connect an accurate pressure gauge to the air suspension. Is the air pressure gauge in the cluster within 11 psi (76 kPa) of the test gauge?	Yes	Gauge is OK. No problem found.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.
5	Raise the lift axle. Connect an accurate pressure gauge to the application side of the lift axle air system. Lower the axle and adjust the pressure. Is the axle pressure on the instrument panel gauge within 11 psi (76 kPa) of the test gauge?	Yes	If the pressure cannot be controlled with the adjustment knob, check the reverse switch and pressure dump valve. Check the pressure adjustment regulator, replace if it is not controlling pressure. Otherwise, there is no problem.
		No	Check air line to gauge for kinks, pinches, or wire ties that are crushing the air line feed. If OK, replace the air pressure gauge.

Table 7, Air Pressure Gauge Diagnosis

Fuel Level Gauge Diagnosis

The fuel level gauge is controlled by the ICU using a variable resistance input from the fuel level sending unit that is located in the fuel tank. The fuel level sending unit resistance varies linearly from 31±2Ω with a full tank to 247±3Ω when empty.

If the ICU3 is measuring a resistance greater than 284Ω between circuit 47 and ground, a fault will be set for fuel level circuit open. If the ICU3 is measuring less than 23.5Ω between circuit 47 and ground, a fault will be set for fuel level circuit shorted low. ServiceLink may be used to monitor for these faults. The gauge will read empty until the measurement from the sensor is between 284Ω and 23.5Ω. Refer to **Table 8** for the fuel level diagnostic procedure.

NOTE: If the fuel level sensor is below the minimum resistance (short to ground) or above the maximum (open), the fuel gauge will read empty. Shorting the fuel sensor wires will not drive the gauge to full scale.

Troubleshooting

Fuel Level Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	If a 100 ohm resistor is available, disconnect the fuel level sender connector and place the resistor across circuit 47 and ground in the wiring harness connector to simulate the fuel level sending unit. Turn the ignition to the ON position and observe the fuel gauge. If, after gauge initialization, the gauge points closely to the half tank mark, then the wiring and ICU are all operating correctly. Jump to Step 4 if there is no problem with the wiring and ICU. Does the fuel level gauge stay at empty even though there is fuel in the tank or is the complaint an inaccurate and intermittent reading? Note - turn the ignition to OFF and disconnect the batteries before continuing.	Stays at Empty	Go to Step 2.
		Inaccurate or Intermittent	Go to Step 4.
2	Disconnect the connector at the fuel level sender and measure the resistance of the sender. What is the resistance of the sender?	Greater than 284Ω or Less than 23.5Ω	Go to Step 4.
		Between 284Ω and 23.5Ω	Go to Step 3.
3	Connect the fuel level sender and disconnect the connectors on the back of the ICU. Measure the resistance in the vehicle wiring between circuit 47 in connector pin D1 and the ground circuit in connector pin D2. What is the resistance of the circuit?	Greater than 284Ω	Troubleshoot and repair an open circuit on either circuit 47 or the ground between the ICU connector and the fuel level sender.
		Between 284Ω and 23.5Ω	This is the valid resistance range. If the fuel tank is full and the resistance is close to 31Ω, replace the ICU. Otherwise no problem is indicated.
		Less than 23.5Ω	Troubleshoot and repair a short to ground on circuit 47 between the ICU connector and the fuel level sender.
4	Remove the fuel sending unit from the fuel tank. Connect an ohm meter to the pins at the fuel level sender connector. Slowly move the level of the float arm from full to empty. See **Fig. 1**. Does the resistance vary linearly from 31±2Ω to 247±3Ω?	Yes	Troubleshoot and repair for corrosion or an intermittent connection in the circuitry between the ICU and the fuel level sender.
		No	Replace the fuel level sending unit.

Table 8, Fuel Level Gauge Diagnosis

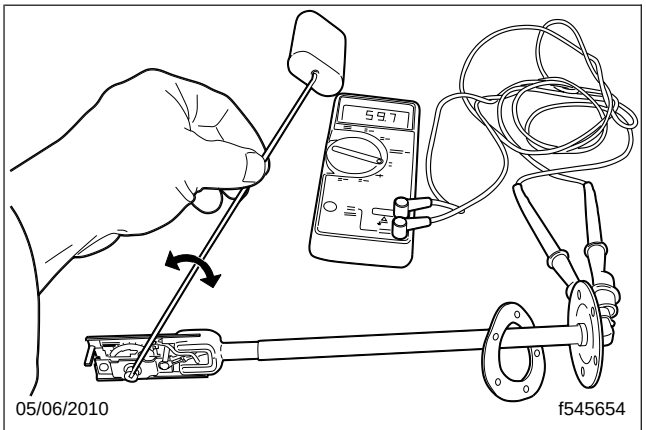


Fig. 1, Testing the Fuel Level Sending Unit

Sensor Driven Gauge Diagnosis

Sensor Driven Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Does the gauge stay pegged at the full scale or the bottom of scale reading, even though the temperature is at some mid-point or is the complaint an inaccurate reading? Note: Turn the ignition to OFF and disconnect the batteries before continuing.	Stays Pegged	Go to Step 2.
		Inaccurate	Go to Step 3.
2	Disconnect the connector at the sensor and measure the resistance of the sensor. Does the sensor measure open, shorted, or some mid-range resistance for that sensor, using the table in **Specifications 400**?	Open or Shorted	Replace the sensor.
		Mid Range Resistance	Locate and repair the wiring fault for that sensor. Use the circuit and pin information tables in **Specifications 400** to identify the circuits to troubleshoot.
3	Remove the sensor and place it in a container of water with a thermometer and heat to a temperature where the resistance can be accurately measured with an ohm meter. Use the resistance table in **Specifications 400** for the sensor under test to determine if the measured resistance is appropriate for the temperature. Does the resistance value match the table value?	Yes	Measure the resistance of the wiring between the ICU and the sensor connector. Locate and repair a partially open or short circuit.
		No	Replace the sensor.

Table 9, Sensor Driven Gauge Diagnosis

Data Driven Gauge Diagnosis

Data Driven Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	If the problem is with the DEF level indicator, use the procedure in **Table 12**. Connect ServiceLink and open the datalink monitor template for the instrument cluster. Start the engine and let it run until the operating condition should register on the gauge. For example, oil temperature must be above the minimum position on the gauge. Is the display on the computer within 5% of the position of the gauge in the ICU?	Yes	Use the troubleshooting procedure for the sensor giving incorrect data. For example, use the engine manufacturers troubleshooting procedure for sensors connected to the engine controller.
		No	Replace the ICU.

Table 10, Data Driven Gauge Diagnosis

DEF Level Indicator Diagnosis

The DEF level indicator is integrated into the fuel gauge, and uses J1939 data from the ACM. The DEF level is measured by a sealed non-contact variable-resistance sensing assembly located in the DEF tank. The DEF level sensor resistance can be measured at the tank connector. For Detroit Diesel engines, the level sensor signal uses pins 1 and 2. For Cummins engines, the level sensor uses pins 1 and 4. On Detroit Diesel engines, when the DEF tank is empty, the sensor will measure approximately 240Ω. When full, it will measure approximately 19.8KΩ. On Cummins engines, when the DEF tank is empty, the sensor will measure approximately 4.8KΩ. When full, it will measure approximately 68Ω. Use the resistance to float height table in **Specifications 400** to test the resistance for a specific float height. When there is no DEF in the tank or when there is a fault in the DEF level sensing circuit, the indicator will flash the red segment until the fault is corrected, or a sufficient amount of DEF is added to the tank. Perform the recommended action in **Table 11** to troubleshoot faults with the DEF level sensing circuitry indicated by fault codes with SPN 1761.

DEF Level Faults from SA 0 or SA 61				
SPN	**FMI**	**Description**	**Behavior**	**Action**
1761	1 17 18 31	DEF level low	The DEF level is low. MIL, CEL, STOP engine lamp, and engine derate may be active.	The DEF tank has run too low. Fill the DEF tank so that it is at least 25% full and idle the engine for 5 minutes. If the problem is still present use the DEF level diagnostic procedure in **Table 12**.
1761	3	DEF level circuit out of range high	The voltage on circuit 532F is greater than the ACM expects.	Troubleshoot circuits 532F and 532F- between the ACM and the temperature level sensor for a wiring fault and also for an open level sensor unit.
1761	4	DEF level circuit out of range low	The voltage on circuit 532F is close to 0 volts.	Troubleshoot circuit 532F between the ACM and the temperature level sensor for a wiring fault and also for a shorted level sensor unit.

Table 11, DEF Level Faults from SA 0 or SA 61

DEF Level Diagnostic Procedure			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition to ON but do not start the engine. Does the DEF level indicator illuminate all segments green, then turn them off beginning from the right, one at a time until the left one becomes amber then red, before either showing a mid-range level, or flashing the left segment red?	Yes	The DEF level indication display is working properly. Go to Step 2.
		No	Replace the ICU3.
2	Use Servicelink to check for any J1939 faults. Is there a fault for SPN 1761 with FMI 3 or 4 (DEF level sensor out of range) or are any J1939 communications fault codes active? NOTE: SPN 1761 FMI 1, 17, 18, or 31 indicate the DEF level is low. There is no wiring fault, but there may be a problem with DEF level indication accuracy.	Yes	If the code is for a FMI 4, troubleshoot for a wiring fault in circuit 532F between the DEF level sensor and the ACM. If the code is FMI 3, go to Step 3. If there is a J1939 communications fault, use the troubleshooting information in this manual to locate and repair communications.
		No or Accuracy Problem	Go to Step 4.
3	Turn the ignition OFF then disconnect the 4 wire connector at the DEF level sender. Use a short jumper wire to short pins 1 and 2 (for Detroit Diesel engine) or pins 1 and 4 (for Cummins engine) together in the vehicle harness side of the connector. Turn the ignition ON without starting the engine. Allow the indicator initialization sequence to complete, then check for fault codes. Is there an active fault for SPN 1761 FMI 4?	Yes	The wiring indicates continuity. Go to Step 4.
		No	Troubleshoot and repair for an open in circuit 532F and/or circuit 532F- between the DEF level sensor and the ACM.
4	Turn the ignition off and disconnect the batteries. Remove the temperature/level sender unit from the DEF tank. Connect an ohm meter to pins 1 and 2 (for Detroit Diesel engine) or pins 1 and 4 (for Cummins engine) at the 4 pin connector. Slowly raise the level of the float from empty to full. Record the resistance range measured. Does the vehicle have a Cummins or a DD engine?	Cummins	If the resistance did not vary from approximately 4.8KΩ at empty to 68Ω at the full position, replace the temperature/level sender unit.
		Detroit Diesel	If the resistance did not vary from approximately 240Ω at empty to 19.68KΩ at the full position replace the temperature/level sender unit.

Table 12, DEF Level Diagnostic Procedure

Fault Code Diagnosis

The ICU3 will display fault codes that are broadcast from other devices on the databus. Follow the procedure in **Table 13** to determine if there is a problem with the ICU3, another device on the databus, a sensor that is connected to the ICU, or with the databus. Fault codes that are generated by the ICU3 can be read using ServiceLink.

Some circuitry faults within the ICU3 will cause the LCD to display "- - - - - - -" (seven dashes). Replace the ICU3 when this is displayed.

Roll call faults occur when the ICU3 is not receiving data from a device that had been on the databus in the past. If a device has been removed from the vehicle (Qualcom for example), perform the resetEE procedure from the ICU3 setup menu. See **Specifications 400** for details of this procedure. Roll call fault messages are originated by the ICU3 for display only. They are not broadcast over the databus and

Troubleshooting

cannot be read by ServiceLink or any other data analysis tool.

Fault codes originated by other devices are echoed on the display when the ignition is first turned on and the park brake is set. **Table 19** identifies the most common ECUs that would broadcast these faults.

Fault Code Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Is the fault code from SA 23, or some other fault?	SA 23	Use **Table 15** to identify the fault code and the troubleshooting procedure.
		Other	Go to Step 2.
2	Does the display only show seven dashes (- - - - - - -) or some other message?	Dashes	The ICU has an internal error. Replace the ICU.
		Other Message	Go to Step 3.
3	Is the message "nO dATA" or another message showing nO something?	Yes	If the message is "nO dATA" or "nO J1939", the ICU is unable to communicate with any other device on the vehicle. Troubleshoot the databus for loss of function. If the message is something with a three letter code, for example "no ENG" there is a roll call fault. A roll call fault will show SPN 639 FMI 07. Use **Table 15** to identify the device that is not communicating and causing a roll call fault.
		No	Use **Table 15** to identify the device broadcasting the fault code. Refer to the troubleshooting subject for that device to determine how to proceed for the fault it is broadcasting.

Table 13, Fault Code Diagnosis

ICU3 J1939 Fault Codes SA 23 (ICU)				
SPN	**FMI**	**Conn/Pin**	**Description**	**Behavior**
96	5	D1 (+) D2 (–)	Fuel Level Circuit Open	The resistance between pins D1 and D2 is greater than 298 ohms. The gauge will point to empty.
ACTION: Use the troubleshooting procedure in **Table 2** beginning at Step 4.				
96	6	D1 (+) D2 (–)	Fuel Level Circuit Short	The resistance between pins D1 and D2 is less than 23.5 ohms. The gauge will point to empty.
ACTION: Disconnect the fuel level sensor connector at the sending unit. Turn the ignition to ON and check the fault code display. If the fault code for fuel level circuit short (FMI 6) is still active, locate and repair the short in circuit 47 between the LBCU and the fuel level sender. Otherwise use the troubleshooting procedure in table 2 beginning at Step 5.				
168	1	n/a	Low Voltage	The ICU is measuring a system voltage of less than 12.0 volts.
ACTION: Troubleshoot the charging system and test the battery cables for voltage drop.				
177	6	C12 (–) C13 (+)	Transmission Temp Sensor Short	The resistance between pins C12 and C13 is less than 70 ohms. The gauge will point full scale.
ACTION: Troubleshoot for a shorted transmission temperature sensor and for a short to ground in circuit 30.				
628	12	n/a	ICU Internal Memory Fault	The ICU has an internal memory fault. The display may show "- - - - - - -", (seven dashes).

ICU3 J1939 Fault Codes SA 23 (ICU)				
SPN	**FMI**	**Conn/Pin**	**Description**	**Behavior**
ACTION: Replace the ICU.				
629	12	n/a	ICU Internal Electronics Fault	The ICU microprocessor or other internal critical electronics has a fault. The display may show "- - - - - - -", (seven dashes).
ACTION: Replace the ICU.				
639	7	n/a	Roll Call Fault	Any other J1939 device that the ICU expects on the network but is not broadcasting will generate a fault code. The source address will be of the device that the ICU is not receiving messages from. Note that this is actually an ICU generated fault code.
ACTION: If a device has been removed from the vehicle or if a used ICU is installed a roll call reset must be performed. Use the "rESEt EE" Screen in the setup menu. If a J1939 device is not broadcasting due to an error, use the troubleshooting procedure for that device to determine the cause of it going off-line.				
2567	0	n/a	Excessive Broadcast Announce Messages (BAM)	Another device on the J1939 databus is transmitting an excessive number of fault messages that are intended for the ICU.
ACTION: Use ServiceLink or scroll through the fault codes that the ICU3 displays to determine which controller has many fault codes. Use the appropriate troubleshooting procedures for that controller to repair its system.				

Table 14, ICU3 J1939 Fault Codes SA 23 (ICU)

Displayed Fault Messages			
Message	**System With Active Fault**	**Message**	**System With Active Fault**
EnG 0	Engine Controller – CPC	EEC 61	Aftertreatment Control Module – ACM
EnG 1	Engine Controller – MCM	CEL 74	Cellular Phone
tCU 3	Transmission Control Unit	SAt 75	Satellite Communications
tSU 5	Transmission Shift Unit	rAd 76	Radio
AbS 11	Antilock Brake Controller	SbU 83	Seat Belt Unit – Space
CdU 42	Collision Detection Unit	SYS ###	Where ### is the source address of any other J1939 controller that is not in this list.
bH 33	Bulkhead Module	E1 235	Expansion Module #1
E2 236	Expansion Module #2	E3 237	Expansion Module #3
E4 238	Expansion Module #4	E5 239	Expansion Module #5

Table 15, Displayed Fault Messages

Gauge Backlighting Diagnosis

Gauge Backlighting Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
1	Is only the air pressure gauge module backlighting affected?	Yes	Go to Test No. 2.
		No	Go to Test No. 3.

Troubleshooting

Gauge Backlighting Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
2	Remove the three air gauge module screws and carefully lift the air gauge module off the back of the ICU while leaving the ribbon cable connected. Inspect the ribbon cable connection to the ICU PC board. Make sure that it is plugged in all the way. Is the ribbon cable connection OK?	Yes	Replace the air pressure gauge module.
		No	Repair the ribbon cable connection as necessary.
3	Turn the headlights on and press the dimmer switch to increase then decrease the backlighting. Is the backlighting inoperative for all of the HVAC, headlight switch, and ICU?	Yes	Troubleshoot the backlighting.
		ICU only	Go to Test No. 4.
4	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage between pins A1(+) and D3(–) while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (dim) and 11.3V (full bright). Does the measured voltage change through this range?	Yes	Replace the ICU.
		No	Go to Test No. 5.
5	Measure voltage between pin A1(+) and a known good ground while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (dim) and 11.3V (full bright). Does the measured voltage change through this range?	Yes	Repair backlighting ground circuit to ICU pin D3 as necessary.
		No	Troubleshoot circuit 29A between the BHM and ICU. Repair the wiring as appropriate.

Table 16, Gauge Backlighting Diagnosis

LCD Diagnosis

LCD Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the headlights on, leaving the ignition in the OFF position. Does the LCD light up and display mileage?	Yes	Go to Step 2.
		No	Turn the ignition ON without starting the engine. If the LCD initializes all segments, then troubleshoot the ICU wakeup feature. Otherwise go to Step 2.

LCD Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
2	Turn the ignition ON without starting the engine. Do all the segments of the LCD turn on and initialize, or is the LCD completely inactive?	Only some segments initialize	Replace the ICU.
		LCD completely inactive	Test for battery power on pin D14, ignition power on pin D15, and the ground on pin D13. Troubleshoot and repair any fault with these circuits as necessary. If these circuits are all working, replace the ICU.
		All segments initialize	There is no problem with the LCD, or there is a more appropriate symptom to troubleshoot such as backlighting.

Table 17, LCD Diagnosis

Mode/Reset Button Diagnosis

Mode/Reset Button Diagnosis			
Test No.	**Test Description**	**Test Result**	**Action**
1	Press the Mode/Reset button several times to determine if it is sticking or binding. Does the button move freely?	Yes	Go to Step 2.
		No	Remove the button cap and inspect for foreign substances in the shaft area. Clean as necessary. It may be necessary to remove the air gauge module from the ICU to clean the shaft and grommet.
2	Follow the procedure in **Subject 110** of this manual to remove the gauge module from the ICU. Note the ribbon cable connection when the gauge module is removed. Is the ribbon cable completely connected?	Yes	Replace the gauge module
		No	Properly connect the ribbon cable and test the Mode/Reset button operation. Install the repaired ICU if it now works. Otherwise replace the gauge module.

Table 18, Mode/Reset Button Diagnosis

Warning and Indicator Lamps Diagnosis

Use **Table 19** to determine if an indicator lamp has a power on bulb check and how it is activated.

The ICU does not set fault codes for lamps that are inoperative. If an indicator does not illuminate, use the **Activation** and **Control Pin** information to determine if the problem is the signal that drives the lamp or if the lamp itself is inoperative.

For data driven indicators, use ServiceLink to monitor the data for the indicator. If the ICU does not illuminate an indicator when ServiceLink shows that it is on, there is a problem with the indicator. The top row lamps are replaceable, for the others the ICU must be replaced.

For indicators that are hardwired, monitor the voltage at the ICU input pin. Use the **Activation** column information to determine when the indicator should illuminate. Troubleshoot the vehicle wiring harness or switch as necessary. Indicators with a power on "bulb check" (even though they are LEDs) are confirmed to work.

In-gauge lamps illuminate during power-on initialization, and when the data to the gauge indicates a fault

Troubleshooting

or an out of normal range condition. An illuminated in-gauge lamp indicates that immediate attention is necessary.

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Left Turn Signal		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	C8	Beep sound when control pin is at 12V or commanded from the BHM.
Right Turn Signal		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	D8	Beep sound when control pin is at 12V or commanded from the BHM.
High Beam		NO	Lamp is ON when 12V is applied to the control pin or lamp is ON when commanded over J1939 from the BHM.	A12	None.
Park Brake		YES	Lamp is ON when commanded over J1939 from the ABS Controller or from the BHM.	Data	Buzzer active when vehicle speed is greater than 2 MPH (3 km/h) (uses speed data from ABS).
Low Air Pressure		YES	Lamp is ON when commanded over J1939 from the BHM.	Data	Buzzer active whenever lamp is on.
Battery Voltage		YES	Lamp is ON when system voltage has been less than 12 volts for longer than 40 seconds. The message is broadcast by the engine controller.	Data	Buzzer active whenever lamp is on.
Fasten Seat Belt		YES	If pin D10 is not hardwired to seat belt buckle, lamp is ON for 15 seconds at power-up only. If pin D10 is hardwired, the bulb check is three seconds long and the lamp is OFF when ground is applied to the control pin (seat belt latched).	N/A or D10	Friendly Chime for 10 seconds when pin D10 is hardwired if park brake is off and seat belt is not latched.
Check Engine Lamp (CEL)		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C15 and Data	None.
Malfunction Indicator Lamp (MIL)		YES	Lamp is ON when ground is applied to the control pin.	A9	None.
Stop Engine		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C16 and Data	None.

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Tractor ABS		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the tractor ABS controller. The lamp will also be ON when the ICU is not receiving data from the ABS controller.	B11 and Data	None.
Trailer ABS		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the trailer ABS controller.	D12 and Data	None.
Cruise Control		YES	Lamp is ON when the cruise enable switch is in the ON position.	Data	None.
DPF Regeneration (REGEN)		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	C10 and Data	None.
High Exhaust Temperature		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the engine controller.	A5 and Data	None.
Water In Fuel		NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller.	C9 and Data	None.
Low Oil Pressure		YES	Lamp is ON when commanded by the engine controller. The lamp will latch on for a minimum of 30 seconds.	Data	Buzzer is active when the lamp is on.
High Coolant Temperature		YES	Lamp is ON when commanded by the engine controller. The lamp will latch on for a minimum of 30 seconds.	Data	Buzzer is active when the lamp is on.
High Transmission Temperature		YES	Lamp is ON when ground is applied to the control pin or Lamp is ON/ FLASHING when commanded by the transmission controller or the retarder.	A4 and Data	None.
Option 1 (Air Filter Restriction)		NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33, SPN 5086.	C14 and Data	None.
Option 2 (Washer Fluid Low)		NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33, SPN 80.	A6 and Data	None.

Troubleshooting

ICU Warning and Indicator Lamps					
Lamp	**Symbol**	**Bulb Check**	**Activation**	**Control Pin**	**Buzzer Operation**
Option 3 (Wait to Start)	WAIT TO START	YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller SA 0, SPN 1081.	A7 and Data	None.
Option 4	—	—	Lamp is ON when ground is applied to the control pin.	A8 and Data	None.
Option 5 (Wheel Spin)	WHEEL SPIN	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the BHM SA 33.	B1 and Data	None.
Option 6 (Low Water)	LOW WATER	NO	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the engine controller SA 0.	B8 and Data	None.
Option 7 (Check Transmission)	CHECK TRANS	YES	Lamp is ON when ground is applied to the control pin or Lamp is ON when commanded by the transmission controller.	C11 and Data	None.
Option 8 (Idle Management)	IDLE MGMT	NO	Lamp is ON when ground is applied to the control pin.	C1 and Data	None.
Option 9	—	NO	Lamp is ON when 12V is applied to the control pin.	D4 and Data	None.

Table 19, ICU Warning and Indicator Lamps

ICU In-Gauge Warning Lamps			
Lamp	**Bulb Check**	**Input Source**	**Activation**
Low Fuel Level	YES	Fuel Level Sensor	When the fuel level is less than 1/8th of a tank the lamp will be ON. A 60 second delay applies to activation and deactivation unless ignition power is cycled and it will immediately indicate for the measured value.
Low DEF Level	YES	Data	When the DEF level is less than 15% of tank capacity, the low DEF light will be ON. When DEF level is less than 5% of tank capacity, the low DEF light will flash.

Table 20, ICU In-Gauge Warning Lamps

Seat Belt Lamp Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Turn the ignition OFF, then turn it to the ON position without starting the engine. Does the lamp always stay on, never illuminate, or only illuminate for 3 to 15 seconds at power on?	Always ON	The ICU has learned that it is in a vehicle that has a seat belt buckle switch hardwired to ICU pin D10. Troubleshoot for an open seat belt buckle switch or open circuit between the seat belt buckle and the ICU. If the vehicle does not have a hardwired seat belt buckle switch, perform the resetEE procedure as described in **Specifications 400**.
		Never ON	The lamp itself is open circuit, replace the ICU3.
		Only ON 3 to 15 Seconds	A vehicle that does not have a hardwired seat belt buckle switch illuminates the lamp for 15 seconds at power-up. A vehicle that has a hardwired seat belt switch illuminates this lamp for three seconds at power-up and then will turn it off if the seat belt input is at ground (seat belt connected). There is no problem with the lamp circuit if it behaves according to this description.

Table 21, Seat Belt Lamp Troubleshooting

Figure 1 is an overview schematic of the ICU3 as it is connected to the vehicle.

The two ICU3 main cab harness connectors are pink and plug into pins located in the center of the unit on the back. Connector #1 has 24 cavities numbered A1 through A12 and B1 through B12. See **Table 1**.

Connector #2 has 32 cavities, numbered C1 through C16, and D1 through D16. See **Table 2**.

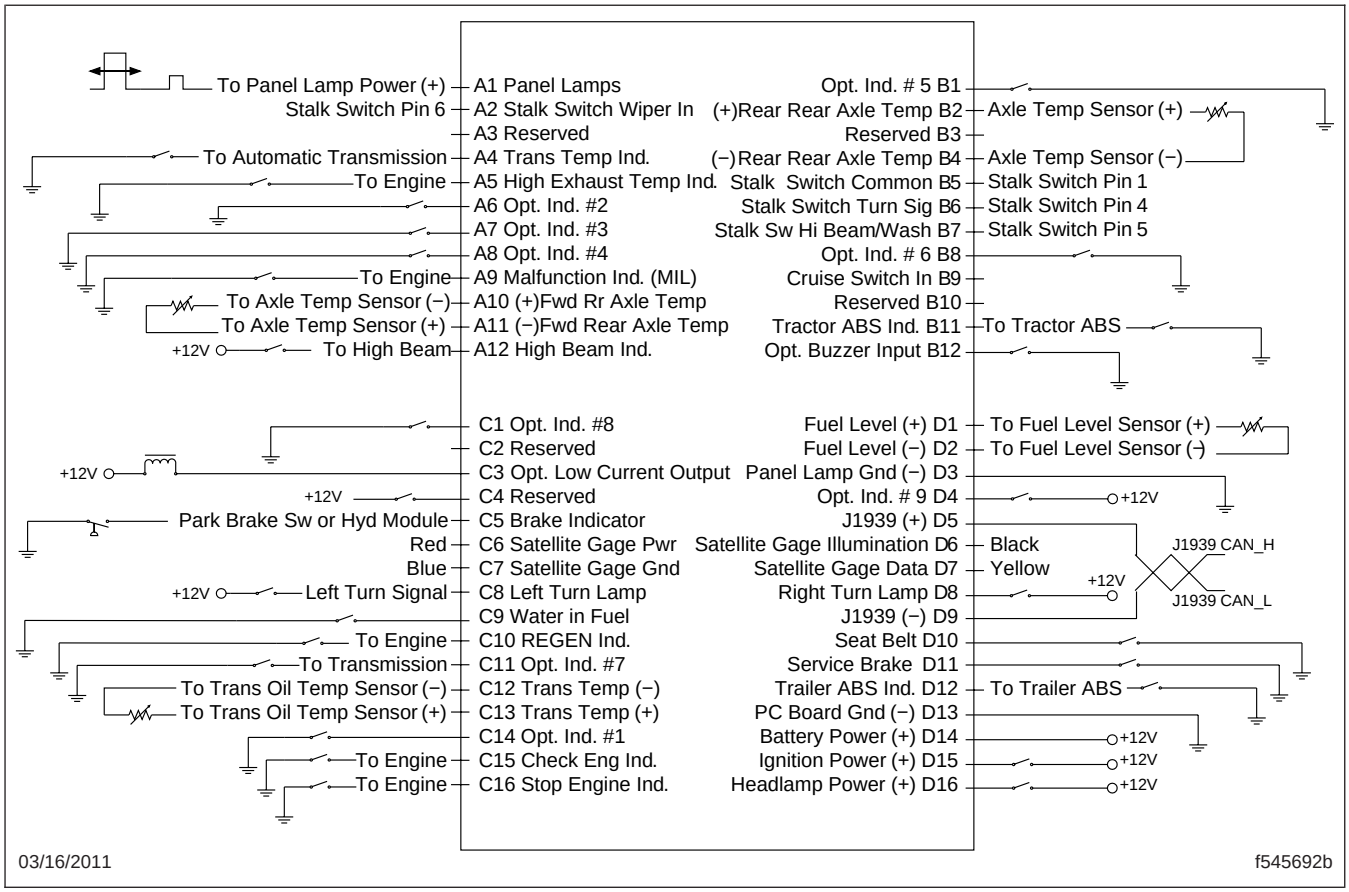


Fig. 1, ICU3 Overview Schematic

ICU3 Connector #1 Pin Assignments, Pins A1 Through B12		
Pin	**Description**	**Wire**
A1	Panel Backlight Power (+)	29A
A2	Multifunction Turn Signal Switch Wiper Input	473C
A3	A3 Reserved	18B
A4	Transmission High Temperature Indicator	30A
A5	High Exhaust Temperature Indicator	492L

Specifications

ICU3 Connector #1 Pin Assignments, Pins A1 Through B12		
Pin	**Description**	**Wire**
A6	Washer Level	320A
A7	Preheater Relay #1 Coil Signal (optional indicator #3)	431B1
A8	Optional Indicator #4	—
A9	MIL	492H
A10	Fwd Rear Axle Temperature (+)	42
A11	Fwd Rear Axle Temperature (–)	42G
A12	High Beam Indicator	222A
B1	Wheel Spin Warning Lamp (optional indicator #5)	376S
B2	Rear Rear Axle Temp Sensor (–)	43
B3	Reserved	
B4	Rear Rear Axle Temp Sensor (+)	43G
B5	Multifunction Turn Signal Switch Common Input	473
B6	Multifunction Turn Signal Switch Turn Signal Input	473A
B7	Multifunction Turn Signal Switch High Beam/Washer Input	473B
B8	Optional Indicator #6	—
B9	Cruise Control Switch Input	440D
B10	Reserved	—
B11	Tractor ABS Indicator	376L
B12	Optional Buzzer Input	29G

Table 1, ICU3 Connector #1 Pin Assignments, Pins A1 Through B12

ICU3 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
C1	Idle Management	472N
C2	Reserved	—
C3	Reserved	—
C4	Reserved	—
C5	Park Brake Indicator	125S
C6	Satellite Gauge Drive Power	437A
C7	Satellite Gauge Drive Gnd	GND
C8	Left Turn Indicator	38J
C9	Water In Fuel Indicator	286
C10	REGEN Indicator	492J
C11	Check Transmission	497A
C12	Transmission Oil Temperature (–)	30G

ICU3 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
C13	Transmission Oil Temperature (+)	30
C14	Optional Indicator #1	—
C15	Check Engine Warning Lamp	440A
C16	Stop Engine Warning Lamp	440S
D1	Fuel Level (+)	47
D2	Fuel Level (–)	47G
D3	Panel Backlight Ground (–)	GND
D4	Optional Indicator #9	—
D5	J1939 (+)	1939+
D6	Satellite Gauge Illumination	437
D7	Satellite Gauge Data	437K
D8	Right Turn Indicator	38K
D9	J1939 (–)	1939–
D10	Optional Seat Belt (EPA10)	435
D11	Reserved	—
D12	Trailer ABS Warning Lamp	376F1
D13	ICU System Ground (–)	GND
D14	Battery Power (+)	81
D15	Ignition Power (+)	81C
D16	Headlamp Power (+)	81C

Table 2, ICU3 Connector #2 Pin Assignments, Pins C1 Through D16

Fuel Level Sensor Resistance		
Gauge Reading	**Sensor Resistance in Ohms**	
	Acceptable Range	**Nominal**
Empty Stop	244.0 to 249.0	246.5
Empty	232.0 to 239.2	235.6
1/8	190.8 to 196.9	193.8
1/4	149.6 to 154.5	152.1
3/8	126.1 to 129.0	127.5
1/2	102.5 to 103.5	103.0
5/8	84.4 to 85.7	85.0
3/4	66.2 to 67.8	67.0
7/8	47.8 to 49.2	48.5
Full	29.4 to 30.6	30.0

Table 3, Fuel Level Sensor Resistance

Specifications

Transmission Oil Temperature Sensor Resistance			
Gauge Temperature in °F	Sensor Resistance in Ohms	Gauge Temperature in °C	Sensor Resistance in Ohms
125	3318	60	2490
163	1626	80	1255
200	837	100	680
238	460	120	390
275	267	140	234
313	162	160	145
350	102	180	95

Table 4, Transmission Oil Temperature Sensor Resistance

Axle Oil Temperature Sensor Resistance—Standard Gauge	
Gauge Temperature	Sensor Resistance: ohms
100°F	5933
125°F	3419
150°F	2079
175°F	1283
200°F	837
225°F	557
250°F	380
275°F	267
300°F	190

Table 5, Axle Oil Temperature Sensor Resistance—Standard Gauge

Axle Oil Temperature Sensor Resistance—Metric Gauge	
Gauge Temperature	Sensor Resistance: ohms
30°C	8060
45°C	4465
60°C	2490
75°C	1503
90°C	915
105°C	595
120°C	390
135°C	267

Axle Oil Temperature Sensor Resistance—Metric Gauge	
Gauge Temperature	Sensor Resistance: ohms
150°C	185

Table 6, Axle Oil Temperature Sensor Resistance—Metric Gauge

Cummins DEF Level Sensor Resistance	
Sensor Resistance (Ohms)	Float Distance (mm) From Top Plate
68	<80
112	80
157	97.6
207	115.2
261	132.8
320	150.4
385	168
485	185.6
539	203.2
629	220.8
731	238.4
847	256
981	273.6
1135	291.2
1316	308.8
1532	326.4
1793	344

Cummins DEF Level Sensor Resistance	
Sensor Resistance (Ohms)	**Float Distance (mm) From Top Plate**
2114	361.6
2521	379.2
3052	396.8
3744	414.4
4812	433

Table 7, Cummins DEF Level Sensor Resistance

DDC DEF Level Sensor Resistance	
Sensor Resistance (Ohms)	**Float Distance (mm) From Top Plate**
19804	54
13764	74
10284	93
8074	113
6534	132
5384	152
4497	172
3799	191
3237	211
2762	230
2375	250
2035	270
1748	289
1493	309
1272	328
1076	348
902	368
744	387
601	407
471	426
353	446
240	<446

Table 8, DDC DEF Level Sensor Resistance

rESEt EE Procedure

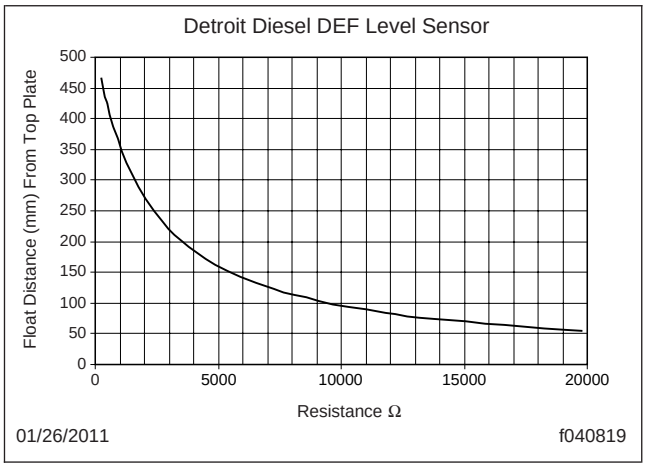
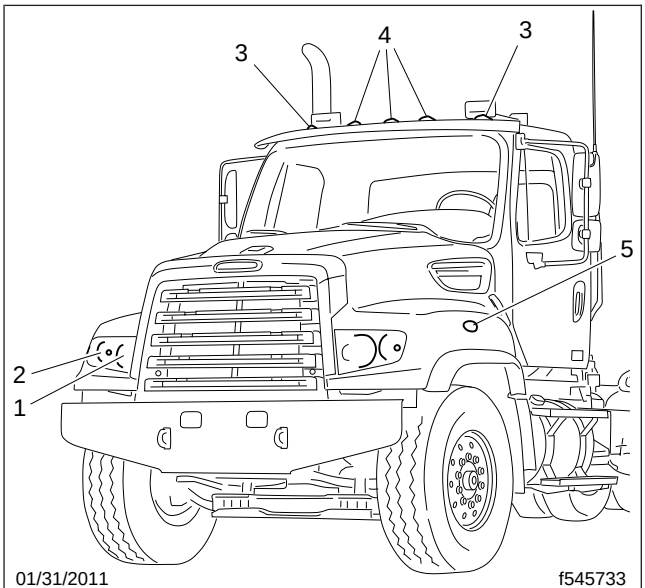


Fig. 7, DDC DEF Level Sensor Resistance

To reset the EE memory in the ICU3, perform the following procedure. This will reset the memory to "forget" all the devices that have been learned.

1. Press the mode/reset button until the display shows SEt UP.
2. Hold the button until the display makes a beep and the word service appears. Depending on the options programmed, some other word may also appear.
3. Hold the button until the display shows rESEt.
4. Press the button once quickly so that EE is also displayed. This is the rESEt EE screen.
5. Hold the button until donE is displayed.

See **Fig. 1** for the locations of the forward exterior lights.



1. Headlight, Low Beam
2. Headlight, High Beam
3. Clearance Lights
4. Identification Lights
5. Side Marker/Turn Signal Light

Fig. 1, Forward Exterior Lights

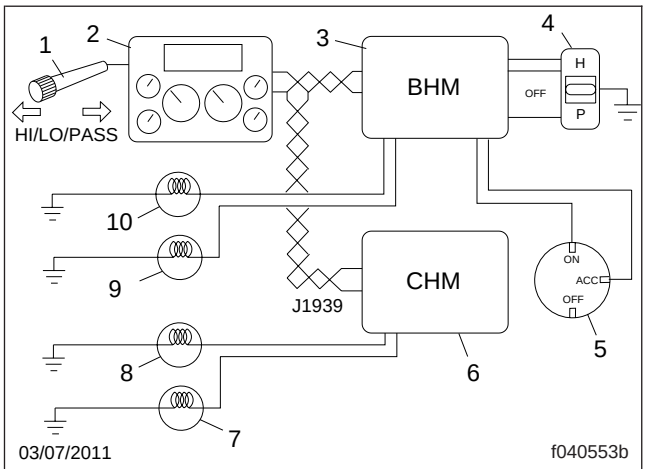
Headlight System

The Bulkhead Module (BHM) takes inputs from the multifunction turn signal switch via a J1939 message from the instrumentation control unit (ICU) as well as the combination headlight/parking light switch, and uses the information to control the headlights. See **Fig. 2**.

Headlight Switch Function

The headlight switch on the dash panel has three positions: off, park (parking lights), and on (headlights). The BHM continuously monitors the position of the headlight switch and broadcasts this information on the J1939 datalink.

There are three circuits that run from the headlight switch to the BHM. One is for the parking lights, the other two are for the headlights. Either of the two headlight circuits running from the switch to the BHM can activate the headlights. The double circuits act as a fail-safe and allow the headlights to work even if one of the two wires is open. See **Fig. 2**.



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Bulkhead Module
4. Headlight Switch
5. Ignition Switch
6. Chassis Module
7. Right Headlight, Low Beam
8. Right Headlight, High Beam
9. Left Headlight, High Beam
10. Left Headlight, Low Beam

Fig. 2, Headlight System Function

The BHM monitors the headlight switch wiring and is capable of detecting error conditions in the headlight switch circuits. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink®.

See **Fig. 1** for the locations of the forward exterior lights on a vehicle with composite headlights.

Headlight Control

The instrumentation control unit (ICU) transmits the multifunction turn signal switch position information via a J1939 message. When the headlight switch is on and high beam or PASS is selected at the multifunction turn signal switch, the BHM activates the left high beam and broadcasts a J1939 message indicating that high beam headlights are commanded on. The CHM controls the right headlight circuit and activates the right high beam. High beams operate only with the ignition on.

The BHM is capable of detecting shorted circuits in the headlight wiring. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink. See **Fig. 2**.

NOTE: If the CHM does not receive J1939 messages from the BHM, the right low beam is activated. If the BHM is in an error state, the left low beam is activated.

Daytime Running Lights

Vehicles can be equipped with daytime running lights (DRL). Daytime running lights are required on vehicles domiciled in Canada. The customer can also request DRL.

IMPORTANT: When adding daytime running lights to a vehicle that was built without DRL, follow the "Adding a Feature" procedure in **Section 54.00, Subject 110**. Adding or changing a reference parameter without following this procedure may have legal consequences for the vehicle owner, which may include fines and having vehicles placed out of service. The regulations in the Federal Motor Vehicle Safety Standards (FMVSS) and Canadian Motor Vehicle Safety Standards (CMVSS) control the illumination intensity of daytime running lights and the required marking of lights used as DRL. Some jurisdictions enforce these regulations during vehicle inspections.

The daytime running lights use either the low-beam headlights or the front turn signal lights, depending on the type of vehicle.

NOTE: A vehicle that uses the low-beam headlights as the DRL cannot be converted to the front turn signal lights as the DRL. The front turn signal lights do not meet the legal requirements for lamp identification for use as DRL.

A vehicle that uses the front turn signal lights as the DRL cannot be converted to the low-beam headlights as the DRL. The headlights will not provide the legally-required illumination intensity.

DRL Using Low-Beam Headlights

Low-beam DRL is activated with the headlight switch off, the ignition on, and the park brake released. When these conditions are met, the BHM activates the left low beam and broadcasts a J1939 message instructing the CHM to activate the right low beam.

When operating as daytime running lights, the low-beam headlights are pulse-width modulated at approximately 85 percent. If the headlight switch is turned on, full battery voltage is supplied to the low beams.

DRL Using Turn Signal Lights

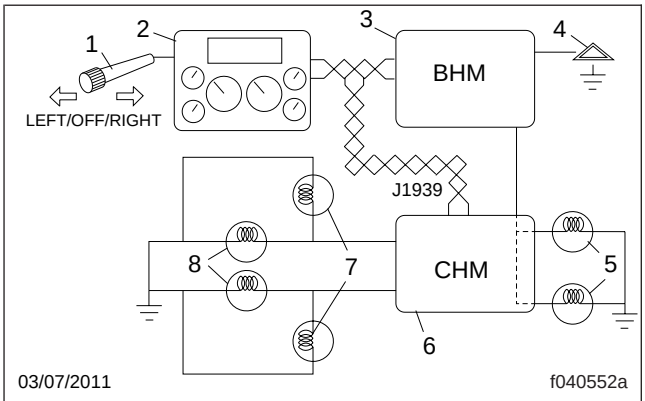
On a vehicle with daytime running lights using turn signal lights, the front turn signals are powered by separate output pins on the CHM. The DRL outputs of the CHM continuously illuminate the front turn signals when the ignition is on, the headlight switch is off, and the turn signals are not active. If the turn signal switch is activated when the DRL is on, the CHM turns on and off the DRL output to the appropriate turn signal.

Turn Signal Lights

The multifunction turn signal switch uses a resistive ladder to supply 3 different voltage values on one circuit to indicate left, right, or no turn signal request. The ICU reads voltage on the multifunction switch turn signal circuit and broadcasts a J1939 message indicating the switch position. The BHM uses this message and the status of the hazard switch to broadcast a J1939 message mandating turn signal lamp control. The CHM uses this message to control the turn signal light output circuits. See **Fig. 3**.

Exterior bulbs that provide turn signal identification often contain dual filaments in order to provide other vehicle lighting such as park lights or marker lights. Exterior turn signals are:

- park/turn signal lights at the front of the vehicle
- side marker/turn signal lights on the front fenders
- taillights at the rear of the vehicle
- raised fender lights (optional) viewable from the front and side of the vehicle



1. Multifunction Turn Signal Switch
2. Instrumentation Control Unit
3. Bulkhead Module
4. Hazard Switch
5. Rear Turn Signal Lights
6. Chassis Module
7. Side Turn Signal Lights
8. Front Turn Signal Lights

Fig. 3, Turn Signal Lights Function

The CHM switches power on and off to all forward turn signals. The BHM operates the rear turn signals by sending pulsed power through the CHM to the taillights. The BHM is capable of detecting short circuits in the turn signal wiring. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink.

Hazard Lights

Hazard lights are also called the four-way flasher lights or four ways. The same bulbs that are used for the turn signals are also used for the hazard lights. The BHM controls the hazard lights using the same strategy as it does for turn signals except that the hazard switch is wired directly to the BHM.

NOTE: The CHM will activate the hazard lights if it does not receive J1939 messaging from the BHM.

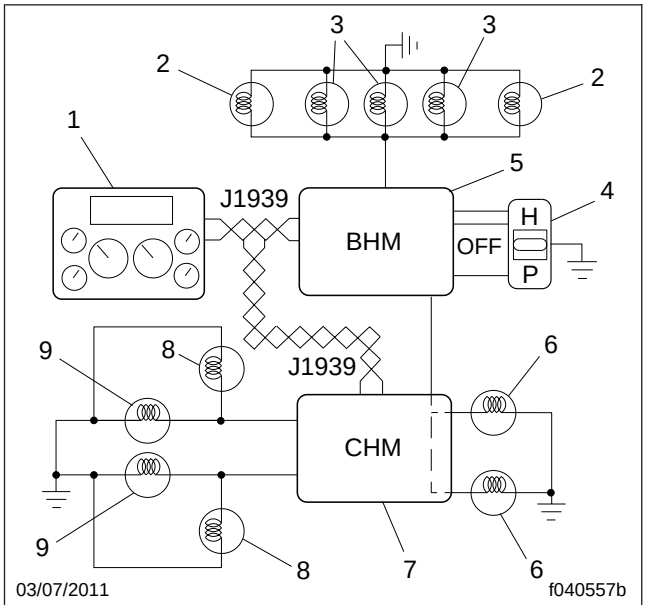
The BHM is capable of detecting short circuits in the right-turn and left-turn signal light wiring. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink. See **Fig. 3**.

Marker Lights

A marker light is any light that indicates the presence of the vehicle. This includes parking lights, taillights, marker lights, identification lights, and clearance lights. See **Fig. 1** for forward maker light locations.

The Bulkhead Module (BHM) continually monitors the position of the headlight switch and broadcasts its position over the J1939 datalink. When the headlight switch is in the headlight or parking light ON position, the BHM supplies battery power to the identification and clearance lights. It also sends battery power through the CHM to the tail lights. The CHM uses the switch position message to control the side marker and park lights.

The BHM is capable of detecting shorted wires in the marker light circuits. Faults detected by the BHM may be reported on the J1939 datalink and may be viewed using ServiceLink. See **Fig. 4**.



1. Instrumentation Control Unit
2. Clearance Light (top of cab)
3. Identification Lights (top of cab)
4. Headlight Switch
5. Bulkhead Module
6. Taillights
7. Chassis Module
8. Side Marker Lights (side of hood)
9. Park Lights (front of hood)

Fig. 4, Marker Lights Function

Variations on Marker Lighting

Marker lights may be programmed or adapted for functionality that differs from the headlight switch. Some common variations of marker light functionality are:

- battery-operated clearance lights
- clearance lights, identification lights, and tail-lights that are on at all times
- clearance lights and identification lights controlled by a marker interrupt switch
- marker lights turn off when the ignition is turned off

When the vehicle is equipped with battery-operated clearance lights, a different harness is used for the clearance and identification lights. The clearance lights are connected directly to the battery splice pack in the vehicle dash, while the identification lights are connected to the BHM.

Vehicles equipped with battery-operated clearance lights are equipped with a battery disconnect switch. The disconnect switch must be turned to the off position to turn off the clearance lights.

Vehicles equipped with marker lights that are programmed to be on at all times are equipped with a battery disconnect switch. These marker lights are turned off by placing the battery disconnect switch to the off position.

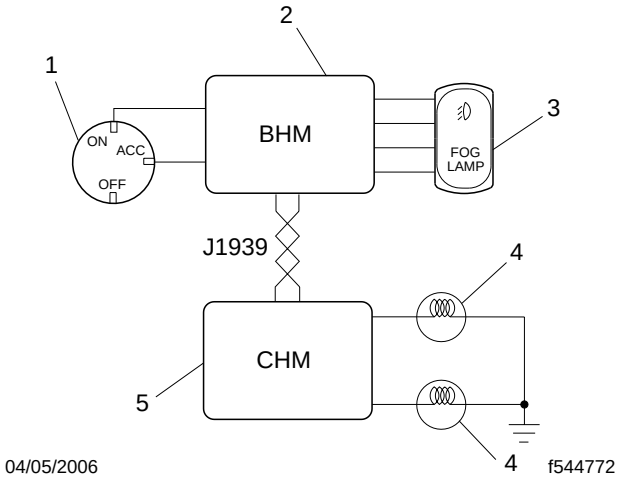
The marker interrupt switch turns on the identification lights, front park lights, side marker lights, and tail-lights when the headlight switch is in the off position. This switch turns off these lights when the headlight switch is in either the park or on positions. The interrupt switch can also be programmed for use with marker lights that are on with the ignition off.

Fog Lights

Fog lights are available as an optional feature. Fog lights may only be activated if the ignition switch is on and the headlight high beams are off.

The fog light switch is a two-position latching smart switch that delivers signals directly to the BHM. When the fog light activation conditions are all met, the BHM broadcasts a J1939 message commanding fog lights on. The CHM controls the fog light output circuits.

The BHM is capable of detecting short circuit faults in the fog lights circuits. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink. See **Fig. 5**.



1. Ignition Switch
2. Bulkhead Module
3. Fog Light Switch
4. Fog Lights
5. Chassis Module

Fig. 5, Fog Lights Function

Snowplow Lights Provision

A provision for installation of snowplow lights is an optional feature. Freightliner does not install snowplow lights or mounting hardware for the lights, only the provision for customer-installed snowplow lights.

A snowplow installed on a vehicle may block the standard vehicle headlights. When this situation occurs, the snowplow light provision allows the customer to install an auxiliary set of headlights and additional park/turn signal lights above the snowplow.

IMPORTANT: The customer installing the snowplow lights is responsible for complying with the regulations regarding snowplow lights and daytime running lights (DRL) functionality in the Federal Motor Vehicle Safety Standards (FMVSS) and the Canadian Motor Vehicle Safety Standards (CMVSS).

When a vehicle is equipped with the snowplow lights provision, the following electrical components are provided with the vehicle:

- dash-mounted PLOW LAMP switch (snowplow light switch)
- snowplow light harness
- upper control module and lower control module mounted in the left, front wheel well

The snowplow lights can only be turned on when the ignition switch is on and the standard headlights are on.

⚠ WARNING

When a vehicle is equipped with snowplow light provision but snowplow lights are not installed, turning the PLOW LAMP switch on turns off both the standard headlights and the daytime running lights using low-beam headlights. Do not turn the PLOW LAMP switch on when snowplow lights are not installed. Doing so could cause an accident resulting in serious personal injury or property damage.

Snowplow Light Control

The snowplow light switch is a two-position, latching smart switch that delivers signals directly to the BHM.

When the snowplow light switch is on and the BHM has determined that the other requirements are met, the BHM broadcasts J1939 messages commanding the snow plow lights on. The CHM signals the upper and lower control modules to switch the headlight output from the standard headlights to the auxiliary headlight connector. The CHM snowplow lights control output is at pin C of the CHM C3 connector. See **Fig. 6**.

The same system of daytime running lights that is used on the standard headlights, whether using the turn signals or the low-beam headlights, is used on the snowplow lights.

The standard lighting circuits are intercepted at the connectors behind the headlights and rerouted through the upper and lower control modules, then back to the headlights.

The two snowplow light connectors are located behind the headlights, one on each side. In addition to the switch headlight output, the snowplow light connectors provide the appropriate turn signal and marker lights, which are active regardless of the snowplow light switch position.

NOTE: The upper control module, which controls the right snowplow lights, and the lower control module, which controls the left snowplow lights, are identical. Both control modules have two 6-pin connectors—one black and one yellow. Make sure that the connectors are paired correctly since the snowplow light harness is not color coded. The snowplow light harness has labels that indicate which connector each branch is intended to connect to. One branch is longer that the other branch. The longer branch is connected to the upper control module.

Daytime Running Lights with Snowplow Lights

When the vehicle is equipped with daytime running lights, the DRL overlay connector connects to the turn signal connector on the snowplow light harness.

Rear Lighting

Typical rear lighting includes:

- stop lights
- turn signal lights
- license plate light
- backup light(s)
- taillights/park lights

All rear-lighting outputs come from the Chassis Module (CHM) via connector C1. The taillights and license lights are directly supplied by the Bulkhead Module (BHM) via a CHM pass-through; the same output controls the cab clearance and identification lights and the front park lights.

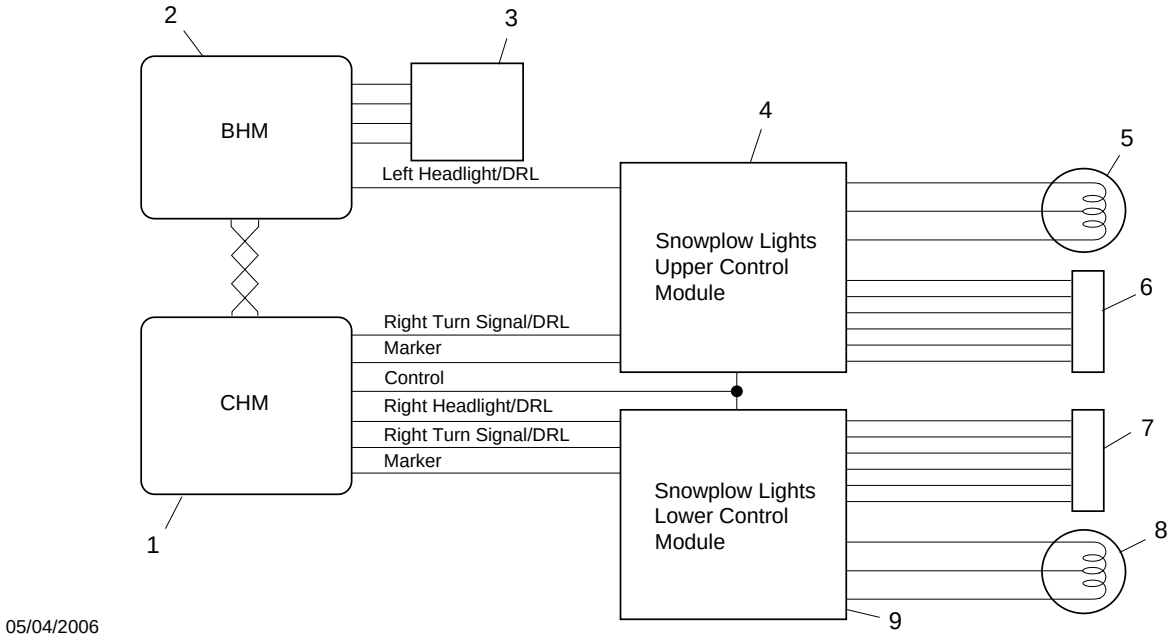
There are two electrical designs for the stop and turn signal lights:

- combination stop/turn signal lights
- separate stop/turn signal lights

Combination Stop/Turn Signal Lights

Combination stop/turn signal lights use a single high-intensity filament of a taillight bulb for stop illumination and turn signal light indication. The CHM controls the high-intensity filament with a single output.

General Information



1. Chassis Module
2. Bulkhead Module
3. Snowplow Lights Switch
4. Upper Control Module for Right Snowplow Lights
5. Right Low- and High-beam Headlights
6. Right Snowplow Light Connector
7. Left Snowplow Light Connector
8. Left Low- and High-beam Headlights
9. Lower Control Module for Left Snowplow Lights

Fig. 6, Snowplow Lights Function

When a vehicle is programmed for combination stop/turn signals, the circuit function operates so that the brake lights are overridden when the hazard lights and/or turn signal lights are on.

Factory-installed rear lights are only provided if a vehicle is ordered with combination stop/turn signal lights; however, the lights can be omitted by requesting a wiring-only provision.

Integral taillights are enclosed lighting assemblies that contain all the rear lights and lighting circuitry. The integral taillights mount on brackets at the rear of each frame rail.

The aft chassis harness connects directly to the left integral taillight via a 5-pin connector. Circuits for the right taillight are wired to a second 5-pin connector on the left taillight housing. See **Fig. 7**.

Individual rear lights are usually mounted along the rear-closing crossmember. Some common harness configurations for individual rear lights are:

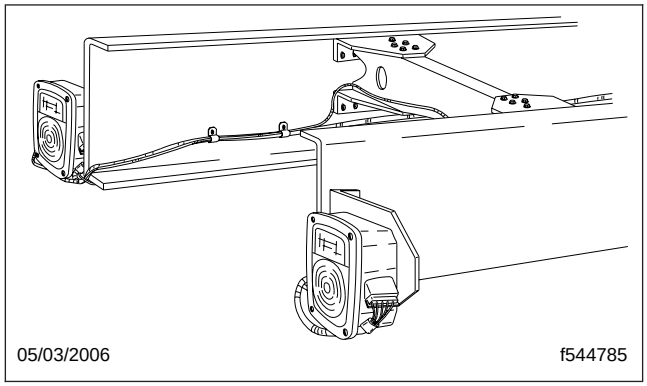


Fig. 7, Integral Taillights

- rear lights with a center backup and license lights
- rear lights with dual backup lights
- rear lights that utilize the taillight jumper

Separate Stop/Turn Signal Lights

A vehicle can be configured for separate stop/turn signal light functionality. A vehicle ordered with separate stop/turn signal light functionality is equipped with only a rear-lighting electrical harness; no rear lights are provided.

Separate stop/turn signal light functionality provides for individual stop and turn signal lights by programming the vehicle to use stop-only outputs and turn-signal-light-only outputs from the CHM.

The harness that is included with separate stop/turn signal light programming connects to CHM connector C1 and routes along the frame rail toward the rear of the vehicle. The harness terminates with a sealed 7-pin connector that contains the rear-lighting outputs for customer adaptation.

Stop Lights

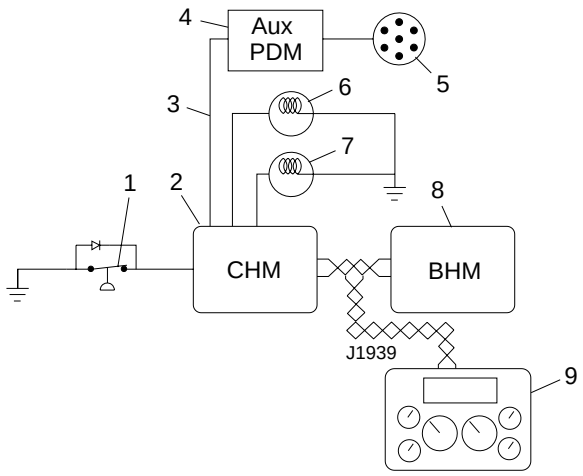
The CHM activates the stop lights when the service brake switch input to the CHM is grounded. The CHM also broadcasts a J1939 message indicating that the brake lights are active.

When the service brake switch or relay grounds the CHM input, the CHM supplies power to the brake light output without any software interaction. This assures stop light activation in the event the microprocessor is in an error state.

On a vehicle equipped with trailer electrical connections, the service brake switch also provides a fail-safe ground to the trailer stop light relay via a circuit board trace in the CHM.

With the service brake switch input grounded, the CHM broadcasts a J1939 message indicating that the stop lights are activated. If the BHM is not awake when this message is sent, the message wakes up the BHM. The BHM broadcasts a service brake status message (part of the CC/VS message) over the J1939 datalink for other ECUs to use. See **Fig. 8**.

On vehicles equipped with hydraulic brakes, the service brake switch input on the CHM is connected through a relay. The relay is controlled by a switch that is mounted to the service brake arm. The stop light relay is mounted in the dash above the base of the steering column. Depressing the service brake closes the stop light switch. The closed stop light switch passes power from a battery-power dash splice pack to the coil of the stop light relay. The



1. Stop Light Switch
2. Chassis Module
3. Trailer Stop Light Relay Signal
4. Auxiliary Power Distribution Module
5. 7-Way Trailer Receptacle
6. Right Stop Light
7. Left Stop Light
8. Bulkhead Module
9. General Datalink Broadcast
10. Instrumentation Control Unit

Fig. 8, Air Brakes Stop Lights

relay energizes and supplies a ground signal to the CHM service brake switch input. See **Fig. 9**.

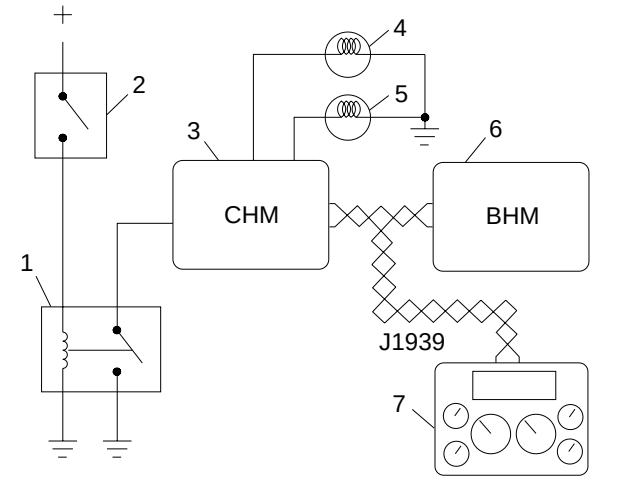
For combination and separate stop/turn signal light functionality, the CHM delivers the stop light outputs from pins L and N of CHM connector C1. With combination stop/turn signal lights, the factory-installed lighting draws 2.1 amps, leaving 5.35 amps available for additional lights. With separate stop/turn signal lights, the outputs at pin L and N are stop-only signals. Since no rear lighting is installed for separate stop/turn signal light functionality, 7.45 amps is available for the left and right stop-only outputs.

The BHM is capable of detecting short circuit in the stop light wiring. Faults detected by the BHM may be reported over the J1939 datalink and can be viewed using ServiceLink.

Backup Lights

Backup lights are activated when BHM Pin B2, G is driven to ground on a manual transmission vehicle,

General Information



1. Stop Light Relay
2. Stop Light Switch
3. Chassis Module
4. Right Stop Light
5. Left Stop Light
6. Bulkhead Module
7. General Datalink Broadcast
8. Instrumentation Control Unit

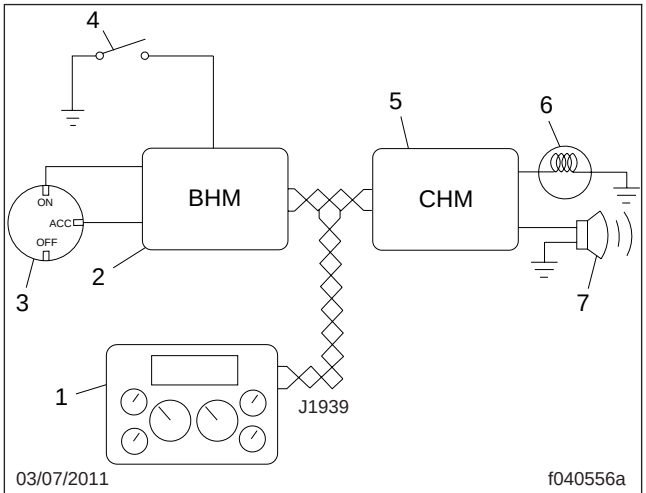
Fig. 9, Hydraulic Brakes Stop Lights

or the BHM receives a "transmission in reverse" J1939 message from the transmission controller. When the BHM determines the vehicle is in reverse, it broadcasts a J1939 message commanding the CHM to activate the backup light(s) and optional audible backup alarm. The backup lights and optional audible backup alarm are connected to three different pins on the CHM connector C1. The maximum combined current capacity for all three pins is 7.45A. See **Table 1**.

The BHM is capable of detecting short circuits in the backup lights/alarm wiring. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink. See **Fig. 10** and **Fig. 11** for backup light mechanization on manual and automated transmissions.

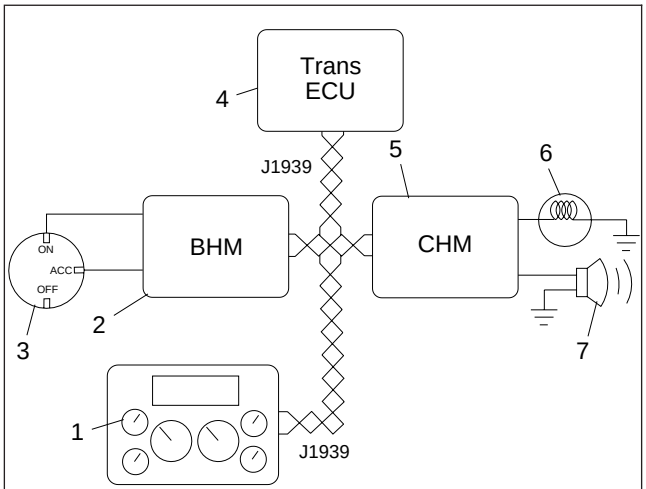
CHM Backup Lights Outputs	
Circuit Description	**Pin Location On CHM Connector C1**
Left Backup Light	A
Backup Alarm	H
Right Backup Light	J

Table 1, CHM Backup Lights Outputs



1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Backup Switch
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 10, Backup Lights on a Vehicle With Manual Transmission



1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Transmission ECU
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 11, Backup Lights on a Vehicle With Automatic or AMT Transmission

See **Table 2** for BHM backup function according to the type of transmission.

Interior Lighting

Interior lighting includes backlighting, dome, and courtesy lighting. Backlighting is the illumination of the instrumentation control unit, gauges, and most of the switch legends.

The Bulkhead Module (BHM) controls the backlighting using a pulse-width modulated (PWM) signal. Pulse-width modulation is a method of controlling the percentage of time that the DC voltage is enabled. For example, a PWM of 80% duty cycle has the signal on 80 percent of the time. See **Fig. 12**.

Courtesy lighting is interior lighting that is turned on by opening a door on the vehicle. Most courtesy lights can also be turned on manually to provide dome/reading lights; however, there are optional door courtesy lights that only provide entrance lighting.

Backlighting

The backlighting function illuminates the dash display and numerous control switches throughout the vehicle cab. Backlighting power is provided to components that include, but are not limited to the:

- instrumentation control unit
- HVAC control panel
- headlight switch
- smart switches
- cruise control switches
- power door lock/window/mirror switches
- transmission dash shifter

Backlighting levels are controlled by a pulse-width modulated signal from the BHM. Backlighting voltage to the components can vary between 10 and 90 percent of battery voltage.

The panel light increase/decrease switch is a two-position, momentary switch that controls the intensity of the backlighting. When upper part of the switch, labeled INCR+ is pressed, a ground circuit to the BHM is completed, indicating a request to increase the backlighting. When the lower part of the switch, labeled DECR– is pressed, a different pin at the BHM is grounded, indicating a request to decrease the backlighting. See **Fig. 13**.

Backlighting is active with the headlight switch in either the on or park positions, or if the marker interrupt switch is toggled while the headlight switch is in the off position.

The BHM monitors the backlighting circuit and is capable of detecting a short circuit when the backlighting output is active. Faults detected by the BHM may be reported over the J1939 datalink and may be viewed using ServiceLink.

Courtesy Lighting

Courtesy lights include:

- dome lights
- reading/map lights
- door entrance lights
- overhead console lights

Backup Lights Function		
Transmission Type	**Input to BHM**	**BHM Conclusion**
Manual Transmission	Backup switch is closed.	Transmission is in reverse.
Automatic or AMT Transmissions	J1939 message from transmission indicates either: • Current Gear = Reverse • Selected Gear = Reverse • Gear Range = R	Transmission is in reverse.

Table 2, Backup Lights Function

General Information

The number and locations of the courtesy lights varies depending on cab configuration and vehicle options. Courtesy lighting variations range from day cabs with one-switch activation (driver door) of a dome light assembly, to crew cabs with four-switch activation of the dome lights, reading lights, and optional door courtesy lights.

The BHM is capable of detecting short circuits in the courtesy lights wiring. Faults detected by the BHM may be reported on the J1939 datalink and may be viewed using ServiceLink.

Dome Lights

Dome lights are installed in all cabs. The basic dome light has a clear lens and is installed above the rear window. On cabs with an overhead console, there is an optional lighting assembly that contains two dome lights and two reading lights. Additional dome lights located in the headliner are available on crew cabs and extended cabs.

A dome light can be turned on by opening a door or pressing the switch on the dome light. There are two separate power circuits coming from the BHM to the dome light assembly. One circuit from pin A of BHM connector B5 has power at all times and is used to turn the light on when the driver presses the switch on the dome light. The other circuit from pin B of BHM connector B5 is powered when a door is opened. See **Fig. 14**.

The number and location of door switches that activate the dome light(s) vary with cab configuration and vehicle options. On day cabs and extended cabs, the driver door switch is standard and the passenger side door switch is optional. On crew cabs, all four door switches are standard.

Reading/Map Lights

Reading lights are clear lights that are available with:

- The optional lighting assembly on a cab with an overhead console;

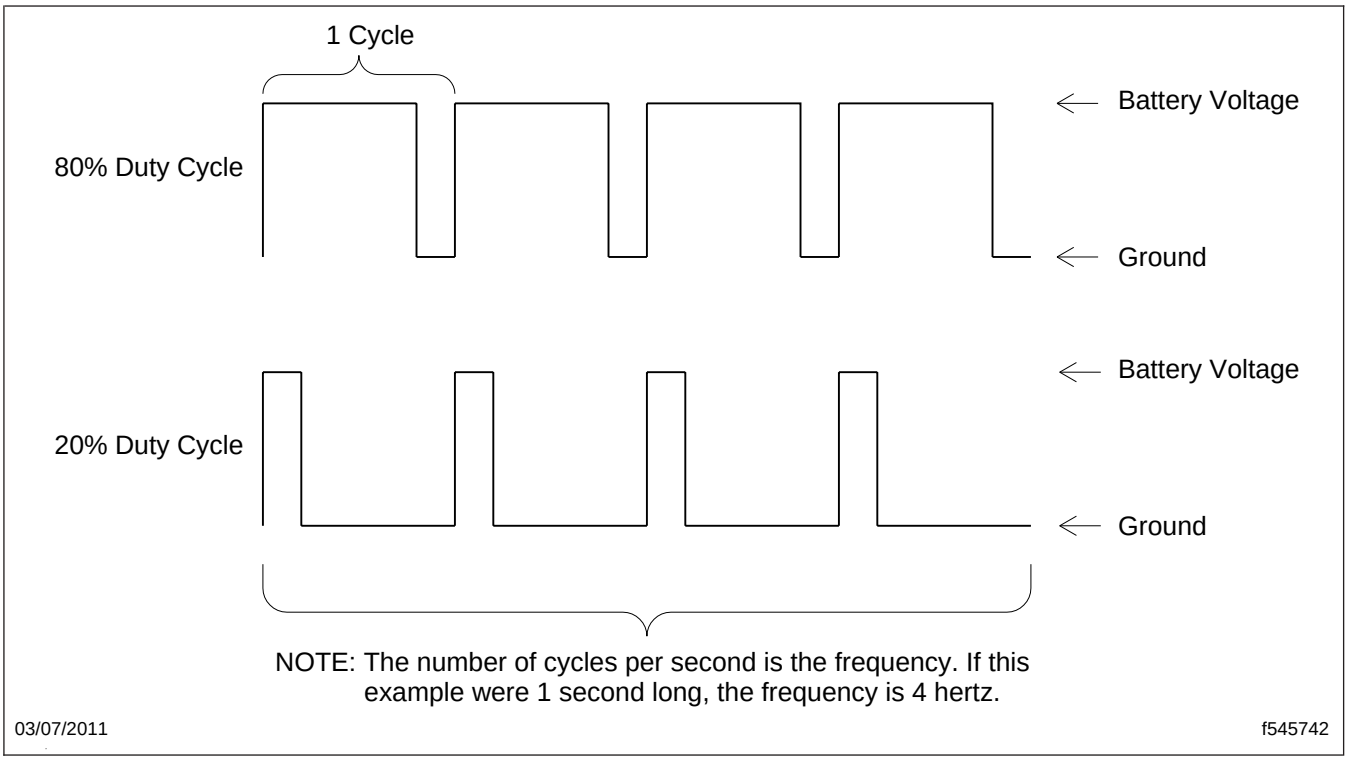
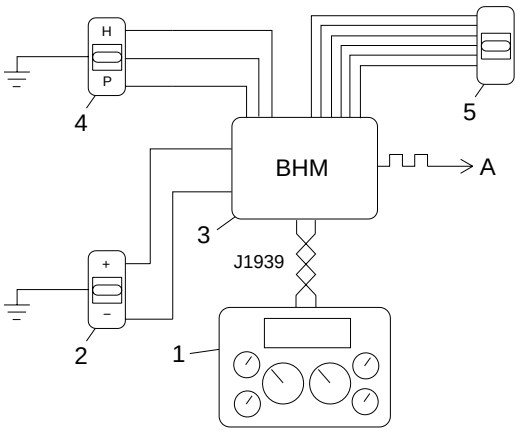


Fig. 12, Pulse Width Modulation



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A. Pulse-width Modulated Signal (illumination feed)

1. Instrumentation Control Unit
2. Dimmer Switch
3. Bulkhead Module
4. Headlight Switch
5. Marker Light Interrupt Switch

Fig. 13, Backlighting Function

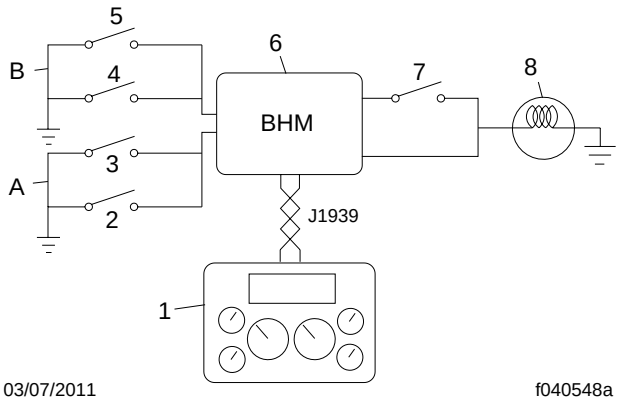
- A crew cab that has optional dome/reading light assemblies.

Map lights are red lights that are available instead of the clear reading lights in the overhead console.

Door Entrance Lights

Door entrance lights are located on the inner door panels. These lights are only activated when a door is opened and can not be turned on manually.

Most cab configurations utilize the dome light output at pin B of BHM connector B5 to activate the door entrance lights. Crew cab configurations use the Chassis Module (CHM) to activate the door entrance lights. For these configurations, the BHM boroad-



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A. Passenger Side B. Driver Side

1. Instrumentation Control Unit
2. Rear Door Switch
3. Front Door Switch
4. Rear Door Switch
5. Front Door Switch
6. Bulkhead Module
7. Dome Light Switch
8. Dome Lamp Bulb

Fig. 14, Dome Light Function

casts J1939 messages requesting courtesy light activation. The CHM then activated the output at pin C of CHM connector C3 to power the door entrance lights.

Current Capacity

If the amperage capacity of the courtesy light circuit is exceeded, the BHM will shutdown the output. When adding additional interior lights are added to a vehicle, do not exceed the current capacity of control module output. See **Table 3** for identification of possible courtesy light outputs and the current capacity of those outputs.

Courtesy Light Outputs				
Module	**Pin**	**Connector**	**Function**	**Current Capacity**
BHM	A	B5	Dome lights battery power	6.7A*
BHM	B	B5	Dome lights and optional door courtesy lights switched power	6.7A

General Information

Courtesy Light Outputs				
Module	**Pin**	**Connector**	**Function**	**Current Capacity**
CHM	C	C3	Door courtesy lights (unused fog light output)	6.7A†

* Pins B5-A and B7-A12 (smart switch battery power) are fed from the same BHM circuit. The maximum combined current capacity for both pins is 6.7A.

† Pins C3-C and C3-D (optional fog light) are fed from the same CHM circuit. The maximum combined current capacity for both pins is 6.7A.

Table 3, Courtesy Light Outputs

Headlight Aim Checking and Adjusting

Before checking or adjusting the headlight aim, complete the following inspection.

- Check that the hood is completely closed, and latched.
- Remove any large amounts of mud or ice present on the underside of the fenders.
- Check the springs for sagging or broken leaves.
- Check the suspension for proper functioning of the leveling mechanism. On cabs with air suspensions, make sure that the height is properly adjusted.
- Check for damage to the hood and hinge assembly. Repair as necessary.
- With the vehicle unloaded, check that the tires are inflated to the recommended air pressure.
- Clean the headlight lenses. Clean by hand only, using a flannel cloth with mild, non-caustic soap or detergent, and water.

Headlight Checking

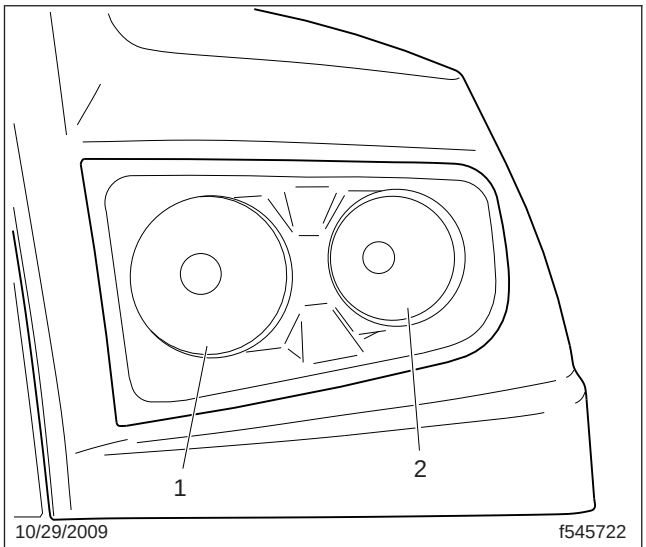
1. Park the vehicle on a level surface, 25 ft (7.6 m) from a screen or wall that can be used for aiming the headlights. Shut down the engine, apply the parking brake, and chock the front tires.

IMPORTANT: The bulb center is indicated by a small circle etched in the center of the headlight lens.

2. On each headlight, find the bulb center. See **Fig. 1**.
3. Measure the distance from the ground to the center of each headlight bulb. Note those distances.
4. On the screen or wall, 25 ft (7.6 m) away, make the appropriate markings directly across from each headlight and at the same height as measured for the headlight. See **Fig. 2**.
5. Turn on the headlights to the low-beam setting. See **Fig. 3** for the ideal and acceptable patterns for both headlights.
    - If either or both headlights do not aim into the inner edges of the centerline shown in **Fig. 3**, follow the adjusting procedure below.
    - If both headlights come close to the inside of each headlight centerline (as shown), no further work is needed.

Adjusting Headlight Aim

The adjusting screw is located on the upper inside corner of the headlight assembly. See **Fig. 4**. Turn the adjusting screw clockwise to raise the beam and counterclockwise to lower it, until the beam pattern meets the acceptable standard.

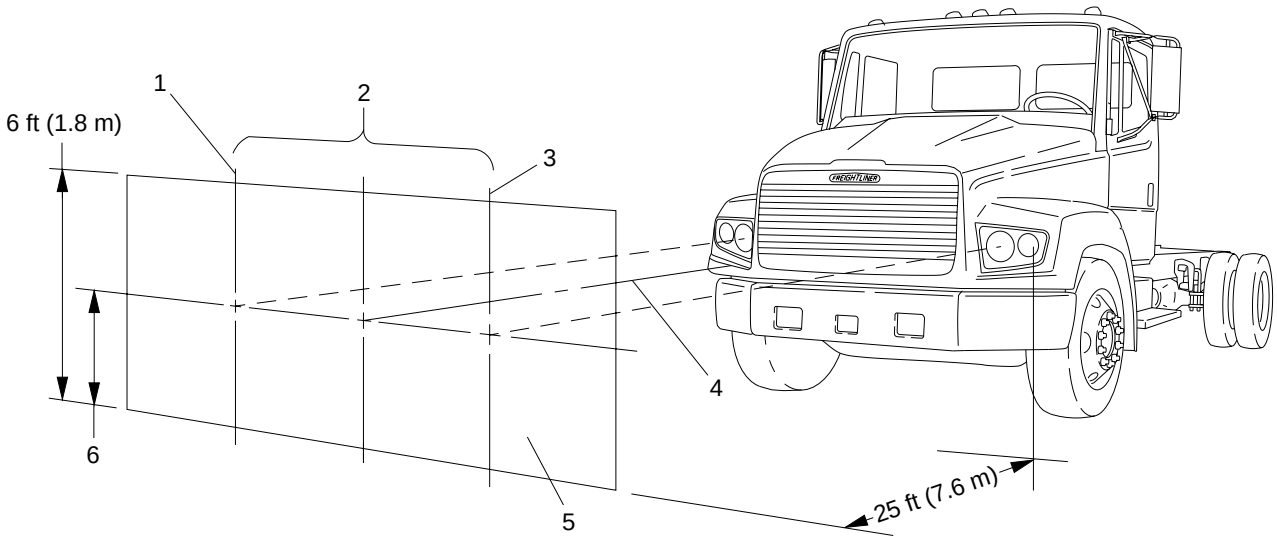


Measure the beam height from the ground to the center of the headlight bulb.

1. High/Low-Beam Headlight
2. Turn Signal

Fig. 1, Headlight/Turn Signal Assembly

Headlight Aim Checking and Adjusting



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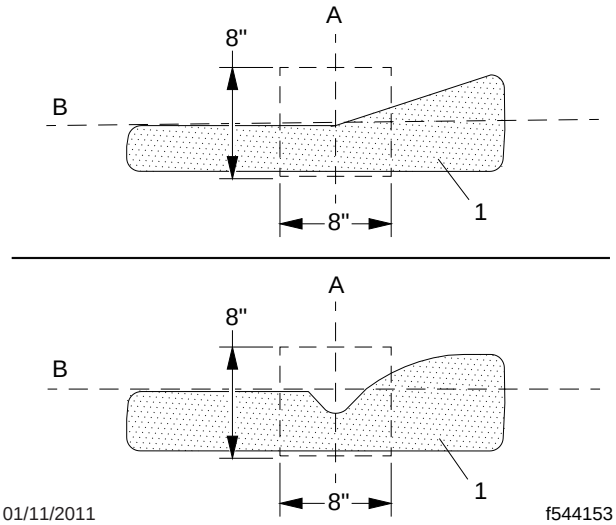
1. Vertical Centerline of Right Headlight
2. Distance Between Headlights
3. Vertical Centerline of Left Headlight
4. Projected Vehicle Centerline
5. Screen or Wall
6. Height of Lamp Centers

Fig. 2, Headlight Aiming Screen or Wall



NOTE: The top view shows the ideal beam pattern; the bottom view shows an acceptable standard.

A. Vertical Centerline
B. Height of Lamp Centers

1. Bright Area

Fig. 3, Headlight Beam Patterns

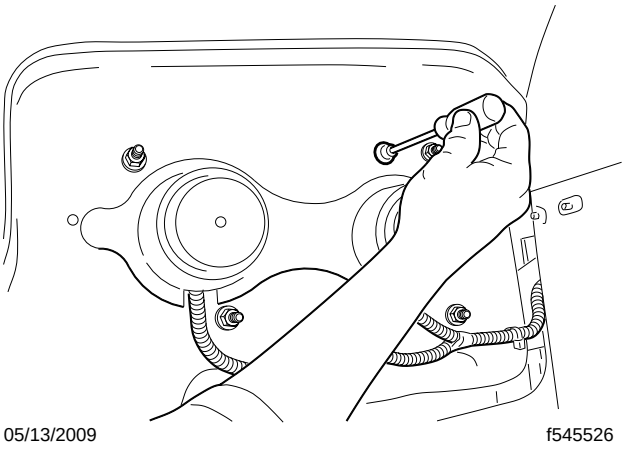
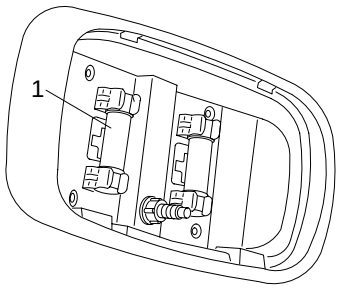


Fig. 4, Headlight Adjusting

Cab Rear Dome Light Bulb Replacement

1. Remove the lens using a flat-blade screwdriver to release the two tabs on the bottom of the lens. Then gently pry the lens from the bottom of the housing.
2. Remove the two bulbs from the lock clips by pulling them straight out. See **Fig. 1**.



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1. Bulb

Fig. 1, Cab Rear Dome Light

3. Press new bulbs into the lock clips.
4. Insert the two tabs on the lens into the slots in the top of the housing, then push the bottom of the lens into place, locking the tabs.

Cab Rear Dome Light Assembly Replacement

1. Remove the lens using a flat-blade screwdriver to release the two tabs on the bottom of the lens. Then gently pry the lens from the bottom of the housing.
2. Insert the screwdriver into the lower slots in the housing to release the two spring clips, then remove the assembly from the headliner.
3. Disconnect the electrical connector.
4. Connect the electrical connector of the new assembly.
5. Align the tabs on the top edge of the new assembly and press the lower edge of the assembly into place until the locking tabs click into place.

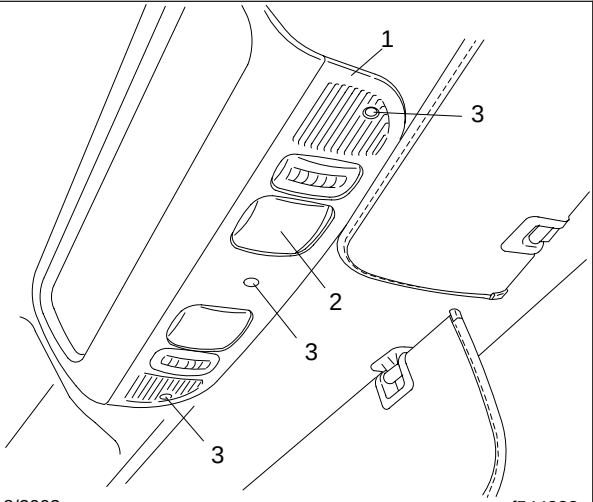
Overhead Console Map/ Reading Light Assembly Bulb Replacement

NOTE: The bulbs are replaceable in the inner larger lights only. The smaller lights use nonreplaceable LEDs.

1. Using a flat-blade screwdriver, release the tab by pushing on the edge of the lens that is indented. Then gently pry the lens from the housing.
2. Remove the bulb from the lock clip by pulling it straight out.
3. Press a new bulb into the lock clip.
4. Insert the tab on the lens into the slots in the housing, then push the lens into place, locking the tabs.

Overhead Console Map/ Reading Light Assembly Replacement

1. Remove the three Torx® capscrews that hold the center overhead panel in place. See **Fig. 2**.



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1. Center Overhead Panel
2. Reading Light With Replaceable Bulb
3. Torx Capscrew

Fig. 2, Overhead Panel With Map/Reading Lights

Interior Lights Replacement

2. Lower the assembly and disconnect the connector to the light assembly.
3. Remove the four capscrews that attach the light assembly to the panel, and remove the light assembly.
4. Using capscrews, install a new light assembly on the panel.
5. Connect the connector to the light assembly.
6. Using capscrews, install the center overhead panel.

Before working on the vehicle, park it on a level surface and shut down the engine. Set the parking brake and chock the front and rear tires.

NOTE: Use gloves or a clean cloth or paper towel when handling halogen bulbs; do not handle them with bare hands. Oil from the skin causes overheating and rapid blowout. If bulbs are handled accidentally, use a cotton swab dipped in rubbing alcohol to remove oil.

Headlights

Headlight and Park/Turn Signal Light Assembly Replacement

1. Open the hood.
2. Remove the headlight splash cover from the rear of the headlight assembly.
3. Disconnect the headlight and park/turn signal light electrical connectors.
4. While holding the headlight assembly in place, remove the four nuts from the mounting studs.
5. Remove the headlight assembly.
6. Place a new assembly on the mounting studs and install the two nuts and washers.
7. Install the upper new headlight assembly into the hood.
8. Install and tighten the 4 nuts onto the mounting studs.
9. Connect the electrical connectors.
10. Verify the proper operation of the lights.
11. Install the headlight splash cover.
12. Check and adjust the headlight aim as described in **Subject 100**.

Headlight Bulb and Front Park/ Turn Bulb Replacement

1. Open the hood.
2. Remove the splash cover from the rear of the headlight assembly.
3. Disconnect the electrical connector.
4. Twist the bulb socket assembly 1/8 turn counterclockwise to remove it from the headlight bucket assembly and access the bulb.
5. Protecting the bulb with gloves or a cloth, unplug it from the socket.
6. Line up the bulb tabs and insert a new bulb into the socket then install the socket into the headlight assembly and twist it 1/8 turn clockwise.
7. Connect the electrical connector.
8. Replace the headlight splash cover and snap it into place.
9. Close the hood.
10. Verify proper operation of the lights.

Cab Clearance and Identification Light Assembly Replacement

1. Access the mounting nuts and electrical connections from inside the cab.
   - 1.1 Remove the left and right overhead map pockets to access the outer two lights.
   - 1.2 Remove the center console/dome light assembly or headliner to access the center three lights.
2. Disconnect the connector.
3. Remove the two mounting nuts and remove the light assembly.
4. Install a new clearance light. Tighten the two nuts to 60 lbf·in (677 N·cm).
5. Seal the hole with silicon sealant.
6. Connect the connector.
7. Replace the headliner or center console/dome lamp and/or map pockets.

Cab Clearance and Identification Light Bulb Replacement

1. From outside the cab, remove the capscrew that attaches the clearance light lens to the base.

Exterior Lights Replacement

2. Lift the lens cover at the rear with a screwdriver, and slide the cover forward off the locking tab.
3. Pull the bulb straight out to remove it.
4. Plug in the new bulb and test for proper operation.
5. Install the lens on the base, making sure that it is fully seated.
6. Secure the clearance light in place with the capscrew.

IMPORTANT: Do not overtighten the capscrew or damage to the lens may occur.

Front Side Marker/Turn Signal Light Assembly Replacement

1. Open the hood.
2. If the harness is being replaced, remove the wire ties securing it at the molded splash guard.
3. Twist the marker/turn signal light connector 1/8 turn counterclockwise to disconnect the connector and harness.
4. Remove the two capscrews that attach the lens to the fender.
5. Remove the marker/turn signal light lens.
6. Using two capscrews, install a new marker/turn signal light lens on the fender.

IMPORTANT: Do not overtighten the capscrews or damage to the lens may occur.

7. Install a new harness, if required, and connect the electrical connector and bulb socket. Twist it clockwise 1/8 turn to secure.
8. If a new harness was installed, secure it to the molded plastic inner wheel well shroud using two tie-straps at the openings. Secure the tie-straps to the connector.

Front Side Marker/Turn Signal Light Bulb Replacement

1. Open the hood.
2. Twist the connector 1/8 turn counterclockwise to unplug the connector and bulb socket.
3. Pull the bulb straight out of the socket to remove it. Push a new bulb straight into the socket to replace it.
4. Insert the connector and bulbs into the lens assembly and turn 1/8 turn clockwise to secure.

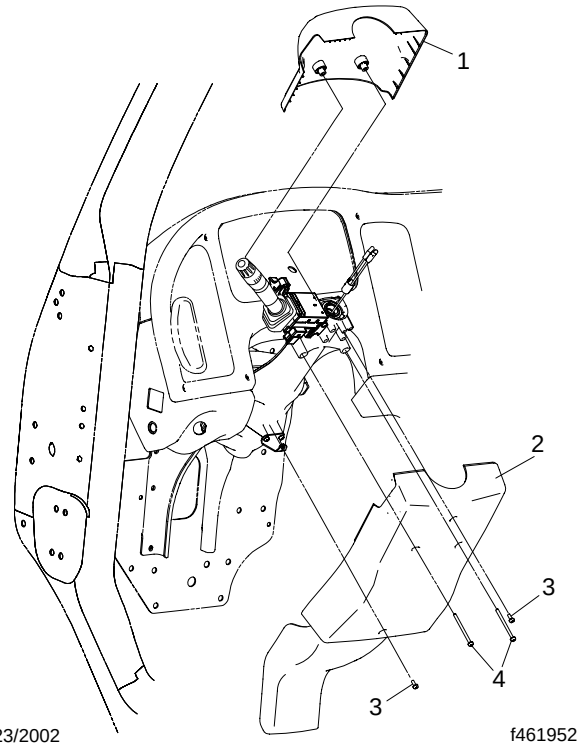
Multifunction Turn Signal Switch Replacement

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The multifunction turn signal switch is mounted on the left side of the steering column, just below the steering wheel.

2. Remove the capscrews that attach the upper and lower clamshell covers to the steering column cover. See **Fig. 1**.

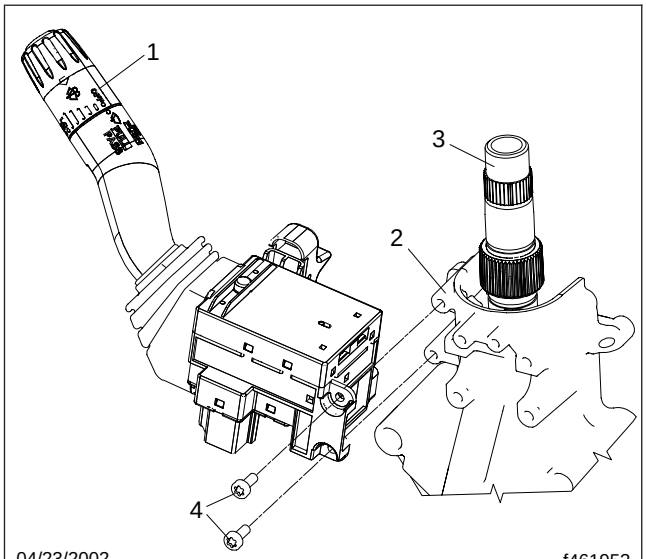


NOTE: Steering wheel shown removed for clarity.

1. Upper Clamshell Cover
2. Lower Clamshell Cover
3. 12-mm Long Capscrew
4. 70-mm Long Capscrew

Fig. 1, Clamshell Covers Installation

3. Remove the capscrews that attach the multifunction turn signal switch to the steering column cover. See **Fig. 2**.
4. Disconnect the two electrical harness connectors from the multifunction turn signal switch, then remove the switch.



1. Multifunction Turn Signal Switch
2. Steering Column Cover
3. Steering Column
4. 15-mm Long Capscrew

Fig. 2, Multifunction Turn Signal Switch Installation

Installation

1. Connect the two electrical harness connectors to the multifunction turn signal switch.
2. Orient the multifunction turn signal switch and use two capscrews to attach the switch to the steering column cover. Torque 7 lbf·ft (9 N·m).
3. Using four capscrews, attach the upper and lower clamshell covers to the steering column cover.
4. Connect the batteries.
5. Verify the operation of the switch functions.

IMPORTANT: Use ServiceLink® to troubleshoot the electrical system. For specific circuit and pin information for how the vehicle is wired, go to the Configuration screen in ServiceLink and select the specific function in which you are interested.

To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

Headlight Switch

Input and Output Conditions

See **Table 1** for the Bulkhead Module (BHM) responses to the headlight switch input/output conditions.

Fault Conditions

See **Table 2** for the headlight switch circuit conditions that will create a fault. In these conditions, the BHM assumes the headlight switch status is on. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

Headlight Switch Input/Output Conditions					
Headlight Switch Inputs to BHM			Outputs from BHM		
Park Lights Signal	Headlight On 1 Signal	Headlight On 2 Signal	Headlight Switch Status	J1939 Headlight On/Off Message	J1939 Headlight Park Message
Open	Open	Open	Off	Off	Off
Closed	Open	Open	Park	Off	On
Open	Closed	Open	On	On	On
Open	Open	Closed	On	On	On
Open	Closed	Closed	On	On	On
Closed	Open	Closed	On*	On	On
Closed	Closed	Open	On*	On	On
Closed	Closed	Closed	On*	On	On

* These are error conditions. For more information see "Fault Conditions."

Table 1, Headlight Switch Input/Output Conditions

Headlight Switch Fault Conditions			
Description of Fault			Action Taken by BHM
Park Lights Signal	Headlight On 1 Signal	Headlight On 2 Signal	
Closed	Closed	Open	BHM may transmit a J1939 fault message.
Closed	Open	Closed	BHM may transmit a J1939 fault message.
Closed	Closed	Closed	BHM may transmit a J1939 fault message.

Table 2, Headlight Switch Fault Conditions

Headlight High Beams

Input and Output Conditions

See **Table 3** for the Bulkhead Module (BHM) responses to the headlight high beams input/output conditions.

Fault Conditions

See **Table 4** for the headlight high beams fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

NOTE: The Flash-To-Pass function of the high beams only operates when the ignition is on and the high beam switch is in the low beam position.

Headlight High Beams Input/Output Conditions				
Inputs to BHM			Outputs from BHM	
Ignition Switch Position	Headlight Switch Position	High Beam Switch Position*	Left High Beam	Right High Beam†
On	On	High Beam/PASS	On	On
On	On	Low Beam	Off	Off
On	Off	High Beam/PASS	Off	Off
Off	On	High Beam/PASS	Off	Off

* Part of the multifunction turn signal switch

† Via J1939 message to the CHM

Table 3, Headlight High Beams Input/Output Conditions

Headlight High Beams Fault Conditions	
Description of Fault	Action Taken by BHM
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transmit a fault message on the J1939 datalink.
Position of multifunction turn signal switch is unavailable or in error.	BHM will assume the multifunction turn signal switch position is low.
BHM fails to receive five consecutive J1939 multifunction turn signal switch position messages from the ICU.	BHM may transmit a J1939 fault message.
BHM receives a J1939 multifunction turn signal switch error message from the ICU.	BHM may transmit a J1939 fault message.
Left high beam wiring shorted.	BHM may transmit a J1939 fault message.
Right high beam wiring shorted.	BHM may transmit a J1939 fault message.

Table 4, Headlight High Beams Fault Conditions

Headlight Low Beams

Input and Output Conditions

See **Table 5** for the Bulkhead Module (BHM) responses to the headlight low beams input/output conditions.

Fault Conditions

See **Table 6** for the headlight low beams fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

NOTE: If the CHM does not see J1939 messages from the BHM, the right low beam is activated. If the BHM fails, the left low beam is activated.

Turn Signal Lights

Input and Output Conditions

See **Table 7** for the Instrumentation Control Unit (ICU) turn signal lights input/output conditions.

See **Table 8** for the Bulkhead Module (BHM) responses to the turn signal lights system input/output conditions.

Headlight Low Beams Input/Output Conditions			
Inputs to BHM		**Outputs from BHM**	
Headlight Switch Position	**High Beam Switch Position***	**Left Low Beam**	**Right Low Beam†**
On	Low Beam	On	On
On	High Beam/PASS	On	On
Off	High Beam/PASS	Off	Off

* Part of the multifunction turn signal switch

† Via J1939 message to the CHM

Table 5, Headlight Low Beams Input/Output Conditions

Headlight Low Beams Fault Conditions	
Description of Fault	**Action Taken by BHM**
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transmit a fault message on the J1939 datalink.
Position of multifunction turn signal switch is unavailable or in error.	BHM will assume the multifunction turn signal switch position is low.
BHM fails to receive five consecutive J1939 multifunction turn signal switch position messages from the ICU.	BHM may transmit a J1939 fault message.
BHM receives a J1939 multifunction turn signal switch error message from the ICU.	BHM may transmit a J1939 fault message.
Left low beam wiring shorted.	BHM may transmit a J1939 fault message.
Right low beam wiring shorted.	BHM may transmit a J1939 fault message.

Table 6, Headlight Low Beams Fault Conditions

Troubleshooting

ICU Turn Signal Lights Input/Output Conditions		
Input to ICU	**Outputs from ICU**	
Multifunction Turn Signal Switch Position	**J1939 Right Turn Message**	**J1939 Left Turn Message**
Left Turn	Off	On
Right Turn	On	Off
Off	Off	Off

Table 7, ICU Turn Signal Lights Input/Output Conditions

Turn Signal Lights System Input/Output Conditions				
Inputs to BHM			**Outputs from BHM**	
J1939 Left Turn Message	**J1939 Right Turn Message**	**Hazard Switch Position**	**Left Turn and Stop Lights**	**Right Turn and Stop Lights**
Off	On	Off	Activated	Deactivated
On	Off	Off	Deactivated	Activated
Off	Off	On	Activated	Activated

Table 8, Turn Signal Lights System Input/Output Conditions

Fault Conditions

See **Table 9** for the turn signal lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

Turn Signal Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Left turn switch position is unavailable or in error.	BHM will assume the J1939 left turn switch position is off.
Right turn switch position is unavailable or in error.	BHM will assume the J1939 right turn switch position is off.
Hazard switch position is unavailable or in error.	BHM will assume the hazard switch is on.
ICU sends an error indicator in the J1939 left turn switch position message.	BHM may transmit a J1939 fault message.
ICU sends an error indicator in the J1939 right turn switch position message.	BHM may transmit a J1939 fault message.
BHM fails to receive five consecutive left turn switch messages from the ICU.	BHM may transmit a J1939 fault message.
BHM fails to receive five consecutive right turn switch messages from the ICU.	BHM may transmit a J1939 fault message.
Left turn signal lights wiring shorted.	BHM may transmit a J1939 fault message.

Turn Signal Lights Fault Conditions	
Description of Fault	**Action Taken by BHM**
Right turn signal lights wiring shorted.	BHM may transmit a J1939 fault message.

Table 9, Turn Signal Lights Fault Conditions

Hazard Lights

Input and Output Conditions

See **Table 7** for the instrumentation control unit turn signal lights input/output conditions.

See **Table 10** for the BHM responses to the hazard lights system input/output conditions.

Fault Conditions

See **Table 10** for the hazard lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

Marker Lights

Input and Output Conditions

See **Table 11** for the Bulkhead Module (BHM) responses to the marker lights input/output conditions.

The marker interrupt switch is optional. If the vehicle does not have a marker interrupt switch, the BHM operates in the same way as if the vehicle has a marker switch that is open (off) all the time.

Fault Conditions

See **Table 12** for the marker lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the headlight switch is turned to off.

Hazard Lights System Input/Output Conditions				
Inputs to BHM			**Outputs from BHM**	
Hazard Switch Position	**J1939 Left Turn Message**	**J1939 Right Turn Message**	**Left-Turn and Stop Lights***	**Right-Turn and Stop Lights***
Off	Off	On	Deactivated	Activated
Off	On	Off	Activated	Deactivated
On	Off	Off	Activated	Activated

* For combination stop/turn lamps. For separate stop and turn lamps, only the turn lamps will be activated.

Table 10, Hazard Lights System Input/Output Conditions

Marker Lights Input/Output Conditions			
Inputs to BHM		Outputs from BHM	
Headlight Switch	Marker Interrupt Switch	Park, Marker, License Plate Lights	Taillights, Identification Lights
Park	Off	Activated	Activated
Park	On	Deactivated	Deactivated
On	Off	Activated	Activated
On	On	Deactivated	Deactivated
Off	Off	Deactivated	Deactivated
Off	On	Activated	Activated

Table 11, Marker Lights Input/Output Conditions

Marker Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Status or position of the headlight switch is in error.	BHM assumes the headlight switch is on, and may transmit a fault message on the J1939 datalink.
Status or position of the marker interrupt switch is unavailable or in error.	BHM assumes that the marker interrupt switch is off, and may transmit a fault message on the J1939 datalink.
Any marker light output wiring is shorted.	BHM may transmit a J1939 fault message.

Table 12, Marker Lights Fault Conditions

Fog Lights

Input and Output Conditions

See **Table 13** for the Bulkhead Module (BHM) responses to the fog lights input/output conditions.

Snowplow Lights Provision

Input and Output Conditions

See **Table 14** for the Bulkhead (BHM) responses to the snowplow light input/output conditions.

Fault Conditions

See **Table 15** for the snowplow lights fault conditions and the resulting actions of the BHM. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted.

If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

Effect of the Snowplow Lights Provision on Forward Lighting System Troubleshooting

Identification of faults in the forward lighting system can proceed normally when the snowplow lights provision is installed and operating correctly. However, problems with the snowplow light control modules and incorrect connections to the snowplow light harness cannot be identified through the J1939 datalink.

A bad snowplow light control module or improper connections can result in one or more lamps not illuminating when directed by the BHM, or in having one or more lamps driven by the incorrect signal. Other indications specifically associated with incorrect connections of the snowplow light harness include relay chatter in one of the snowplow light control modules

or a fault message indicating the park light and/or low-beam output is shorted.

Troubleshooting headlight, turn signal light, and park light operation when the snowplow light provision is present is facilitated by having snowplow lights installed; however, it is possible to do all checks with a digital multimeter to check the snowplow light connector pins instead.

Stop Lights

Input and Output Conditions

See **Table 16** for the Bulkhead Module (BHM) responses to the stop lights input/output conditions.

The service brake switch directly controls the trailer stop light relay. The stop light switch input pin is connected with a circuit board trace directly to the trailer stop light relay pin in the Chassis Module (CHM).

Fog Lights Input/Output Conditions				
Inputs to BHM			Outputs	
Ignition Switch Position	J1939 High Beam Status from ICU	Fog Light Switch	J1939 message from BHM to CHM	Fog Lights
Off	Off	On	Deactivate	Off
On	On	On	Deactivate	Off
On	Off	On	Activate	On

Table 13, Fog Lights Input/Output Conditions

Snowplow Lights Input/Output Conditions		
Inputs to BHM		Outputs from BHM
Snowplow Lights Signal	Headlight Switch Position	Snowplow Lights J1939 Message
Open	On	Off
Closed	On	On
Open	Off	Off
Closed	Off	Off

Table 14, Snowplow Lights Input/Output Conditions

Snowplow Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Snowplow light switch is in error.	BHM will assume the snowplow light switch is off, and may transmit a fault message on the J1939 datalink.
Headlight switch is in error.	BHM will assume the headlight switch is on, and may transit a fault message on the J1939 datalink.

Table 15, Snowplow Lights Fault Conditions

Stop Lights Input/Output Conditions			
Input to BHM from CHM	Outputs from BHM		
Service Brake Switch	J1939 Service Brake Message	Left Stop Light	Right Stop Light
Closed	Depressed	Activated	Activated
Open	Released	Deactivated	Deactivated

Table 16, Stop Lights Input/Output Conditions

Fault Conditions

See **Table 17** for the stop lights fault conditions that create faults. The reference parameters that program the BHM determine whether a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the service brake switch is open.

Diagnostics for a Vehicle With Air Brakes

The stop light switch monitors pressure in the service brake system. Its main purpose is to control the stop lights. This switch closes at approximately 3.5 ±1.5 psi (24 ±10 kPa). See **Table 16** for testing of the stop light switch.

Backup Lights

Input and Output Conditions

See **Table 18** for the Bulkhead Module (BHM) responses to the backup lights input/output conditions.

Fault Conditions

See **Table 19** for the backup lights system conditions that will create a fault. The reference parameters that program the BHM determine whether a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

On a vehicle with an automatic transmission, the BHM has **additional** J1939 fault messages that may be broadcast. Any J1939 fault message may be transmitted until the ignition switch is turned off. See **Table 20**.

Stop Lights Fault Conditions	
Description of Fault	Action Taken by BHM
Left stop light wiring is shorted.	BHM may transmit a J1939 fault message.
Right stop light wiring is shorted.	BHM may transmit a J1939 fault message.

Table 17, Stop Lights Fault Conditions

Backup Lights Input/Output Conditions		
Inputs to BHM		Output from BHM
Ignition Switch	Transmission Status	Backup Lights/Alarm*
On/Acc	Reverse	On
On/Acc	Not Reverse	Off
Off	Reverse	Off
Off	Not Reverse	Off

* Via J1939 message to the CHM

Table 18, Backup Lights Input/Output Conditions

Backlighting

Input and Output Conditions

See **Table 21** for the Bulkhead Module (BHM) responses to the backlighting input/output conditions.

Fault Conditions

See **Table 22** for the backlighting conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until both the headlight switch and the marker interrupt switch are turned off.

Dome Light Fault Conditions

See **Table 23** for the dome light conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink. Fault messages may be transmitted on the J1939 datalink until the ignition switch is turned off.

Backup Lights System Fault Conditions	
Description of Fault	Action Taken by BHM
Ignition switch status is in error.	BHM will assume the ignition switch is in the on position and may transmit a fault message on the J1939 datalink.
Backup lights/alarm wiring shorted.	BHM may transmit a J1939 fault message.

Table 19, Backup Lights System Fault Conditions

Backup Lights System Fault Conditions for a Vehicle With an Automatic Transmission or Automated Mechanical Transmission (AMT)	
Description of Fault	Action Taken by BHM
BHM fails to receive five consecutive J1939 messages from the transmission ECU.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.
Transmission ECU sends an error indicator in the J1939 message to the BHM.	BHM may transmit a J1939 fault message and assume the transmission is in reverse.

Table 20, Backup Lights System Fault Conditions for a Vehicle With an Automatic Transmission or Automated Mechanical Transmission (AMT)

Troubleshooting

Backlighting Input/Output Conditions				
Inputs to BHM		**Outputs from BHM**		
Headlight Switch	**Marker Interrupt Switch**	**Backlight Status**	**Illumination**	**Percent Battery Voltage Output**
On/Park	Off	On	Dependent on dimmer switch position (range dim to bright).	Dependent on dimmer switch position (range 10 to 90%).
Off	On	On	Bright	100%
On/Park	On	Off	Off	0%
Off	Off	Off	Off	0%

Table 21, Backlighting Input/Output Conditions

Backlighting Fault Conditions		
Failed Component or Circuit	**Description of Fault**	**Action Taken by BHM**
Backlight dimmer switch	BHM sees panel light increase and panel light decrease simultaneously.	BHM may transmit a J1939 fault message.
Headlight switch	Headlight switch is in error.	BHM will assume the headlight switch is on.
Marker interrupt switch	Marker interrupt switch is in error.	BHM will assume the marker interrupt switch is off and may transmit a fault message on the J1939 datalink.
Backlighting power output	Backlighting power wiring is shorted.	BHM may transmit a J1939 fault message.

Table 22, Backlighting Fault Conditions

Dome Light Fault Conditions	
Description of Fault	**Action Taken by BHM**
Dome light power (hot at all times) wiring is shorted.	BHM may transmit a J1939 fault message.
Dome light switched (hot with door switch closed) wiring is shorted.	BHM may transmit a J1939 fault message.

Table 23, Dome Light Fault Conditions

Wiring Diagrams

IMPORTANT: The following wiring diagrams provide circuit concepts for the forward lighting electrical system. These details may not correspond to every vehicle. Use EZ-Wiring to access the appropriate schematic for the vehicle.

See **Fig. 1** for wiring details of the control inputs.

See **Fig. 2** for wiring details of the control outputs.

See **Fig. 3** for a wiring diagram of the optional fog lights.

See **Fig. 4** for a wiring diagram of the optional snowplow lights provision.

Circuit Identification

See **Table 1** for a connector face view and pinout chart of the headlight connectors on the forward chassis harness.

See **Table 2** for a connector face view and pinout chart of the park/turn signal light connectors on the forward chassis harness.

See **Table 3** for a connector face view and pinout chart of the side marker/turn signal light connectors on the forward chassis harness.

See **Table 4** for a connector face view and pinout chart of the snowplow light connectors on the snowplow light harness.

Specifications

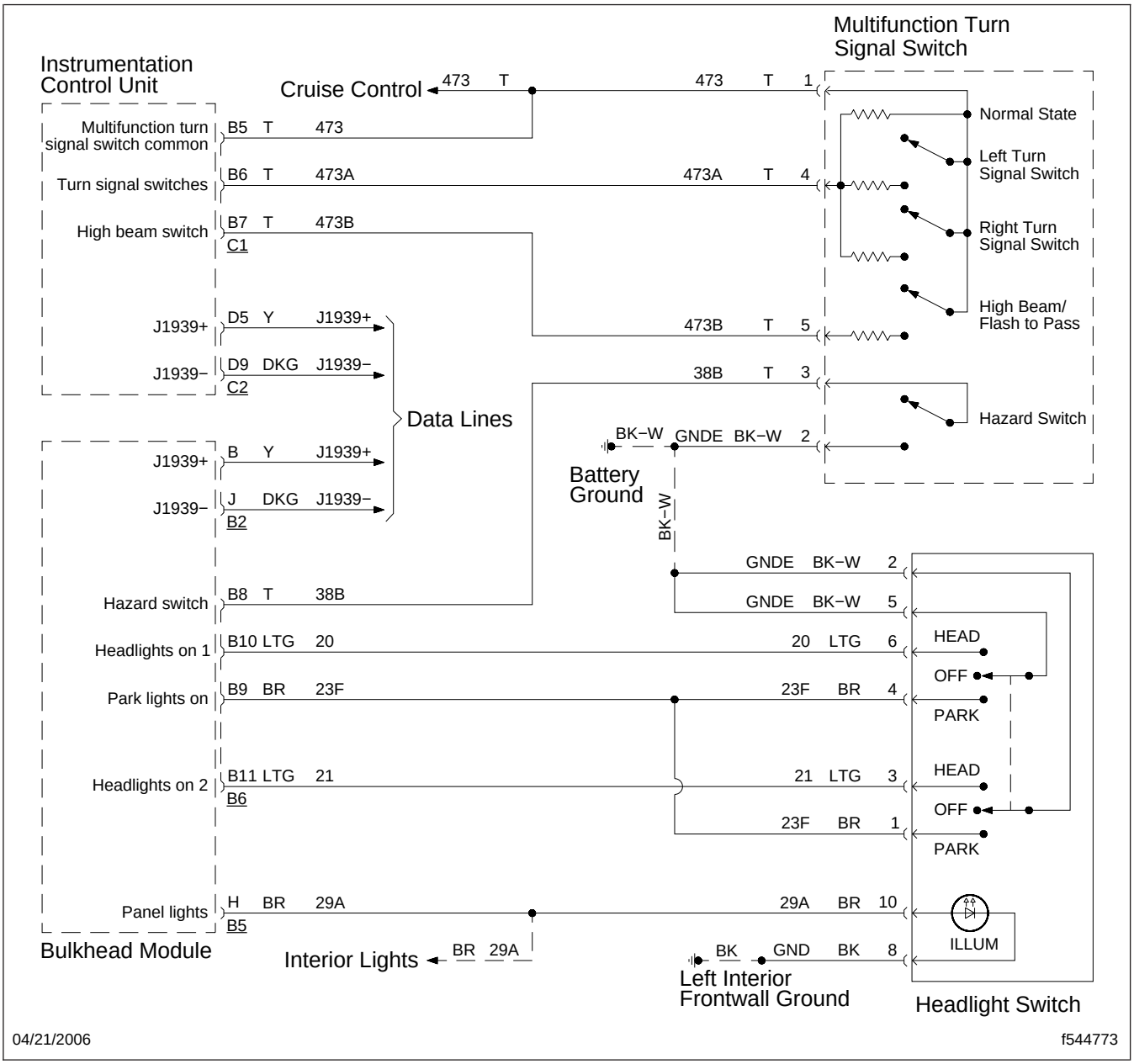


Fig. 1, Forward Exterior Lighting Inputs

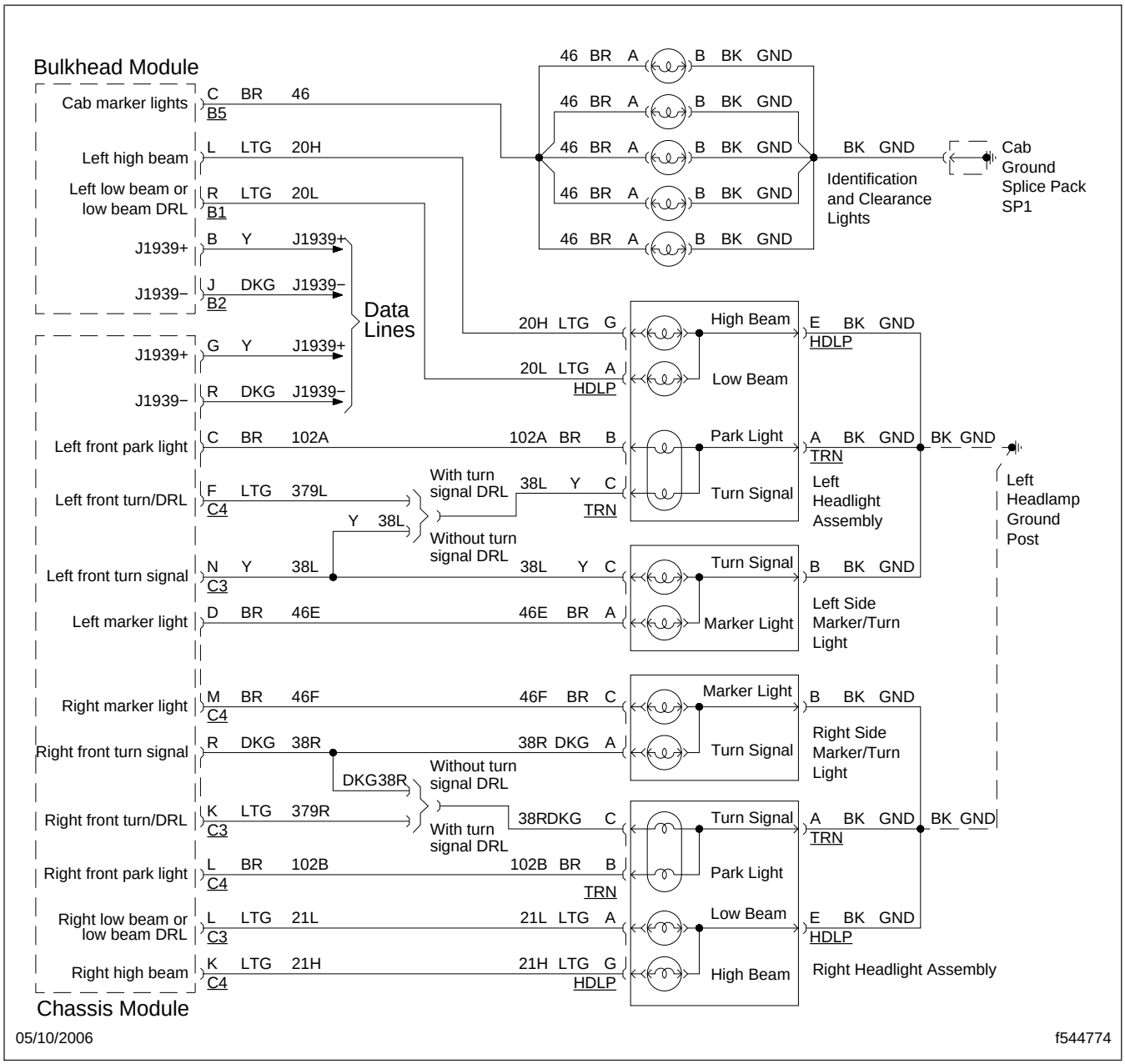


Fig. 2, Forward Exterior Lighting Outputs

Specifications

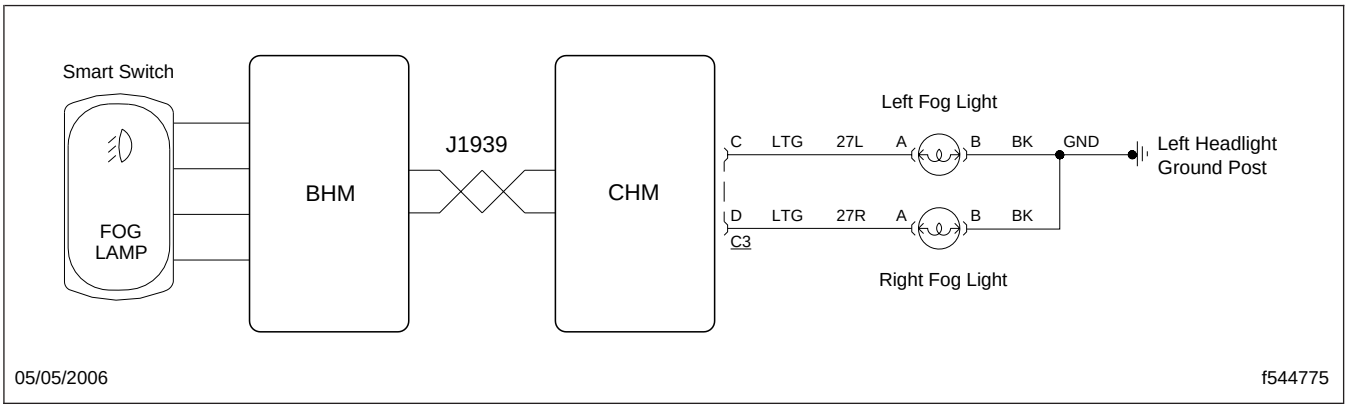


Fig. 3, Fog Lights Wiring Diagram

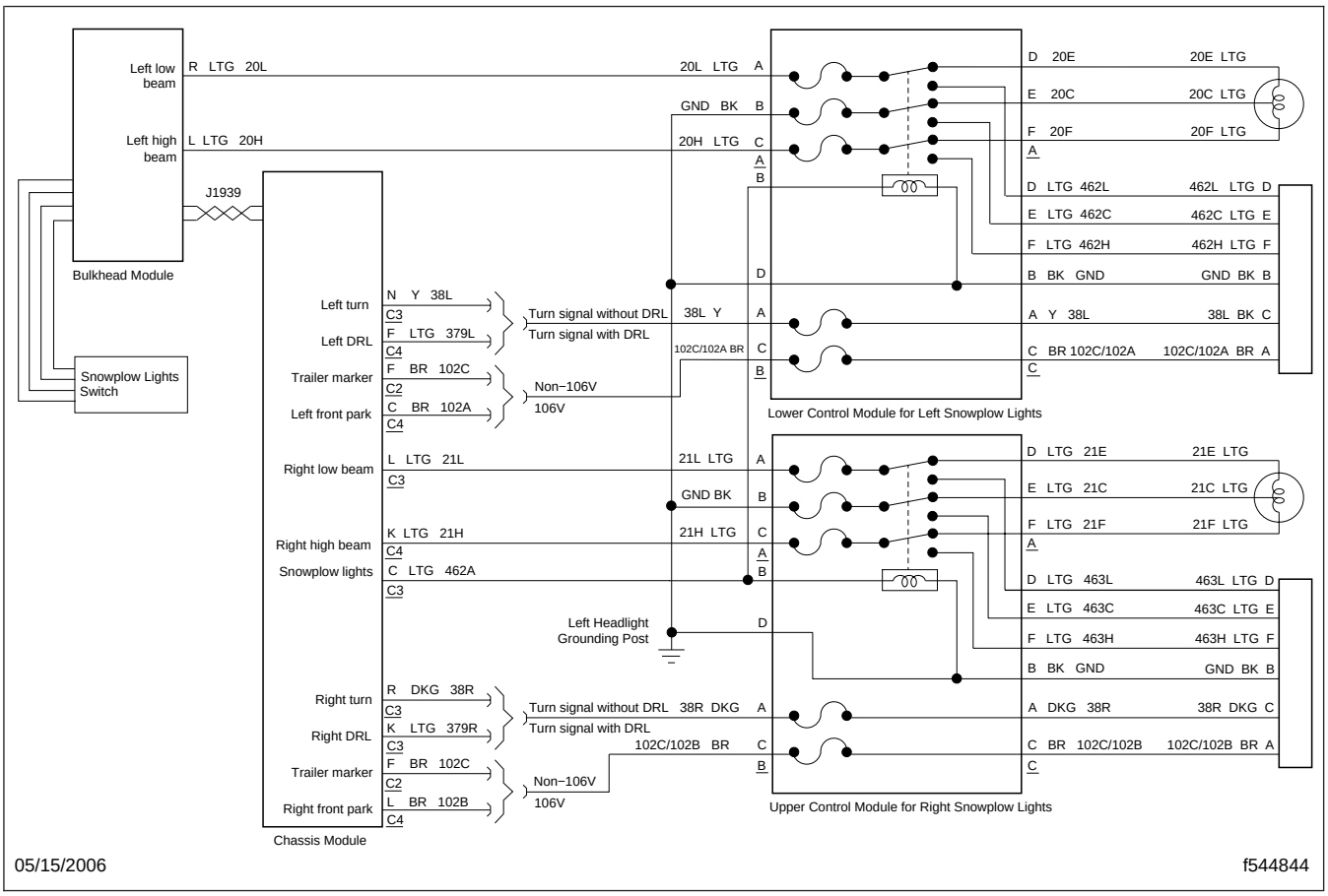


Fig. 4, Snowplow Lights Provision Wiring Diagram

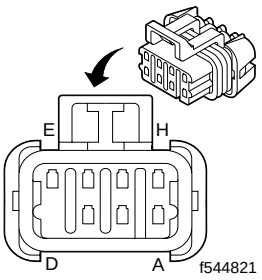
Forward Chassis Harness Headlight Connectors					
Connector Pin	Signal Name	Left Headlight		Right Headlight	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
					
A	Low Beam	20L	LTG	21L	LTG
B	—	—	—	—	—
C	—	—	—	—	—
D	—	—	—	—	—
E	Ground	GND	BK	GND	BK
F	—	—	—	—	—
G	High Beam	20H	LTG	21H	LTG
H	—	—	—	—	—

Table 1, Forward Chassis Harness Headlight Connectors

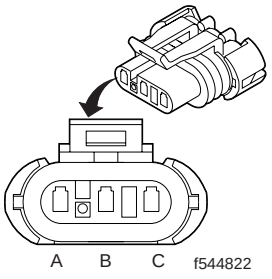
Forward Chassis Harness Park/Turn Signal Light Connectors					
Connector Pin	Signal Name	Left Park/Turn Signal Light		Right Park/Turn Signal Light	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
					
A	Ground	GND	BK	GND	BK
B	Park Light	102A	BR	102B	BR
C	Turn Signal	38L	Y	38R	DKG

Table 2, Forward Chassis Harness Park/Turn Signal Light Connectors

Specifications

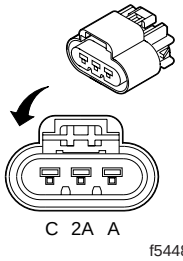
Forward Chassis Harness Side Marker/Turn Signal Light Connectors					
Connector Pin	Signal Name	Left Side Marker/Turn Signal Light		Right Side Marker/Turn Signal Light	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
 f544820					
A	Marker Light	46E	BR	46F	BR
B	Ground	GND	BK	GND	BK
C	Turn Signal	38L	Y	38R	DKG

Table 3, Forward Chassis Harness Side Marker/Turn Signal Light Connectors

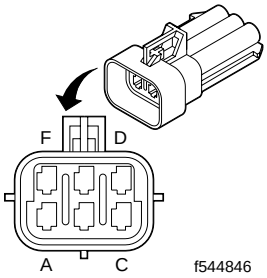
Snowplow Light Connectors					
Connector Pin	Signal Name	Left Side Connector		Right Side Connector	
		Circuit Number	Circuit Color	Circuit Number	Circuit Color
 f544846					
A	Park Light	102C/102A	BR	102C/102B	BR
B	Ground	GND	BK	GND	BK
C	Turn Signal	38L	Y	38R	DKG
D	Auxiliary Low Beam	462L	LTG	463L	LTG
E	Auxiliary Headlight Ground	462C	LTG	463C	LTG
F	Auxiliary High Beam	462H	LTG	463H	LTG

Table 4, Snowplow Light Connectors

Wiring Diagrams

IMPORTANT: The following wiring diagrams provide circuit concepts for the rear lighting. These details may not correspond to every vehicle. ServiceLink® is the diagnostic tool for troubleshooting the electrical system. For specific circuit and pin information on how the vehicle is

wired, use EZ-Wiring to access the appropriate schematic for the vehicle. To troubleshoot specific inputs and outputs of this system, go to the Templates screen in ServiceLink and select the template for the function in which you are interested.

See **Fig. 5** for wiring details of the control inputs for the rear lights.

Combination Stop/Turn Signal Lights

See **Fig. 6** for wiring details of the control outputs for integrated rear lights.

See **Fig. 7** for wiring details of the control outputs for individual rear lights.

Separate Stop/Turn Signal Lights

If an order for a vehicle includes separate stop/turn signal lights functionality, the vehicle is not equipped with rear lights. Only a harness connection that supplies the lighting outputs is provided. See **Fig. 8** for wiring details of the control outputs at the rear lighting connection.

Circuit Identification

See **Table 1** for a connector face view and pinout chart of the CHM Connector C1.

See **Table 2** for a connector face view and pinout chart of the aft chassis harness rear light connector for vehicles with combination stop/turn signal lights.

See **Table 3** for a connector face view and pinout chart of the aft chassis harness rear light connector for vehicles with separate stop/turn signal lights.

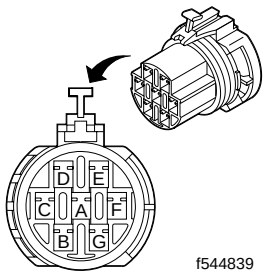
Rear Light Connector (separate stop/turn signal)				
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Color**	**Circuit Number**
 f544839				
A	Backup Light	Output	DKBL	120B
B	Taillights and License Light	Output	BR	23
C	Right Turn Signal Light	Output	DKG	38R
D	Right Stop Light	Output	R-W	39R
E	Ground	Ground	BK	GND
F	Left Turn Signal Light	Output	Y	38L
G	Left Stop Light	Output	R-W	39L

Table 5, Rear Light Connector (separate stop/turn signal)

Specifications

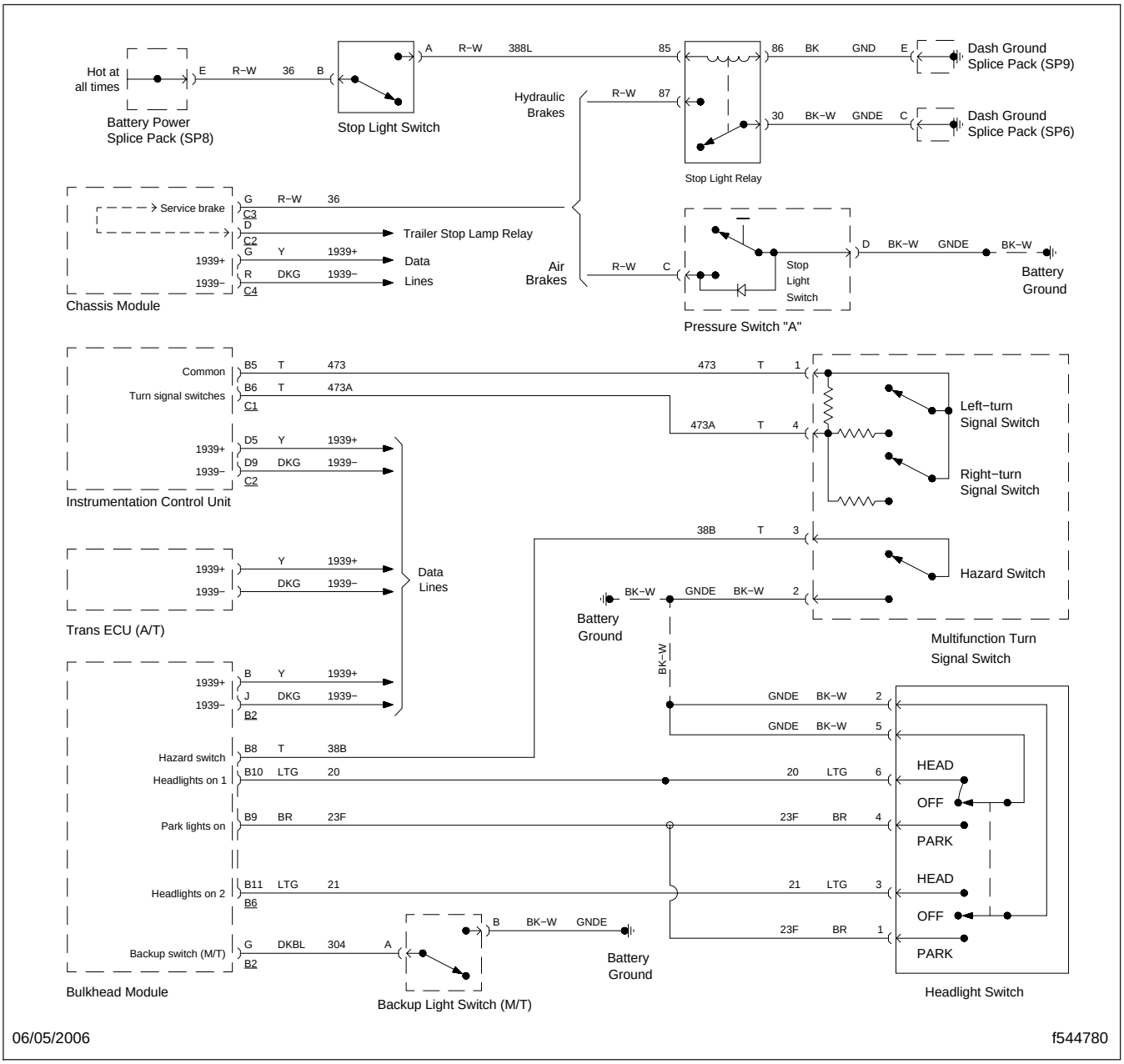


Fig. 5, Rear Exterior Lighting Inputs

Multifunction Turn Signal Switch

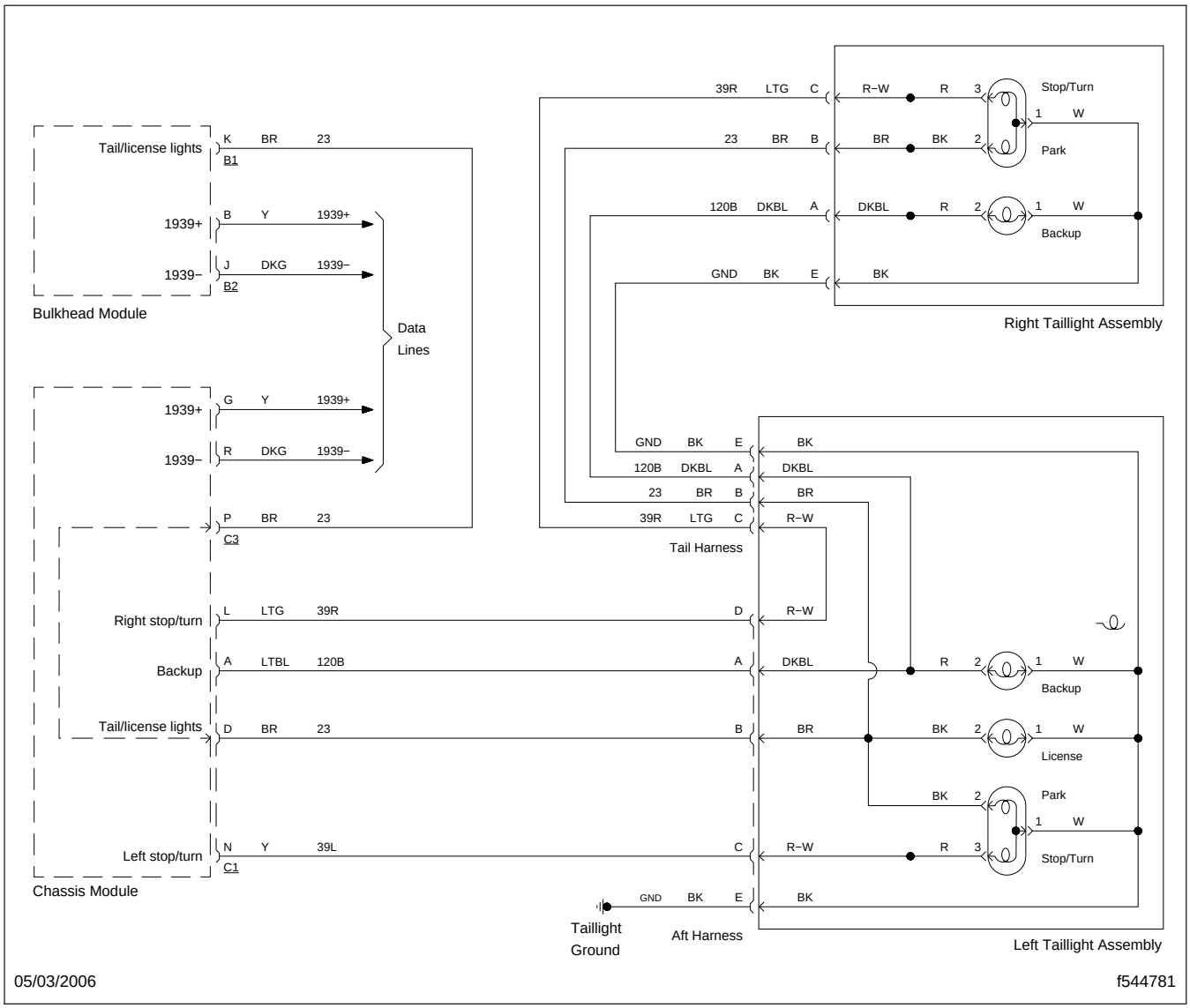


Fig. 6, Lighting Outputs for Integrated Rear Lights (combination stop/turn signal)

Specifications

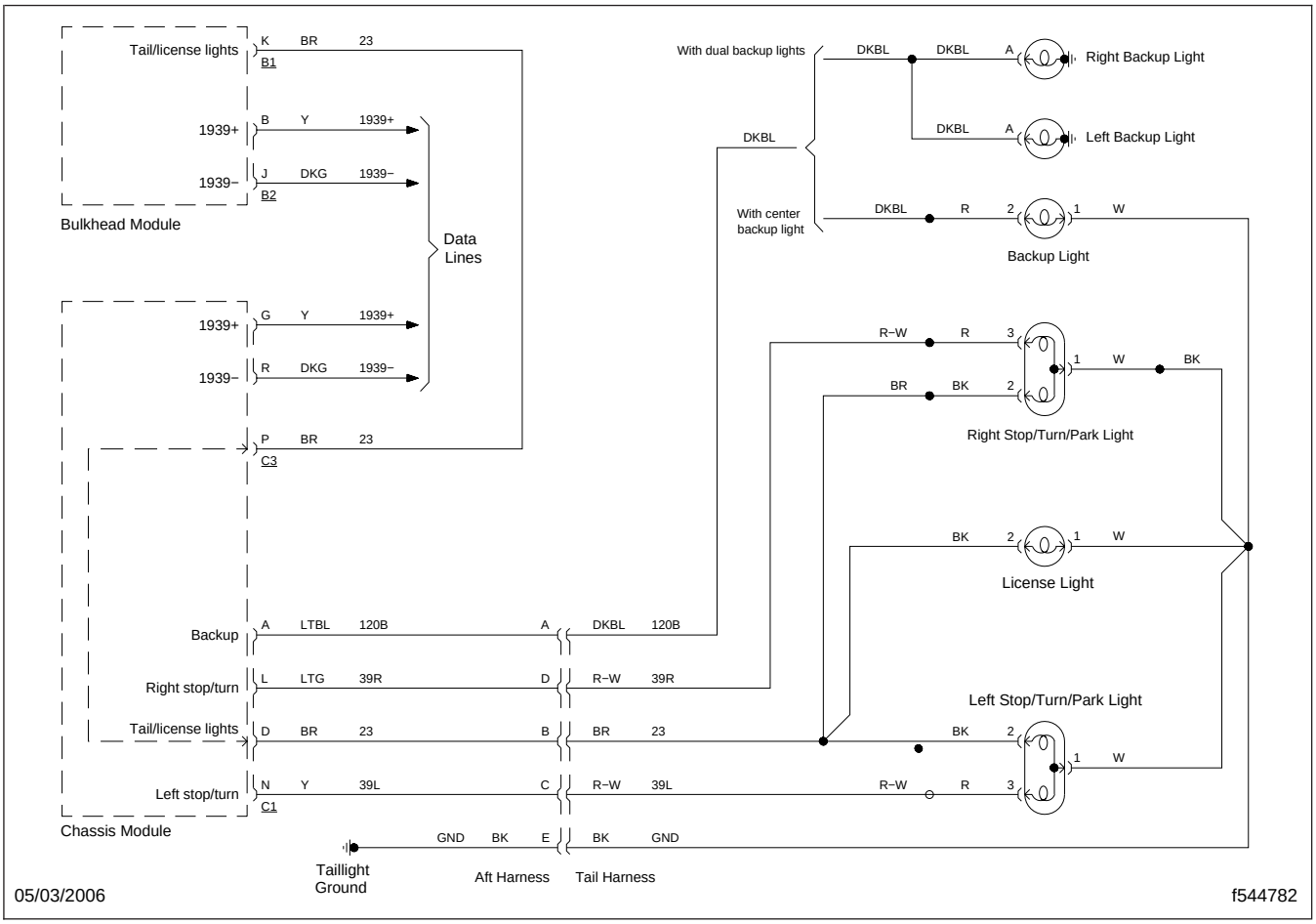


Fig. 7, Lighting Outputs for Individual Rear Lights (combination stop/turn signal)

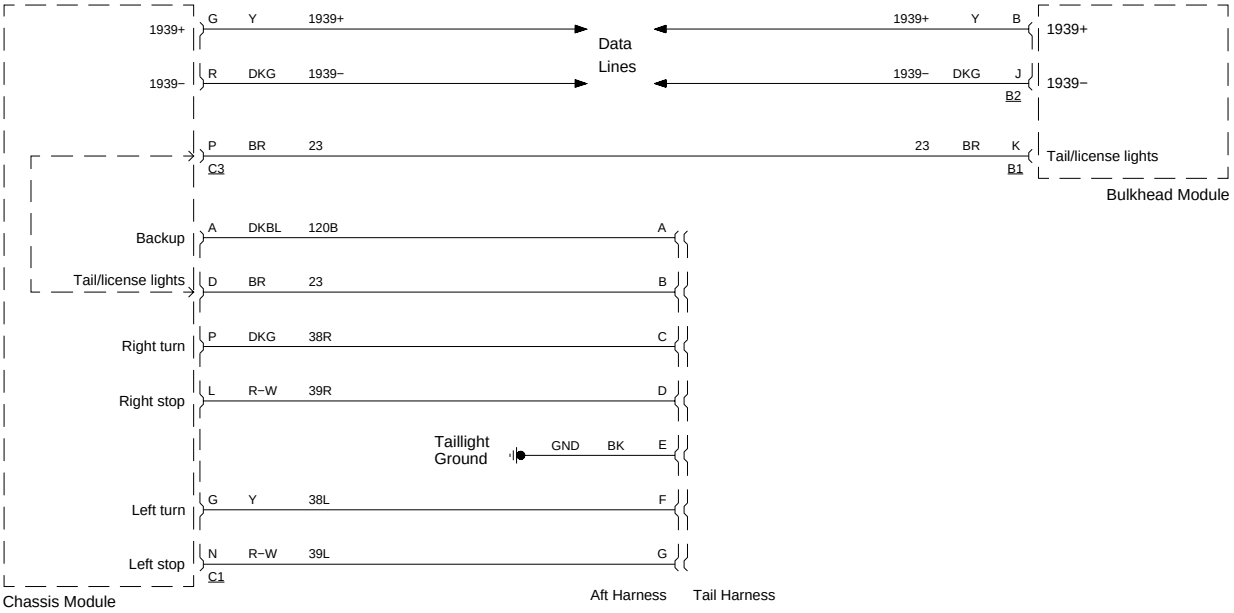


Fig. 8, Rear Lighting Connection (separate stop/turn signal)

Multifunction Turn Signal Switch Resistor Values		
Description	**Resistor**	**Value in Ohms**
Pin 6 Wiper Off (normal position)	R1	24
Pin 6 Wiper Intermittent 1	R2	56
Pin 6 Wiper Intermittent 2	R3	100
Pin 6 Wiper Intermittent 3	R4	160
Pin 6 Wiper Intermittent 4	R5	240
Pin 6 Wiper Intermittent 5	R6	390
Pin 6 Wiper Low Speed	R7	680
Pin 6 Wiper High Speed	R8	1600
Pin 5 Normal Position	R9	1500
Pin 5 Windshield Washer	R10	300
Pin 5 High Beam/Flash High Beam	R11	180
Pin 4 Normal Position	R12	1500
Pin 4 Left Turn Signal	R13	300
Pin 4 Right Turn Signal	R14	180

Table 6, Multifunction Turn Signal Resistor Values

Specifications

Multifunction Turn Signal Switch Resistance Range Values		
Description	**Resistor**	**Resistance Range in Ohms**
Pin 6 Wiper Off (normal position)	R1	23.8 – 24.2
Pin 6 Wiper Intermittent 1	R2	55.4 – 56.6
Pin 6 Wiper Intermittent 2	R3	99.0 – 101.0
Pin 6 Wiper Intermittent 3	R4	158.4 – 161.6
Pin 6 Wiper Intermittent 4	R5	237.6 – 242.4
Pin 6 Wiper Intermittent 5	R6	386.1 – 393.9
Pin 6 Wiper Low Speed	R7	673.2 – 686.8
Pin 6 Wiper High Speed	R8	1584.0 – 1616.0
Pin 5 Normal Position	R9	1485.0 – 1515.0
Pin 5 Windshield Washer	R9 and R10 in parallel	247.5 – 252.5
Pin 5 High Beam/Flash High Beam	R9 and R11 in parallel	159.1 – 162.3
Pin 5 Washer and High Beam	R9, R10 and R11 in parallel	103.6 – 105.7
Pin 4 Normal Position	R12	1485.0 – 1515.0
Pin 4 Left Turn Signal	R12 and R13 in parallel	247.5 – 252.5
Pin 4 Right Turn Signal	R12 and R14 in parallel	159.1 – 162.3

Table 7, Multifunction Turn Signal Switch Resistance Range Values

See **Fig. 9** for a wiring diagram of the multifunction turn signal switch.

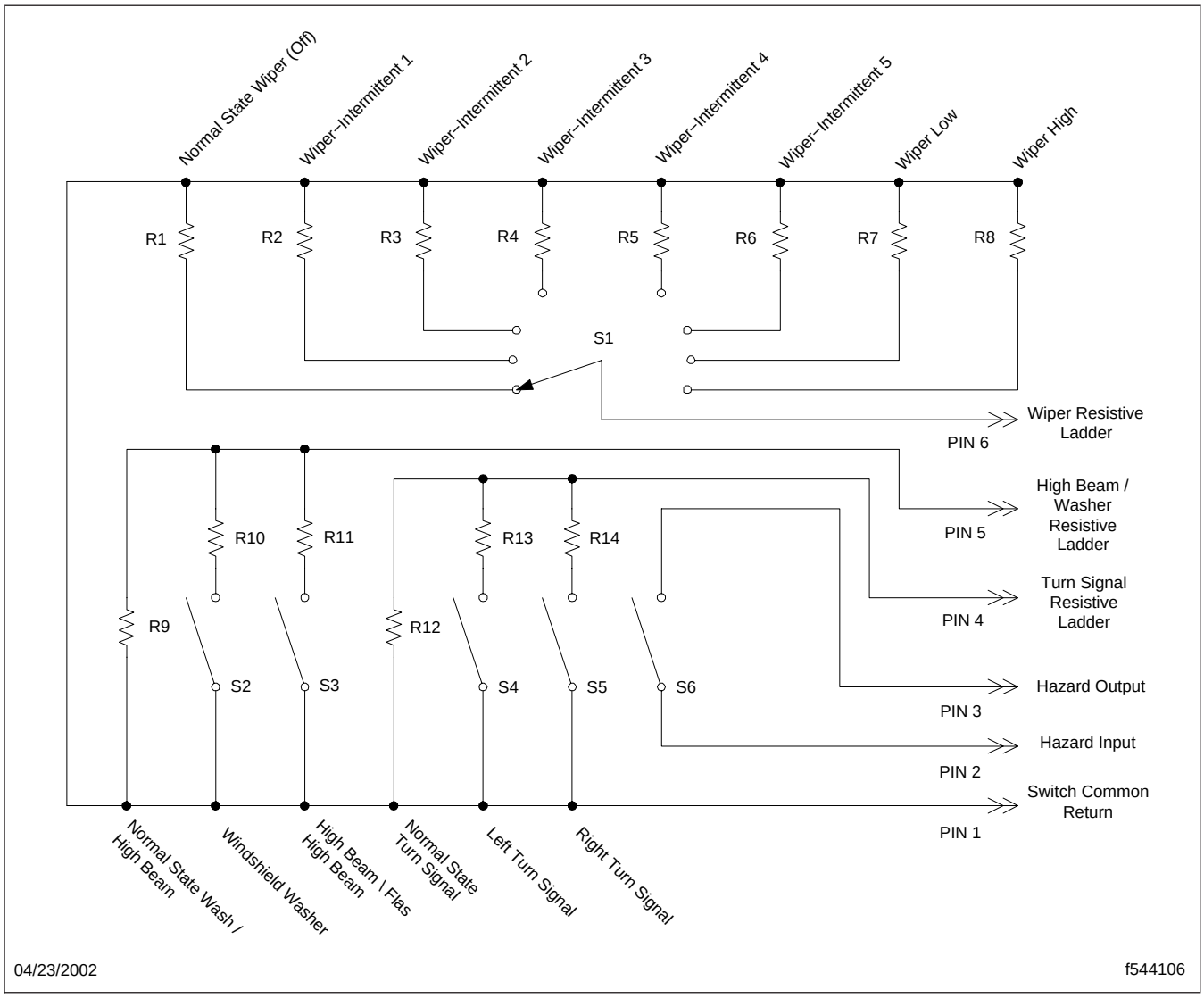


Fig. 9, Multifunction Turn Signal Switch Wiring Diagram

General Information

Lead-Acid Batteries

Batteries are electrochemical devices that store chemical energy. When the battery is connected to an external load, such as a starter, the chemical energy is converted into electrical energy and current flows through the circuit.

The battery has three functions:

- To supply power to start the engine.
- To stabilize the voltage in the electrical system. The battery filters high voltage transients and protects electronic components in the vehicle.
- To supply power when the vehicle's electrical load requirements go beyond what the charging system can supply or when the engine is not running.

All lead-acid batteries use plates made of two unlike metals held apart by separators. One of the metals becomes the positive plate, the other the negative plate. These plates are then grouped in pairs, alternating negative and positive. The groups are connected in series, and each plate group (cell) produces about two volts. Thus, a battery with six cells is a 12-volt battery.

In conventional liquid-electrolyte batteries (wet cells), each battery contains a group of plates immersed in a solution of electrolyte (dilute sulfuric acid).

Batteries may produce hydrogen gas when being charged. The vents allow the escape of gases produced in the battery.

NOTE: Liquid-electrolyte batteries must be kept in an upright position to prevent electrolyte leakage. Tipping a wet cell beyond a 45-degree angle in any direction can allow a small amount of electrolyte to leak out the vent holes.

Proper testing will indicate the battery condition. For more information, see **Troubleshooting 300**.

Absorbed Glass Mat (AGM) Batteries

Absorbed Glass Mat (AGM) batteries are lead-acid batteries in which the electrolyte is contained in a fiberglass mat. AGM batteries are physically similar to standard batteries. Carefully check the label on every battery to be certain it is AGM, and **never install AGM batteries in the same circuit with other types of batteries.**

AGM batteries are designed for high cranking amps and repeated cycle service to accommodate many of the auxiliary loads on vehicle electrical systems. They offer good protection against damage due to vibration, and are leak- and spill-proof, even if cracked or broken. Also, they self-discharge more slowly, and generate less heat when charging or discharging.

IMPORTANT: AGM batteries may be damaged or ruined by equipment designed for other types of batteries. AGM battery chargers must be regulated to a charge voltage less than 15.4 DCV; many chargers provide excessive voltage. To get full service from AGM batteries, carefully follow the battery manufacturer's instructions regarding charging rates and procedures.

Parasitic Battery Drain

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough that the starter will not be able to crank the engine.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off.

A typical parasitic drain falls into the 25 to 325 mA (0.025 to 0.325 amps) range. Multiply the drain (in amps) by the time (in hours) the batteries sit without being recharged. The result is the amount of ampere-hours consumed by the parasitic drain. The actual drain may be small, but over time the batteries grow steadily weaker.

At warm temperature of 77°F (25°C), using approximately 40 percent of the total available ampere-hours will bring fully charged batteries to a no-start condition. In colder temperatures, the batteries will reach a no-start condition sooner.

A vehicle with a 325 mA drain and a fully charged 70 RC battery will last between five and six days. But if the batteries are at only 65 percent of full-charge, they are going to last only two days before causing a no-start condition.

General Information

IMPORTANT: If the batteries begin storage at 90 percent of full charge, reduce the available ampere-hours accordingly.

General Safety Precautions

WARNING

Keep sparks, flames, burning cigarettes, etc. away from batteries. Batteries generate explosive gases, which could cause a battery to explode, causing serious personal injury, including blindness.

When charging the batteries, gas forms in each cell and escapes through the vent holes. In poorly ventilated areas, the gas lingers around the battery several hours after it has been charged. The gas is explosive around sparks, flame, or other intense heat; if ignited, it could cause the battery to explode. Follow these precautions when charging the batteries.

- Wear safety glasses or a face shield when working with batteries. When many batteries are handled, wear rubber gloves and an apron to protect clothing.
- Make sure that the area is well ventilated.
- Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.
- Make sure that the charger cable leads are clean and making good connections. A poor connection could cause an electrical arc which could ignite the gas mixture and explode the battery.
- Do not break live circuits at the terminals because a spark usually occurs at the point where a live circuit is broken. Use care when connecting or disconnecting booster leads or cable clamps on chargers.
- Do not smoke near batteries that are being charged or have recently been charged. Keep the batteries away from open flames or sparks.
- If the battery is frozen, let it reach room temperature and completely thaw before trying to charge it. Check for leaks and cracks before charging the battery. Replace the battery if leaks or cracks are seen.
- Take care that tools or metal objects do not fall across the battery terminals.

WARNING

Do not install any lead-acid battery in a sealed container or enclosure. Allow hydrogen gas caused by overcharging to escape. Exploding hydrogen gas can cause blindness or other bodily injury.

CAUTION

If a metal object connects an ungrounded battery terminal to a nearby metal part of the vehicle which is grounded, it could short out the batteries, causing sparks and possible property damage.

Battery Electrolyte Safety Precautions

WARNING

Protect skin and eyes from battery electrolyte (acid). Electrolyte is corrosive and could result in serious personal injury if splashed on your skin or in your eyes.

If electrolyte is splashed on your skin or in your eye, force the eye open, rinse it with cool, clean water for about five minutes and call a doctor immediately. Do not add eye drops or other medication unless advised by the doctor.

If electrolyte is swallowed, drink several large glasses of milk or water. Follow with milk of magnesia, a beaten raw egg, or vegetable oil. Call a doctor immediately.

Use extreme care to avoid spilling or splashing electrolyte. Electrolyte spilled or splashed on your body or clothing should be neutralized with baking soda or household ammonia, then rinsed with clean water.

Electrolyte can also damage painted or unpainted metal vehicle parts. If electrolyte is spilled or splashed on any metal surface, neutralize and rinse it with clean water.

To prevent possible skin burns, do not wear watches, rings, or other jewelry while performing maintenance work on the batteries.

Battery Safety Precautions

WARNING

Do not apply pressure to the end walls of a plastic-case battery. This could cause electrolyte to squirt from the vents, possibly resulting in serious injury to skin or eyes.

When handling plastic-case batteries, use a battery carrier. If one is not available, lift these batteries with your hands placed at opposite corners of the battery.

Emergency Starting Using Booster Cables

WARNING

Before jump-starting a vehicle, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

WARNING

Batteries release explosive gas. Do not smoke when working around batteries. Put out all flames and remove all sources of sparks or intense heat in the vicinity of the battery. Do not allow the vehicles to touch each other. Do not lean over the batteries when making connections, and keep all other persons away from the batteries. Failure to follow these precautions could lead to severe personal injury as a result of an explosion or acid burns.

NOTICE

Make sure both electrical systems are the same voltage. Electronic devices on both vehicles can be damaged when connected to a vehicle with a different operating voltage.

1. Apply the parking brakes and turn off all lights and other electrical devices. Ensure that the vehicles are not touching and both ignition switches are turned to the OFF position.

IMPORTANT: Do not attempt to jump start a damaged battery.

2. Remove the battery box cover. See **Fig. 1** for the standard battery compartment location.

NOTICE

Always connect the batteries and jumper cables correctly (positive-to-positive and negative-to-negative). Connecting a charging device backwards (positive-to-negative) can severely damage the vehicle electrical content and cause non-warrantable failures.

IMPORTANT: On vehicles equipped with optional jump start posts, connect to these posts instead of the battery terminals. Jump start posts may be installed in various locations on the vehicle. See **Fig. 2**.

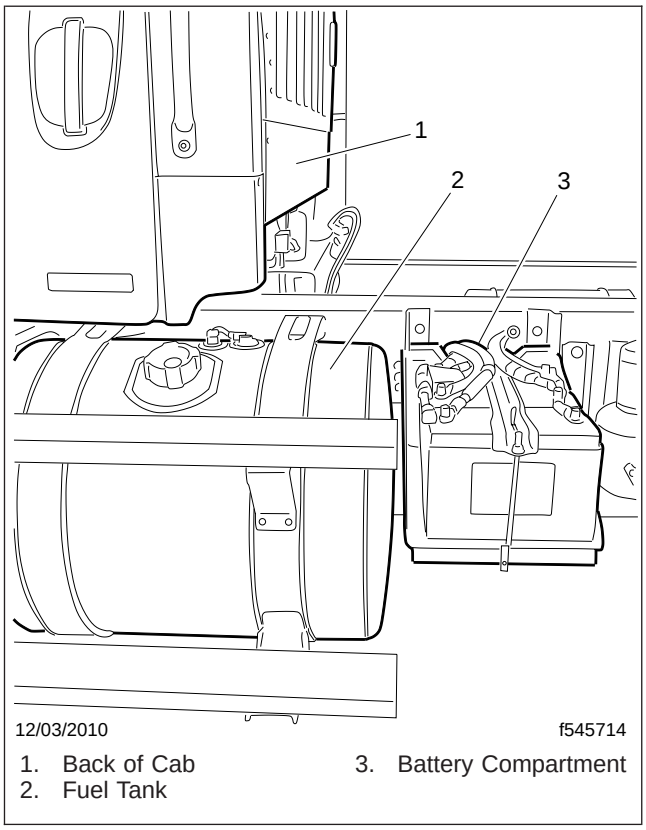


Fig. 1, Standard Battery Compartment Location

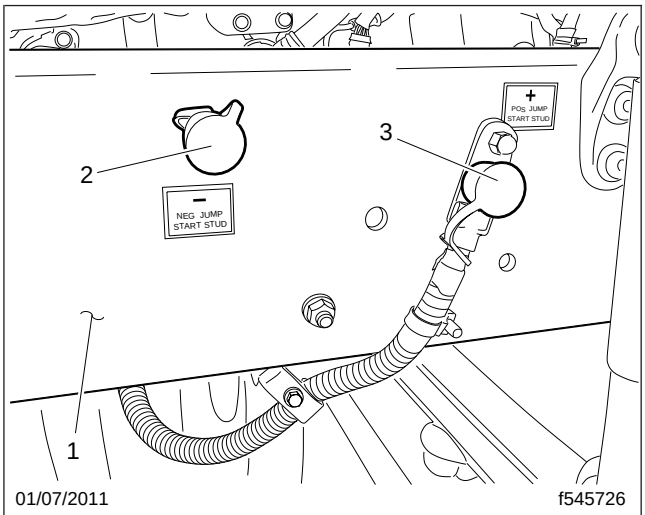
3. Connect the positive (+) jumper cable to the positive terminal or jump start post on the discharged battery. See **Fig. 3**.
4. Connect the other end of the positive jumper cable to the positive terminal or jump start post on the booster battery providing the charge.

WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

5. Connect the negative (-) jumper cable to the negative terminal or jump start post on the booster battery.

Emergency Starting Using Booster Cables



1. Frame Rail
2. Negative Jump Start Post
3. Positive Jump Start Post

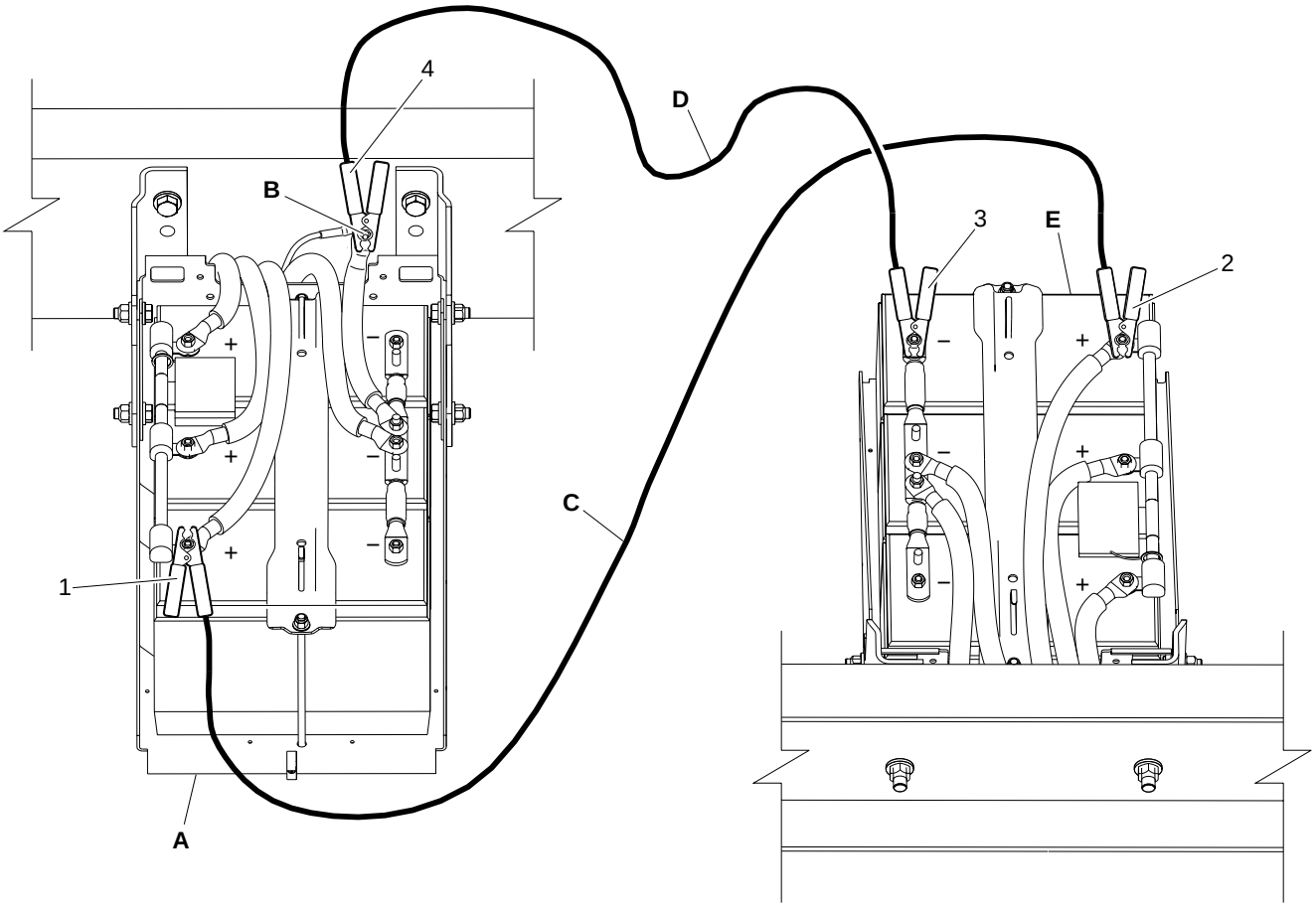
Fig. 2, Possible Jump Start Post Location (passenger-side engine compartment)

6. Connect the other end of the negative jumper cable to the negative ground stud on the vehicle requiring the jump start.
7. Start the engine of the vehicle providing the jump start and let the engine run a few minutes to charge the batteries of the other vehicle.
8. Attempt to start the engine of the vehicle receiving the jump. Do not operate the starter longer than 30 seconds, and wait at least two minutes between starting attempts to allow the starter to cool.
9. When the engine starts, let it idle a few minutes.

⚠ WARNING

Do the next step exactly as instructed and do not allow the clamps of one cable to touch the clamps of the other cable. Otherwise, a spark could occur near a battery, possibly resulting in severe personal injury from explosion and acid burns.

10. Disconnect the negative jumper cable from the negative cable stud on the jump-started vehicle.
11. Disconnect the negative jumper cable from the booster battery.
12. Disconnect the positive cable from the booster battery.
13. Disconnect the other end of the positive jumper cable from the jump-started vehicle.
14. Install the battery box cover; be sure it is positioned properly before fastening the latch.



Disconnect jumper cables in the REVERSE order that they were connected.

A. Discharged Battery
B. Negative Ground Stud
C. Positive Jumper Cable
D. Negative Jumper Cable
E. Booster Battery

1. 1st Connection: Positive Jumper Cable to Discharged Battery
2. 2nd Connection: Positive Jumper Cable to Booster Battery
3. 3rd Connection: Negative Jumper Cable to Booster Battery
4. 4th Connection: Negative Jumper Cable to Negative Ground Stud (discharged battery)

Fig. 3, Jumper Connections

⚠ WARNING

Before charging a battery, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

When charging batteries, always wear eye protection. During charging, batteries give off explosive hydrogen gas. Exploding gas can cause blindness or other bodily injury.

Battery Charging

AGM batteries may be charged only with a charger that is specified for AGM batteries. Many older chargers operate at a voltage that is too high for AGM batteries and will cause permanent damage. Never combine AGM and flooded batteries together for charging or for use in a vehicle.

See **Table 1** for voltage to approximate battery state of charge for flooded batteries.

Voltage to Approximate Battery State of Charge for Flooded batteries		
Voltage		State of Charge
Flooded	AGM	
12.6	12.8	100%
12.4	12.6	75%
12.2	12.3	50%
12.0	12.0	25%
11.8	11.8	0%

Table 1, Voltage to Approximate Battery State of Charge for Flooded batteries

1. If the batteries are not installed in the vehicle, install the lead adapters on the battery positive and negative posts.
2. Connect the charger to the battery following the manufacturer's instructions. Slightly rock the charger's clamps to insure a complete connection.

IMPORTANT: If the battery feels hotter than 125°F (52°C) or if rapid gassing or spewing of electrolyte occurs, lower the charging rate or stop charging the battery and allow it to cool.

3. When finished, turn the charger off.

⚠ WARNING

Always turn the charger off before disconnecting it. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

Battery Removal, Cleaning and Inspection, and Installation

WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery, make sure all electrical loads such as lights, ignition, and accessories, are turned off.
2. Chock the tires.
3. Remove the battery box cover.
4. Disconnect the negative battery cable leads.
5. Disconnect the positive battery cable leads.
6. Disconnect the battery interconnect cables.
7. Remove the battery holddowns. Then remove the batteries from the carrier.

Cleaning and Inspection

1. Inspect all battery cables and interconnectors for wear, and replace them if necessary. Remove corrosion from cables, terminals, and battery posts with a wire brush and a solution of baking soda and water. Rinse thoroughly with clean water, and dry.
2. Clean and tighten the battery ground cable at the weld stud on the frame rail. Inspect and ensure that the nut is self-locking and that a flat washer is used. Do not use a split-lock washer or star washer. Torque the nut 15 to 18 lbf·ft (20 to 24 N·m). Seal the area with red dielectric enamel.
3. Inspect the retainer assembly and battery box. Replace worn or damaged parts. Remove any corrosion with a wire brush and wash with a weak solution of baking soda and water. Rinse with clean water and dry. To prevent rusting, paint the retainer assembly if needed.
4. Be sure foreign objects, such as stones, bolts, and nuts, are removed from the battery box.

Installation

1. Be sure that the replacement battery has a sufficient capacity to cover the electrical needs of the vehicle.

NOTICE

Using an under-capacity battery will result in poor performance and premature battery failure, resulting in damage or reduced life of the starter.

2. Be sure the battery is at full charge when installed. If the battery has been in storage for some time, or if the installation is being made in subfreezing temperatures, give the battery a top-off charge before installing it. For instructions, see **Subject 120**.
3. Place the batteries in the carrier with the terminals in the proper position as referenced earlier. The batteries must rest level in the carrier.
4. Install the battery holddown and tighten it to 12 lb·ft (8 N·m). See **Fig. 1**.

NOTICE

Do not overtighten the battery holddown. Overtightening could damage the batteries.

5. To provide corrosion protection, apply lithium dielectric grease liberally to the terminal pads, then install the interconnectors.

IMPORTANT: Many electrical components are located outside of the cab in areas subjected to harsh weather and road spray. Some components also have exposed metal electrical terminals, which, when subjected to harsh conditions, may suffer corrosion at the electrical connection.

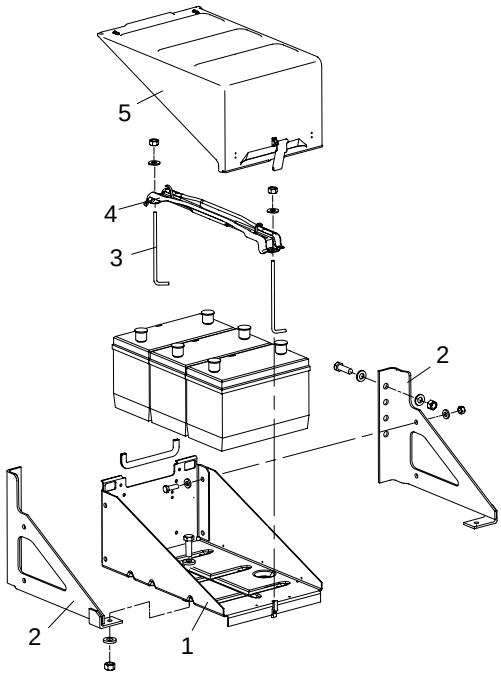
6. Connect the battery interconnecting cables to the batteries and check for correct polarity with respect to the vehicle. Connect the ground cables last.

NOTICE

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. Generally

Battery Removal, Cleaning and Inspection, and Installation



1. Battery Box
2. Bracket, Battery Box
3. Holddown Bolt
4. Holddown
5. Battery Box Cover

Fig. 1, Battery Box, Battery, and Battery Holddown

those are 10 to 15 lbf·ft (14 to 20 N·m). Proper torque is important for electrical system operation.

8. Start the engine and check the operation of the charging system. If needed, repair the charging system to obtain the correct charging output. For instructions, see the appropriate section in **Group 15**.

NOTICE

Make sure all battery posts are covered with dielectric grease to protect against corrosion.

Battery Box Removal and Installation

WARNING

Before doing any of the following procedures, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Steel Battery Box

Removal

1. Park the vehicle, shut down the engine, and set the parking brake. Chock the tires.
2. See **Subject 130** for procedures to remove the batteries.
3. Before working on the battery box, make sure all electrical loads such as lights, ignition, and accessories, are turned off.
4. Pull on the end of the holddown latch until the end clears the cover-mounted catch. Pivot the latch out of the way, then lift off the battery box cover. See **Fig. 1**.
5. Remove the fasteners that hold the battery box to the brackets.
6. Remove the battery box.

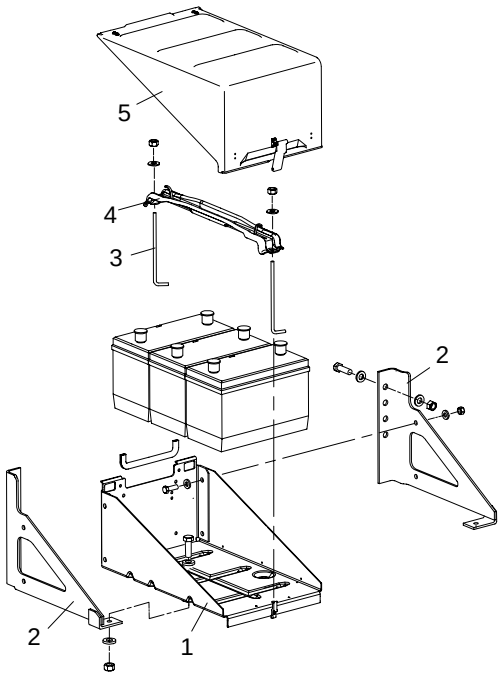
Installation

1. Line up the holes in the battery box with the holes in each mounting bracket.
2. Install the fasteners that attach the battery box to the mounting brackets. Tighten the fasteners to 18 lbf·ft (24 N·m).
3. Place the batteries in the battery box with the terminals in the proper position. Make sure the batteries rest level in the box. See **Subject 130** for procedures to correctly install the batteries.
4. Install the battery holddowns. Tighten each nut to 12 lbf·ft (9 N·m).

CAUTION

Do not overtighten the battery holddowns. Overtightening could damage the batteries.

5. Place the battery box cover over the battery box and fasten the latch.



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1. Battery Box
2. Bracket, Battery Box
3. Holddown Bolt
4. Holddown
5. Battery Box Cover

Fig. 1, Steel Battery Box (typical)

Troubleshooting

If the batteries pass testing, check for the following causes:

1. Accessories were left on overnight.
2. A slipping alternator belt, high resistance in the wiring, or a defective alternator is causing the batteries to discharge.
3. The electrical loads are exceeding the charging system capacity.
4. Wires in the electrical system are shorted or pinched.
5. There are loose or damaged battery cable-to-terminal connections.
6. The batteries are still connected in a vehicle that has been out of service. Small current drains of accessories that are connected all the time can discharge the batteries in a few days. Batteries left in a discharged condition are subject to freezing.

Electrical Drain and Parasitic Load

Batteries are replenished each time the vehicle is driven with normal vehicle use. In long-term parking situations, however, parasitic drains may discharge the batteries enough to cause a no-start condition.

A parasitic drain is an electrical load that draws current from the batteries when the ignition remains off. Some devices, such as the electronic control unit (ECU), the bulkhead module (BHM), the chassis module (CHM), the antilock braking system (ABS), and radio memory are intended to draw a very small current continuously. These draws are measured in milliamps (mA). Current draw should be less than 325 milliamps with no circuits active and the ECU, BHM, CHM, and ABS turned off.

Problem—The Batteries Are Undercharged

Problem—The Batteries Are Undercharged	
Possible Cause	**Remedy**
The drive belt is loose.	Check the drive belt and tensioner. Refer to the drive belt subject in the appropriate engine section in **Group 01** for instructions. If necessary, tighten to the manufacturer's specifications. Start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The drive belt is damaged or missing.	Check the drive pulleys for locked bearings. Repair or replace any damaged components. Replace the drive belt and start the engine. Check the alternator voltage and output. Refer to the troubleshooting subject in the alternator section in **Group 15** for instructions.
The batteries are undercharged.	Perform a battery test. Charge or replace batteries as needed. If the batteries were discharged, start the engine and check the alternator voltage and output. Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The alternator or battery cables are undersized.	Perform a cable load drop test.
The alternator is malfunctioning.	Refer to the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The isolator relay is not operating correctly (optional battery isolator system only).	Refer to **Group 82, Subject 300** in this manual for instructions.

Battery Troubleshooting

1. **Check battery pack voltage to determine state of charge**.

   If equipped, set Load Disconnect Switch to "Off." With the DMM probes on the positive and negative posts of the battery pack, record the voltage. Due to differences in their design and operation, flooded cell and AGM batteries have different voltages at the same state of charge.

   Batteries should be fully charged before further testing. If batteries are not fully charged, they will draw current to recharge during testing, invalidating the troubleshooting test results. Fully charged batteries ensure reliable diagnosis.

   See **Table 1** for voltage as an approximate indicator of state of charge for AGM and flooded batteries.

   If the battery pack will not charge to 100% state of charge, there may be a shorted cell. Break the pack into individual batteries and test individually using an approved tester. Go to **Check 3, Individual Battery Testing**. After batteries have been tested individually, verify pack voltage once again.

Flooded	AGM	SoC
12.6	12.8	100%
12.4	12.6	80%
12.3	12.4	60%
12.1	12.2	40%
12	12	20%
11.8	11.8	0%

Table 1, Voltage to Approximate State of Charge (SoC)

2. **Remove surface charge: HVAC blower, lights on, 5 min.**

   Surface charge refers to a higher initial charge (volts), when discharging, in recently-charged batteries. This charge is a "shallow" charge, meaning that the charging-induced chemical reaction has mostly occurred at the surface of the lead plates, and has not equalized throughout the lead. Drawing current from the batteries before testing removes the surface charge, allowing for a better assessment of the "deep charge" state of the lead plates.

   After the surface charge is removed, the batteries need to be at least 80% SoC for further testing. See **Table 1** for voltage as an approximate indicator of state of charge.

3. **Test Individual Batteries**.

   IMPORTANT: Batteries should only be tested individually.

   3.1 Remove the negative cables of the batteries first, and secure the leads out of the way before touching the positive cables. Remove the battery cables and clean the terminal pads with a wire brush. The adapters will not make sufficient contact with dirty or corroded contact pads.

   3.2 Connect the battery tester's positive and negative clamps to the lead base terminal pads at the positive and negative studs. See **Fig. 1**.

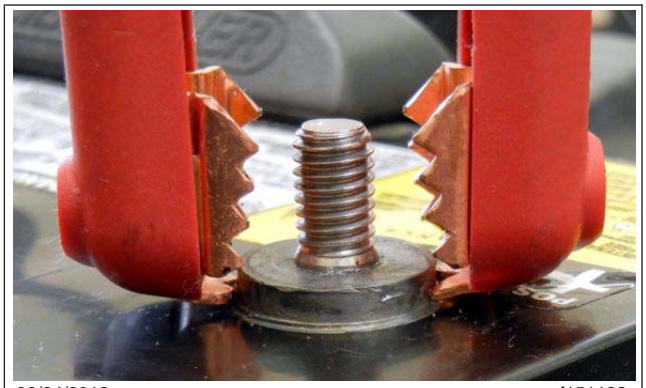

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Fig. 1, Tester Clamps Attached to the Post

The threaded portion of the battery posts are *not* the right place to clip: the steel threads won't make a good connection. The base of the post, on the lead, is the best place to clip. Taking a few extra seconds to make sure the tester, DMM, and carbon pile clips are well-connected can be the difference between a useful and a useless test.

NOTE: If the lead base is too small to clamp to, only lead stud adapters should be used, never nuts. The lead stud adapters must be screwed down tight against the cleaned lead base using a

hand tool. Lead adapters are available at most tool vendors.

Refer to the battery tester instruction manual for complete testing instructions.

If the battery tester requires the CCA rating of the battery, it should be on the battery label. See **Fig. 2**.

3.3 If the battery fails, enter the battery serial number and print out the result. The sensor windows on the tester and printer must be aligned to transmit the test results to the printer.

Fig. 2, Battery Label

See **Table 1** for recharge times. Refer to the commercial batteries page at **www.dekabatteries.com** for more information.

Recharge Time Using a Typical Charger (hours)						
Open Circuit Voltage		State of Charge	Charger Maximum Rate			
Flooded	AGM		50 Amps	30 Amps	20 Amps	10 Amps
12.6V	12.8V	100%	Ready to Use			
12.4V	12.6V	75%	0.6	0.9	1.3	2.5
12.2V	12.3V	50%	1.2	1.9	2.7	5.1
12.0V	12.0V	25%	1.8	2.9	4.3	10.7
11.8V	11.8V	0%	2.5	4.0	5.7	10.7

Table 1, Recharge Time Using a Typical Charger

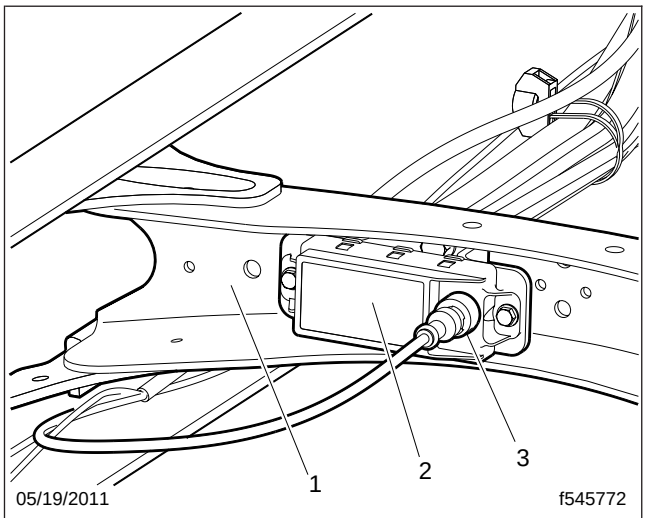
General Information

The Electronic Stability Control (ESC) system provides complete directional stability (yaw control) in oversteer and understeer conditions, such as the ability to reduce the likelihood of drift-out or jackknife. The ESC system includes an additional solenoid valve for front axle braking, a brake pressure sensor, a Steering Angle Sensor (SAS), and an Electronic Stability Control ECU (ESC module) with an integrated yaw rate sensor. The additional sensors allow the ECU to determine where the driver is attempting to steer the vehicle and how much brake demand is required in order to more precisely control the vehicle in an emergency situation. The additional front solenoid valve allows for individual wheel braking on the steering axle to provide yaw control.

Electronic Stability Control Module

The ESC module is mounted under the cab on the crossmember located behind the transmission. See **Fig. 1** .

The ESC module has two sensors: a lateral accelerometer and a yaw rate sensor. During cornering, lateral acceleration causes a force directed at the vehicles center of gravity, and, if high enough, can cause a vehicle to roll. The yaw rate sensor provides rotational sensing that can be used to detect and help prevent vehicle spinout or jackknife. The ESC module has one 4-pin connector that is used to communicate with the ABS ECU.



1. Crossmember
2. ESC Module
3. ABS Connector

Fig. 1, Electronic Stability Control Module

Removal

IMPORTANT: Do not move, rotate, or relocate the ESC module without first contacting the Meritor WABCO customer service center.

1. Shut down the engine and chock the tires.
2. Disconnect the electrical connector.
   - 2.1 Turn the collar on the connector counterclockwise until it stops.
   - 2.2 Disconnect the connector.
3. Remove the two screws from each side of the ESC module.
4. Remove the ESC module.

Installation

1. Position the ESC module on the crossmember and install two screws and nuts. Tighten the screws 16 lbf·ft (22 N·m).
2. Connect the electrical connector.

NOTE: When the module is replaced, calibration is necessary. ESC calibration requires calibration of the steering angle sensor and initialization of the ESC module.

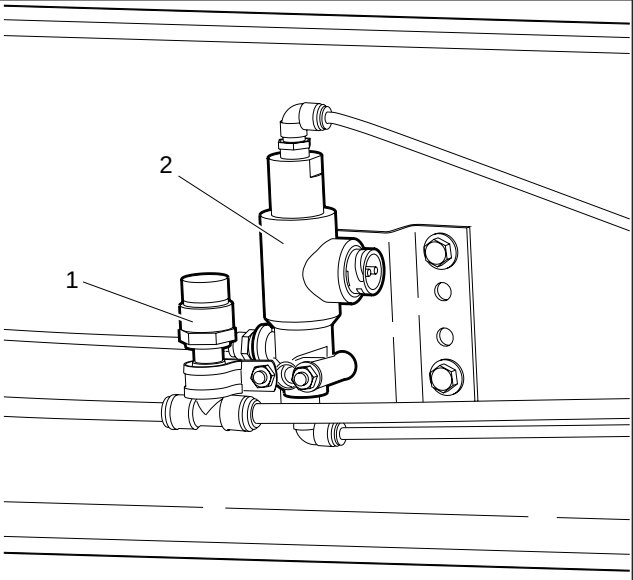
3. Calibrate the new ESC module. Refer to the *Meritor WABCO ESC End of Line Calibration Procedure*. The procedure can be found in the appendix of the latest version of the Meritor WABCO Maintenance Manual (MM-0112). This document is available at the **Meritor WABCO website**.

NOTE: For complete instructions for using TOOLBOX software, refer to the ArvinMeritor "TOOLBOX User's Manual, TP-99102."

RSC Valve Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the electrical connector from the roll stability control (RSC) valve. See **Fig. 1** for the non towing installation, and **Fig. 2** for the towing installation.



1. Roll Stability Control Valve
2. Brake Demand Pressure Sensor

Fig. 1, Pressure Sensor Mounted on the Frame Rail

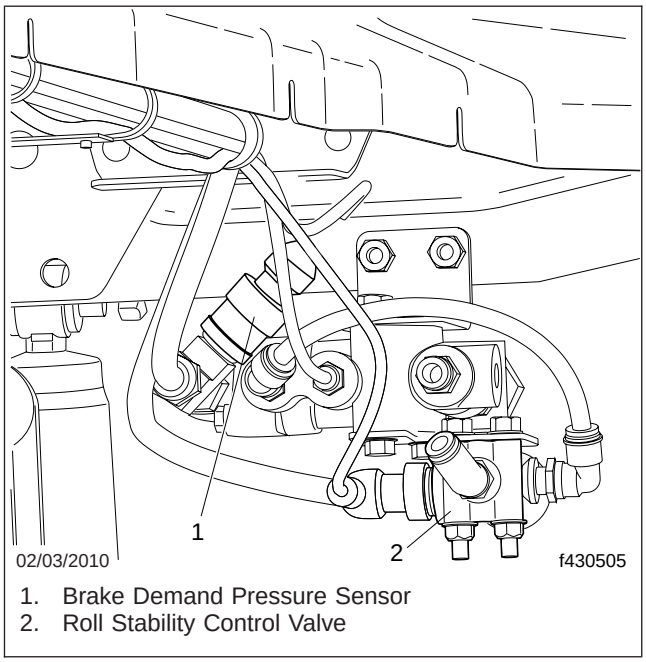
3.1 Turn the collar on the connector counterclockwise until it stops.

3.2 Disconnect the connector.

4. Disconnect the air lines.
5. Remove the mounting screws and nuts.
6. Remove the RSC valve.

Installation

1. Position the RSC valve on the bracket and install the mounting screws and nuts. Tighten the screws 13 lbf·ft (18 N·m).
2. Connect the air lines.



1. Brake Demand Pressure Sensor
2. Roll Stability Control Valve

Fig. 2, Pressure Sensor Mounted on the Tailer Protection Valve

3. Connect the electrical connector to the RSC valve. Hand-tighten only.
4. Verify operation of the RSC valve.

4.1 Connect the blue gladhand to a 50 cubic inch (819 cubic cm) air tank.

4.2 Start the vehicle and allow the air reservoirs to fully charge.

4.3 Shut down the engine.

4.4 Turn the ignition to ON. Verify that the ATC/RSC/ESC indicator lamp operates correctly.

4.5 Activate the RSC valve using the Meritor WABCO PC Diagnostics tool, TOOLBOX.

4.6 Check for air leaks at the RSC valve. If the RSC valve leaks, make the necessary repairs.

4.7 If the RSC valve fails to cycle, turn off the ignition and make sure the electrical connections are tight. Turn the ignition switch on and check the valve again. If the RSC valve still fails to cycle, check for fault codes.

Front Solenoid Valve Removal and Installation

The solenoid valve is located on the frontwall. See **Fig. 1**.

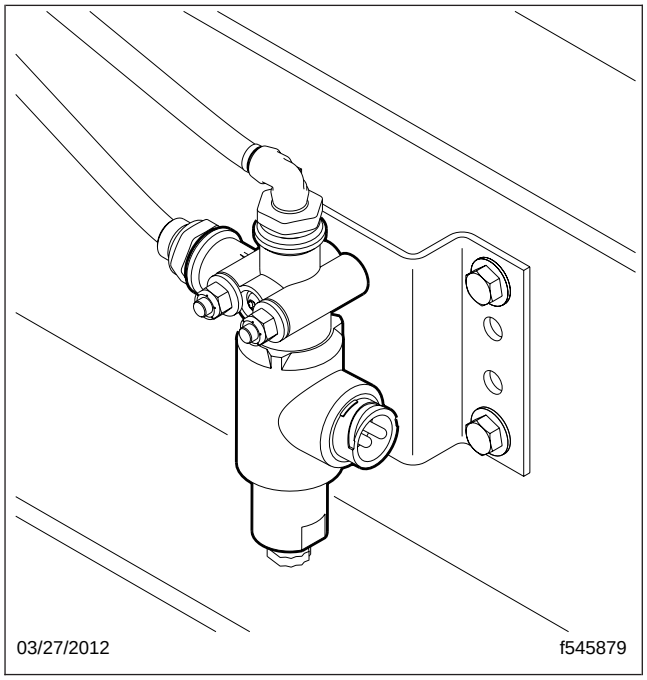


Fig. 1, Front Solenoid Valve

Removal

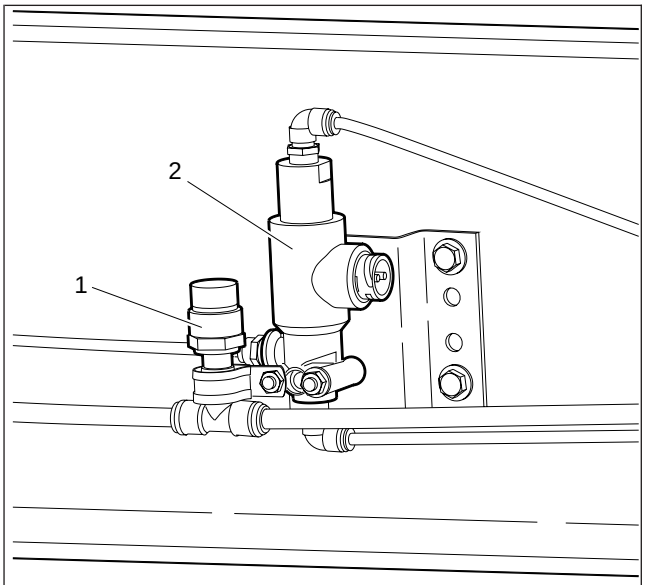
1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the electrical connector from the front solenoid valve.
   - 3.1 Turn the collar on the connector counterclockwise until it stops.
   - 3.2 Disconnect the connector.
4. Disconnect the air lines.
5. Remove the two mounting screws and nuts.
6. Remove the front solenoid valve.

Installation

1. Mount the new solenoid valve and install the two screws and nuts. Tighten the nuts to 8 lbf·ft (11 N·m).
2. Connect the air lines to the front solenoid valve.
3. Connect the electrical connector to the front solenoid valve. Hand-tighten only.
4. Verify the operation of the solenoid valve.
   - 4.1 Start the vehicle and allow the air reservoirs to fully charge.
   - 4.2 Shut down the engine.
   - 4.3 Apply the brakes and check for air leaks at the front solenoid valve.
   - 4.4 Turn the ignition to ON. Verify that the ATC/RSC/ESC indicator lamp operates correctly.
   - 4.5 Activate the front solenoid valve using the Meritor WABCO PC Diagnostics tool, TOOLBOX.
   - 4.6 Check for air leaks at the front solenoid valve. If valve leaks, make necessary repairs.
   - 4.7 If front solenoid valve fails to cycle, turn off the ignition and make sure the electrical connections are tight. Then, turn the ignition switch on and check the valve again. If the front solenoid valve still fails to cycle, check for fault codes.

Removal

1. Shut down the engine and chock the tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the wiring from the pressure sensor. See **Fig. 1** and **Fig. 2**.



1. Roll Stability Control Valve
2. Brake Demand Pressure Sensor

Fig. 1, Pressure Sensor Mounted on the Frame Rail

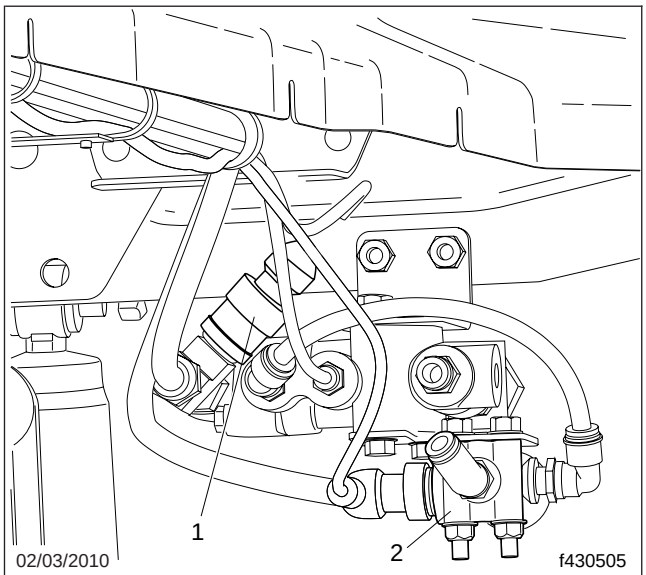
3.1 Turn the flange on the connector counterclockwise until it stops.

3.2 Disconnect the connector.

4. Remove the pressure sensor.

Installation

1. Install the new air pressure sensor. Make sure that the pressure sensor is secured; the connector end should be higher than the threaded end to prevent freezing water from disabling the sensor.
2. Connect the electrical connector to the pressure sensor. Hand-tighten only.
3. Verify operation of the pressure sensor.



1. Brake Demand Pressure Sensor
2. Roll Stability Control Valve

Fig. 2, Pressure Sensor Mounted on the Tailer Protection Valve

3.1 Connect the blue gladhand to a 50 cubic inch (819 cubic cm) air tank.

3.2 Start the engine and allow the air reservoirs to fully charge.

3.3 Shut down the engine.

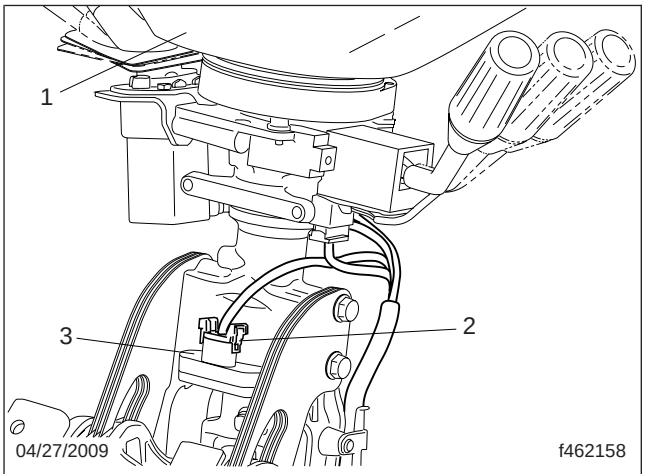
3.4 Apply the brakes and check the pressure sensor fitting for leaks.

3.5 Test drive the vehicle to verify that the ATC/RSC/ESC indicator lamp operates correctly.

Steering Angle Sensor Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Remove the knee bolster panel, located below the steering column. Remove the four fasteners.
3. Remove the steering column.
   - 3.1 Remove the pinch bolt and nut from the upper end yoke on the steering column shaft. Discard the pinch bolt and nut.
   - 3.2 Slide the upper-end yoke off the splines on steering column shaft.
4. Remove the 7-pin connector from the steering angle sensor. See **Fig. 1**.



1. Steering Column
2. 7-Pin Connector
3. Steering Angle Sensor

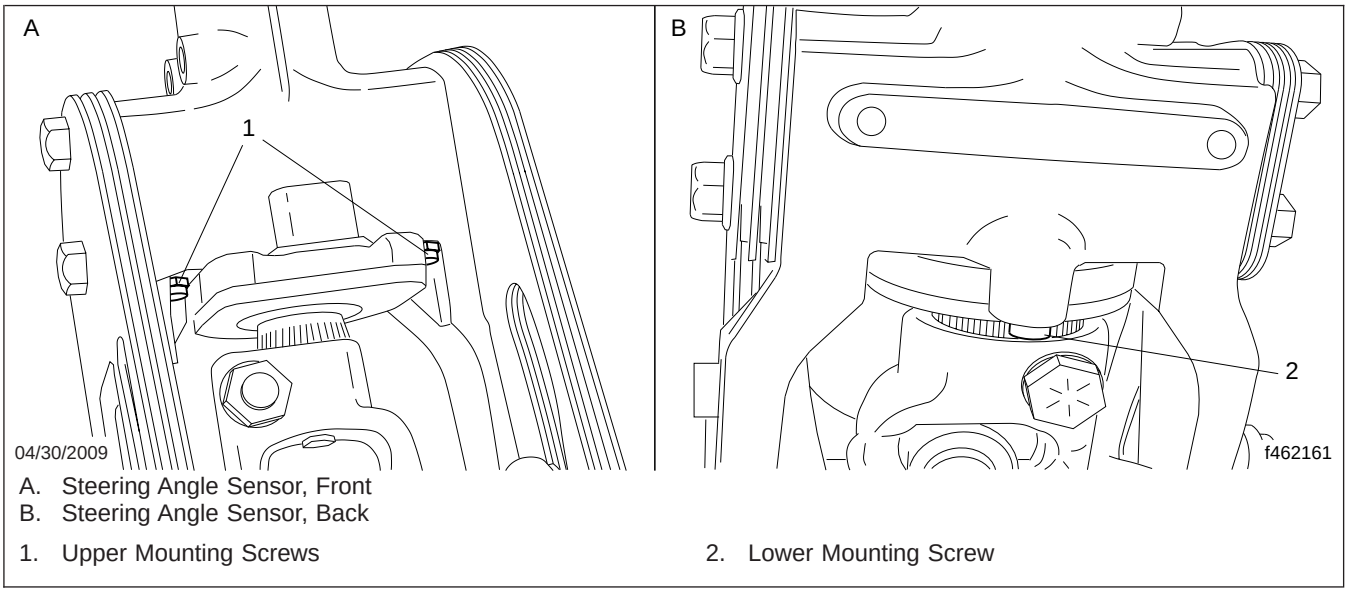
Fig. 1, Steering Column Assenmbly

5. Remove the 3 screws (two upper, one lower) holding the steering angle sensor to the steering column. See **Fig. 2**. Discard the 3 T20 screws and remove the steering angle sensor.

Installation

1. Apply a small amount of grease to the tab in the middle of the steering angle sensor opening, and to the groove of the steering shaft.
2. Place the new steering angle sensor on the steering shaft, making sure to align the guide pin on the steering angle sensor into the grooved slot on the steering shaft. Make sure the steering angle sensor is facing the same direction as originally installed.
3. Secure the steering angle sensor onto the steering column using three new T20 screws.
4. Using a new pinch bolt and nut, attach the upper end yoke to the steering column shaft. Tighten the bolt 30 to 35 lbf·ft (41 to 47 N·m).
5. Connect the 7-pin connector onto the new steering angle sensor.
6. Install the steering column.
   - 6.1 Slide the upper-end yoke on to the splines on steering column shaft.
   - 6.2 Install the pinch bolt and nut on the upper end yoke on the steering column shaft.
7. Install the knee bolster. Tighten the four screws 26 to 34 lbf·in (295 to 385 N·cm).
8. Install the steering column upper and lower covers. Tighten the screws 26 to 34 lbf·in (295 to 385 N·cm).

Steering Angle Sensor Removal and Installation



A. Steering Angle Sensor, Front
B. Steering Angle Sensor, Back

1. Upper Mounting Screws
2. Lower Mounting Screw

Fig. 2, Steering Angle Sensor

Solenoid Valve Tests

1. **Test the voltage on the affected solenoid valve connector.**

   1.1 Disconnect the 4-pin connector from the solenoid valve.

   1.2 Switch the ignition to the ON position

   1.3 Measure the voltage between all pins in the solenoid connector and a good ground.

   Is voltage present on any pin?

   YES → Check the wiring for a short to power. Repair as necessary.

   NO → Go to test 2.

2. **Measure the voltage between all pins in the solenoid connector and +12V power.**

   Is voltage present on any pin?

   YES → The wire shorted to ground. Repair as necessary.

   NO → Go to test 3.

3. **Measure the resistance between pins 1 and 2 on the solenoid valve.**

   Is the resistance between 7 and 14 ohms?

   YES → Go to test 4.

   NO → Clean the electrical contacts on the solenoid and test again. If the resistance is still not correct, replace the solenoid valve.

4. **Measure the resistance of the solenoid valve through the wiring to the ABS ECU.**

   Is the resistance between 7 and 14 ohms?

   YES → Check for other electrical faults. The ABS ECU or the solenoid valve may be faulty.

   NO → Clean the electrical contacts and check wiring between the ABS ECU and solenoid valve. Repair as necessary. If the resistance is still not correct, replace the solenoid valve.

Fault Codes

Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	1	ESC – Initialization Not Complete	—	—	Important: Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	88	2	ESC – System Configuration	—	—	The ESC module is not compatible with the ABS ECU. Contact OEM or Meritor WABCO for ECU combinations.

Troubleshooting

Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	5	ESC – CAN Datalink Loss	Remove the 4-pin connector from the ESC Module. Turn the ignition ON. Measure the voltage between pins 1 and 2 of the 4-pin connector.	Voltage	Verify fault. Check ESC Module wiring for intermittent connection. Check for open connection on ESC Module and insure it is tight and clear of debris/corrosion. Repair as necessary. If fault persists, ESC module or ABS ECU may be faulty.
					No Voltage	Check wiring in circuit 376A from ESC Module to ABS ECU unit. Repair as necessary.
136	88	9	ESC – CAN Datalink Incorrect or Missing	Remove the 4-pin connector from the ESC Module. Measure the resistance between pins 3 and 4 on the 4-pin connector.	Resistance is approximately 90 ohms.	Verify fault. Check ESC Module wiring for intermitent connection and insure it is tight and clear of debris/corrosion. Repair as necessary. Measure the resistance from the ABS ECU X4 18-pin connector and insure approximate 90 ohms is measured. If fault persists, ESC module or ABS ECU may be faulty.
					Resistance is much less or much greater than 90 ohms.	Check wiring between the ESC Module and ABS ECU. Repair as necessary. If fault persists, the ESC Module or ABS ECU may be faulty.
136	88	12	ESC – Internal Fault	Check the ESC Module and its mounting location. Verify that the ESC module is mounted horizontally and properly secured to the cross member. Check the 4-pin connector on the ESC Module and insure it is tight and clear of debris and corrosion. Check the wiring between the ESC module and the ABS ECU.	—	Verify fault. Clear code from ECU memory. Check for other fault codes that may have occurred with this fault, as this could indicate faulty wiring or poor connection at ESC module. If fault persists, the ESC module may be faulty.

Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	88	13	ESC – Initialization Required	—	—	Important: Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	88	14	ESC – Module Mounting Fault	Check the ESC Module and its mounting location. Verify the ESC module is mounted horizontally and properly secured to the crossmember. Check the 4-pin connector on the ESC Module and insure it is tight and clear of debris and corrosion. Check wiring between the ESC module and the ABS ECU.	—	Verify fault. Clear code from ECU memory. If fault persists, the ESC module may be faulty.
136	89	1, 2, 7 or 8	SAS – Steering Angle Sensor various faults	—	—	Visually check the installation of the steering sensor and mount to ensure it is properly seated. If any vehicle work related to the steering system has been performed, the SAS must be calibrated and the ESC module initialized. Refer to Meritor WABCO's End of Line (EOL) procedure for the initialization process. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.

Troubleshooting

Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	89	9	SAS – Commutation Fault	Remove the 7-pin connector from the Steering Angle Sensor. Measure the resistance between pins 3 and 4 of the 7-pin connector.	Resistance is approximately 90 ohms.	Verify fault. Check Steering Angle Sensor wiring. Check for open connection between the ABS ECU and Steering angle sensor. Ensure connection is tight and clear of debri/corrosion. Repair as necessary. If fault persists, the SAS or ABS ECU may be faulty.
					Resistance is much less or much greater than 90 ohms.	Check wiring between the SAS and ABS ECU. Repair as necessary. If fault persists, the SAS Sensor or ABS ECU may be faulty.
136	89	12	SAS – Sensor Defective	Disconnect the 7-pin connector from the steering angle sensor. Turn ignition ON. Measure the voltage between pins 1 and 2 of the 7-pin connector.	Voltage	Check Steering Angle Sensor wiring. Check for intermitent connection between the ABS ECU and Steering angle sensor. Ensure conenction is tight and clear of debri/corrosion. If fault persists, the ABS ECU may be faulty.
					No Voltage	Check the wiring in circuit 576A between the SAS and the ABS ECU. Repair as necessary.
136	89	13	SAS – Not Calibrated	—	—	Refer to Meritor WABCO's SAS calibration procedure. This procedure can be found in Meritor WABCO's Maintenance Manual MM-0112. This document is available through Meritor WABCO or their website.
136	89	14	SAS – Internal Fault	—	—	Check SAS and its mounting location. Verify the SAS is securely mounted and the connector is free of debris and corrosion. SAS may be faulty.
136	16	5	BLS/Pressure Sensor	Disconnect the 18-pin X4 connector from the ABS ECU. Measure the voltage between pin 8 of the 18-pin (X4) connector and ground.	Voltage	Wire shorted to power, check wiring and repair as necessary.
					No Voltage	Open circuit or shorted to ground. Check wiring and repair as necessary.

Fault Codes						
MID	**SID**	**FMI**	**Fault Description**	**Test**	**Result**	**Action**
136	19	2	Front Axle Brake Valve – Open	Disconnect connector X4 from the ABS ECU. Measure the resistance between pins 16 and 13 of the 18-pin (X4) connector.	Open circuit, or high resistance.	Check Front solenoid valve wiring for corrosion or open connection. Repair as necessary. If fault persists, replace the front solenoid valve.
					Resistance is 7-14 ohms.	Correct resistance is measured. Check wiring for intermitent connection. Repair as necessary. If Front valve passes test, ABS ECU may be faulty.
136	19	5	Trailer Brake Valve (RSC) Open	Disconnect connector X3 from the ABS ECU. Measure the resistance between pins 13 and 8 of the 15-pin (X3) connector.	Open circuit, or high resistance.	Check RSC valve wiring for corrosion or open connection. Repair as necessary. If fault persists, replace the RSC valve.
					Resistance is 7-14 ohms.	Correct resistance is measured. Check wiring for intermitent connection. Repair as necessary. If RSC valve passes test, ABS ECU may be faulty.
136	19	12	SAS and ESC Module – Shorted to Ground	Disconnect connector X4 from the ABS ECU. Measure the resistance between pin 7 of the 18-pin (X4) connector and ground.	Low Resistance	Wire shorted to ground, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in circuit 376A or open circuit. If fault persists, ABS ECU may be faulty.
136	55	3	Brake Pressure Sensor – Shorted to Battery	Disconnect the 4-pin connector from the Brake Pressure Sensor. Measure the resistance between pin 3 of the 4-pin connector and power.	Low Resistance	Wire shorted to power, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in circuit 402. If fault persists, sensor may be faulty.
136	55	5	Brake Pressure Sensor – Open or shorted to ground.	Disconnect the 4-pin connector from the Brake Pressure Sensor. Measure the resistance between pin 2 of the 4-pin connector and ground.	Low Resistance	Wire shorted to ground, check wiring and repair as necessary.
					High Resistance	Verify fault. Check for intermitent fault in ground circuit or open circuit. If fault persists, sensor may be faulty.

Table 1, Fault Codes

General Information

The bulkhead module (BHM) controls the operation of the chassis module (CHM), expansion module (EXM), and switch hub module (SHM) in the system along with a variety of other vehicle components either directly or indirectly.

The Bulkhead Module is mounted through the frontwall on the driver's side of the vehicle, slightly below and outboard of the steering column.

Awake State and Sleep State

The bulkhead module, chassis module, and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awake, the remaining components wake up if they are not already awake.

When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door
- turning on the hazard lights
- turning the ignition switch to any position other than off
- turning on the headlight/parking lights
- pressing the service brake switch

The BHM, CHM, and ICU enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs, and all other power down requirements are met.

To check whether or not the electrical system is going into a sleep state:

1. Enter the vehicle.
2. Shut the doors.
3. Remove your foot from the service brake.

NOTE: One minute after these conditions are met, and provided that none of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

4. Make sure the ignition switch and hazard switch are in the off position.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 1, Parameters

Bulkhead Module Removal and Installation

Removal

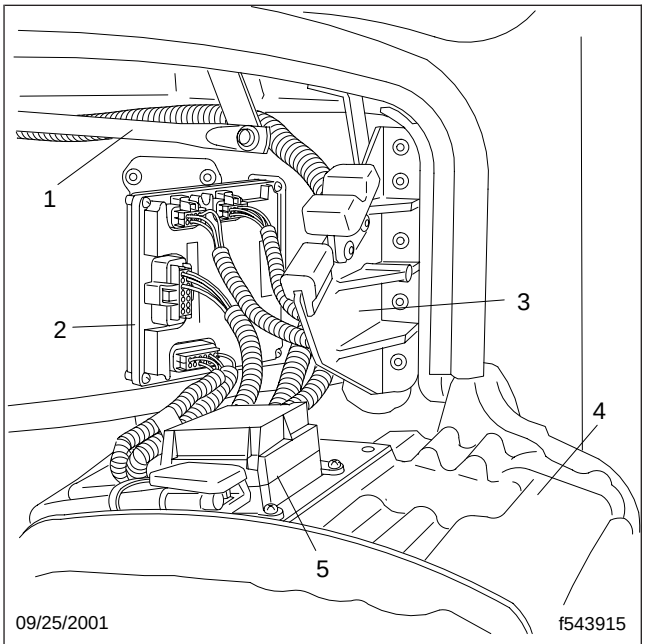
Follow the troubleshooting procedures in this section to solve electrical problems before replacing the bulkhead module. If troubleshooting indicates a malfunction of the module, try flashing the parameters and the software before replacing the module. For flashing instructions, see **Subject 110**.

Also check the external wiring. See **Troubleshooting 300**.

1. Chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Open the hood.

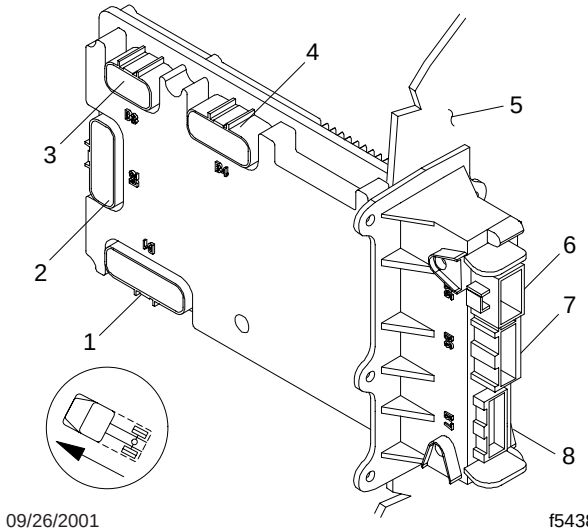
NOTE: The bulkhead module is located on the frontwall slightly below and outboard of the steering column. See **Fig. 1**.

4. Disconnect the harnesses B1 through B4 from the engine side of the bulkhead module. See **Fig. 2**.



1. Wiper Linkage Arm
2. Bulkhead Module
3. Hood Support Bracket
4. Inner Fender
5. Main Power Distribution Module

Fig. 1, Bulkhead Module from the Engine Side



1. B1, Forward Chassis Harness Connector
2. B2, Engine Harness Connector
3. B3, Frontwall Harness Connector
4. B4, Frontwall Harness Connector
5. Frontwall
6. B5, Dash Harness Connector
7. B6, Dash Harness Connector
8. B7, Dash Harness Connector

Fig. 2, Bulkhead Module Harness Connections

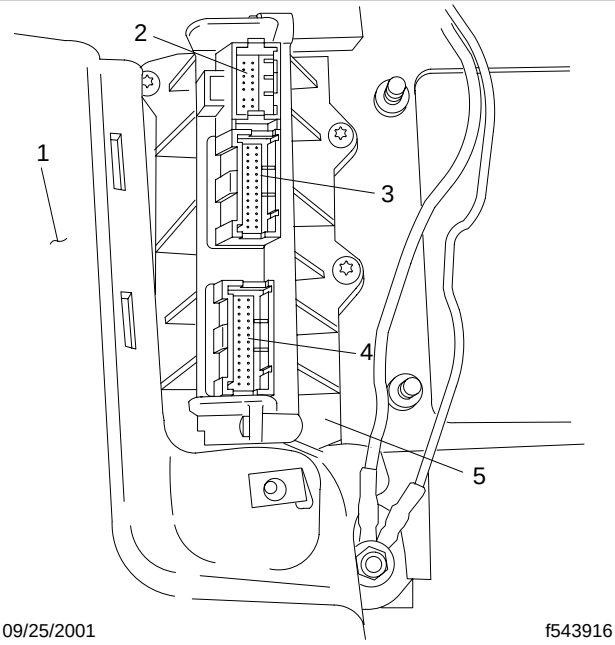
4.1 Slide the grey terminal lock outward.

4.2 Press the terminal release tab and pull the connector away from the BHM.

4.3 Repeat for the remaining connectors.

5. Remove the tread plate from the driver door entry.
6. Remove the kick panel from the left side of the driver footwell.
7. Disconnect bulkhead harnesses B5 through B7 from the bulkhead module on the cab side of the frontwall. See **Fig. 3**.
8. Remove the five Torx® capscrews that secure the BHM to the cab side of the frontwall, then remove the BHM by pulling it through the opening into the cab. The diagnostic connector may need to be removed for clearance.

Bulkhead Module Removal and Installation



1. Driver Footwell Kick Panel
2. B5, Dash Harness Connector
3. B6, Dash Harness Connector
4. B7, Dash Harness Connector
5. Bulkhead Module

Fig. 3, Bulkhead Module from the Cab Side

Installation

1. Place the BHM through the frontwall opening from the cab side, then secure it with five Torx capscrews and torque them 48 lbf·in (540 N·cm).

NOTE: The sixth capscrew in the lower right corner is used to retain the kick panel.

2. Connect bulkhead harnesses B5 through B7 to the BHM on the cab side of the frontwall.
3. Install the diagnostic connector if it was removed.
4. Install the kickpanel in the left side of the driver footwell and secure it with Torx capscrews.
5. Install the tread plate at the driver door entry.
6. Connect bulkhead harnesses B1 through B4 to the BHM on the engine side of the frontwall.
7. Connect the batteries.
8. Close the hood.
9. Flash the BHM with the parameters for the vehicle. For instructions on flashing the BHM, see **Subject 110**.

Flashing the Bulkhead Module

When the bulkhead module (BHM) is flashed, both the application software and reference parameters (identified as "Features" in ServiceLink) are flashed to the BHM.

Flashing is done in ServiceLink® in the BHM "Flashing" screen. See the *ServiceLink User Guide* for more information on flashing.

Normally, it is only necessary to flash the BHM in one of the following situations:

- When, as a last resort in the troubleshooting process, the BHM is suspected of being faulty. This is to confirm that the problem is hardware related.
- When a replacement BHM is installed on a vehicle that originally had an older version of the application software.

In all other situations, it is only necessary to perform the "Refresh Features List" in ServiceLink in the "Features" screen. This applies the appropriate reference parameters to the BHM specific to the vehicle. See the *ServiceLink User Guide* for more information on refreshing the features list.

NOTE: Pay particular attention to the first "NOTICES" screen when you open ServiceLink. This screen will contain timely details on matters pertaining to successfully flashing and applying reference parameters to the BHM.

IMPORTANT: The following is a general description of how the electrical system works. ServiceLink® is the diagnostic tool for troubleshooting the electrical system. For specific circuit and pin information for how the vehicle is wired, go to the configuration screen in ServiceLink and select the specific function in which you are interested. To troubleshoot specific inputs and outputs of this system, go to the templates screen in ServiceLink and select the template for the function.

Contents of Subject 300

A/C Clutch Function

Alternator Charging Function (optional)

Backup Lights and Alarm

Cigar Lighter Function

Clutch Switch Function

Electric Horn

Ignition System

Low Air Pressure Warning Function

Park Brake (pneumatic) Function

Wake Function

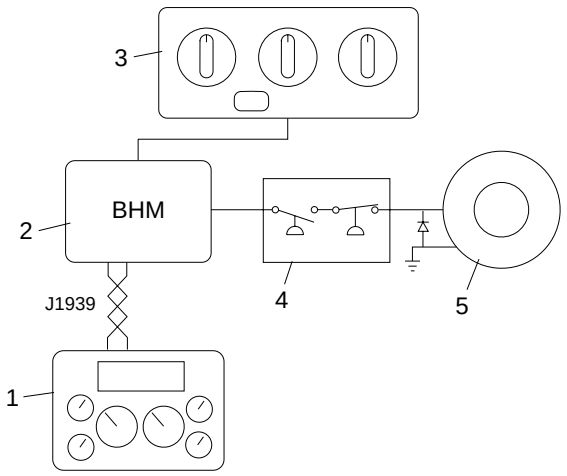
A/C Clutch Function

Description

The HVAC control panel does not directly control the clutch on the A/C compressor. When the driver selects the A/C button and other control conditions are met, the control panel sends an A/C clutch request signal to the bulkhead module (BHM).The BHM responds by activating the A/C compressor clutch. See **Fig. 1**.

Compressor cycling is handled in the same manner. When the control panel determines that the compressor needs to be cycled, it sends a signal to the BHM. The BHM reacts by cycling the compressor. The HVAC control panel contains the logic to prevent the compressor from cycling more than four times per minute.

The BHM monitors the A/C compressor clutch wiring and is capable of detecting a shorted circuit when



1. Instrumentation Control Unit
2. Bulkhead Module
3. HVAC Control Panel
4. Binary Pressure Switch
5. A/C Compressor Clutch

Fig. 1, A/C Clutch Function

the A/C clutch is being driven. Faults detected by the BHM may be reported over the J1939 datalink and viewed using ServiceLink.

Input and Output Conditions

Table 1 displays the A/C clutch system inputs to the BHM and how it will react to these inputs.

A/C Clutch Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**A/C Clutch Request**	**A/C Clutch**
On/Acc	On	Engaged
On/Acc	Off	Not Engaged
Off	On	Not Engaged

Table 1, A/C Clutch Function Input/Output Conditions

Fault Conditions

Table 2 displays how the BHM handles faults that it detects in the A/C clutch system. The reference parameters that configure the BHM determine whether

or not a fault code is broadcast. Therefore, even if the BHM detects a fault, a fault code may not be transmitted. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink.

Alternator Charging Function (optional)

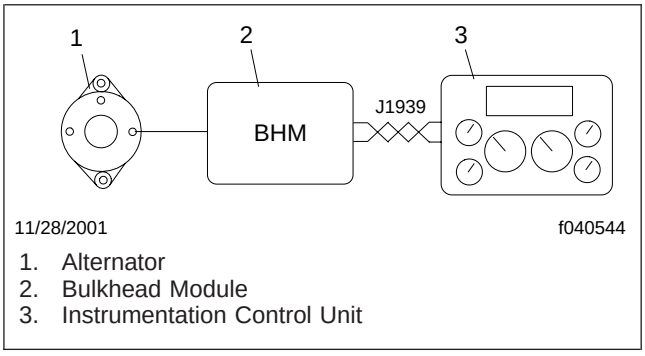
Description

NOTE: Some vehicles will have the alternator "I" terminal hardwired directly to the NO CHARGE light on the ICU.

The NO CHARGE light on the Instrumentation Control Unit (ICU) is an optional indicator used to alert the operator to the presence of a problem with the alternator.

The BHM monitors voltage input from the "I" terminal on the alternator and sends a J1939 message to the ICU to report the status of the alternator. This message is used by the ICU to turn the NO CHARGE light on or off.

The NO CHARGE light illuminates when the BHM does not detect voltage at the "I" terminal of the alternator. Once illuminated, the NO CHARGE light remains on until the BHM detects 14 volts at the alternator "I" terminal. Once off, the NO CHARGE light remains off until the BHM detects 0 volts at the alternator "I" terminal. See **Fig. 2**.



1. Alternator
2. Bulkhead Module
3. Instrumentation Control Unit

Fig. 2, Alternator Charging Function

Input and Output Conditions

Table 3 displays the charging system inputs to the BHM and how it will react to these inputs.

Backup Lights and Alarm

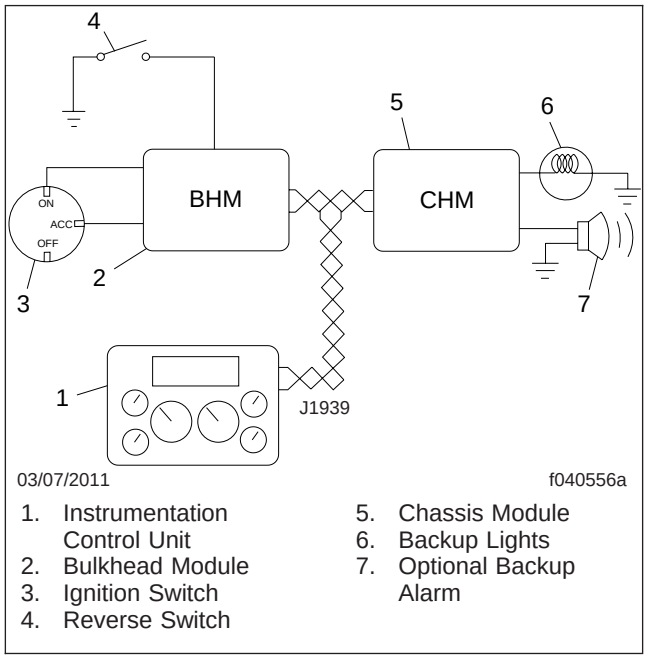
Description

The backup function provides a warning when the transmission is placed into reverse gear. The BHM determines when the vehicle is in reverse using J1939 data from an automated transmission controller, or a switch in a manual transmission and broadcasts a J1939 message for the Chassis Module (CHM) to activate the backup lights and alarm.

The BHM is capable of detecting short circuits in the backup lights/alarm wiring on the CHM. Faults detected by the BHM may be reported over J1939 and may be viewed through ServiceLink.

Input and Output Conditions

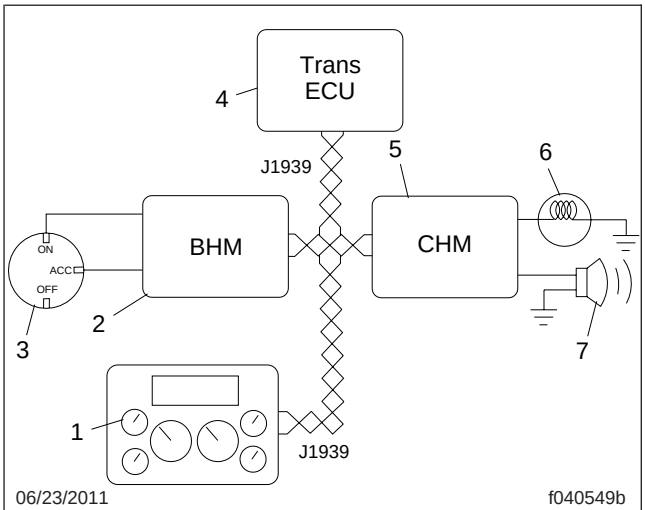
Activation of the backup lights/alarm varies with the transmission type. Manual transmissions use a standard switch to signal the BHM that the transmission is in reverse. Automatic transmissions broadcast a J1939 message when they are placed into reverse gear. See **Fig. 3** and **Fig. 4**. Also see **Table 4**.



1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Reverse Switch
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 3, Backup Function, Manual Transmission

Table 5 displays the backup lights and alarm system inputs to the BHM and how it will react to these inputs.



1. Instrumentation Control Unit
2. Bulkhead Module
3. Ignition Switch
4. Transmission ECU
5. Chassis Module
6. Backup Lights
7. Optional Backup Alarm

Fig. 4, Backup Function, Automatic Transmission

Fault Conditions

Table 6 displays how the BHM handles faults it detects in the backup lights and alarm system. The reference parameters that configure the BHM determine whether or not a fault code is broadcast. If the BHM is programmed to transmit fault codes, they can be viewed through ServiceLink.

On vehicles with automatic transmissions, the BHM has *additional* J1939 fault codes. See **Table 7**.

Cigar Lighter Function

Description

The cigar lighter provides 12 volt power (up to 15 amps). Once the BHM has been initialized, it supplies power at this port regardless of the position of the ignition switch. Every time battery power is disconnected or when the CLDS is turned off, the BHM must be initialized by turning the ignition switch to the ON position to initialize the BHM.

A/C Clutch Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Status and or position of the ignition switch is in error.	BHM will assume the ignition switch is on.
A/C clutch wiring is shorted.	BHM may transmit a J1939 fault message.

Table 2, A/C Clutch Function Fault Conditions

Alternator Charging Function Input/Output Conditions		
Input to BHM from Alternator "I" Terminal	**Output from BHM via J1939 Message to ICU**	**Output from ICU**
14 volts	Charge status of J1939 message is high.	NO CHARGE light is off.
0 volts	Charge status of J1939 message is low.	NO CHARGE light is on.

Table 3, Alternator Charging Function Input/Output Conditions

Troubleshooting

Backup Function		
Transmission Type	**Input to BHM**	**BHM Conclusion**
Manual transmission	Backup switch is closed.	Transmission is in reverse.
Automatic transmissions	J1939 message from transmission indicates either: • Current Gear = Reverse • Selected Gear = Reverse • Gear Range = R	Transmission is in reverse.

Table 4, Backup Function

Backup Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**Transmission Status**	**Backup Lights/Alarm***
On/Acc	Reverse	On
On/Acc	Not Reverse	Off
Off	Reverse	Off
Off	Not Reverse	Off

* Via J1939 message to the CHM

Table 5, Backup Function Input/Output Conditions

Backup Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch status is in error.	BHM will assume the ignition switch is in the on position and may transmit a fault message over J1939.
Backup lights/alarm wiring shorted.	BHM may transmit a J1939 fault message.

Table 6, Backup Function Fault Conditions

Backup Function Fault Conditions, Automatic Transmissions	
Description of Fault	**Action Taken by BHM**
BHM is not receiving J1939 messages from the transmission ECU.	BHM may transmit a J1939 fault code and assume the transmission is in reverse.
Transmission ECU sends an error indicator in the J1939 message to the BHM.	BHM may transmit a J1939 fault code and assume the transmission is in reverse.

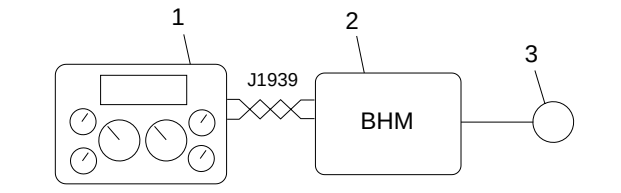
Table 7, Backup Function Fault Conditions, Automatic Transmissions

The BHM is capable of detecting short circuits in the cigar lighter wiring. Faults detected by the BHM may be reported over J1939 and may be viewed through ServiceLink. See **Fig. 5**.

Fault Conditions

Table 8 displays how the BHM handles faults that it detects in the cigar lighter system. The reference parameters that configure the BHM determine whether or not a fault code is broadcast. Therefore, even if

the BHM detects a fault, a fault code may not be transmitted.



1. Instrumentation Control Unit
2. Bulkhead Module
3. Cigar Lighter

Fig. 5, Cigar Lighter Function

Cigar Lighter Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Cigar lighter wiring shorted.	BHM may broadcast a J1939 fault code.

Table 8, Cigar Lighter Function Fault Conditions

Clutch Switch Function

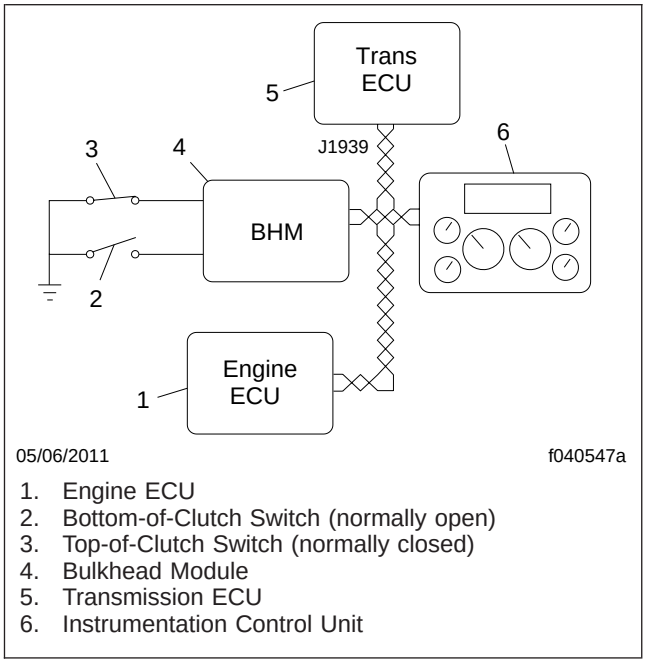
Description

NOTE: Only vehicles with a manual or three-pedal automated mechanical (AMT) transmission are equipped with a clutch pedal. The clutch switch is integrated into the clutch pedal assembly.

The BHM reads the status of the top-of-clutch and bottom-of-clutch switches. The top-of-clutch switch information is broadcast over J1939. The bottom-of-clutch switch input is used for a starter system interlock. The BHM, engine ECU, and transmission ECU use the clutch position status information as inputs for systems such as starting and cruise control.

While both switches are mounted to the clutch pedal assembly, they are activated at different times during the operation of the clutch. As the clutch pedal is pressed towards the floor, the top-of-clutch switch changes from closed to open, and the BHM transmits this information over the J1939 datalink. As the clutch pedal reaches the floor, the bottom-of-clutch switch is activated. It will change from open to closed, as the pedal is fully depressed.

The BHM monitors the top- and bottom-of-clutch switch wiring and is capable of detecting error conditions. Faults detected by the BHM will be reported over J1939 and may be viewed through ServiceLink. See **Fig. 6**.



1. Engine ECU
2. Bottom-of-Clutch Switch (normally open)
3. Top-of-Clutch Switch (normally closed)
4. Bulkhead Module
5. Transmission ECU
6. Instrumentation Control Unit

Fig. 6, Clutch Switch Function

Input and Output Conditions

Table 9 displays the clutch switch system inputs to the BHM and the clutch switch position status it broadcasts.

Clutch Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Top-of-Clutch Switch	**Bottom-of-Clutch Switch**	**J1939 Clutch Switch Message**
Closed	Open	Clutch pedal is released.
Open	Closed	Clutch pedal is depressed.

Troubleshooting

Clutch Function Input/Output Conditions		
Inputs to BHM		**Output from BHM**
Top-of-Clutch Switch	**Bottom-of-Clutch Switch**	**J1939 Clutch Switch Message**
Open	Open	Clutch pedal is partially depressed.
Closed	Closed	Clutch pedal is in error state.*

* This is an error condition, see the Fault Conditions paragraph for more information.

Table 9, Clutch Function Input/Output Conditions

Fault Conditions

Table 10 displays how the BHM handles faults in the clutch switch system. The reference parameters that configure the BHM determine whether or not a fault code is broadcast. If the BHM is programmed to transmit fault codes, they can be viewed using ServiceLink.

Clutch Function Fault Conditions		
Inputs to BHM		**Output from BHM**
Top-of-Clutch Switch	**Bottom-of-Clutch Switch**	
Closed	Closed	BHM transmits a J1939 fault code.

Table 10, Clutch Function Fault Conditions

Horn (electric) Function

Description

The electric horn is controlled by the bulkhead module (BHM). See **Fig. 7**. The horn switch in the steering wheel grounds circuit 25 to activate the input at BHM connector B6, B1. This input activates the WAKE circuit. When ground is applied to this input, the BHM, CHM, and other ECUs on J1939 are powered.

To activate the horn, the BHM supplies battery power to the output circuit at connector B3, E. Fault code SPN 6995 indicates a fault on this output circuit.

The horn bracket is an important part of the horn system. If the bracket is cracked, distorted, or has contact with other components, then the horn will not sound correctly.

Input and Output Conditions

When the horn switch input on BHM connector B6, B1 is at ground, the BHM activates the horn output on connector B3, E. The output is powered using the VBAT2 and VBAT6 power supply to the BHM. The horn input is one of the "wake" inputs to the BHM. If the BHM is powered down and in the sleep state, activating the horn input will "wake" the BHM. This also "wakes" the other modules in the system. See **Fig. 7**.

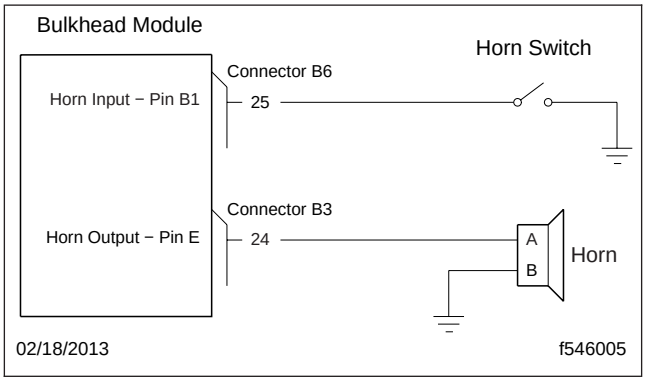


Fig. 7, Horn (electric) Function

Refer to **Table 11** for horn troubleshooting topics.

Electric Horn Troubleshooting	
Problem	**Reference Table**
Fault code SPN 6995 is active.	**Table 12**
The horn stays on all the time.	**Table 13**
The horn does not work at all.	**Table 14**

Table 11, Electric Horn Troubleshooting

Fault Code SPN 6995 from Source Address 33 is Active			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Connect ServiceLink, and read BHM fault codes. Is SPN 6995 with FMI 4 or 6 active?	Yes	The BHM disables the horn output circuit until the next key switch cycle when this fault is logged. Troubleshoot circuit 24 for a short to ground, or for multiple horns connected. When the problem is repaired, cycle the ignition switch and clear history codes with ServiceLink.
		No	Go to step 2.
2	Is SPN 6995 with FMI 5 active?	Yes	Troubleshoot for an open horn, and for a wiring fault on circuit 24 between the BHM and the horn.
		No	Refer to **Table 13** or **Table 14**.

Table 12, Fault Code SPN 6995 from Source Address 33 is Active

The Horn Stays ON All the Time			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Connect ServiceLink, then open the BHM template for the electric horn. Does the template show that the horn switch is active?	Yes	Remove the horn button from the steering wheel and test for continuity. The horn button should only have continuity when it is pressed. If the horn button is OK, continue to troubleshoot circuit 25 between the steering column and the BHM for a wiring fault short to ground.
		No	Troubleshoot circuit 24 between the BHM and the horn for a short to battery power.

Table 13, The Horn Stays ON All the Time

Troubleshooting

The Horn Does Not Work at All			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Connect ServiceLink, then open the BHM template for the electric horn. Press and hold the horn button. Does the template show that the horn button input is active?	Yes	Go to step 2.
		No	Remove the horn button from the steering wheel. Test continuity of the horn button. It should show very low resistance when pressed. If the horn button is OK, continue to troubleshoot for an open in circuit 25 between the steering wheel and the BHM.
2	When the horn button is pressed, does the template show that the output becomes active?	Yes	Troubleshoot for an open horn, and for a wiring fault on circuit 24 between the BHM and the horn.
		No	Troubleshoot for a short to ground in circuit 24, between the BHM and the horn. When the wiring fault is repaired, cycle power to the BHM to reset the horn inhibit.

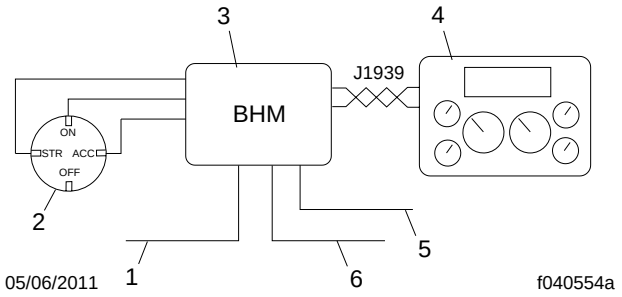
Table 14, The Horn Does Not Work at All

Ignition System

Description

The ignition switch has four positions: off, accessory, on, and start. The BHM monitors the position of the ignition switch and broadcasts this information on the J1939 datalink when it is in the awake state. There are three circuits that run from the ignition switch to the BHM. One is for the accessory position, one is for the on ("Ignition") position, and one is for the start position.

The BHM monitors the ignition switch wiring and will detect some error conditions in the ignition switch circuits. Faults detected by the BHM may be reported over J1939 and may be viewed through ServiceLink. See **Fig. 8**.



1. Accessory Power (12V+)
2. Ignition Switch
3. Bulkhead Module
4. Instrumentation Control Unit
5. Start Power
6. Ignition Power (12V+)

Fig. 8, Ignition System Function

Input and Output Conditions

Table 15, **Table 16** , and **Table 17** displays how the BHM reacts given the status of the ignition switch.

Accessory Power Function Input/Output Conditions	
Input to BHM from Ignition Switch	**Output from BHM to Accessory Power Circuits**
Acc	On
Off	Off
On	On

Accessory Power Function Input/Output Conditions	
Input to BHM from Ignition Switch	**Output from BHM to Accessory Power Circuits**
Start	Off

Table 15, Accessory Power Function Input/Output Conditions

Ignition Power Function Input/Output Conditions	
Input to the BHM from the Ignition Switch	**Output from the BHM to the Ignition Power Circuits**
Acc	Off
Off	Off
On	On
Start	On

Table 16, Ignition Power Function Input/Output Conditions

Fault Conditions

Table 18, **Table 19**, and **Table 20** displays ignition switch circuit conditions that will create a fault. The reference parameters that program the BHM determine whether or not a fault code is broadcast. If the BHM is programmed to transmit fault codes, they can be viewed using ServiceLink.

Ignition Switch Function Input/Output Conditions			
Inputs to BHM			**Output from BHM**
Ignition Switch Accessory Circuit	**Ignition Switch On Circuit**	**Ignition Switch Start Circuit**	**J1939 Ignition Switch Position Message**
Open	Open	Open	Off
Closed	Open	Open	Acc
Closed	Closed	Open	On
Open	Closed	Closed	Start
Open	Open	Closed	On*
Closed	Open	Closed	On*
Open	Closed	Open	On*

* These are error conditions. For more information see the "Fault Conditions" paragraph under the "Ignition System, Ignition Switch Function" heading.

Table 17, Ignition Switch Function Input/Output Conditions

Accessory Power Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and will transmit a fault code on the J1939 datalinks.
The accessory power output wiring is shorted.	BHM may transmit a J1939 fault code.

Table 18, Accessory Power Function Fault Conditions

Troubleshooting

Ignition Power Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and may transmit a fault code on the J1939 datalinks.
The ignition power output wiring is shorted.	BHM may transmit a J1939 fault code.

Table 19, Ignition Power Function Fault Conditions

Ignition Switch Function Fault Conditions			
Description of Fault			**Action Taken by BHM**
Ignition Switch Accessory Circuit	**Ignition Switch On Circuit**	**Ignition Switch Start Circuit**	
Open	Open	Closed	BHM transmits a J1939 fault code.
Closed	Open	Closed	BHM transmits a J1939 fault code.
Open	Closed	Open	BHM transmits a J1939 fault code.

Table 20, Ignition Switch Function Fault Conditions

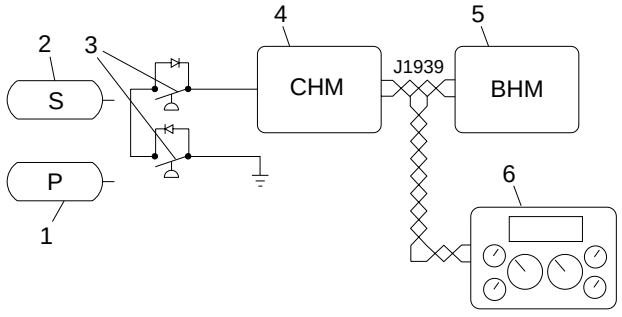
Low Air Pressure Warning Function

Description

The Chassis Module (CHM) monitors the low air pressure switches and broadcasts a J1939 message indicating the switch status. The low air pressure switches are located in the primary, and secondary air systems. These switches are wired in series and electrically open when air pressure is low. The switch point to closed is at 70 +/- 5 psi. The BHM sends a J1939 message indicating whether the low air pressure warning light should be on or off. See **Fig. 9**.

Input and Output Conditions

Table 21 shows the logic of the low air pressure monitoring system.



1. Primary Air
2. Secondary Air
3. Low Air Pressure Switches
4. Chassis Module
5. Bulkhead Module
6. Instrumentation Control Unit

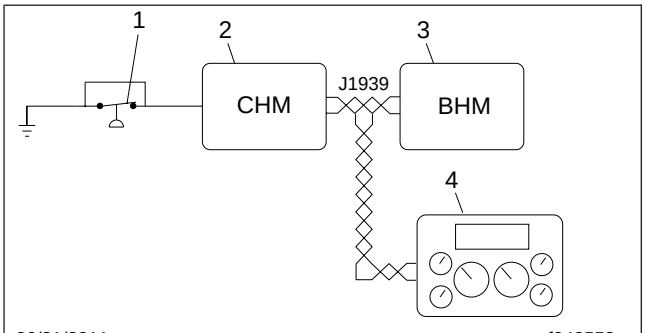
Fig. 9, Low Air Pressure Warning Function

Park Brake (pneumatic) Function

Description

The Chassis Module (CHM) monitors the park brake switch in the air system and broadcasts a J1939 message indicating the status of this input. The park brake switch is electrically closed with low air pressure (park brake applied) and opens at 73 +/- 7 psi.

The BHM translates the CHM message for park brake switch status and broadcasts it over J1939. The ICU activates a telltale when the park brake is engaged. The ICU also activates the warning chime when the drivers door is open and the parking brake is NOT set. See **Fig. 10**.



1. Park Brake Pressure Switch
2. Chassis Module
3. Bulkhead Module
4. Instrumentation Control Unit

Fig. 10, Park Brake (pneumatic) Function

Input and Output Conditions

Table 22 shows the logic of the park brake switch system.

Low Air Pressure Warning Function Input/Output Conditions				
Inputs to CHM		**Input to BHM from CHM**	**Output from BHM to ICU**	**Input from ICU to BHM**
Secondary Air Pressure Switch	**Primary Air Pressure Switch**	**J1939 Low Air Pressure Switch Status Message**	**J1939 Low Air Pressure Warning Light Command Message**	**J1939 Low Air Pressure Warning Light Status Message**
Open	Open	Open	Enabled	On
Open	Closed	Open	Enabled	On
Closed	Open	Open	Enabled	On
Closed	Closed	Closed	Disabled	Off

Table 21, Low Air Pressure Warning Function Input/Output Conditions

Park Brake (pneumatic) Function		
Input to CHM from Park Brake Pressure Switch	**Input to BHM from CHM J1939 Park Brake Status**	**Output from BHM to ICU J1939 Park Brake Light Status**
Closed	Engaged	On
Open	Disengaged	Off

Table 22, Park Brake (pneumatic) Function

Wake Function

See **Subject 050** for additional information on the awake state and sleep state of the BHM.

Wake-Up Initiation

The BHM wakes the chassis module (CHM), expansion module (EXM), and switch expansion module (SEM) by pulling the wake circuits from 12V down to approximately 4V. The EXM and SEM are optional.

The wake circuits remain active at 4V only as long as one or more of the inputs that initiate a wake re-

main active. See **Fig. 11** for wake circuit connectivity and inputs that initiate a wake.

The BHM wakes the instrumentation control unit (ICU) by applying 12V to its wake circuit.

The BHM initiates other modules to wake up when one or more of the following inputs to the BHM is active:

- driver door open
- passenger door open (optional input)
- headlight switch ON
- hazard lights switch ON
- ignition switch is not in the OFF position
- electric horn switch ON
- BHM wake-up line input grounded

The CHM initiates a wake to the BHM, which in turn wakes all other modules when the service brakes are applied.

When all of the initiating inputs are inactive, the wake circuits float back to approximately 12V (except the wake circuit between the BHM and ICU). The ICU wake circuit remains active at 12V until the system enters a sleep state.

Sleep Initiation

When all the inputs that initiate a wake are inactive for 60 seconds, the BHM signals the modules to sleep state by sending a message via J1939. The BHM also causes the ICU to sleep by removing power from its wake circuit.

NOTE: One minute after these conditions are met, and provided that one of the parameters in **Table 23** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

Table 23, Parameters

Troubleshooting Quick Checks

If the ICU chimes when the door is opened, check for an open or short to power in the wake circuit between the BHM and CHM—the BHM cannot determine the park brake status and assumes it is not set while the door is open.

If the ICU does not display the odometer when the door is opened, check the VBAT 2 circuit from fuse 20 in the main PDM and check for an open in the BHM to ICU wake circuit.

Detailed wake system troubleshooting procedures are described in **Table 24**.

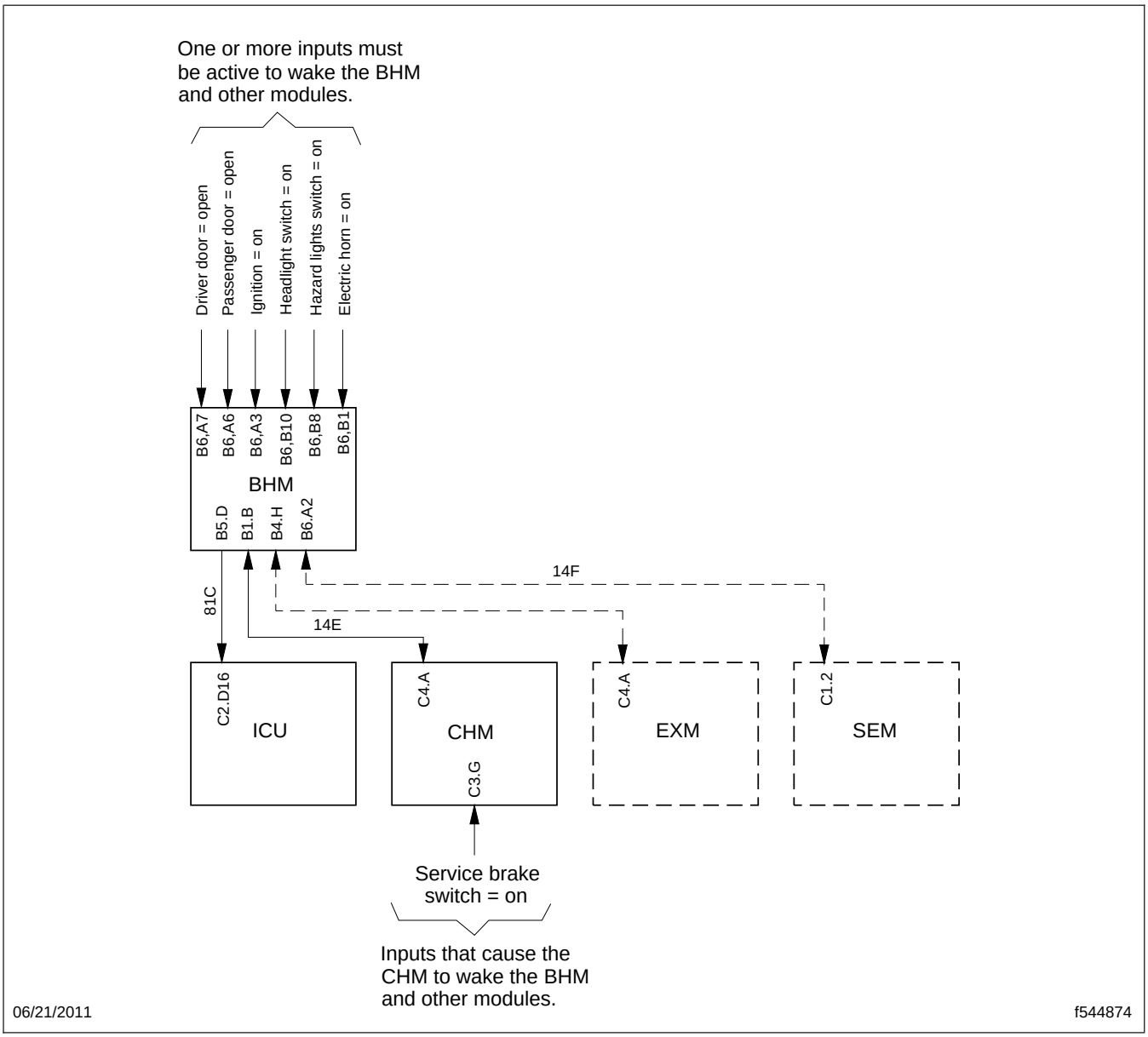


Fig. 11, Simplified Wake Schematic

Troubleshooting

Wake Circuits Troubleshooting Procedures			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Open the "Wake Function" Datalink Monitor template. See **Fig. 12**. Put the system into a sleep state by: • Closing the doors. • Turning off the headlight switch. • Turning off the hazard lights switch. • Turning off the ignition switch. • Releasing the brake pedal. Are any of the BHM and CHM initiating inputs still in an active state on the template (yellow)?	Yes	Check the inputs that are remaining active. For example, if the driver door switch remains active (open) when the door is closed, check the door switch itself and the circuit wiring. Repair as necessary.
		No	**Go to test no. 2.**
2	If everything works correctly after meeting the conditions in test no. 1, the system should go to sleep within 60 seconds. The template indicates this when all of the annunciators show an exclamation mark (!)*. NOTE: If the vehicle has one of the following reference parameters, the system will remain awake for 24 hours or longer: 26-01017-002, 26-01019-003, 26-01019-004, or 26-01019-005. NOTE: This troubleshooting step describes a special circumstance that is not typical of the majority of vehicles. If the system is not working correctly, one or more of the Wake Circuits in the right column of the "Wake Function" Datalink Monitor template remains active (yellow) after 60 seconds. Within 60 seconds of meeting the conditions in test no. 1, do all of the annunciators on the template show an exclamation mark (!)*?	Yes	**Go to test no. 6.**
		No	**Go to test no. 3.**
3	In the second column of the template under "Other Module Wake Circuits–Status" is the status of all the annunciators "LOW-Wake" (yellow)? NOTE: Disregard the annunciators for modules not on the vehicle; these will show an exclamation mark (!)*.	Yes	Check the wake circuits between the BHM and the following modules for a short to ground: • CHM • EXM • SEM Repair as necessary.
		No	**Go to test no. 4.**

Wake Circuits Troubleshooting Procedures			
Test No.	**Test Procedure**	**Test Result**	**Action**
4	If the B5.D BHM to ICU annunciator status is "ON" in the second column of the template under "BHM Wake Circuits–Status," continue with this test. If not, **go to test no. 5.** Disconnect BHM connector B5. Test for voltage on pin B5.D (harness side). Is voltage present?	Yes	The wake circuit between the BHM and ICU is shorted to power. Repair as necessary.
		No	**Go to test no. 5.**
5	In the second column of the template under "BHM Wake Circuits–Status," check the status of the annunciator labeled **B1.B BHM to CHM** **B4.H BHM to EXM** **B6.A2 BHM to SEM**. Is the annunciator status "LOW-Wake" (yellow)?	Yes	If this is the only active annunciator, replace the BHM.
		No	Check the other modules for ignition circuits that are shorted to power (not powering down when the ignition is off). If no problem is found, the system may not be going to sleep because the BHM is not sending the J1939 go-to-sleep message. Try a test BHM to confirm.
6	Starting with the system in the sleep state, activate one of the inputs that initiates a wake, such as opening the driver's door. If the system is functioning properly, all of the annunciators on the template in the second column should be active (yellow) for ECUs equipped on the vehicle as long as the input remains active. For example, the door is open. NOTE: If the vehicle is not equipped with an SEM or EXM, it is normal for the status of these annunciators to be "!"*. Are all of the appropriate second column annunciators active?	Yes	**Go to test no. 8.**
		No	**Go to test no. 7.**
7	Which annunciator is not active?	B5.D BHM to ICU	Replace the BHM.
		B1.B BHM to CHM B4.H BHM to EXM B6.A2 BHM to SEM	Replace the BHM.
		Any one of the "Other Module Wake Circuits–Status" for ECUs that are on the vehicle.	Check for an open in the wake circuit between the BHM and the module that is not showing active. If OK, check power, ground, and the J1939 datalink to the ECU that is not responding.

Troubleshooting

Wake Circuits Troubleshooting Procedures			
Test No.	**Test Procedure**	**Test Result**	**Action**
8	Does the ICU wake up when the door is opened? This is indicated by the odometer being displayed.	Yes	No problem found.
		No	Check the wake circuit between the BHM and ICU for open. If OK, check fuse 20 in the main PDM and VBAT2 power supply to BHM B4.G. If OK, ICU may be faulty. Repair as necessary.

* The exclamation mark (!) will show on the versions of this template released with ServiceLink version 4.0 and higher. On templates released in ServiceLink versions prior to 4.0, if the annunciator is flashing, the flashing takes precedence over the status that it is displaying.

Table 24, Wake Circuits Troubleshooting Procedures

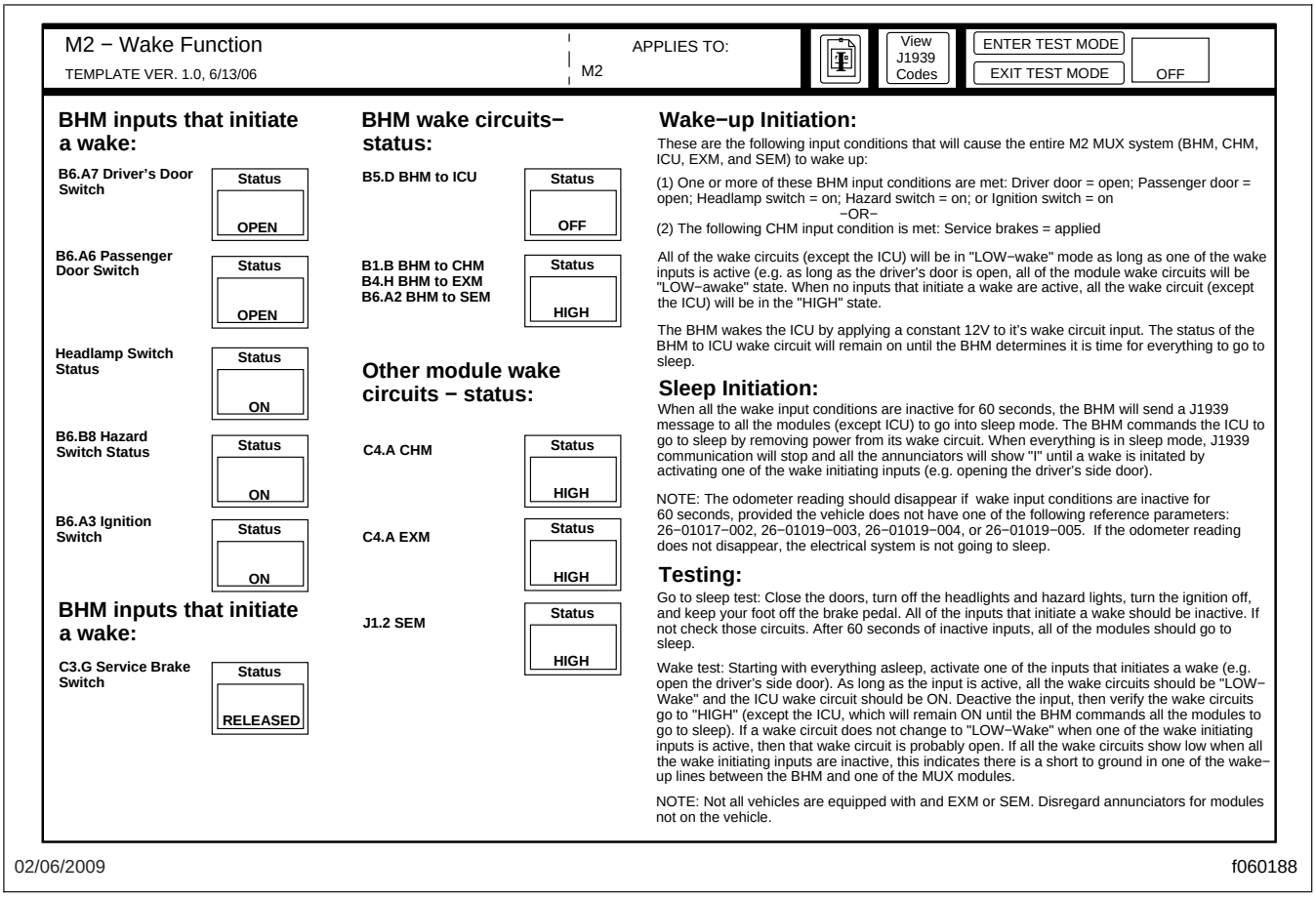


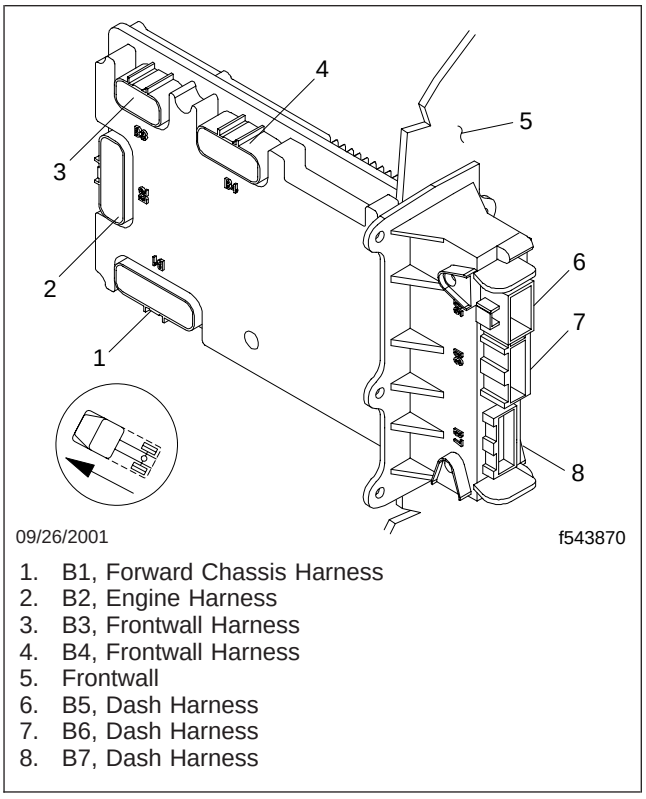
Fig. 12, Wake Function Datalink Monitor Template

Specifications

See **Fig. 1** for an illustration of the bulkhead module (BHM) harness connections.

See **Fig. 2** for maximum allowable current load for the full BHM output circuits.

See **Fig. 3** for an illustration of the BHM with pinout assignments and harness connections.



1. B1, Forward Chassis Harness
2. B2, Engine Harness
3. B3, Frontwall Harness
4. B4, Frontwall Harness
5. Frontwall
6. B5, Dash Harness
7. B6, Dash Harness
8. B7, Dash Harness

Fig. 1, Bulkhead Module Harness Connections

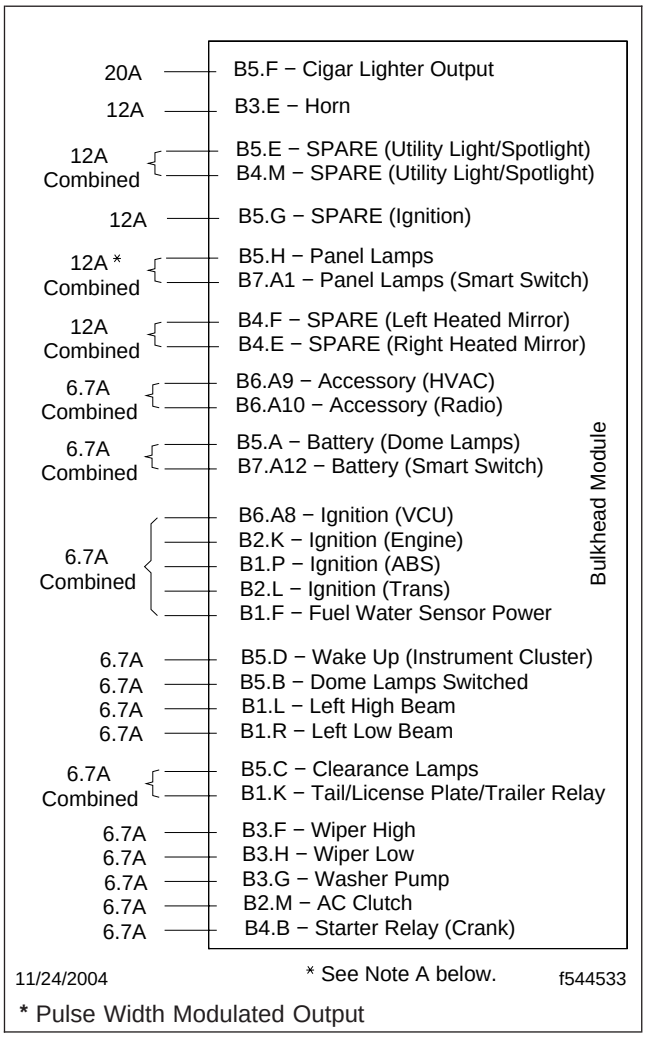
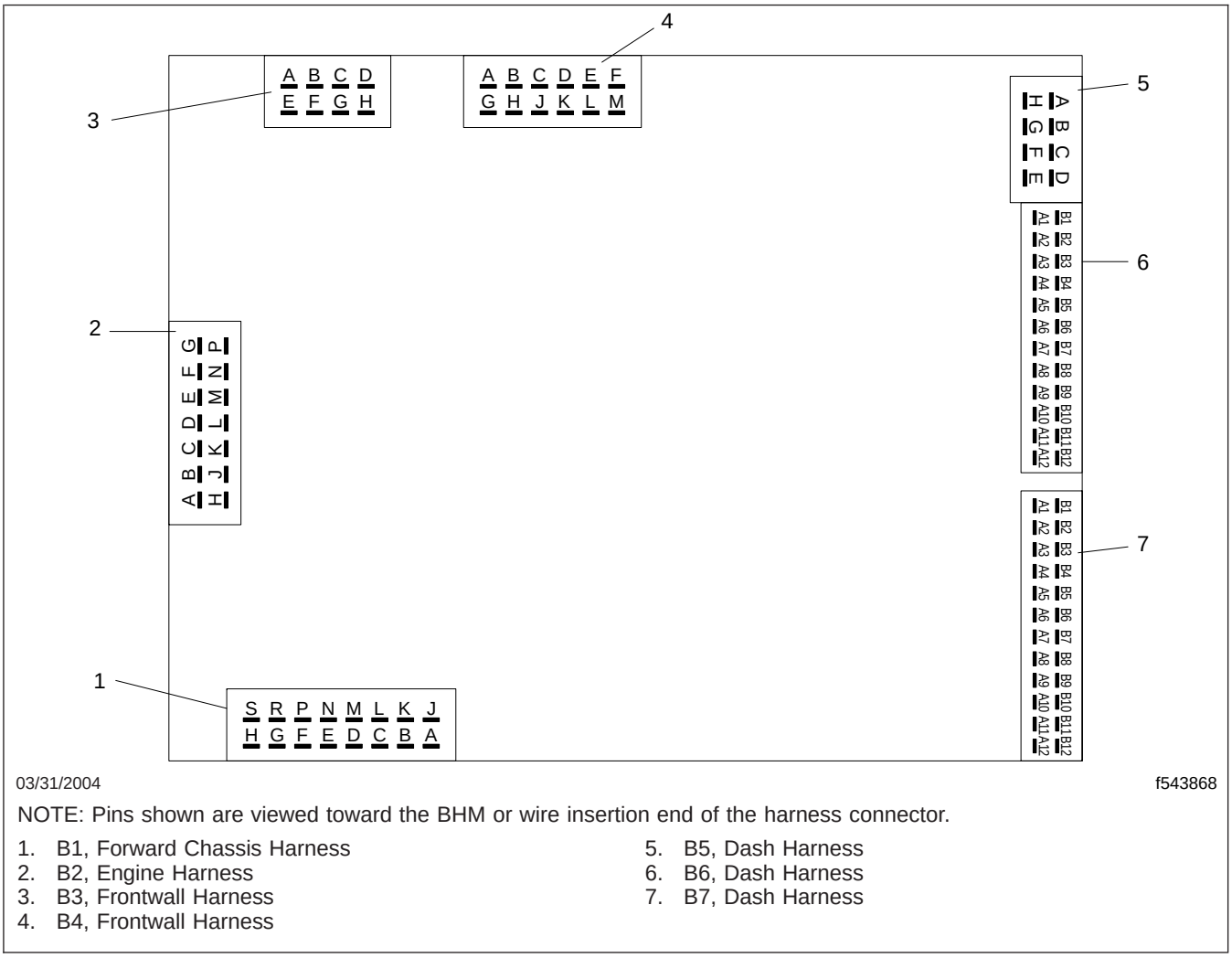


Fig. 2, Maximum Allowable Current Load for the Full-Feature Bulkhead Module Output Circuits

Specifications



NOTE: Pins shown are viewed toward the BHM or wire insertion end of the harness connector.

1. B1, Forward Chassis Harness
2. B2, Engine Harness
3. B3, Frontwall Harness
4. B4, Frontwall Harness
5. B5, Dash Harness
6. B6, Dash Harness
7. B7, Dash Harness

Fig. 3, Bulkhead Module With Pinout Assignments and Harness Connections

Connector B1 Forward Chassis Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B1-A	—	—
B1-B	Module Wake-Up Signal	Digital Input/ Output
B1-C	Spare Digital Input 4	Digital Input
B1-D	—	—
B1-E	Ground	Power Ground
B1-F	Fuel/Water Sensor Ignition Power	Digital Output
B1-G	Ground	Signal Ground
B1-H	—	—

Connector B1 Forward Chassis Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B1-J	Battery Power (VBAT5)	Power
B1-K	Tail Lamps/License Plate Lamp/Trailer Tail Relay	Digital Output
B1-L	Left High Beam	Digital Output
B1-M	Fuel/Water Separator (spare digital input 5)	Digital Input
B1-N	Battery Power (VBAT3)	Power
B1-P	ABS Ignition Power	Digital Output
B1-R	Left Low Beam	Digital Output
B1-S	—	—

Table 1, Connector B1 Forward Chassis Harness Pinouts

Connector B2 Engine Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B2-A	—	—
B2-B	J1939+ Datalink	Datalink
B2-C	—	—
B2-D	—	—
B2-E	—	—
B2-F	—	—
B2-G	Backup Switch (spare digital input 3)	Digital Input
B2-H	—	—
B2-J	J1939– Datalink	Datalink
B2-K	Engine ECU Ignition Power	Digital Output
B2-L	Transmission ECU Ignition Power	Digital Output
B2-M	A/C Clutch	Digital Output
B2-N	—	—
B2-P	Alternator Charging	Digital Input

Table 2, Connector B2 Engine Harness Pinouts

Connector B3 Frontwall Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B3-A	J1939– Datalink	Datalink
B3-B	J1939+ Datalink	Datalink
B3-C	Wiper Parked Position	Digital Input
B3-D	Main Battery Power (VBAT1)	Power
B3-E	Horn	Digital Output
B3-F	Wiper Motor High Speed	Digital Output

Specifications

Connector B3 Frontwall Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B3-G	Washer Pump	Digital Output
B3-H	Wiper Motor Low Speed	Digital Output

Table 3, Connector B3 Frontwall Harness Pinouts

Connector B4 Frontwall Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B4-A	Air Filter Restriction/Spare #9	Digital Input
B4-B	Starter Relay	Digital Output
B4-C	Ground	Ground
B4-D	Spare Digital Input 2	Digital Input
B4-E	Right Heated Mirror (spare digital output)	Digital Output
B4-F	Left Heated Mirror (spare digital output)	Digital Output
B4-G	Main Battery Power (VBAT2)	Power
B4-H	Module Wake-Up Signal	Digital Input/Output
B4-J	—	—
B4-K	Main Battery Power (VBAT4)	Power
B4-L	Washer Fluid Level (spare digital input 8)	Digital Input
B4-M	Utility Light/Spotlight (spare digital output)	Digital Output

Table 4, Connector B4 Frontwall Harness Pinouts

Connector B5 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B5-A	Dome Lamps Battery	Digital Output
B5-B	Dome Lamps Switched	Digital Output
B5-C	Clearance Lamps (cab)	Digital Output
B5-D	Instrument Cluster Wake-Up	Digital Output
B5-E	Utility Light/Spotlight (spare digital output)	Digital Output
B5-F	Cigar Lighter	Digital Output
B5-G	Ignition Power, Other (spare digital output)	Digital Output
B5-H	Panel Lamps	Digital Output

Table 5, Connector B5 Dash Harness Pinouts

Connector B6 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B6-A1	Ignition Switch Accessory Position	Digital Input
B6-A2	Module Wake-Up Signal	Digital Input

Connector B6 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B6-A3	Ignition Switch On	Digital Input
B6-A4	—	—
B6-A5	Ignition Switch Start	Digital Input
B6-A6	Passenger Door Open (spare digital input 10)	Digital Input
B6-A7	Driver Door Open	Digital Input
B6-A8	VCU Ignition Power	Digital Output
B6-A9	HVAC Power	Digital Output
B6-A10	Radio Power	Digital Output
B6-A11	—	—
B6-A12	—	—
B6-B1	Horn Switch	Digital Input
B6-B2	Top of Clutch Switch (spare digital input 7)	Digital Input
B6-B3	Bottom of Clutch Switch (spare digital input 6)	Digital Input
B6-B4	—	—
B6-B5	Panel Lamps Increase	Digital Input
B6-B6	Panel Lamps Decrease	Digital Input
B6-B7	A/C Clutch Request	Digital Input
B6-B8	Hazard Switch	Digital Input
B6-B9	Headlamp Switch PARK Position	Digital Input
B6-B10	Headlamp Switch On Position	Digital Input
B6-B11	Headlamp Switch On 2 Position	Digital Input
B6-B12	—	—

Table 6, Connector B6 Dash Harness Pinouts

Connector B7 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B7-A1	Panel Lamps (smart switch)	Digital Output
B7-A2	Smart Switch 3 ID 1	Analog Input
B7-A3	Smart Switch 3 ID 2	Analog Input
B7-A4	Smart Switch 3 Input	Analog Input
B7-A5	Smart Switch 3 Indicator	Digital Output
B7-A6	Smart Switch 4 ID 1	Analog Input
B7-A7	Smart Switch 4 ID 2	Analog Input
B7-A8	Smart Switch 4 Input	Analog Input
B7-A9	Smart Switch 4 Indicator	Digital Output
B7-A10	Smart Switch 5 ID 1	Analog Input

Specifications

Connector B7 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B7-A11	Smart Switch 5 ID 2	Analog Input
B7-A12	Smart Switch Battery Power	Digital Output
B7-B1	Smart Switch 1 ID 1	Analog Input
B7-B2	Smart Switch 1 ID 2	Analog Input
B7-B3	Smart Switch 1 Input	Analog Input
B7-B4	Smart Switch 1 Indicator	Digital Output
B7-B5	Smart Switch 2 ID 1	Analog Input
B7-B6	Smart Switch 2 ID 2	Analog Input
B7-B7	Smart Switch 2 Input	Analog Input
B7-B8	Smart Switch 2 Indicator	Digital Output
B7-B9	Ground	Signal Ground
B7-B10	Smart Switch 5 Indicator	Digital Output
B7-B11	Smart Switch 5 Input	Analog Input
B7-B12	—	—

Table 7, Connector B7 Dash Harness Pinouts

Power Supply Fuses and Associated Outputs for the Bulkhead Module				
BHM Power Input	**BHM Power Input Pin**	**Main PDM Fuse to BHM Input**	**BHM Outputs Supplied**	**BHM Output Pin**
Power In			**Power Out**	
VBAT1	B3.D	Fuse 22 (30A)	Battery (dome lamps)	B5.A
			Battery (smart switches)	B7.A12
			Ignition (VCU)	B6.A8
			Ignition (engine)	B2.K
			Ignition (ABS)	B1.P
			Ignition (trans)	B2.L
			Fuel Water Sensor Power	B1.F
			Dome Lamps Switched	B5.B
			Left Low Beam	B1.R
			A/C Clutch	B2.M
			Smart Switch 1 Indicator	B7.B4
			Smart Switch 2 Indicator	B7.B8
			Smart Switch 3 Indicator	B7.A5
			Smart Switch 4 Indicator	B7.A9
			Smart Switch 5 Indicator	B7.B10
			Battery (smart switch)	B7.A12

Power Supply Fuses and Associated Outputs for the Bulkhead Module				
BHM Power Input	**BHM Power Input Pin**	**Main PDM Fuse to BHM Input**	**BHM Outputs Supplied**	**BHM Output Pin**
Power In			**Power Out**	
VBAT2	B4.G	Fuse 20 (30A)	Accessory (HVAC)	B6.A9
			Accessory (radio)	B6.A10
			Wake Up (instrument cluster)	B5.D
			Left High Beam	B1.L
			Wiper High	B3.F
			Horn	B3.E
VBAT3	B1.N	Fuse 18 (30A)	Wiper Low	B3.H
			Spare 8.0A HSD (ignition)	B5.G
			Panel Lamps	B5.H
			Panel Lamps (smart switch)	B7.A1
VBAT4	B4.K	Fuse 15 (30A)	Clearance Lamps	B5.C
			Tail Lamps/License Plate Lamp/Trailer Tail Relay	B1.K*
			Washer Pump	B3.G
			12V Output (cigar lighter)	B5.F
VBAT5	B1.J	Fuse 7 (30A)	Spare 8.5A (utility light/spotlight)	B5.E / B4.M
			Left Heated Mirror	B4.F
			Right Heated Mirror	B4.E

* This output supplies power to the Chassis Module pass-through for the tail lamps, license plate lamp, and trailer tail lamp relay.

Table 8, Power Supply Fuses and Associated Outputs for the Bulkhead Module

NOTE: Currents listed are the maximum allowable combined current load for each output circuit. When maximum allowable current load is exceeded, the BHM software will shut off the output circuit.

In Test Mode, the outputs will deliver more current than the maximum allowable current values shown. When testing, do not exceed the maximum combined values for more than a few seconds or the life of the output driver inside the BHM may be shortened.

Bulkhead Module Fault Codes

General Information

Use **Table 1** to identify fault codes, and an overview of the diagnostic procedure for fault codes generated by the bulkhead module, SA 33.

The information in the connector column indicates the typical connector and pin for the affected circuit.

Always use the appropriate schematic for the vehicle as different option content modifies which connector and pin are actually used. BHM B1, A indicates that the typical circuit is BHM connector B1, pin A. CHM indicates the Chassis Module.

J1939 Fault Codes From Bulkhead Module (SA 33)

SPN	FMI	Fault Description	Diagnosis	Circuit	ECU Conn/ Pin
84	19	Vehicle speed received data error	Troubleshoot for a fault with the vehicle speed sensor and wiring, as described in the engine service literature. The vehicle speed sensor is part of the engine management system, and the data is broadcast from the engine ECU over J1939 or J1708 on EPA07 and older vehicles.	data	—
598	7	Clutch switch fault	The top-of-clutch switch and bottom-of-clutch switch are both measured as closed at the same time. Troubleshoot for clutch switch shorted, or for a wiring fault between the clutch switch and the BHM. Engine starting is disabled and other optional functions may be interrupted until the fault is corrected and the ignition switch is cycled.	440C top 15K bottom	**BHM** B6, B2 B6 (top) B3 (bottom)
879	5	Front left turn lamp — current below expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates the bulb is open, or the wiring between the BHM and the bulb is an open circuit.	38L	**CHM** C3, N
879	6	Front left turn lamp — current above expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates that the lamps connected to this circuit are drawing more current than the circuit is designed to supply, or there is a wiring fault shorting this circuit to ground.	38L	**CHM** C3, N
881	5	Front right turn lamp — current below expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates that the bulb is open, or the wiring between the BHM and the bulb is an open circuit.	38R	**CHM** C3, R
881	6	Front right turn lamp — current above expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates that the lamps connected to this circuit are drawing more current than the circuit is designed to supply, or there is a wiring fault shorting this circuit to ground.	38R	**CHM** C3, R
882	4	Marker lamps — voltage below expected value	The BHM drives the 5 cab overhead clearance and ID lamps from connector B5, pin C on circuit 46. All other marker and tail lamps are driven from BHM connector B1, K on circuit 23. This circuit connects to the CHM as an input at connector J3, P. The CHM passes the signal through to power the tail lamps and marker lamps from connector C2, pin G and also from connector C1, pins D, E, and F. Troubleshoot for a wiring short-to-ground fault on any of the CHM output or BHM output circuits discussed above. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	23, 46, 23A, 23C	**BHM** B1, K B5, C **CHM** J3, P C2, G C1, D C1, E C1, F

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
882	5	Marker lamps — current below expected value	The BHM measures the current on this circuit when the lamps are commanded ON. This fault indicates some bulbs are open or the wiring between the BHM and the bulbs is open circuit.	23, 46, 23A, 23C	**BHM** B1, K B5, C **CHM** J3, P C2, G C1, D C1, E C1, F
882	6	Marker lamps — current above expected value	The BHM drives the 5 cab overhead clearance and ID lamps from connector B5 pin C on circuit 46. All other marker and tail lamps are driven from BHM connector B1,K on circuit 23. This circuit connects to the CHM as an input at connector J3,P. The CHM passes the signal through to power the tail lamps and marker lamps from connector C2 pin G and also from connector C1 pins D, E, and F. Troubleshoot for a wiring short to ground fault on any of the CHM output or BHM output circuits discussed above. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	23, 46, 23A, 23C	**BHM** B1, K B5, C **CHM** J3, P C2, G C1, D C1, E C1, F
1487	7	Backlighting intensity switch circuit fault	The backlighting dimmer switch connects ground to circuit 29C in the increase intensity position. It connects ground to circuit 29 in the decrease intensity position. If both circuits are at ground, this fault is set.	29, 29C	**BHM** B6, B5 B6, B6
1550	5	AC compressor clutch — current below expected value	The BHM measures the current on this circuit when the AC compressor is commanded ON. This fault indicates the clutch circuit is open or the wiring between the BHM and the AC compressor clutch is high resistance or open.	97F, 97C, 98Z	**BHM** B2, M
1550	6	AC compressor clutch — current above expected value	The BHM measures the current on this circuit when the AC compressor clutch is commanded ON. This fault indicates that the circuit is drawing more current than it is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	97F, 97C, 98Z	**BHM** B2, M
2003	19	Transmission controller not broadcasting expected message	The BHM expects to receive data from the transmission controller. This fault indicates that the transmission ECU is not broadcasting or there is a fault with the J1939 databus. Also troubleshoot the power feed circuits to the transmission controller.	data	—
2071	19	Chassis module not broadcasting expected message	The BHM expects to receive data from the chassis module. This fault indicates that the CHM is not broadcasting or there is a fault with the J1939 databus. Also troubleshoot the power feed circuits to the CHM.	data	—
6890	8	DRL output fault	The CHM does not suupport PWM type DRLs. The vehicle has a BHM mismatch with the CHM. Replace the CHM with one that is compatible with the BHM.	379L 379R	**CHM** C3, K C4, F

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6891	4	CHM power feed VBAT1 — low voltage	The output circuits that are powered by VBAT1 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT1 supply to the CHM.	14G	**CHM** C4, P
6892	4	CHM power feed VBAT2 — low voltage	The output circuits that are powered by VBAT2 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT2 supply to the CHM.	14G	**CHM** C3, J
6893	4	CHM power feed VBAT3 — low voltage	The output circuits that are powered by VBAT3 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT3 supply to the CHM.	14G	**CHM** C4, J
6906	7	PTO 2 no pressure feedback	The PTO 2 output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for PTO 2 air solenoid fault, and for air pressure switch open circuit fault.	variable	variable
6907	7	PTO 2 pressure detected fault	The PTO 2 output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for PTO 2 air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6908	7	PTO 1 no pressure feedback	The PTO 1 output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for PTO 2 air solenoid fault, and for air pressure switch open circuit fault.	variable	variable
6909	7	PTO 1 pressure detected fault	The PTO 1 output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for PTO 2 air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6910	7	Axle lift 2 no pressure feedback	The axle lift 2 output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for axle lift 2 air solenoid fault, and for air pressure switch open circuit fault.	variable	variable
6911	7	Axle lift 2 pressure detected fault	The axle lift 2 output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for axle lift 2 air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6912	7	Remote start switch stuck in crank	BHM connector B6, A5 is at battery voltage for more than 30 seconds and the key is in the ON position. The remote start switch circuit 15D is at ground, and the remote start relay is active. Troubleshoot the pneumatic remote start switch system in trucks with a bucket lift, or the remote start switch applicable to the vehicle.	15D, 15	**BHM** B6, A5

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6915	4	BHM 8 amp ignition output circuit — voltage below expected value	The BHM supplies battery power on this circuit when the key is in the RUN or CRANK positions. Troubleshoot for a wiring fault shorting this circuit to ground or for too many optional circuits spliced into it that is causing the BHM to turn it off. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	81C	**BHM** B5, G
6915	5	BHM 8 amp ignition output circuit — current below expected value	The BHM supplies battery power on this circuit when the key is in the RUN or CRANK positions. Troubleshoot for an open circuit fault.	81C	**BHM** B5, G
6915	6	BHM 8 amp ignition output circuit — current above expected value	The BHM supplies battery power on this circuit when the key is in the RUN or CRANK positions. Troubleshoot for a wiring fault shorting this circuit to ground or for too many optional circuits spliced into it that is causing the BHM to turn it off. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	81C	**BHM** B5, G
6916	19	Wiper park position — data fault	The wiper switch is in the OFF position and the BHM park input from the wiper motor is not in park position. Troubleshoot for a wiper motor park switch circuit fault.	—	**BHM** B3, C **ICU** A2
6917	19	Four way flashers — data fault	The ICU broadcasts the state of the turn signal indicators to the BHM. When this fault is active, the four-way flashers are on and the ICU is not controlling the turn signal indicators according to the BHM command. Replace the ICU.	—	**BHM** B6, B8
6918	7	Missing smart switch	The BHM is not detecting the presence of all the smart switches it is configured to have. Use ServiceLink to determine which smart switch is missing. From the BHM screen, click on the "Configuration" tab then click the "Check for Missing Smart Switches" box. The switch ID will be missing from the Smart Switch the vehicle is expected to have.	—	—
6919	7	Duplicate smart switch	The BHM is detecting more than one smart switch with the same ID number present on the vehicle. The outputs controlled by the switch and the indicator in the switch are commanded OFF. The position information for the switch becomes Not Available. Remove the duplicate Smart Switch, then use ServiceLink to verify that the correct Smart Switches are configured for the vehicle. From the BHM screen, click the "Features" tab. The reference parameters that configure the Smart Switches are identified in this list.	—	—

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6920	7	Extra smart switch	The BHM is detecting one or more smart switches connected to the vehicle that have not been configured with BHM parameters. Use ServiceLink to identify which Smart Switches are configured for the vehicle. From the BHM screen, click the "Features" tab. The reference parameters that configure the Smart Switches are identified in this list. Determine if the extra switch is not required for the vehicle or if the switch has been installed but the necessary reference parameter has not been programmed into the BHM.	—	—
6921	7	BHM microprocessor fault	Replace the BHM.	—	—
6922	7	Wake up circuit fault	The wake up circuit is powered to a battery voltage circuit. One of the ECUs using circuit 14E is holding this circuit ON, or there is a wiring fault. Use the procedure in service bulletin **54-266**.	14E	**BHM** B1, B B1, D B4, H B6, A2 **CHM** C4, A **SHM** J1, C **SEM** J1, 2
6923	7	Wiper park circuit fault	When the wiper switch is turned to the OFF position, the BHM expects to see ground on the park switch circuit within 5 seconds. This fault is set if ground is not detected. Troubleshoot for an open in circuit 317, or an open park switch in the wiper motor.	317	**BHM** B3, C
6924	19	Wiper switch ON/OFF logic fault	The ICU reads the wiper switch position and sends the status of the switch to the BHM. This fault becomes active when the ICU reads that either the LO speed or HI speed is active when the wiper switch is also in the OFF position. Troubleshoot for a inoperative stalk switch.	473C	**ICU** A2
6925	19	Wiper switch HI/LO logic fault	The ICU reads the wiper switch position and sends the status of the switch to the BHM. This fault becomes active when the ICU reads that both LO speed and HI speed are active at the same time. Troubleshoot for an inoperative stalk switch.	473C	**ICU** A2
6926	7	Marker interrupt switch fault	The BHM reads the marker-interrupt smart switch. If the switch input is activated for too long, this fault becomes active. Troubleshoot for the marker interrupt switch stuck in the active position, or for the user holding it too long.	variable	variable
6928	7	Suspension proportioning — no pressure feedback	The suspension proportioning output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for a suspension proportioning air solenoid fault, and for an air pressure switch open circuit fault.	variable	variable

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6929	7	Suspension proportioning — pressure detected	The suspension proportioning output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for suspension proportioning air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6931	7	Suspension dump — no pressure feedback	The suspension dump output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for suspension dump air solenoid fault, and for air pressure switch open circuit fault.	variable	variable
6932	7	Suspension dump — pressure detected	The suspension dump output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for suspension dump air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6944	6	Fuel water separator heater circuit — current above expected value	The BHM measures the current on this circuit. This fault indicates that the circuit is drawing more current than it is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. Troubleshoot for a wiring fault shorting this circuit to ground, and for a short in the heater. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	196	**CHM** C3, A
6951	7	Fifth wheel slide — no pressure feedback	The fifth wheel slide output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for a fifth wheel slide air solenoid fault, and for an air pressure switch open circuit fault.	variable	variable
6952	7	Fifth wheel slide — pressure detected	The fifth wheel slide output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for a fifth wheel slide air solenoid fault, and for an air pressure switch short circuit fault.	variable	variable
6954	7	End of frame air — no pressure feedback	The End of Frame air output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for an End of Frame air solenoid fault, and for an air pressure switch open circuit fault.	variable	variable
6955	7	End of frame air — pressure detected	The End of Frame air output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for an End of Frame air solenoid fault, and for an air pressure switch short circuit fault.	variable	variable
6958	6	Brake air dryer circuit — current above expected value	The BHM measures the current on this circuit. This fault indicates that the circuit is drawing more current than it is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. Use the schematic in module 84A to assist troubleshooting this circuit. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	94	**BHM** B4, M

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6961	7	Axle lift # 1 — no pressure feedback	The axle lift 1 output circuit has been commanded ON, but air pressure is not detected at the pressure feedback switch. Troubleshoot for axle lift 1 air solenoid fault, and for air pressure switch open circuit fault.	variable	variable
6962	7	Axle lift # 1 — pressure detected	The axle lift 1 output circuit is commanded OFF, but air pressure is detected at the pressure feedback switch. Troubleshoot for axle lift 1 air solenoid fault, and for air pressure switch short circuit fault.	variable	variable
6965	4	BHM VBAT 5 input — voltage below expected value	The output circuits that are powered by VBAT5 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT5 supply to the BHM.	14H	**BHM** B1, J
6966	4	BHM VBAT 4 input — voltage below expected value	The output circuits that are powered by VBAT4 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT4 supply to the BHM.	14H	**BHM** B4, K
6967	4	BHM VBAT 3 input — voltage below expected value	The output circuits powered by VBAT3 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT3 supply to the BHM.	14H	**BHM** B1, N
6968	4	BHM VBAT 2 input — voltage below expected value	The output circuits that are powered by VBAT2 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT2 supply to the BHM.	14H	**BHM** B4, G
6969	4	BHM VBAT 1 input — voltage below expected value	The output circuits that are powered by VBAT1 will all be inoperative. Other fault codes may be present, but troubleshoot for this first. The fuse in the main PDM powering this circuit may be open. The root cause could be excessive loads on an output, or a short to ground in the VBAT1 supply to the BHM.	14H	**BHM** B3, D
6970	5	Wiper high speed circuit — current below expected value	The BHM measures the current on this circuit when the windshield wipers are operating on high speed. This fault indicates the wiper motor high speed circuit is open, or the wiring between the BHM and the wiper motor is open circuit. Test for an open wiper motor and use the schematic in module 66B to assist troubleshooting the circuit.	318	**BHM** B3, F
6970	6	Wiper high speed circuit — current above expected value	The BHM measures the current on this circuit when the windshield wipers are operating on high speed. This fault indicates the wiper motor high speed circuit is short to ground, or the wiring between the BHM and the wiper motor is short to ground. Use the schematic in module 66B to assist troubleshooting the circuit.	318	**BHM** B3, F

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6971	5	Wiper low speed circuit — current below expected value	The BHM measures the current on this circuit when the windshield wipers are operating on low speed. This fault indicates the wiper motor low speed circuit is open, or the wiring between the BHM and the wiper motor is open circuit. Test for an open wiper motor and use the schematic in module 66B to assist troubleshooting the circuit.	316	**BHM** B3, H
6971	6	Wiper low speed circuit — current above expected value	The BHM measures the current on this circuit when the windshield wipers are operating on low speed. This fault indicates the wiper motor low speed circuit is short to ground, or the wiring between the BHM and the wiper motor is short to ground. Use the schematic in module 66B to assist troubleshooting the circuit.	316	**BHM** B3, H
6972	19	Windshield wiper high speed switch — data error	The ICU is unable to broadcast a valid wiper high speed switch position to the BHM. Troubleshoot for a wiper switch fault or for loss of J1939 communication from the ICU.	—	**ICU** A2
6973	19	Windshield wiper low speed switch — data error	The ICU is unable to broadcast a valid wiper low speed switch position to the BHM. Troubleshoot for a wiper switch fault or for loss of J1939 communication from the ICU.	—	**ICU** A2
6974	19	Windshield wiper switch — data error	The ICU is unable to broadcast a valid wiper switch position to the BHM. Troubleshoot for a wiper switch fault or for loss of J1939 communication from the ICU.	—	**ICU** A2
6976	5	Windshield washer pump circuit — current below expected value	The BHM measures the current on this circuit when the windshield washer pump is operating. This fault indicates the windshield washer pump is open circuit, or the wiring between the BHM and the windshield washer pump is open circuit. Test for an open washer pump and use the schematic in module 66B to assist troubleshooting the circuit.	320	**BHM** B3, G
6976	6	Windshield washer pump circuit — current above expected value	The BHM measures the current on this circuit when the windshield washer pump is operating. This fault indicates the windshield washer pump is short to ground, or the wiring between the BHM and the windshield washer pump is short to ground. Use the schematic in module 66B to assist troubleshooting the circuit. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	320	**BHM** B3, G
6977	19	Windshield washer switch — data error	The ICU is unable to broadcast a valid windshield washer switch position to the BHM. Troubleshoot for a washer switch fault or for loss of J1939 communication from the ICU.	—	**ICU** B7
6978	19	Right turn signal switch — data error	The ICU is unable to broadcast a valid turn signal switch position to the BHM. Troubleshoot for a turn signal switch fault or for loss of J1939 communication from the ICU.	—	**ICU** B6
6979	19	Left turn signal switch — data error	The ICU is unable to broadcast a valid turn signal switch position to the BHM. Troubleshoot for a turn signal switch fault, or for loss of J1939 communication from the ICU.	—	**ICU** B6

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6980	5	Right stop/turn lamp — current below expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates the bulb is open, or the wiring between the BHM and the bulb is open circuit.	39R	**CHM** C1, L
6980	6	Right stop/turn lamp — current above expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates that the lamps connected to this circuit are drawing more current than the circuit is designed to supply, or there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	39R	**CHM** C1, L
6981	5	Left stop/turn lamp — current below expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates the bulb is open, or the wiring between the BHM and the bulb is open circuit.	39L	**CHM** C1, N
6981	6	Left stop/turn lamp — current above expected value	The BHM measures the current on this circuit when the lamp is commanded ON. This fault indicates that the lamps connected to this circuit are drawing more current than the circuit is designed to supply, or there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	39L	**CHM** C1, N
6982	5	Wake up / ICU power output circuit — current below expected value	The BHM measures the current on this circuit when the wake up/ICU power output circuit is commanded ON. This fault indicates an open circuit.	81C	**BHM** B5, D
6982	6	Wake up / ICU power output circuit — current above expected value	The BHM measures the current on this circuit when the wake up/ICU power output is commanded ON. This fault indicates that the wake up/ICU power circuit is drawing more current than the circuit is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. Some BHM configurations force this circuit off until the ignition switch is cycled.	81C	**BHM** B5, D
6983	5	Starter relay output — current below expected value	The BHM measures the current on this circuit when the starter output is commanded ON. This fault indicates the magnetic switch or the wiring between the BHM and the magnetic switch is open circuit.	472S	**BHM** B4, B
6983	6	Starter relay output — current above expected value	The BHM measures the current on this circuit when the starter output is commanded ON. This fault indicates that the magnetic switch circuit is drawing more current than the circuit is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	472S	**BHM** B4, B
6984	5	Ignition accessory output circuit — current below expected value	The BHM measures the current on this circuit when the accessory output is commanded ON. This fault indicates an open circuit. Use the vehicle schematics to determine what devices are powered by this circuit.	295A or 98	**BHM** B6,A9 or **BHM** B6,A10

Bulkhead Module Fault Codes

<table>
<tr><th colspan="6">J1939 Fault Codes From Bulkhead Module (SA 33)</th></tr>
<tr><th>SPN</th><th>FMI</th><th>Fault Description</th><th>Diagnosis</th><th>Circuit</th><th>ECU Conn/ Pin</th></tr>
<tr><td>6984</td><td>6</td><td>Ignition accessory output circuit — current above expected value</td><td>The BHM measures the current on this circuit when the accessory output is commanded ON. This fault indicates that the accessory circuit is drawing more current than the circuit is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.</td><td>295A or 98</td><td>BHM
B6,A9
or
B6,A10</td></tr>
<tr><td>6985</td><td>5</td><td>Ignition output circuit — current below expected value</td><td>The BHM measures the current on this circuit when the ignition output is commanded ON. This fault indicates an open circuit. Use the vehicle schematics to determine what devices are powered by this circuit.</td><td>439W+ 376C, 223A, 439A, 81C</td><td>BHM
B1, F
B1, P
B2, L
B2, K
B6, A8</td></tr>
<tr><td>6985</td><td>6</td><td>Ignition output circuit — current above expected value</td><td>The BHM measures the current on this circuit when the ignition output is commanded ON. This fault indicates that the ignition circuit is drawing more current than the circuit is designed to supply, and possibly there is a wiring fault shorting this circuit to ground. Some BHM configurations force this circuit off until the ignition switch is cycled.</td><td>439W+ 376C, 223A, 439A, 81C</td><td>BHM
B1, F
B1, P
B2, L
B2, K
B6, A8</td></tr>
<tr><td>6985</td><td>7</td><td>The CHM ignition input circuit is not measuring the same state as the BHM ignition output circuit</td><td>The BHM ignition output circuit is ON and the CHM ignition input circuit is measuring OFF, or the opposite combination is occurring. This could indicate a combination of wiring faults in the ignition ON circuit to the CHM.</td><td>81C</td><td>CHM
C3, M
and
BHM
B6, A8</td></tr>
<tr><td>6986</td><td>7</td><td>Ignition switch circuits to BHM are in an invalid combination</td><td>The voltage on the 3 ignition-switch input circuits is expected to be a combination of the values shown below. This fault is active when any of the "Error" combinations occur. Troubleshoot for a wiring fault between the ignition switch and the BHM, or for a defective ignition switch.

<table>
<tr><th>ACC B6, A1</th><th>IGN B6, A3</th><th>Crank B6,A5</th><th>State</th></tr>
<tr><td>0</td><td>0</td><td>0</td><td>Off</td></tr>
<tr><td>12</td><td>0</td><td>0</td><td>Acc</td></tr>
<tr><td>0</td><td>12</td><td>0</td><td>Error</td></tr>
<tr><td>12</td><td>12</td><td>0</td><td>On</td></tr>
<tr><td>0</td><td>0</td><td>12</td><td>Error</td></tr>
<tr><td>12</td><td>0</td><td>12</td><td>Error</td></tr>
<tr><td>0</td><td>12</td><td>12</td><td>Crank</td></tr>
<tr><td>12</td><td>12</td><td>12</td><td>Error *</td></tr>
</table>

* Unless the truck has remote start, this is the remote crank signal.</td><td>52,15, 305, 306</td><td>BHM
B6, A1
B6, A3
B6, A5</td></tr>
</table>

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6987	5	Tail lamp circuit — current below expected value	The BHM measures the current on this circuit when the tail lamp output is commanded ON. This fault indicates the tail lamp circuit from the BHM to the CHM, or the wiring between the CHM and the lights is open circuit.	23, 23A, 23C	**BHM** B1, K and **CHM** C1, D C1, E C1, F C2, G C3, P
6987	6	Tail lamp circuit — current above expected value	The BHM measures the current on this circuit when the tail lamp output is commanded ON. This fault indicates that the tail lamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	23, 23A, 23C	**BHM** B1, K and **CHM** C1, D C1, E C1, F C2, G C3, P
6988	5	Left low beam headlamp circuit — current below expected value	The BHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates the headlamp circuit or the wiring between the BHM and the lamp is open circuit.	20L	**BHM** B1, R
6988	6	Left low beam headlamp circuit — current above expected value	The BHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates that the headlamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground.	20L	**BHM** B1, R
6989	5	Right low beam headlamp circuit — current below expected value	The CHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates the headlamp circuit or the wiring between the CHM and the lamp is open circuit.	21L	**CHM** C3, L
6989	6	Right low beam headlamp circuit — current above expected value	The CHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates that the headlamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground.	21L	**CHM** C3, L
6990	5	Left high beam headlamp circuit — current below expected value	The BHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates the left high beam headlamp circuit or the wiring between the BHM and the lamp is open circuit.	20H	**BHM** B1, L
6990	6	Left high beam headlamp circuit — current above expected value	The BHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates that the left high beam headlamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	20H	**BHM** B1, L

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6991	5	Right high beam headlamp circuit — current below expected value	The CHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates the right high beam headlamp circuit or the wiring between the CHM and the lamp is open circuit.	21H	**CHM** C4, K
6991	6	Right high beam headlamp circuit — current above expected value	The CHM measures the current on this circuit when the headlamp output is commanded ON. This fault indicates that the right high beam headlamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	21H	**CHM** C4, K
6992	19	High beam switch status — data not available	The BHM is not receiving valid data from the ICU for high beam switch status. Troubleshoot for a fault with the multifunction switch high and low beam circuits to the ICU.	473B	ICU B7
6993	7	Headlamp switch inputs to BHM are in an invalid combination	There are two headlamp ON circuits and one park lamp ON circuit from the headlight switch to the BHM. Both headlamp ON circuits must be at the same voltage. The park lamp circuit from the headlight switch can not be ON when the headlamp circuits are ON. This fault will be active when either of these two fault conditions are present. Troubleshoot for a headlight switch fault, and a wiring fault between the headlight switch and the BHM.	20, 21, 23F	**BHM** B6, B9 B6, B10, B6, B11
6994	19	Hazard lamp switch — circuit out of range	The hazard lamp switch closes a circuit from BHM pin B6, B8 through a resistor in the switch unit to ground. Troubleshoot for a fault in the wiring or an error in the switch assembly.	38B	**BHM** B6, B8
6995	4	Electric horn — voltage below expected value	The BHM measures the current on this circuit when the horn is commanded ON. Troubleshoot for a short to ground in the wiring between the BHM and the horn. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	24	**BHM** B3, E
6995	5	Electric horn — current below expected value	The BHM measures the current on this circuit when the horn is commanded ON. Troubleshoot for high resistance or open circuit between the BHM and the horn.	24	**BHM** B3, E
6995	6	Electric horn — current above expected value	The BHM measures the current on this circuit when the horn is commanded ON. Troubleshoot for a short to ground in the wiring between the BHM and the horn. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	24	**BHM** B3, E
6996	5	Dome lamp switched power circuit — current below expected value	The BHM measures the current on the dome lamp circuit that is controlled by the door switches when the lamp output is commanded ON. This fault indicates the dome lamp bulb or the wiring between the BHM and the light is open circuit.	108D	**BHM** B5, B

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
6996	6	Dome lamp switched power circuit — current above expected value	The BHM measures the current on the dome lamp circuit that is controlled by the door switches when the lamp output is commanded ON. This fault indicates the dome lamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	108D	**BHM** B5, B
6997	4	Cigar lighter circuit — voltage below expected value	The BHM measures the voltage on this circuit when the lighter output is powered ON. This fault indicates the lighter circuit is measuring lower voltage than the BHM expects. Troubleshoot for a short to ground or for too many accessories connected to this circuit. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	57	**BHM** B5, F
6997	5	Cigar lighter circuit — current below expected value	The BHM measures the current on this circuit . This fault indicates the lighter or the lighter circuit between the BHM and the lighter is high resistance or open circuit.	57	**BHM** B5, F
6997	6	Cigar lighter circuit — current above expected value	The BHM measures the current on this circuit when the lighter output is powered ON. This fault indicates the lighter circuit is drawing more current than the circuit is designed to supply. Troubleshoot for a short to ground or too many accessories connected to this circuit. Some BHM configurations force this circuit off until the ignition switch is cycled.	57	**BHM** B5, F
6998	5	Smart switch battery power circuit — current below expected value.	The BHM measures the current on the smart switch power circuit. Troubleshoot for an open circuit between the BHM and the smart switches.	41	**BHM** B7, A12
6998	6	Dome lamp battery power circuit — current above expected value	The BHM measures the current on the dome lamp circuit that is powered by the BHM. This circuit is powered ON when the BHM is in awake state. This fault indicates the dome lamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. Some BHM configurations force this circuit off until the ignition switch is cycled.	41	**BHM** B5, A
6999	5	Backup lamp circuit — current below expected value	The CHM measures the current on this circuit when the backup lamp output is commanded ON. This fault indicates the backup lamp circuit or the wiring between the CHM and the lamp is open circuit.	120B	**CHM** C1, A C1, H C1, J
6999	6	Backup lamp circuit — current above expected value	The CHM measures the current on this circuit when the backup lamp output is commanded ON. This fault indicates that the backup lamp circuit is drawing more current than it is designed to supply and possibly there is a wiring fault shorting this circuit to ground. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	120B	**CHM** C1, A C1, H C1, J

Bulkhead Module Fault Codes

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
7000	4	Backlighting circuit — voltage below expected value	The BHM measures the current on this circuit when the backlighting is ON. Troubleshoot for a short to ground in the backlighting circuits. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	29A	**BHM** B5, H
7000	5	Backlighting circuit — current below expected value	The BHM measures the current on this circuit when the backlighting is ON. Troubleshoot for an open circuit in the backlighting wiring.	29A	**BHM** B5, H
7000	6	Backlighting circuit — current above expected value	The BHM measures the current on this circuit when the backlighting is ON. Troubleshoot for a short to ground in the backlighting circuits. The fault remains active until the ignition is turned ON when the fault is no longer present. Some BHM configurations force this circuit off until the ignition switch is cycled.	29A	**BHM** B5, H
524280	31	Component ID mismatch	The BHM is in a non-recoverable boot mode. Replace the BHM and contact the help desk to arrange for shipping this BHM to DTNA engineering.	—	—
524281	31	Application to parameters fail	Reflash the BHM — disconnect ServiceLink and cycle the ignition switch.	—	—
524282	12	Parameter data fails checksum	Reflash the BHM — disconnect servicelink and cycle the ignition switch.	—	—
524283	12	Application code fails checksum	Reflash the BHM — disconnect servicelink and cycle the ignition switch.	—	—
524284	12	Boot block checksum fail	The BHM is in a non-recoverable boot mode. Replace the BHM.	—	—
524285	4	Boot hold line is active	The BHM is in a non-recoverable boot mode. Replace the BHM and contact the help desk to arrange for shipping this BHM to DTNA engineering.	—	—
524286	12	RAM test fails	The BHM is in a non-recoverable boot mode. Replace the BHM.	—	—

Table 1, J1939 Fault Codes From Bulkhead Module (SA 33)

The Purpose of Multiplexing

Multiplexing is defined as sending multiple electronic signals through the same circuit.

Multiplexing allows the 108SD and 114SD electrical system to simultaneously perform tasks and to monitor components over a common databus. A multiplexed system uses electronic control units (ECUs) to operate the system. The electrical system components, such as sensors, switches, and lamps, are connected to the ECUs, which collect and control all information about the components by communicating on the data bus.

Multiplexing was introduced in vehicles in the 1980's with the first electronically controlled engines and the initial use of the J1708/J1587 databus. The concept was taken a step further in the early 1990's when transmissions were electronically connected to engines in order to control engine speed and torque output during shifting. Multiplexing has now been applied to the entire vehicle.

General Information

Multiplexing the signals from switch inputs and controlling electrical load outputs reduces the amount of wiring on a vehicle. Rather than having individual wires transmitting voltage from switches to relays that then supply power to the components, the multiplexed system continuously monitors the status of all switches (input devices) and sends messages over the J1939 datalink to control outputs.

The ECU's on the vehicle have diagnostic capability. Many input and output circuits are equipped with the ability for the ECU to determine abnormal conditions and set a fault for the circuit. Each circuit with diagnostic capability is assigned suspect parameter number (SPN). Common terminology is to call this number a fault code. Fault codes are further defined with failure modes. When a fault is set as active, it will also have a failure mode indicator (FMI) that specifies the type of fault. See **Table 1** for J1939 failure mode indicators. Fault codes are displayed on the instrument cluster display and they may also be viewed using ServiceLink®, or the engine diagnostic software.

See **Fig. 1** for an example of how the headlamp signal inputs and outputs are handled in the multiplexed system. When the headlamp switch is turned on, the BHM senses the input. The BHM is programmed with circuit-to-pin parameters for each input signal and where those outputs are located (such as on the BHM, CHM, EXM, or other controller). In this example, the outputs for the left headlamp low beam are located on the BHM and the outputs for the right headlamp low beam are located on the CHM. The BHM can directly activate the left headlamp low beam. The right headlamp low beam outputs are located on the CHM; the BHM sends a message over J1939 to the CHM for it to activate those outputs. Once the CHM receives the message, it activates the correct outputs and sends a message back to the BHM reporting the new status of the outputs. This fail-safe design allows at least one headlight to work even if the BHM or CHM should fail.

J1939 Failure Mode Identifiers	
FMI	**Description**
00	Data valid but above normal operational range–Most severe level
01	Data valid but below normal operational range–Most severe level
02	Data erratic, intermittent, or incorrect
03	Voltage above normal or shorted high
04	Voltage below normal or shorted low
05	Current below normal or open circuit
06	Current above normal or grounded circuit
07	Mechanical system not responding or out of adjustment
08	Abnormal frequency, pulse width, or period
09	Abnormal update rate

General Information

J1939 Failure Mode Identifiers	
FMI	**Description**
10	Abnormal rate of change
11	Root cause not known
12	Bad intelligent device or component
13	Out of Calibration
14	Special Instructions
15	Data valid but above normal operational range–Least severe level
16	Data valid but above normal operational range–Moderately severe level
17	Data valid but below normal operational range–Least severe level
18	Data valid but below normal operational range–Moderately severe level
19	Received network data in error
20	Data Drifted High
21	Data Drifted Low
31	Condition Exists

Table 1, J1939 Failure Mode Identifiers

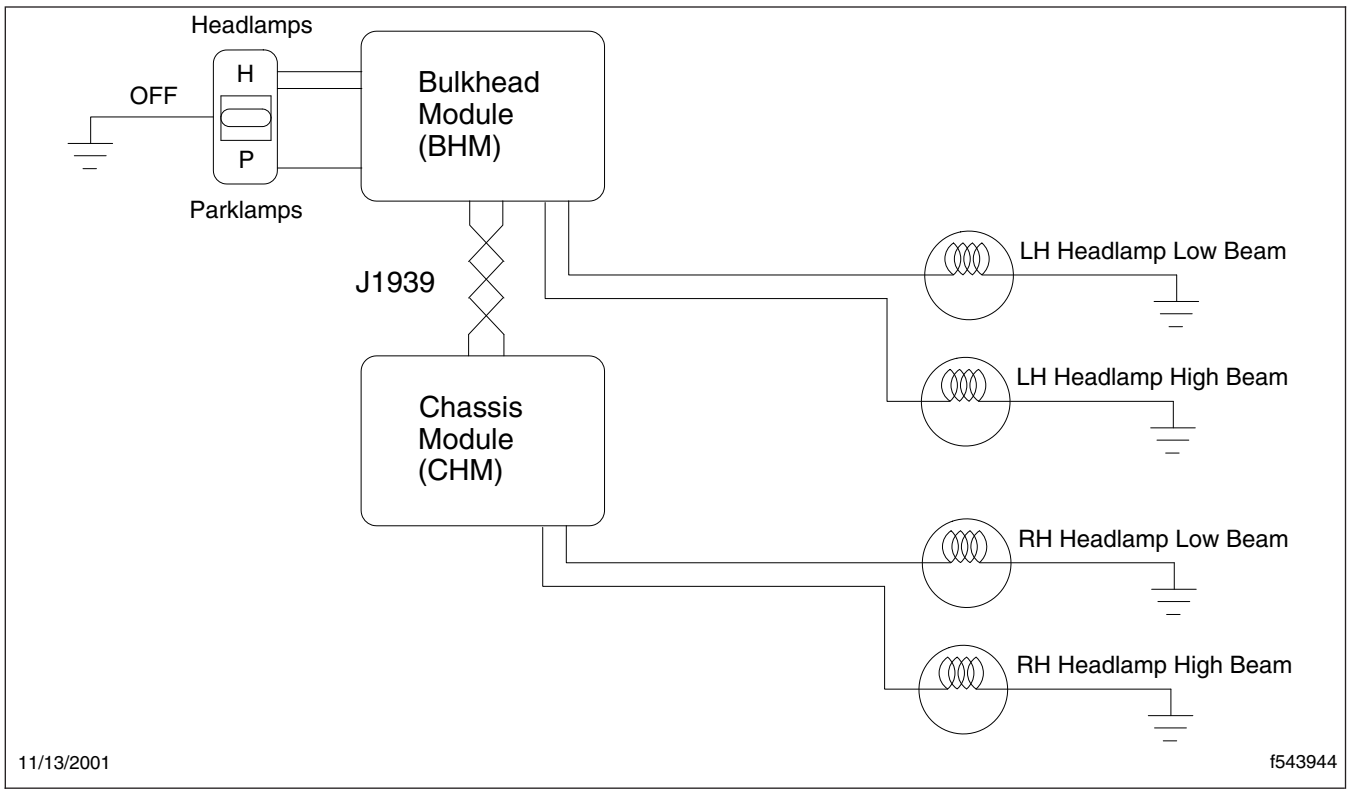


Fig. 1, Headlamp Switch Example

Abbreviations and Terms

Use the following list to determine the meaning of the abbreviations and terms used in **Group 54**.

AAVA Auxiliary Air Valve Assembly

ABS Antilock Braking System

Activate To begin operating.

Address A unique location code for a device or data.

AMU Air Management Unit

API Application Programming Interface

ATC Automatic Traction Control

BHM Bulkhead Module

CAN Controller Area Network

CHM Chassis Module

Configure To set up a program or system for a particular device or set of devices.

Databus See datalink.

Datalink A collection of wires connecting system components through which data is transmitted.

DRL Daytime Running Lights

DTC Diagnostic Trouble Code

ECM Engine Control Module

ECU Electronic Control Unit, a device that communicates on a datalink.

EEPROM Electrically Erasable Programmable Read-Only Memory

EMC Electromagnetic Compatibility

EMI Electromagnetic Interference

EOL End of Line

ESD Electrostatic Discharge

EXM Expansion Module

Fault Code A limited set of alphanumeric characters representing a corresponding error message. Fault codes are made up of a SA, SPN, and FMI.

FMEA Failure Mode Effects Analysis

FMI Failure Mode Indicator. The part of a J1939 fault code that identifies how a part of or item on a device failed.

FMVSS Federal Motor Vehicle Safety Standard

HSD High Side Driver

HVAC Heating, Ventilating, and Air Conditioning

ICU Instrumentation Control Unit

Input A signal that feeds the status of an external event into the system.

J1708/1587 An older vehicle communications network protocol intended to provide simple information exchange, including diagnostic data between electronic control devices.

J1939 A high speed vehicle communications network using the CAN protocol, which permits any device to transmit a message on the network when the datalink is idle. Each message includes an identifier that defines the message priority, who sent it, and what data is contained within it. Collisions are avoided due to the arbitration process that occurs while the identifier is transmitted, permitting high priority messages to get through with minimal delay.

LCD Liquid Crystal Display

LCL Low Coolant Level

LED Light-emitting Diode

Legend The icon, symbol or text on a warning light cover illuminated by a telltale lamp.

LSD Low Side Driver

MID Message Identifier. Identifies any device that communicates on J1939.

Multiplexing The process of combining several messages for transmission over the same signal path.

Output The signal or message that comes out of a system component or device.

Parameter A predetermined variable in a set, each of which restricts or defines the specific capabilities of the system as a whole. Used to customize the configuration of the system.

Pass-through Inputs and outputs on a device capable of allowing data to be transmitted through it without affecting the message or the device.

PCB Printed Circuit Board

PLC Power Line Carrier

PRD Product Requirements Document

PWM Pulse Width Modulation

SA Source Address. Identifies any device that communicates on J1939.

Abbreviations and Terms

SAE Society of Automotive Engineers

Smart Switch Configurable input device, called "smart" because it is recognized by the system not by its position or physical characteristics but by its resistance value.

SPN Suspect Parameter Number. The part of a J1939 fault code that identifies what part of or circuit on a device that failed.

Status Condition, position, or relative position of an input or output at a specific time.

TDS Technical Development Specifications

Telltale Any of a number of colored warning lights on the ICU instrument cluster that illuminates an icon, symbol, or text covering it.

UL Underwriters Laboratory

VCU Vehicle Control Unit

Reference Parameters

Reference parameters are used to assign the control operations of the system. Input signals, output signals, diagnostic activity, and ECU capability is configured and controlled by software that reads the parameters.

Parameters may be changed to allow new content to be added to a vehicle. To change parameters, the PC-based tool, ServiceLink, is used. With ServiceLink, the configurable reference parameters for an ECU can be changed and reprogrammed using the "Features" screen.

There is a reference parameter for each multiplexed feature. Every reference parameter has its own part number with the prefix 26-. Reference parameters are listed under their part number in bills of material (BOM) and in PartsPro®.

Changing Features and Options

The Features screen in ServiceLink displays the features that are installed in the BHM by listing the reference parameter numbers and their descriptions. From this screen, the user can reload all the currently installed features or make changes to the vehicle by entering new reference parameters.

When adding features to a 108SD and 114SD vehicle, consider the following before adding features to the vehicle.

ServiceLink® is the software tool that allows addition and modification of the parameters and features of the SD multiplexed system. To access ServiceLink training follow these steps.

1. Go to **www.AccessFreightliner.com** and click on **Tools and Services**.
2. Click on **Aftermarket Resource Center** and log on.

Floating Pins

Floating pins means that a pin in a connector is not always assigned to the same circuit on every vehicle. Use the Configuration screen in ServiceLink to verify pin assignment. G06 drawings are general guides and are not vehicle specific. Use the circuit to pin tables (CTP) that are accessed using EZ-Wiring.

Adding a Feature

Use the following instructions to add features to the vehicle.

1. Contact Freightliner Parts Technical Support and provide the representative with the vehicle identification number (VIN) and the data code requested. The representative will advise of the availability of the feature.

NOTE: Reference parameters, such as 26-XXXXX-XXX, are needed to determine circuit availability for the desired feature.

2. When the reference parameters are applied to the BHM, ServiceLink will provide any necessary wiring instructions via a table with columns for device, connector, pin location, circuit number, and action. This table will be used to make circuit changes to the BHM, CHM, or EXM as necessary to add the features.

Splicing Into the Electrical System

If electronic devices are added outside of the multiplexed electrical system, there are a few options for obtaining authorized interface points.

- Data code 353-XXX provides various options for vehicle wiring interfaces, including back of cab, frontwall, and end-of-frame locations. Data code 148-XXX provides options for engine wiring, and data code 34C-XXX provides options for transmission wiring. Go to **www.Access-Freightliner.com** for more information.
- Inside the cab, there are splice packs behind the center dash that provide interface points for ignition voltage, ground, and panel lamp illumination.

IMPORTANT: When bypassing the multiplex electrical system, the interface points previously mentioned are the only authorized points. **Do not** splice in to any other electrical wiring.

Troubleshooting

With the multiplexed electrical system, traditional multimeter-based current, voltage and resistance measurements are supplemented, or in some cases replaced, by software tools that can read and control the electronic signals and devices of the system. ServiceLink® is the tool that is used to troubleshoot the 108SD and 114SD electrical system.

The following screens can be accessed under the Bulkhead Module icon:

- **General Info**—Displays information about the BHM such as make, model, hardware version, and software version.
- **Faults**—Displays the active and historic faults for all of the control modules on the multiplexed electrical system.
- **Configuration**—Displays the pinout for all of the control modules on the multiplexed electrical system compared to the host.
- **Features**—Displays the features that are installed in the BHM. From this screen the user can reload all the currently installed features, or make changes to the vehicle by entering new reference parameters.
- **Flashing**—Allows the user to update or reflash the operating software of the BHM.
- **Templates**—Gives a directory of Datalink Monitor Templates available for troubleshooting the multiplexed electrical system. These templates allow the user to monitor and manipulate the inputs and outputs of the electrical system.

The other control module icons, listed below, will have only a General Info screen, a Faults screen, and a Templates screen.

- Chassis Module (CHM)
- Expansion Module (EXM)

Device Communications

For identification of the ECUs broadcasting on the J1939 databus, see **Table 1**.

NOTE: Customer-installed ECUs may not be listed.

J1939 Source Addresses	
SA	**Controller Application**
0	Engine Controller
1	Motor Control Module
3	Transmission
5	Shift Controller
11	Tractor Brake Controller - ABS
15	Retarder
17	Predictive Cruise Control
23	Instrument Cluster
25	HVAC Control Unit - Front
28	Navigation
29	Vehicle Security
33	Body Controller - BHM
37	Gateway
40	Cab Display 1 - Predictive Cruise Control
42	Headway - Forward Looking Radar
49	Switch Hub Module - SHM
51	Tire Pressure Controller
58	HVAC Control Unit - Rear
61	Exhaust Emission Controller - ACM
68	Auxiliary Heater - Parksmart
71	Chassis Controller - CHM
74	Cellular Communications - Virtual Technician
75	Communications, Satellite - Qualcom
76	Radio
83	Airbag and Restraint Controller
84	Cab Display 2
128	Switch Expansion Module - 1
129	Switch Expansion Module - 2
130	Switch Expansion Module - 3
131	Switch Expansion Module - 4
133	Switch Expansion Module in Error State
140	Driver Interface Unit

Specifications

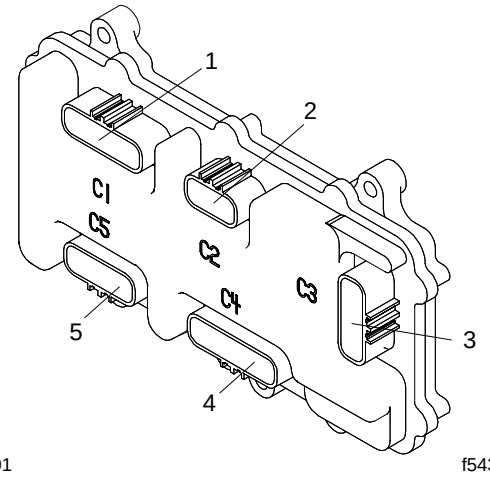
J1939 Source Addresses	
SA	**Controller Application**
232	Lane Guidance
235	Expansion Module - 1
249	Offboard Service Diagnostic Tool

Table 1, J1939 Source Addresses

General Information

The Chassis Module (CHM) responds to activate and deactivate outputs according to J1939 commands from the BHM. The CHM also broadcasts the status of its inputs and outputs over J1939.

The CHM is usually mounted on the left frame rail, under the cab. There are five connectors on the CHM. Each connector is assigned to related vehicle functions. See **Fig. 1**.



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1. C1, Taillight Harness
2. C2, Trailer Module Harness
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. Auxiliary Air Valve Assembly (AAVA) Harness

Fig. 1, Chassis Module Harness Connectors

Awake State and Sleep State

The BHM, CHM, and instrumentation control unit (ICU) are, as a group, in an awake state or a sleep state depending on vehicle conditions. When any of these electronic components are awake, the remaining components wake up if they are not already awake. When the BHM, CHM, and ICU are in an awake state, the odometer reading appears on the dash driver display screen.

One of the following actions will cause the BHM, CHM, or ICU to go into an awake state:

- opening the door
- turning on the hazard switch
- turning the ignition switch to any position other than off
- turning on the headlight/parking light switch
- depressing the service brake

The BHM, CHM, and ICU will enter a sleep state when they are no longer actively controlling any outputs or responding to any inputs and all other power down requirements are met.

To check whether or not the electrical system is going into a sleep state:

1. Enter the vehicle.
2. Shut the doors.
3. Remove your foot from the service brake.
4. Make sure the ignition switch and hazard switch are in the off position.

Parameters		
Parameter Part Number	**Description**	**Hours**
26-01017-002	Switched Center Pin Power	24
26-01019-003	Exterior Lighting	16,667
26-01019-004	Exterior Lighting	16,667
26-01019-005	Exterior Lighting	16,667

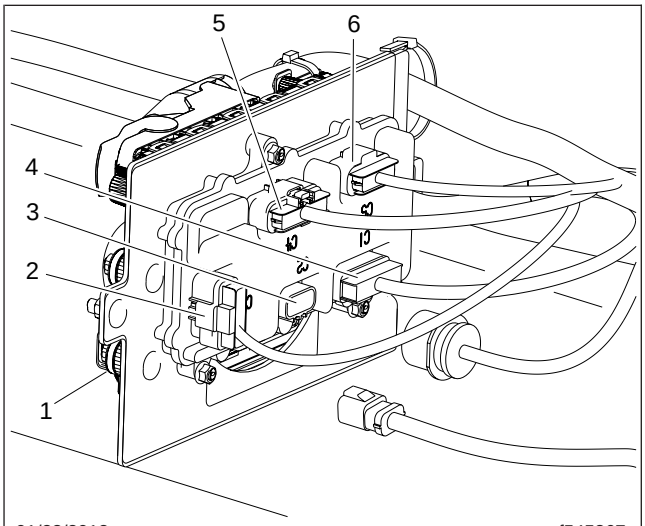
Table 1, Parameters

NOTE: One minute after these conditions are met, and provided that one of the parameters in **Table 1** has not been added to the BHM, the odometer reading should disappear. If the odometer reading does not disappear, the electrical system is not going to sleep.

Replacement

IMPORTANT: The parameters that configure the CHM input and output control are programmed into the bulkhead module (BHM). Faults with CHM circuits are reported by the BHM using source address 33. Description of CHM circuits and fault code troubleshooting procedures can be found in **Section 54.07, Troubleshooting 300**.

1. Disconnect the negative leads from the batteries.
2. Disconnect the harness connectors on the Chassis Module by pulling the grey locking tab outward 1 mm then pressing on the black tab in the center of the grey locking tab. The connector can now be removed. See **Fig. 1** .



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1. Aftertreatment Control Module
2. C3, Forward Chassis Harness
3. C2, Trailer Module Harness
4. C1, Taillight Harness
5. C4, Forward Chassis Harness
6. C5, Auxiliary Air Valve Assembly (AAVA) Harness

Fig. 1, Chassis Module Connectors

3. Remove the three locknuts that secure the CHM to the bracket, then remove the CHM.
4. Properly orient the Chassis Module on its mounting plate. Using locking nuts, secure the CHM.
5. Connect the harnesses to the CHM, then push the grey locking tabs inward toward the CHM so they snap into locked position.
6. Connect the batteries.

Chassis Module

See **Fig. 1** for maximum allowable current load for Chassis Module output circuits.

See **Fig. 2** for an illustration of the CHM pin assignments.

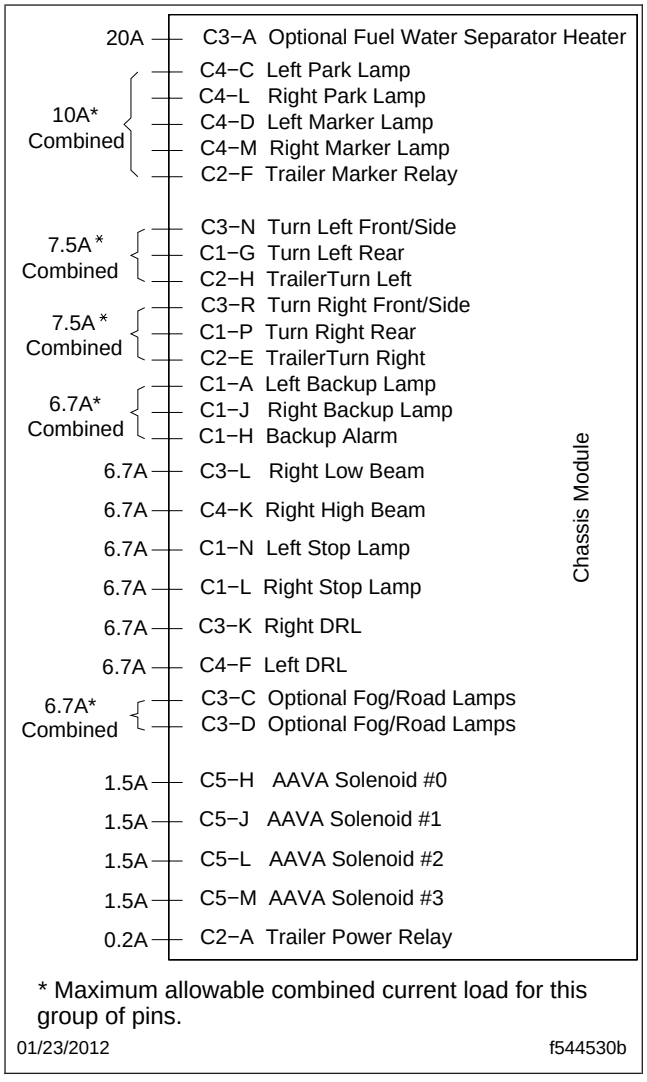
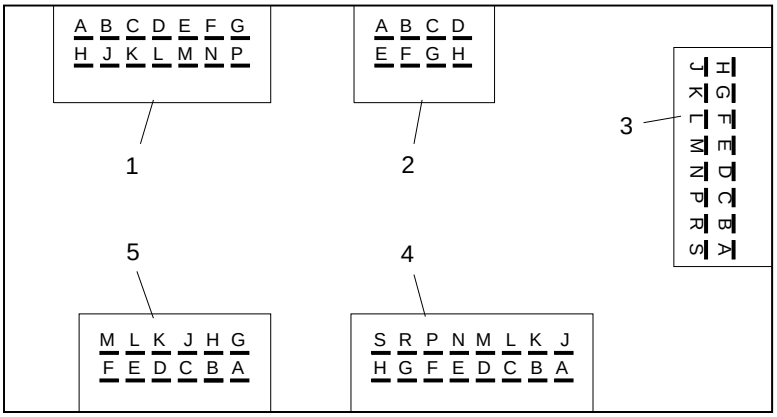


Fig. 1, Maximum Allowable Current Load for the Full Chassis Module Output Circuits

Amperage listed is the maximum allowable combined amperage for each output circuit. When maximum allowable amperage is exceeded, the CHM may turn off the output.

When using ServiceLink in Test Mode, the outputs will deliver more current than the maximum allowable current values shown. When testing, do not exceed the maximum combined values for more than a few seconds or the life of the output driver inside the module may be shortened.

Specifications



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1. C1, Taillight Harness
2. C2, Trailer Module Harness
3. C3, Forward Chassis Harness
4. C4, Forward Chassis Harness
5. C5, Auxiliary Air Valve Assembly Harness

Fig. 2, Chassis Module Pin Assignments

Taillight Harness Circuits at Connector C1		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C1-A	Left Backup Lamp	Digital Output
C1-D	Left Taillight Pass-Through	Pass-Through
C1-E	Right Taillight Pass-Through	Pass-Through
C1-F	License Plate Lamp	Digital Output
C1-G	Left Rear Turn Lamp	Digital Output
C1-H	Backup Alarm	Digital Output
C1-J	Right Backup Lamp	Digital Output
C1-L	Right Stop Lamp	Digital Output
C1-N	Left Stop Lamp	Digital Output
C1-P	Right Rear Turn Lamp	Digital Output

Table 1, Taillight Harness Circuits at Connector C1

Trailer Module Harness Circuits at Connector C2		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C2-A	Trailer Power Relay	Digital Output
C2-C	Ground	Power Ground
C2-D	Trailer Stop Lamp Relay Pass-Through	Pass-Through

Trailer Module Harness Circuits at Connector C2		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C2-E	Trailer Right Turn Lamp	Digital Output
C2-F	Trailer Marker Lamps Relay	Digital Output
C2-G	Trailer Taillight Relay Pass-Through	Pass-Through
C2-H	Trailer Left Turn Lamp	Digital Output

Table 2, Trailer Module Harness Circuits at Connector C2

Forward Chassis Harness Circuits at Connector C3		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C3-A	Fuel/Water Separator Heater	Digital Output
C3-B	—	—
C3-C	Fog/Road Lamps	Digital Output
C3-D	Fog/Road Lamps	Digital Output
C3-E	Low Air Pressure	Digital Input (active low)
C3-F	Park Brake	Digital Input (active low)
C3-G	Service Brake	Digital Input (active low)
C3-H	Ground	Power Ground
C3-J	Main Battery Power (VBAT2)	Power
C3-K	Right DRL	Digital Output
C3-L	Right Low Beam	Digital Output
C3-M	Ignition	Digital Input (active high)
C3-N	Left Front/Side Turn Lamp	Digital Output
C3-P	Taillight/License Plate Lamps Pass-Through	Pass-Through
C3-R	Right Front/Side Turn Lamp	Digital Output
C3-S	Battery Power (VBAT4)	Power

Table 3, Forward Chassis Harness Circuits at Connector C3

Forward Chassis Harness Circuits at Connector C4		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C4-A	Module Wake-Up Signal	Digital Input/Output
C4-B	Address Identification A	Analog Input
C4-C	Left Park Lamp	Digital Output
C4-D	Left Marker Lamp	Digital Output
C4-E	Address Identification C	Analog Input
C4-F	Left DRL	Digital Output

Specifications

Forward Chassis Harness Circuits at Connector C4		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C4-G	J1939+ Datalink	Datalink
C4-H	Ground (address identification D)	Signal Ground
C4-J	Main Battery Power (VBAT3)	Power
C4-K	Right High Beam	Digital Output
C4-L	Right Park Lamp	Digital Output
C4-M	Right Marker Lamp	Digital Output
C4-N	Address Identification B	Analog Input
C4-P	Main Battery Power (VBAT1)	Power
C4-R	J1939– Datalink	Datalink
C4-S	Ground	Power Ground

Table 4, Forward Chassis Harness Circuits at Connector C4

Auxiliary Air Valve Assembly Harness Circuits at Connector C5		
Connector and Pin Numbers	**Signal Name**	**Signal Type**
C5-A	AAVA Analog Input 0	Digital Input (active low), Analog Input
C5-B	AAVA Analog Input 1	Digital Input (active low), Analog Input
C5-C	Ground	Signal Ground
C5-F	AAVA Analog Input 2	Digital Input (active low), Analog Input
C5-G	AAVA Analog Input 3	Digital Input (active low), Analog Input
C5-H	AAVA Solenoid 0	Digital Output
C5-J	AAVA Solenoid 1	Digital Output
C5-L	AAVA Solenoid 2	Digital Output
C5-M	AAVA Solenoid 3	Digital Output

Table 5, Auxiliary Air Valve Assembly Harness Circuits at Connector C5

Power Supply Fuses and Associated Outputs for the Chassis Module				
CHM Power Input	**CHM Power Input Pin**	**Fuse Supplying CHM Power Input**	**CHM Outputs Supplied**	**CHM Output Pin**
Power In			**Power Out**	
VBAT1	C4.P	Fuse 19 (30A)	Right Low Beam	C3.L
			Turn Right Front/Side	C3.R
			Turn Right Rear	C1.P
			Right Stop Lamp	C1.L
			Left Stop Lamp	C1.N
			Right DRL	C3.K
			Fog/Road Lamps	C3.C/C3.D
			Trailer Turn Right	C2.E
VBAT2 VBAT4	C3.J	Fuse 17 (30A)	Left Park Lamp	C4.C
			Right Park Lamp	C4.L
			Left Marker Lamp	C4.D
			Right Marker Lamp	C4.M
			Trailer Marker Relay	C2.F
			Right High Beam	C4.K
			Left Backup Lamp	C1.A
			Right Backup Lamp	C1.J
			Backup Alarm	C1.H
			Turn Left Front/Side	C3.N
			Turn Left Rear	C1.G
			Left DRL	C4.F
			Trailer Turn Left	C2.H
VBAT3	C4.J	Fuse 13 (30A)	Fuel Water Separator Heater	C3.A
			AAVA Solenoid 0	C5.H
			AAVA Solenoid 1	C5.J
			AAVA Solenoid 2	C5.L
			AAVA Solenoid 3	C5.M

Table 6, Power Supply Fuses and Associated Outputs for the Chassis Module

General Information

Smartplex is a configurable system that allows a common set of electronic components to manage different options in various vehicle configurations. Smartplex allows the customer to select the switches needed for the vehicle, then configure the output circuits for specific functions.

Smartplex allows up to 24 switches and indicators in the overhead console, and 6 hardwired input circuits, to control twelve 20-amp output circuits and ten 6.7-amp output circuits. See **Fig. 1**. Any combination of smart switches and hardwire input circuits can be configured to operate the output circuits that are wired to customer interface connector 1A, and customer interface connector 2A. The configuration is programmable with ServiceLink using parameters that can be accessed using the "Parameter Search Tool".

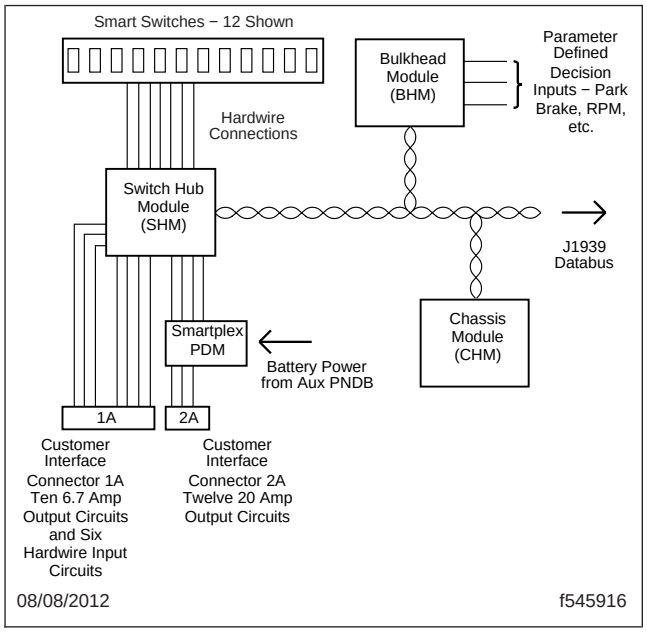

Fig. 1, Smartplex System Diagram

Smartplex performs operations that would otherwise require large bundles of wire and multiple sensors for the same function. **Fig. 2** details the order in which Smartplex evaluates inputs and controls outputs.

Parameter Configuration

The parameters used to configure Smartplex are verified by using the "Parameter Search Tool." See **Fig. 3**. The search tool is available to authorized users on *AccessFreightliner*.

General Information

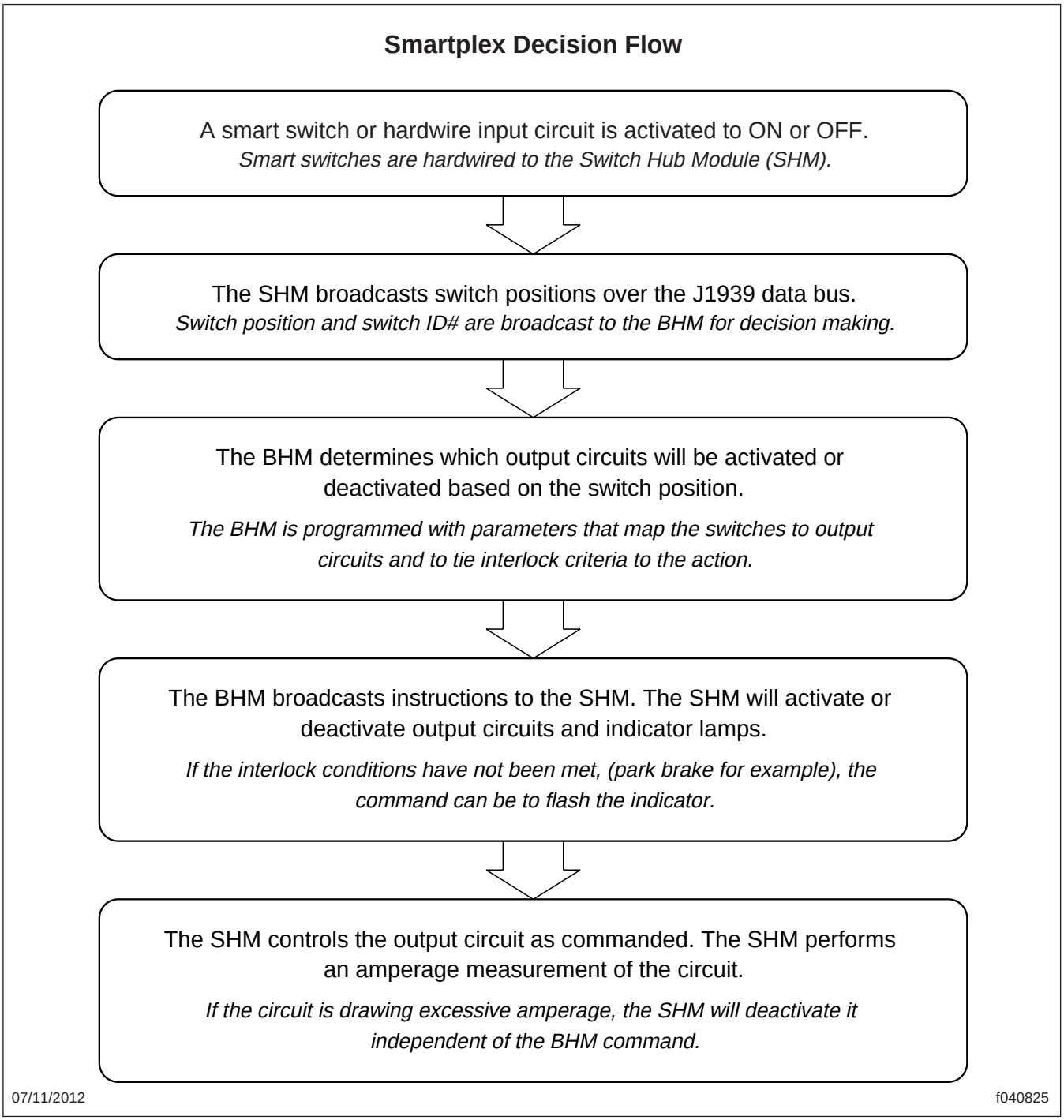

Fig. 2, Smartplex Decision Flow

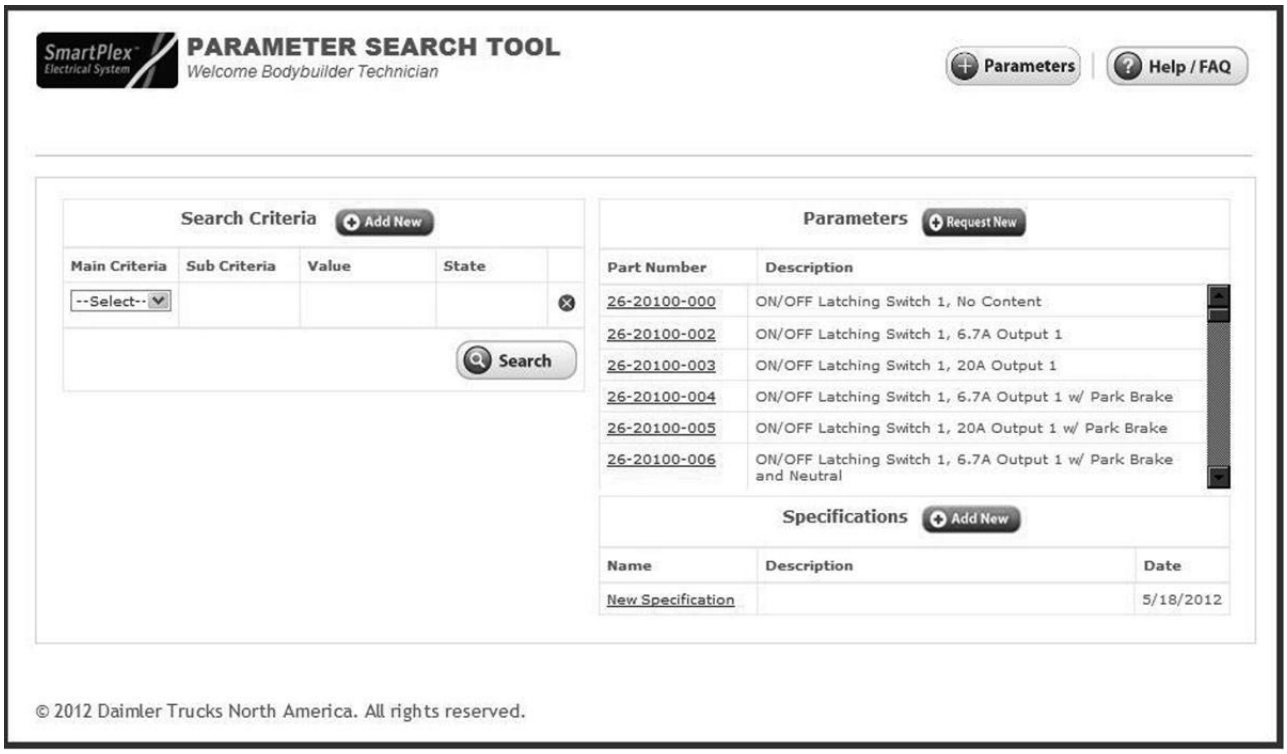

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Fig. 3, Parameter Search Tool

Switch Hub Module

Removal

1. Remove the center smart switch panel in the overhead console. See **Fig. 1**.

   NOTE: The center trim panel and the map/reading light panel can be removed from the overhead console as a single unit.

   1.1 Remove the five screws that secure the center trim panel and the map/reading light panel to the overhead console. See **Fig. 1**, refs. 4 and 6.

   1.2 Slide the panel to the right until the locking tabs release, then pull it from the overhead console.

   1.3 Remove the four screws that secure the smart switch panel, then remove the panel. See **Fig. 1**, ref. 2.

NOTE: The switch hub module is attached to the mounting bracket with hook and loop tape.

2. Gently lift the switch hub module from the mounting bracket, then remove it from the vehicle.
3. Remove the connectors from the switch hub module. See **Fig. 2**.

Installation

1. Install the connectors on the switch hub module.
2. Install the switch hub module on the mounting bracket and ensure that it is secure.
3. Install the center smart switch panel and secure it with the four mounting screws. Tighten the screws securely.
4. Position the center trim panel and map/reading light panel assembly on the overhead console, then slide it to the left until it engages with the locking tabs. Install the five mounting screws, then tighten them securely.

Smart Switches

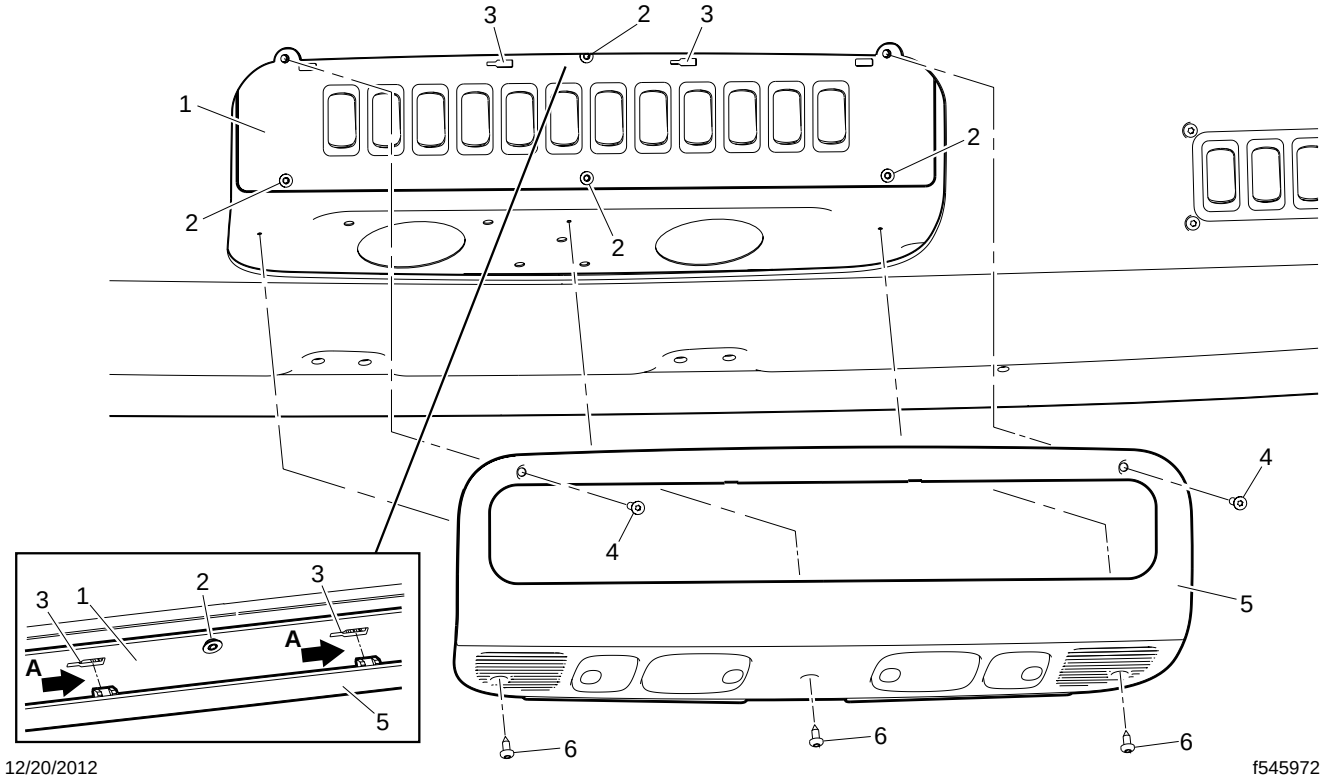
Removal

1. Remove the fascia panel. See **Fig. 3**.
2. Remove the mounting plate.
3. Squeeze the tab on both sides of the smart switch.
4. Remove the switch.

Installation

1. Install the new smart switch.
2. Install the mounting plate.
3. Position the fascia panel on the mounting plate, then install the screws.
4. Tighten the screws securely.

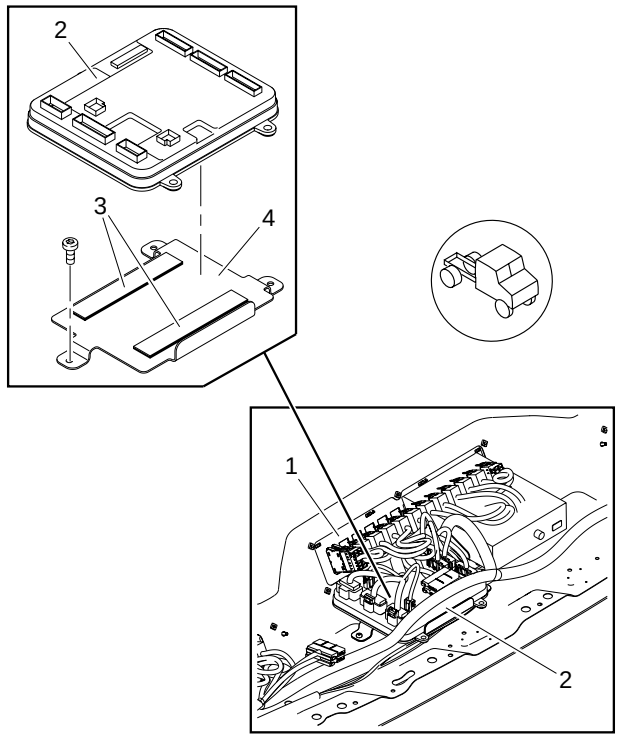
Removal and Installation



A. The trim panel *must* be slid to the right before it will release from the overhead console.

1. Center Smart Switch Panel
2. Smart Switch Plate Screws
3. Center Trim Panel Locking Slots
4. Center Trim Panel Mounting Screws
5. Center Overhead Console Trim Panel
6. Map/Reading Light Panel Mounting Screws

Fig. 1, Center Overhead Console Assembly



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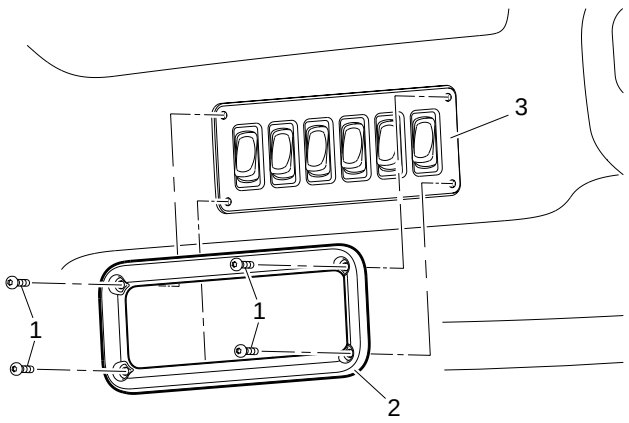
1. Center Smart Switch Panel (connector side)
2. Switch Hub Module
3. Hook and Loop Tape
4. Mounting Bracket

Fig. 2, Switch Hub Module Installation in the Headliner, Overhead View (roof not shown for clarity)



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1. Mounting Screws
2. Fascia Panel
3. Mounting Plate

Fig. 3, Smart Switch Assembly

Troubleshooting

ServiceLink makes two templates available to troubleshoot the Smartplex system:

- The "Smartplex Switches" template monitors switch operation and identifies the unique ID of each smart switch. The switch hub module (SHM) and bulkhead module (BHM) use the ID to electronically map the switch to the output circuit it controls. This template also allows the user to force the indicator in the switch on and off.
- The "Smartplex Outputs" template determines if the SHM output circuit is commanded ON or OFF by the BHM and the SHM. This template allows the user to force the output circuit on and off, and also displays indicators for the 6 hardwire switch inputs to the SHM.
- Both templates display ignition voltage and the power supply status to the SHM.

The SHM is capable of generating J1939 fault codes for specific failures. **Table 1** identifies these fault codes.

Fault Codes from SHM Source Address 49			
SPN	**FMI**	**Description**	**Troubleshooting**
2033	19	No J1939 Communication with the BHM	Connect ServiceLink to see if the BHM shows up as an ECU on the left hand sidebar. Continue by using the troubleshooting instructions in the BHM manual.
6914	4	Smart Switch Battery Supply Power – Out of Range, Low	Disconnect SHM connectors J5, J6, and J7 one at a time to narrow down which bank of switches the short is occurring in. Pin 26 in each of these 3 connectors is the smart switch power supply circuit.
524283	12	SHM Software Memory Fail	Flash the SHM with the appropriate version of software.
524285	4	SHM is in Boot Mode	Use ServiceLink to flash the SHM with the appropriate version of software. If flashing does not correct this fault, replace the SHM.
524286	12	SHM Memory Fail	Replace the SHM.

Table 1, Fault Codes from SHM Source Address 49

Refer to **Table 2** for a list of procedures for diagnosing problems with the Smartplex system.

Smartplex Symptom Based Troubleshooting	
Symptom	**Remedy**
No Smart Switches or Outputs Operate	**Table 3**
"Missing Smart Switch", or "Extra Smart Switch", or "Duplicate Smart Switch"	**Table 4**
ServiceLink Reports a Circuit-to-Pin Error	**Table 5**
One Smartplex Switch or Output Does Not Operate	**Table 6**
None of The 20-Amp Smartplex Outputs are Operating	**Table 7**
A Smart Switch Indicator Does Not Illuminate but The Output Works	**Table 8**
The Smart Switch Backlighting Does Not Illuminate	**Table 9**

Table 2, Smartplex Symptom Based Troubleshooting

Troubleshooting

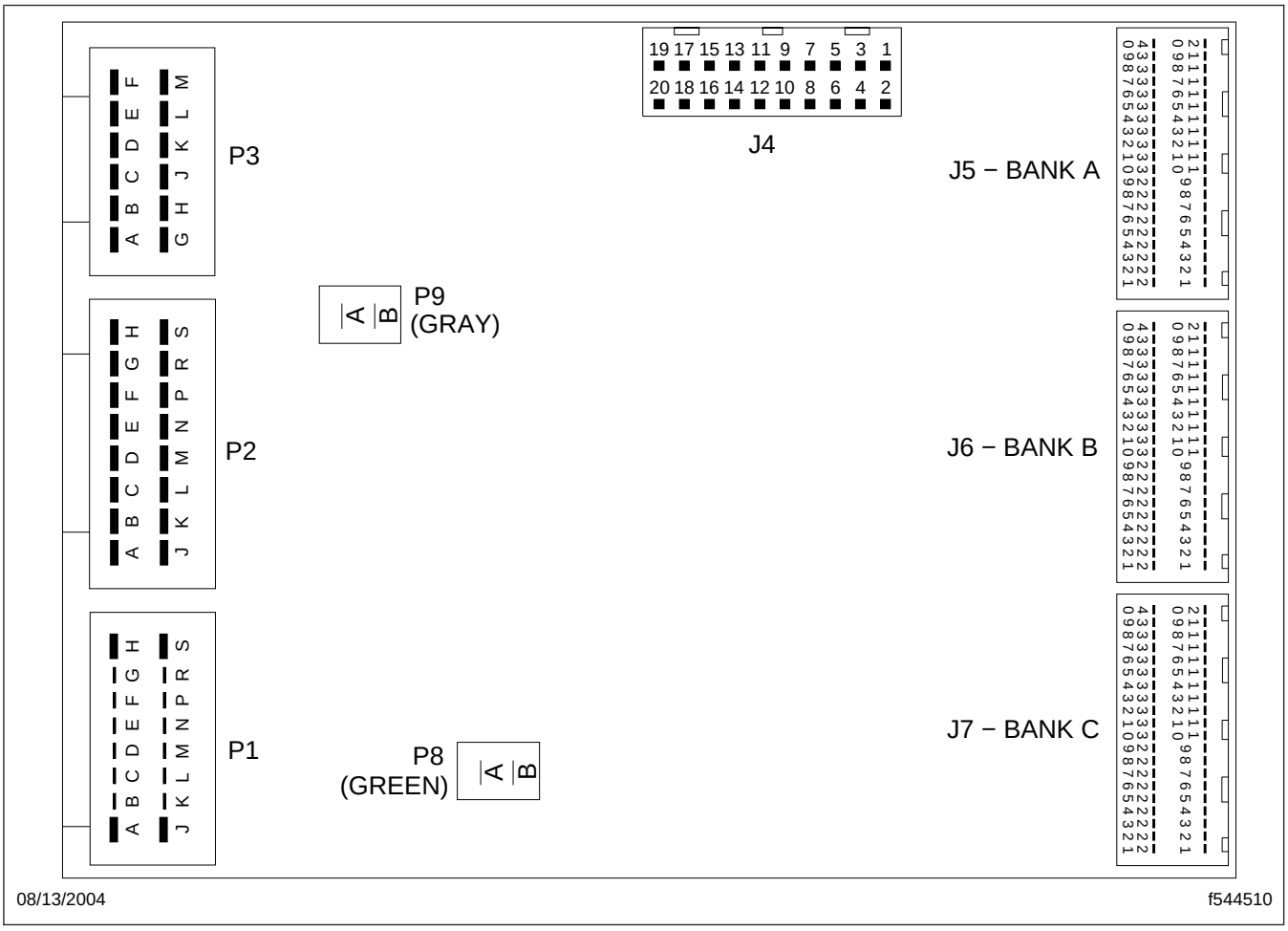


Fig. 1, Switch Hub Module Connector Pin Out

No Smart Switches or Outputs Operate			
Step	**Test**	**Result**	**Action**
1	Open ServiceLink and click on the"Switches" template, then observe the power indicators on the top row. Is power present on all 3 SHM power source circuits?	Yes	Go to step 2.
		No	If all the indicators have yellow triangles over their display, there is no data communication with the SHM. Troubleshoot for a J1939 data bus fault. Use the J1939 Datalink template to see which devices are communicating. If power is not present, access the SHM and troubleshoot for a wiring fault on the circuits that are not indicating battery voltage.

No Smart Switches or Outputs Operate			
Step	**Test**	**Result**	**Action**
2	Is the power to the smart switches indicator showing that power is ON?	Yes	Click on the “Enter Test Mode” button then click the ON button for a smart switch that is equipped with an indicator lamp. (Not all switches have an indicator.) The template will not show that the indicator has been turned on, but the indicator in the smart switch will illuminate if the SHM is operating. If the indicator did not illuminate, replace the SHM, otherwise continue with step 3.
		No	Troubleshoot for a wiring fault in each of the three smart switches wiring bundles for a short to ground. Repair as required.
3	Click the "Exit Test Mode" button. Operate a smart switch that is indicating a valid ID number. Does the "State" display change appropriately?	Yes	The SHM switch position sensing appears to be working correctly. Close the Smartplex Switches template and open the Smartplex Outputs template. The “BHM Command Status” indicator shows the message the BHM is sending to the SHM for output control. The “SHM Output Status” shows what the SHM is doing with the BHM command. If the SHM Output Status is not operating the outputs according to the BHM command, replace the SHM. If the outputs are operating correctly, measure voltage for outputs that are ON at the Smartplex PDM and at the customer interface connectors. Repair the customer installed wiring. If the BHM Command Status indicators have yellow triangles, there is a problem with the BHM – continue with step 4.
		No	Troubleshoot for a wiring fault in the wiring bundles connecting the smart switches. If there are no wiring faults, replace the SHM.
4	Do the BHM status indicators show yellow triangles?	Yes	The BHM is not communicating over the J1939 data bus. Use the J1939 Datalink template to determine which devices are not communicating, including the BHM to help locate a databus fault. Check power to the BHM. Use the BHM troubleshooting instructions in the BHM troubleshooting manual.
		No	The BHM parameters mapping the switches to the outputs may not be programmed for the vehicle. Use the "Parameter Search Tool" to verify the parameter configuration and ServiceLink to flash the intended parameters.

Table 3, No Smart Switches or Outputs Operate

Troubleshooting

"Missing Smart Switch", or "Extra Smart Switch", or "Duplicate Smart Switch"			
Step	**Test**	**Result**	**Action**
This troubleshooting section is for diagnosing problems with SHM smart switches that are located in the overhead console. The smart switches that are wired to the SHM are managed by parameters in the BHM. The BHM parameters tie the smart switch to an electrical action. When a switch is not present but a parameter is programmed for it, or a switch is present with no programmed parameter, ServiceLink indicates this condition. Smart switches are also connected directly to the BHM, and are also used in SEMs (switch expansion modules).			
1	Is the fault for a missing, duplicate, or extra smart switch?	Missing	Go to step 2.
		Duplicate	Go to step 3.
		Extra	Go to step 4.
2	This fault becomes active if there is a missing indicator. Open ServiceLink. Click on the "Bulkhead Module" icon, then click the "Configuration" tab. When the screen opens, click on the "Check for Missing Smart Switches" button. The missing switch will appear on a blue row in the dialog box. Record the switch ID number and the parameter number (RPN). Close the dialog box, then select the "Features" tab and scroll down the list to locate the parameter number. The description for this parameter identifies the switch type, position, and the output it controls. If this parameter is for an indicator, its label will be described. Is a switch or indicator with this description physically present in the overhead console?	Yes	Open the "Switches" template and view the switch ID number. It should be 768, indicating there is a fault with the switch or the wiring between the SHM and the switch. Repair the wiring or replace the switch, as appropriate.
		No	This fault may be due to switches that are intended to be connected directly to the BHM, or are used in a SEM. BHM and SEM switch troubleshooting is covered in the applicable workshop manual section. The parameter for the switch identifies the switch and the operation of this function. If this switch is intended for the vehicle, add the switch identified by the parameter. If the switch is not wanted on this vehicle, change the parameter to "no content". Typically, this can be done by changing the last 3 digits of the parameter to -000.
3	Click the "Switches" template. Look at the switch IDs and find the switches that are shown twice. Does the "Switches" template show two switches with the same ID number?	Yes	Remove the duplicate switch and watch the switch ID number on the template transition to a high number, such as 792 and then to 768.
		No	If there are no duplicate switches shown on this template, the duplicate switch could be in the dash. Unplug each dash smart switch for 15 seconds. When the duplicate switch is unplugged, the active fault will clear on the ServiceLink "Faults" screen after 15 seconds.

"Missing Smart Switch", or "Extra Smart Switch", or "Duplicate Smart Switch"			
Step	**Test**	**Result**	**Action**
4	Click on the "Bulkhead Module" icon, then click the "Configuration" tab. When the screen opens, click on the "Check for Missing Smart Switches" button. Any extra switches will appear on rows that are colored tan. Record the switch ID number, then open the "Smartplex" switches template. If the extra switch is a Smartplex switch in the overhead console, the template will show its ID number and position. Does the template show a switch with this switch ID number?	Yes	If the switch is intended to be used in this vehicle, determine the correct parameter to program into the BHM. Use the "Parameter Search Tool" to identify the desired parameter. Program this parameter to the BHM using ServiceLink. If the switch is not necessary for the vehicle, remove it and place a close-out cover in the opening.
		No	The extra switch is not connected to the Smartplex SHM. It may be located on the vehicle dash connected directly to the BHM, or is in a SEM.

Table 4, "Missing Smart Switch", or "Extra Smart Switch", or "Duplicate Smart Switch"

ServiceLink Reports a Circuit-to-Pin Error			
Step	**Test**	**Result**	**Action**
When opening any of the ServiceLink Configuration tabs, the error dialog appears: 07/11/2012 f120227 This condition indicates a mismatch with the parameters that are recorded in the Freightliner mainframe data and the parameters that the vehicle is capable of supporting.			
1	Click on the 'Bulkhead Module" icon, then click the "Configuration" tab. Does the error dialog shown above pop up?	Yes	Investigate the parameter and circuit number noted in the error message dialog box. If the circuit is for a parameter that was generated using the "Parameter Search Tool", use ServiceLink to remove the parameter. If the error is still present, contact the Dealer Help Desk. If there is no error, the problem was likely caused by creating a parameter incompatibility with the "Parameter Search Tool."
		No	If there is an error dialog box present indicating an error with “hex file generation from PrePar” present, there is a mainframe parameter mismatch. Contact the Dealer Help Desk.

Table 5, ServiceLink Reports a Circuit-to-Pin Error

Troubleshooting

One Smartplex Switch or Output Does Not Operate			
Step	**Test**	**Result**	**Action**
1	Open ServiceLink and click on the "Switches" template and slowly cycle the switch through its positions. Is the switch state changing as expected?	Yes	Note the switch ID number for this switch. Click on the "Info" button at the top of the switches template. When the text file opens, scroll down to the crossover information section. Note the switch ID number, and record the parameter base number. Continue with step 2.
		No	The switch or the wiring between the SHM and the switch is at fault. Troubleshoot the wiring for a fault before replacing the switch.
2	Close the "Switches" template and click on the BHM icon, then click the "Features" tab. Scroll down the features list to locate the parameter number recorded from step 1. The output controlled by this switch is listed, along with any interlock conditions. Note this information, then open the "Outputs" template. If there are no outputs defined for this parameter, no physical output is expected to activate. Are all the interlock conditions for this output met?	Yes	Go to step 3.
		No	Troubleshoot for a fault with the interlock circuit, after insuring that the vehicle is in a condition where the interlocks are met.
3	Open the "Outputs" template. Slowly cycle the switch. Does the BHM command status indicator on the template activate correctly to the switch state?	Yes	Go to step 4.
		No	If all the interlock conditions are met, there is a parameter programming problem for this switch/output. Use the "Parameter Search Tool" to locate the correct parameter, then use ServiceLink to apply the parameter.
4	Is the output on customer interface connector 1A or 2A?	Connector 1A	If connector 1A of the SHM output status indicator shows **OFF** or **Error**, the circuit is using more than the 6.7 amp capacity. The circuit may have a short, or it may need to be remapped to one of the 20-amp outputs on connector 2A. If the SHM output status is **ON**, measure the voltage for this output at the customer interface connector. If battery voltage is present, the fault is downstream of the Smartplex system and is with the body equipment. Otherwise, troubleshoot for a wiring fault between the SHM and the customer interface connector.
		Connector 2A	Measure the voltage for this output at the customer interface connector. If battery voltage is present, the fault is downstream of the Smartplex system and is with the body equipment. If there is no voltage at the connector, troubleshoot for a fault in the wiring between the SHM and the Smartplex body builder PDM, or for a fuse and relay fault in the Smartplex body builder PDM.

Table 6, One Smartplex Switch or Output Does Not Operate

None of The 20-Amp Smartplex Outputs are Operating			
Step	**Test**	**Result**	**Action**
1	Open the "Outputs" template and observe the indicators for the 0.5-amp outputs driving 20-amp relays. Does the SHM output status show that any of the outputs are ON?	Yes	Check the battery supply power to the Smartplex PDM that is located under the access panel behind the drivers seat. Check the PDM for corrosion or damage. Locate and repair any wiring fault.
		No	Turn on a smart switch that is configured for one of these outputs, then follow the "Yes" instructions above.

Table 7, None of The 20-Amp Smartplex Outputs are Operating

A Smart Switch Indicator Does Not Illuminate but The Output Works			
Step	**Test**	**Result**	**Action**
1	Open the "Switches" template and observe the indicator on the template and the one on the switch. Change the switch from OFF to ON. Does the template indicator status show ON or OFF?	ON	The indicator bulb in the switch is open circuit, or there is a wiring fault between the SHM and the switch. Troubleshoot for a wiring fault in the indicator circuit and repair as appropriate. Otherwise, replace the smart switch.
		OFF	Click on the "Enter Test Mode" button on the switches template. Click the ON button next to the switch indicator. The indicator on the template does not come on in test mode, but the lamp in the switch will illuminate if the switch is equipped with an indicator lamp. If the switch does not illuminate it is not equipped with an indicator.

Table 8, A Smart Switch Indicator Does Not Illuminate but The Output Works

The Smart Switch Backlighting Does Not Illuminate			
Step	**Test**	**Result**	**Action**
1	Open the "Smartplex Switches" template and observe the backlighting indicator on the top row of the template. With the vehicle running lamps turned ON, and the backlighting intensity turned at maximum, does the indicator show the backlighting is ON, OFF, or ERR/NA?	ON	Troubleshoot for a wiring fault in the backlighting circuits from SHM connectors J5, J6, and J7 that are inoperative.
		OFF	The backlighting is not being commanded ON by the bulkhead module. The bulkhead module commands the SHM to turn backlighting ON with J1939 messaging.
		ERR/NA	The SHM has detected an over amperage, or under amperage condition for the backlighting circuit. Troubleshoot for a wiring fault with all the backlighting circuits from SHM connectors J5, J6, and J7. Disconnect each of these connectors one at a time to isolate the group of smart switches that has the fault.

Table 9, The Smart Switch Backlighting Does Not Illuminate

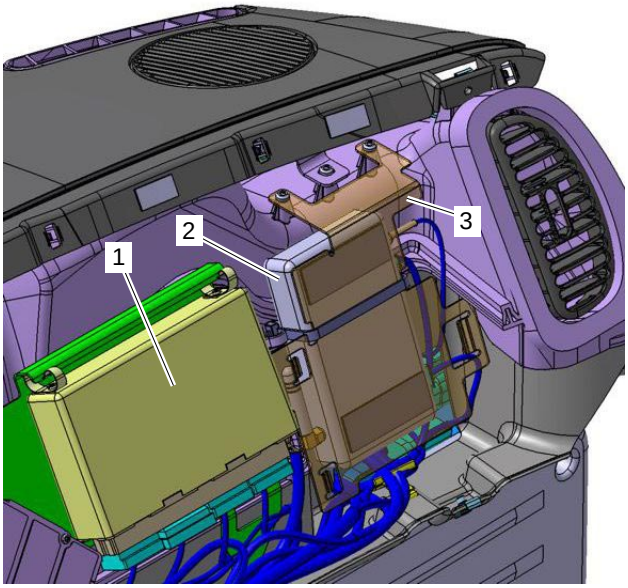
General Information

The Virtual Technician (VT) ECU generates diagnostic information to aid the Detroit® Customer Support Center and the technician in diagnosing complex engine control issues. The system creates sensor log files, captures fault codes, and sends alert messages and other advanced diagnostic information to the Detroit® Customer Support Center. The ECU utilizes GPS navigation, GSM (cellular telephone) communication, and a J1939 connection for databus monitoring. Virtual Technician does not require any driver input to function.

The Virtual Technician ECU is located behind the dash on the passenger-side of the vehicle. See **Fig. 1** for vehicles with a flat dash and **Fig. 2** for vehicles with a wing dash. The ECU can safely be removed from the mount while remaining wired into the vehicle for visual diagnostic purposes.

There are three modes of operation for the Virtual Technician ECU:

- **Registration Mode**: The vehicle identification number (VIN), engine serial number, and GPS ID are gathered at the manufacturing facility in this mode. Registration mode also occurs when a new unit is installed at the dealership.
- **Normal Operation Mode**: This mode occurs after electronic registration of the unit. In this mode, the ECU gathers fault codes, ring buffer files, and GPS data. This mode monitors the databus for general information and fault codes. Transmission of this information to Detroit® generally occurs within 4 minutes of collection depending on GSM network availability. Normal mode also allows for over-the-air updates of VT firmware.
- **Dormant Mode**: In dormant mode, activity and data usage is minimized or eliminated. This mode is activated only by remote modification of the firmware settings by the CSC. This may occur if the VT subscription ends.



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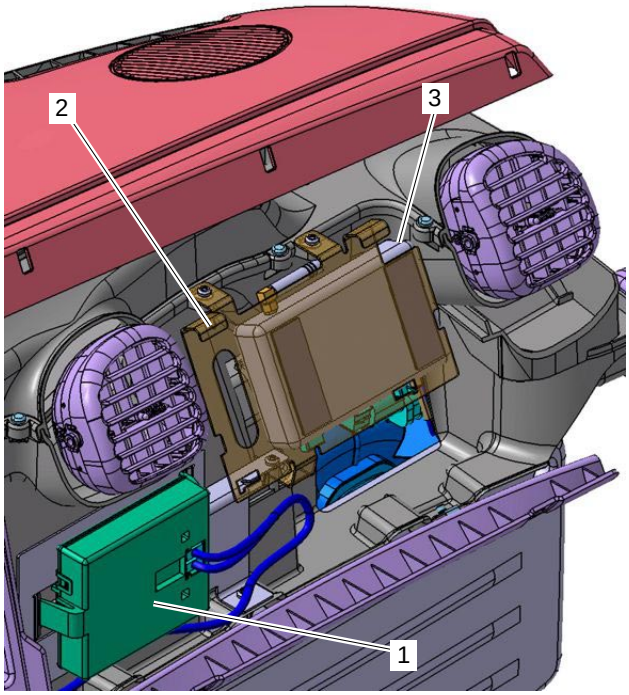
1. Common Powertrain Controller
2. Virtual Technician ECU
3. Mounting Bracket

Fig. 1, Virtual Technician ECU, Flat Dash Installation

General Information



12/12/2011 f545863

1. Gateway Module
2. Mounting Bracket
3. Virtual Technician ECU

Fig. 2, Virtual Technician, Wing Dash Installation

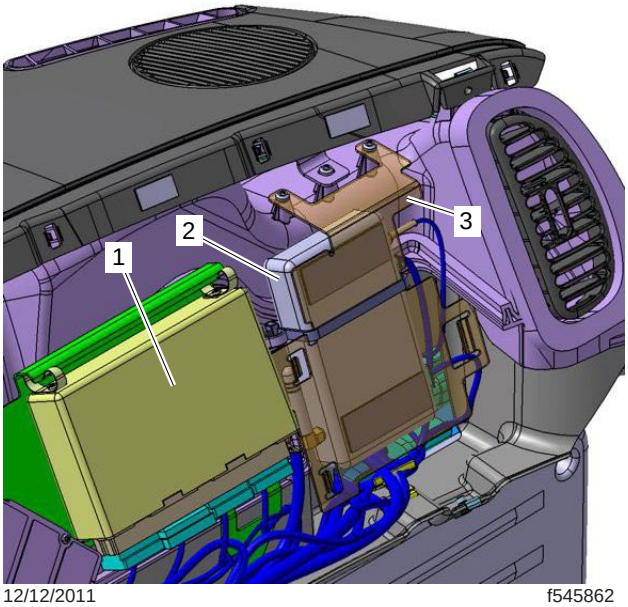
Virtual Technician ECU Removal and Installation

Removal

1. Park the vehicle and shut down the engine.
2. Remove the passenger-side dash.
3. Remove the Virtual Technician ECU mounting bracket to view LEDs for diagnostic information. See **Fig. 1** and **Fig. 2**. The LEDs are located on the left side of the ECU.
4. Refer to **Troubleshooting, 300** for diagnostic information. If the Virtual Technician ECU needs to be replaced, call the *Detroit® Customer Support Center*.
5. Disconnect the 4-pin and 10-pin connectors to the ECU.
6. Disconnect the GPS antenna cable.
7. Remove the ECU from the vehicle.

Installation

1. Connect the 4-pin and 10-pin connectors to the new ECU.
2. Screw on the GPS antenna cable to the threaded GPS connection.
3. Position the new Virtual Technician ECU in the vehicle.
4. Install the mounting bracket.
5. Install the passenger-side dash panel.
6. Verify the operation of the ECU.
   - 6.1 Start the vehicle and drive to an open area, at least 40 feet (12 meters) away from any buildings. Park the vehicle and keep the ignition in the ON position. Apply the parking brake.
   - 6.2 Call the *Detroit® Customer Support Center*. Make sure to have the vehicle serial number and the Virtual Technician serial number available so that the new ECU can be registered.

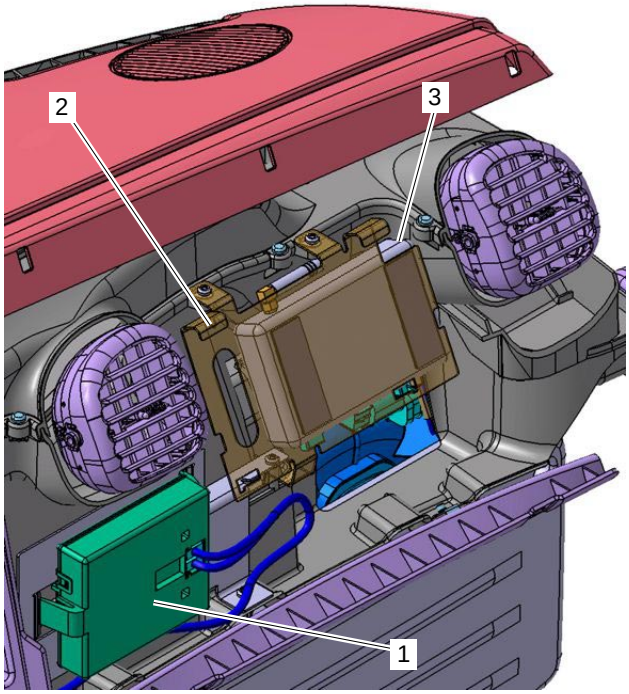


12/12/2011 f545862

1. Common Powertrain Controller
2. Virtual Technician ECU
3. Mounting Bracket

Fig. 1, Virtual Technician ECU, Flat Dash Installation

Virtual Technician ECU Removal and Installation



12/12/2011 f545863

1. Gateway Module
2. Mounting Bracket
3. Virtual Technician ECU

Fig. 2, Virtual Technician, Wing Dash Installation

Replacement

NOTE: Before removing the GPS antenna, call the *Detroit® Customer Support Center* for diagnosis of the problem and instructions for repair. The GPS antenna is mounted externally to the passenger-side cowl.

1. Park the vehicle, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the passenger-side lower kick panel.
3. Remove the A-pillar outer panel.
4. Disconnect the antenna pigtail from the antenna cable.
5. Loosen the nut securing the antenna to the passenger-side cowl, and remove the antenna.
6. Remove the rubber grommet and pigtail from the cab.
7. Mount the new antenna to the cowl and tighten the mounting nut.
8. Run the new pigtail into the cab, and secure the attached rubber grommet over the insertion hole.
9. Connect the antenna pigtail to the antenna cable.
10. Install the passenger-side lower kick panel.

Modes of Operation

There are three modes of operation for the Virtual Technician ECU:

- **Registration Mode**: The vehicle identification number (VIN), engine serial number, and GPS ID are gathered at the manufacturing facility in this mode. Registration mode also occurs when a new unit is installed at the dealership.
- **Normal Operation Mode**: This mode occurs after electronic registration of the unit. In this mode, the ECU gathers fault codes, ring buffer files, and GPS data. This mode monitors the databus for general information and fault codes. Transmission of this information to Detroit® generally occurs within 4 minutes of collection depending on GSM network availability. Normal mode also allows for over-the-air updates of VT firmware.
- **Dormant Mode**: In dormant mode, activity and data usage is minimized or eliminated. This mode is activated only by remote modification of the firmware settings by the CSC. This may occur if the VT subscription ends.

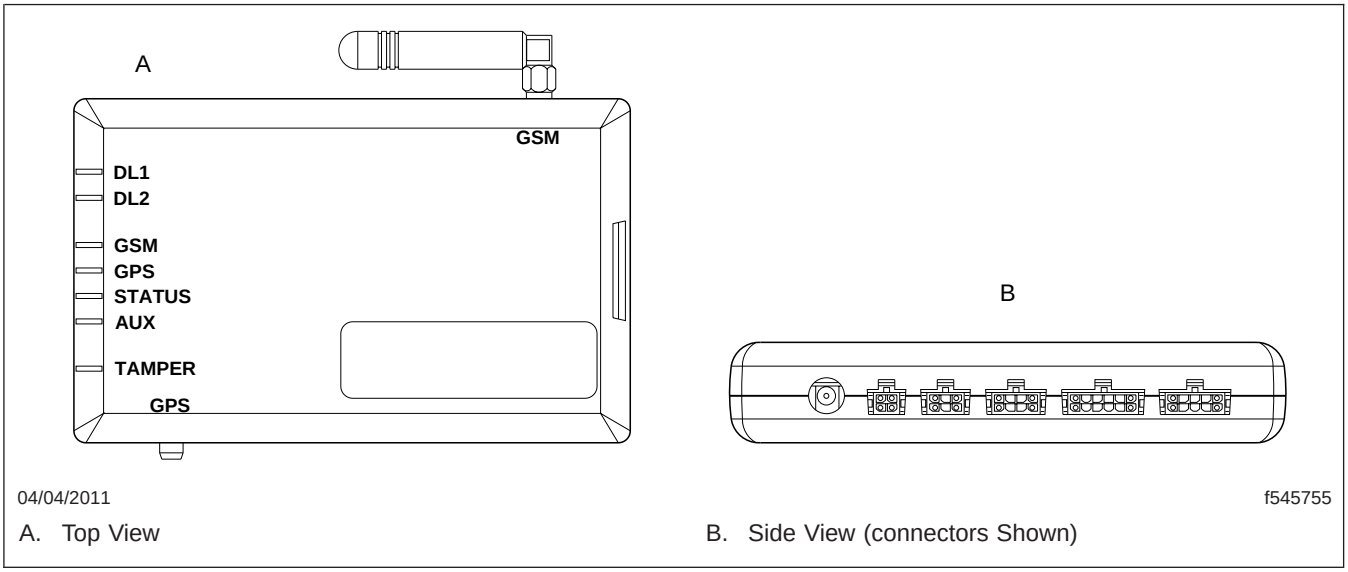
Diagnostic Overview

All testing of the GPS and cellular reception must be done outside, and at a distance of at least 40 feet (12 meters) from any buildings. This ensures adequate GPS signal strength and good cellular reception.

Diagnosing Virtual Technician requires access to the ECU to view the LEDs on the unit. The LEDs provide diagnostic information needed by the technician and the CSC (Customer Support Center). To access the unit, refer to **Subject 100**. To diagnose the unit, turn the ignition to the ON position.

There are seven LEDs visible on the VT ECU module. If no LEDs light up with the ignition ON, diagnose supplied power and ground to the unit. See **Table 1**and **Fig. 1**.

Troubleshooting



A. Top View

B. Side View (connectors Shown)

Fig. 1, Virtual Technician ECU

Diagnostic LEDs			
Name	**Color**	**Function**	**Action**
DL1	Red	**Red Blink (1Hz)**: J1708 connectivity (disabled). No J1708 activity detected (device is awake). Device is not wired for J1708 connectivity.	Red is the normal and expected state.
DL2	Red and Green	**Red Blink (1Hz)**: J1939 connectivity. No J1939 activity detected (device is awake). **Green Blink (1Hz)**: J1939 activity detected (device is awake) .	Green blink is expected, if LED is blinking red diagnose J1939 connectivity issue at the terminals.
GSM	Green	**Solid**: GPS connection successful. **One Blink**: Initializing. **Two Blinks**: Acquiring time zone information. **Three Blinks**: Attempting to make a GPS connection.	Solid is expected – if otherwise call the Customer Support Center for further instruction.
GPS	Green	**Solid**: Satellites acquired. **One Blink**: Acquiring satellites.	Refer to J1939 fault codes if a problem is suspected.

Diagnostic LEDs			
Name	**Color**	**Function**	**Action**
Status	Green	**Solid**: Engine running. **One Blink**: Engine not running; no data to send. **Two Blinks**: Data is available to be sent. **Four Blinks**: GPS storage log is full.	Refer to J1939 fault codes if a problem is suspected.
AUX	Red	**Solid**: GSM Modem Comm. Error, or panic line is active. **Two Blinks**: Not Used. **Three Blinks**: GSM modem is not starting up. **Four Blinks**: SIM Card read error. **Five Blinks**: GSM CTS (clear-to-send) line is active.	Refer to J1939 fault codes if a problem is suspected.
Tamper	Red	Disabled	N/A

Table 1, Diagnostic LEDs

Fault Codes

NOTE: The VT ECU source address (SA) is usually 74. Due to the addition of other telematics devices, SA 74 may be taken by another ECU. In this case the VT ECU will be assigned another source address. This has no effect on the operation of the ECU or the vehicle.

Fault Codes				
Fault	**SPN**	**FMI**	**Details**	**Action**
Sim Card Error	524283	11	Installed SIM Card cannot be read.	Contact CSC/ Replace ECU
GPS Shorted	524286	4	Center lead shorted to ground or cable ground.	Check the antenna cable; replace GPS antenna if necessary
GPS Not Connected	524286	5	Antenna open or cut.	Attach GPS antenna. Replace antenna if wiring damaged
NAND Full	524285	0	Full	Contact CSC/ Replace ECU
NAND ++Checksum Error	524285	2	Error	Contact CSC/ Replace ECU

Troubleshooting

Fault Codes				
Fault	**SPN**	**FMI**	**Details**	**Action**
NAND I/O Error	524285	11	Cannot read/write.	Contact CSC/ Replace ECU
uSD Full	524284	0	Full	Contact CSC/ Replace ECU
uSD Checksum Error	524284	2	Read/write error	Contact CSC/ Replace ECU
uSD I/O Error (micro SD)	524284	11	Cannot read/write – not present	Contact CSC/ Replace ECU
RTC Error (real time clock)	524282	11	VTECU RTC out of range	Contact CSC/ Replace ECU

Table 2, Fault Codes

Updating Firmware

The approved method for updating the VT ECU firmware is through an over-the-air (OTA) update. OTA updates occur when VT is sent a firmware file over the GSM connection. This allows remote programming of modules in the field. If a software issue is suspected, contact the Detroit® Customer Support Center for further diagnostics.

The OTA process begins by scheduling the device to update to Zonar and Daimler approved firmware. Once the OTA update is scheduled the device uploads the necessary data. The download occurs when the ignition wire is powered off and the device is no longer seeing engine RPM data. The OTA process is underway when the Tamper, Aux, Status, GSM and GPS LEDs all blink together at a 1hz rate.

The device must stay powered on while the OTA update is downloading. Cycling the ignition will not interrupt an OTA update. The module will stop downloading only if power is removed from the unit. Data is not collected during an OTA update.

Virtual Technician ECU Connector Reference

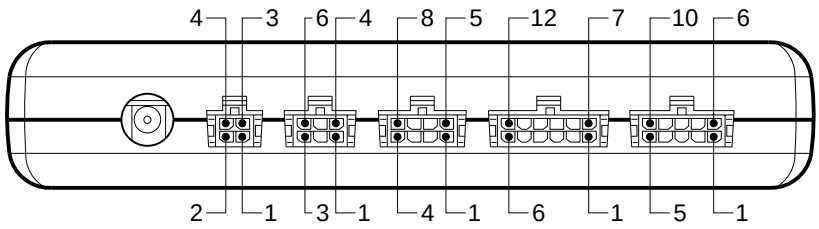


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Fig. 1, ECU Connector Reference

Power Connector						
Connector	**Pin**	**Name**	**Type**	**Minimum**	**Maximum**	**Notes**
4-Pin	1	Power	Input	8 VDC	30 VDC	Requires External Fuse
	2	Ignition	Input	0 VDC	30 VDC	Requires External Fuse 0 VDC = Logic 0 1.8 VDC = Logic 1
	3	Ground	—	0 VDC	0 VDC	—
	4	Panic Switch	Input	0 VDC	5 VDC	Ground Closure Switch Only

Table 1, Power Connector

Expansion and Diagnostics Connector						
Connector	**Pin**	**Name**	**Type**	**Minimum**	**Maximum**	**Notes**
6-Pin	1	RS-232 TX	Output	-15 VDC	15 VDC	Proprietary
	2	Ground	—	0 VDC	0 VDC	—
	3	5V Supply	Output	5 VDC	5 VDC	—
	4	RS-232 RX	Input	-15 VDC	15 VDC	Proprietary
	5	DSR-IN	Input	-15 VDC	15 VDC	—
	6	Panic Switch	Input	0 VDC	5 VDC	Ground Closure Switch Only

Table 2, Expansion and Diagnostics Connector

Specifications

EVIR Connector						
Connector	**Pin**	**Name**	**Type**	**Minimum**	**Maximum**	**Notes**
8-Pin	1	RS-232 TX	Output	-15 VDC	15 VDC	Proprietary
	2	CTS IN	Input	-15 VDC	15 VDC	—
	3	DSR OUT	Output	-15 VDC	15 VDC	—
	4	Power Out	Output	—	—	System Supply Voltage, Unregulated
	5	NC	—	—	—	—
	6	Ground	—	—	—	—
	7	NC	—	—	—	—
	8	RS-232 RX	Input	-15 VDC	15 VDC	Proprietary

Table 3, EVIR Connector

General Purpose I/O Connector						
Connector	**Pin**	**Name**	**Type**	**Minimum**	**Maximum**	**Notes**
12-Pin	1	GPIO 1	Input	0 VDC	30 VDC	0 VDC = Logic 0 1.8 VDC = Logic 1
	2	GPIO 3	Input	0 VDC	30 VDC	0 VDC = Logic 0 1.8 VDC = Logic 1
	3	GPIO 5	Input	0 VDC	30 VDC	0 VDC = Logic 0 1.8 VDC = Logic 1
	4	SPI-IN	Input	0	3.3 VDC	Proprietary
	5	SPI-OUT	Output	0	3.3 VDC	Proprietary
	6	SPI-CLK	Output	0	3.3 VDC	Proprietary
	7	GPIO 2	Input	0 VDC	30 VDC	0 VDC = Logic 0 1.8 VDC = Logic 1
	8	GPIO 4	Input	0 VDC	30 VDC	0 VDC = Logic 0 1.8 VDC = Logic 1
	9	SPI-CS	Output	0	3.3 VDC	Proprietary
	10	Relay	Output	—	2 A	Open Drain Output
	11	Ground	—	—	—	—
	12	3.3V Supply	Output	3.3 VDC	3.3 VDC	—

Table 4, General Purpose I/O Connector

Vehicle Communication Connector						
Connector	**Pin**	**Name**	**Type**	**Minimum**	**Maximum**	**Notes**
10-Pin	1	J1939 –H	—	–27 VDC	40 VDC	—
	2	CAN-Shield	—	0 VDC	0 VDC	J1939, –11 Only
	3	J1708 (–)	—	—	—	
	4	NC	—	—	—	—
	5	NC	—	—	—	—
	6	J1939 –L	—	–27 VDC	40 VDC	—
	7	J1708 (+)	—	—	—	Disabled
	8	NC	—	—	—	—
	9	NC	—	—	—	—
	10	Ground	—	0 VDC	0 VDC	—

Table 5, Vehicle Communication Connector

General Information

A "datalink" is an electrical network that connects two or more computers to exchange data. The simplest datalink is a pair of wires between two computers. Freightliner uses datalinks to connect the Electronic Control Units (ECUs) for the electronically controlled vehicle systems with each other and with the Instrumentation Control Unit (ICU). A personal computer using Freightliner's ServiceLink diagnostic software can also be connected to the network via a datalink.

Datalink Systems

Different types of datalinks are used to connect certain ECUs. The vehicle may have any of the following datalinks:

J1587/J1708

J1587/J1708 is a low speed vehicle datalink that communicates information between the ECUs on the vehicle. The J1587 datalink is also referred to as J1708. See **Fig. 1**. J1708 refers to the SAE standard for the physical part of the datalink, such as the wiring and the electronic components. J1587 refers to the SAE standard for the messaging protocol that communicates on the J1708 network. In the context of vehicle repair, the terms J1708 and J1587 are used interchangeably.

The J1587 datalink uses a twisted pair of wires to reduce interference from digital messages being sent on the wires. Wire colors for the J1587 datalink are:

- Orange **J1587 Low**
- Green **J1587 High**

J1939

J1939 is a high-speed vehicle datalink that communicates information between ECUs on the vehicle. See **Fig. 2**.

Unlike the J1587 datalink, the J1939 datalink allows an ECU to broadcast requests as well as information. Examples of information that can be communicated on the J1939 datalink are:

- engine rotational speed;
- road speed;
- transmission tailshaft speed;
- engine retarder deactivation request;
- engine torque reduction request.

The J1939 datalink uses a twisted pair of wires to reduce interference from digital messages being sent on the wires. Wire colors for the J1939 datalink are:

- Yellow **J1939 High**
- Green **J1939 Low**

The back bone of the J1939 datalink is the section of the datalink that is between two terminating resistors. An ECU can be connected anywhere along the length of the backbone in between the terminating resistors. The wiring between the ECU and the J1939 backbone is called a circuit. The maximum distance of the terminating resistor is 3 feet from the last ECU or diagnostic connector.

The purpose of the terminating resistors is to minimize the reflection of data on the datalink which can cause J1939 messages to become partially or completely lost. Terminating resistors prevent this from occurring. Each terminating resistor is 120 Ohms, but the equivalent of two 120 Ohms resistors in parallel is 60 Ohms. With both resistors installed in the circuit, there should be 60 Ohms measured at any two points between **J1939 High** and **J1939 Low** in the circuit.

Each ECU is generally connected to the J1939 backbone using a tee connector or splice. See **Fig. 3**.

Making the Pinout Measurements Easier to See

The pins on the diagnostic connector may be difficult to see when testing. If the pins are difficult to see, use a Y-cable as an extension to the diagnostic connector to make test measurements easier. See **Fig. 4** for a drawing of the connector at the end of the Y-cable and the corresponding 9-pin diagnostic connector pins.

NOTE: Be sure to attach a meter with a proper jumper kit to prevent unintentional shorting to other pins and possible damage to ECUs.

The Roll Call

To check the readiness of the ECUs on the datalink, the ICU sends a signal to other ECUs and expects a response from each. This "Roll Call" procedure tells the ICU which ECUs are functioning correctly. When

General Information

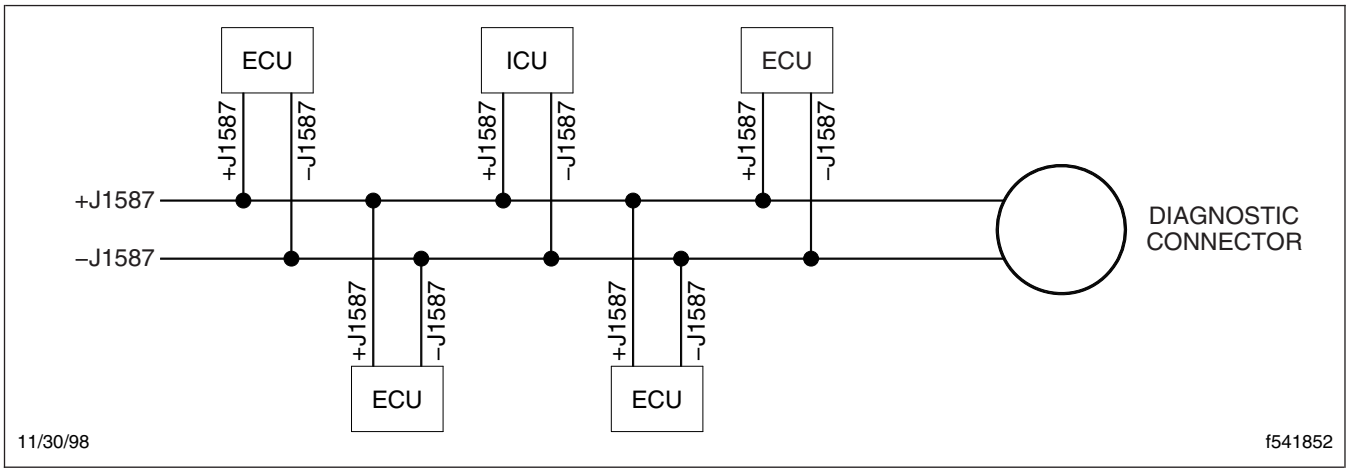


Fig. 1, J1587 Datalink

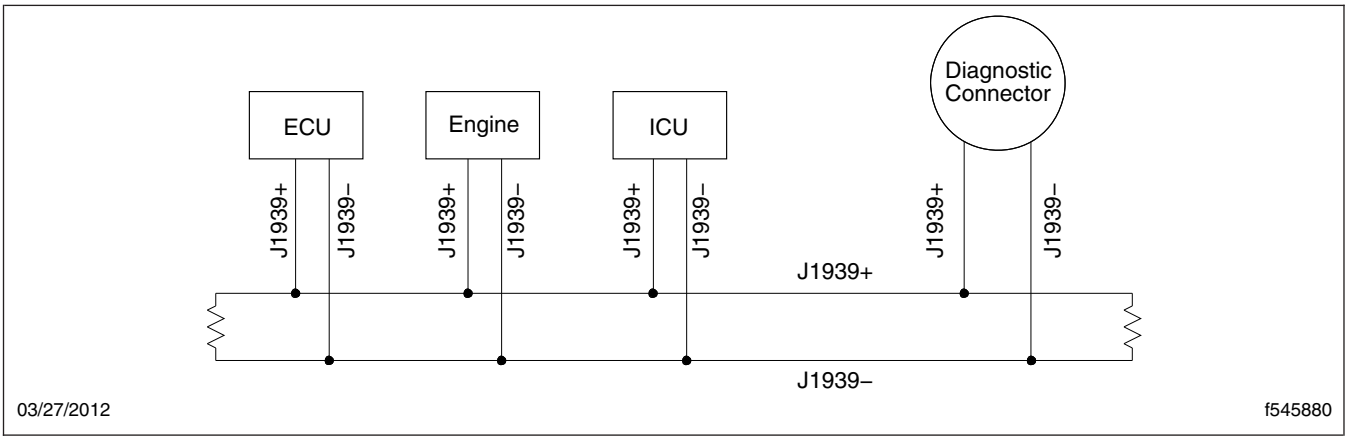


Fig. 2, J1939 Datalink

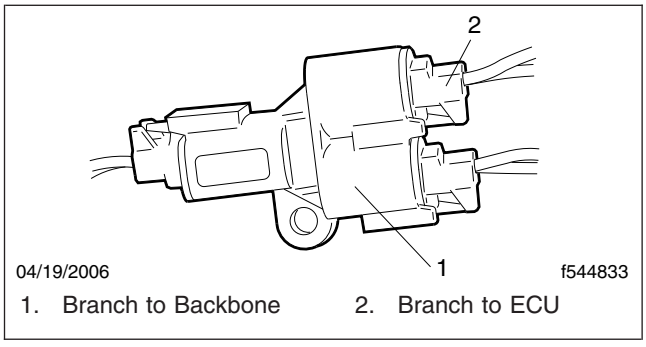


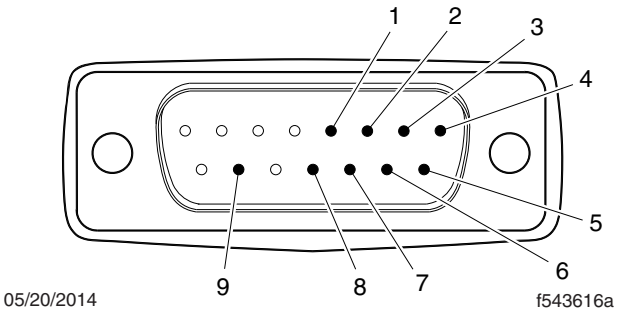
Fig. 3, J1939 Tee Connector

the list of functioning ECUs is compared against the parameter list of factory-installed ECUs that are supposed to respond, the technician can determine which ECUs or datalinks are bad.

If the ICU does not receive a signal on the datalink from one or more of the active ECUs, it displays a roll call fault. The roll call fault is displayed *only* on the dash driver display screen. It is not broadcast on the datalink; therefore, it cannot be read by Service-Link. However, Servicelink can be used to determine if an ECU is not responding because it polls all ECUs on the datalink when it first connects to the vehicle datalink.

Datalink Junction Blocks

For the J1587 datalink, the wires routed through the vehicle cab have two datalink junction blocks and two datalink connections. The ICU3 uses only one connection to the ICU.



1. Pin H (Diagnostic CAN High)
2. Pin A
3. Pin E
4. Pin B
5. Pin F
6. Pin G
7. Pin C (J1939 High)
8. Pin D (J1939 Low)
9. Pin J (Diagnostic CAN Low)

Fig. 4, Y-Cable Pinouts

Locating J1939 Wiring Diagrams

The J1939 wiring diagram can be found in module 160. Other modules may also contain datalink wiring information. See **Table 1**.

Use PartsPro® to obtain drawing numbers for installation drawings, harness assembly drawings, and wiring diagrams applicable to the vehicle being worked on.

Component Module Locations	
Component	**Module Number**
General J1939 harness drawings, schematics, and installation drawings	160
Engine harness and installation drawings	283 and 286
Transmission harness and installation drawings	34A and 343
ABS harness and installation drawings	330, 332, and 333

Table 1, Component Module Locations

Datalink Repairs

J1587 and J1922 Repairs

Use the same methods of repair for the twisted-pair datalink wiring as are used for the other wires on the vehicle. However, the datalink wires must be twisted at a rate of a minimum one turn per inch (25 mm) of length.

J1939 Repairs

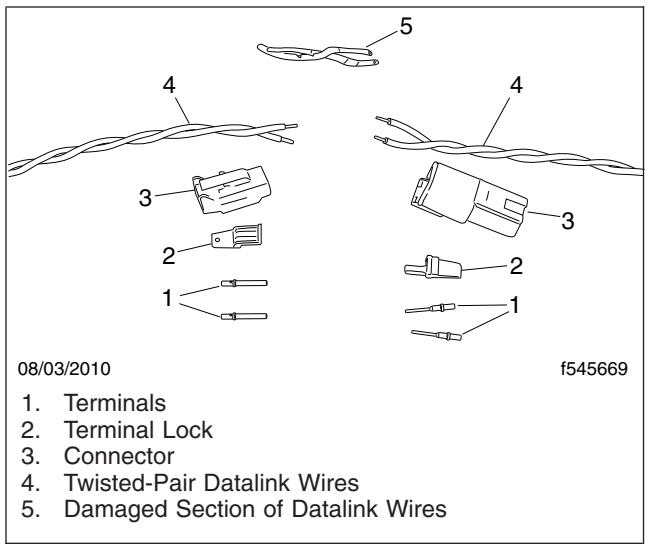
A special cable must be used for repairs to the J1939 datalink wiring. The two types of J1939 cable ("heavy" and "lite") can be spliced together as long as the pass-through connectors are the "heavy" type. The "lite" cable (because of its lower cost) is recommended for repairs on both types of J1939 cable. Refer to Appendix C of SAE J1939-11 for the special procedures for repairing the "heavy" J1939 datalink.

Parts

Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.
2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of Datalink Wires

Fig. 1, Datalink Splice Parts

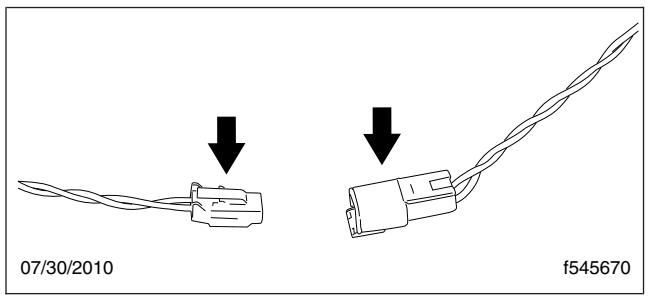


Fig. 2, Datalink Connectors

Datalink Repairs

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

General Information

This Troubleshooting subject has three main parts:

- Troubleshooting Tables

  Use the Troubleshooting Tables to get ideas on what could be causing the problem and the possible remedies to that problem.

- Troubleshooting Procedures

  Follow the Troubleshooting Procedures section to isolate the areas that have faults and to know which tests to perform.

- Testing Procedures

  The Testing Procedures section has the individual tests and specifications needed to determine whether a part must be repaired or replaced.

NOTE: Be sure to attach a meter with a proper jumper kit to prevent unintentional shorting to other pins and possible damage to ECUs.

Troubleshooting Tables

Use the following troubleshooting tables to find remedies to possible causes of datalink problems.

Problem—Power-On Roll Call Reports Fault

Problem—Power-On Roll Call Reports Fault	
Possible Cause	**Remedy**
The ECU does not support roll call function (ICU1/2M only).	Reset the ECU parameter to disable roll call.
The datalink wiring has a fault.	Repair or replace the wiring.
Wrong power supply voltage or ground to ECU.	Replace the fuse or circuit breaker, charge the battery, the check connections.
The connector has a fault - (Pass-through, Branch, Diagnostic)	Repair or replace the wiring.
The ECU has a fault.	Replace the ECU.
The ICU has a fault.	Replace the ICU.
The terminating resistor for J1939 datalink is missing or has a fault.	Replace the terminating resistor.
The branch length is too long on J1939 datalink.	Shorten "lite" branch to less than 10 feet (3 m).
The battery is discharged or is bad.	Charge or replace the battery.

Problem—ServiceLink Will Not Connect

Problem—ServiceLink Will Not Connect	
Possible Cause	**Remedy**
ICU is older series that does not support roll call.	Use ICU for display of active fault codes only.
One or more ECUs has a fault.	Remove suspected ECUs one at a time until ServiceLink can be connected.
ServiceLink computer is not configured or connected correctly.	Check the computer settings, communication adaptor and cabling between the computer, communication adaptor, and diagnostic connector.
Connector types are different.	The J1939 datalink and new J1587 datalinks have 9-pin connectors. Connect an adapter or use the ICU for the diagnostics information display.
Battery is discharged, has a bad connection, or has a fault.	Charge, clean terminals, or replace battery.

Troubleshooting

Problem—Missing Data on Datalink-Driven Gauges

Problem—Missing Data on Datalink-Driven Gauges *	
Possible Cause	**Remedy**
ICU or engine ECU is not communicating on datalink.	Test wiring and ICU or engine ECU.
Datalink wiring has a fault.	Test and repair wiring.
Connector or junction block has a fault.	Repair or replace connector.
Incorrect voltage to ECUs	Test datalink and vehicle wiring.

* Datalink-driven gauges include: engine oil pressure, coolant temperature, engine oil temperature, turbo air pressure, tachometer, speedometer

Troubleshooting Procedures

To find the part of the datalink system that is causing a problem, follow the Troubleshooting Procedures and refer to the appropriate Troubleshooting Tests for the test points and specifications. Perform the steps of the Troubleshooting Procedures in sequence until you locate the fault.

The seven steps to diagnosing a datalink problem are:

1. Determine which types of datalink are installed on the vehicle.

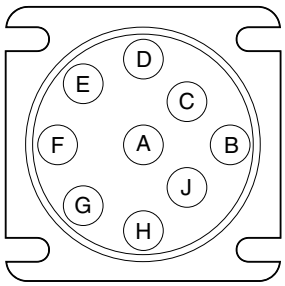
   1.1 Check the diagnostic connector. A 6-pin connector (or a 9-pin connector without pins C and D installed) is used for J1587 datalinks. See **Fig. 1** . J1939 datalinks have pins C and D installed in the 9-pin diagnostics connector.

   1.2 Check the wires. J1939 cable has a heavy jacket. Note that some non-Freightliner ECUs have their J1587 wires inside a jacket as well. If all the wiring has a jacket, the datalink is a J1939 datalink.

   If the J1939 cable has a drain wire inside the shielding, it is a "heavy" cable. The J1939 "lite" cable (with no drain wire) can be spliced into a section of "heavy" cable.

   1.3 Determine whether a Cummins IS Series, Caterpillar CFE, or a Mercedes-Benz engine is installed with an ABS system that has traction control. These systems use a J1939 datalink.

   1.4 A J1939 datalink is used when an Eaton® Fuller® AutoShift transmission is installed. The WABCO EBS (brake-by-wire) system and certain Eaton VORAD EVT-300 systems also require J1939 datalinks. Certain other ECUs may require a J1939 datalink.



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NOTE: Pins C and D are not installed in the J1587 diagnostics connector.

1. Pin A Battery (Low)
2. Pin B Battery (High)
3. Pin C (J1939 High)
4. Pin D (J1939 Low)
5. Pin E (Shield)
6. Pin F (J1587 High)
7. Pin G (J1587 Low)
8. Pin H (Diagnostic CAN High)
9. Pin J (Diagnostic CAN LOW)

Fig. 1, J1939/J1587 9-Pin Diagnostics Connector

2. Determine which ECUs are not communicating with ServiceLink.

   2.1 Connect to the vehicle with ServiceLink

   2.2 Compare the ICU roll call list with ServiceLink ECU list.

   Note: Some ECUs cannot communicate with the ICU, but will appear on the ServiceLink parameter list. The ICU2L and ICU3 rollcall function is limited to the engine ECU and the ABS ECU.

   2.3 If an ECU is not communicating on the datalink, disconnect all the generic ECUs, one at a time, until no faults are displayed on the ICU screen or until ServiceLink

connects to the system. The last ECU to be disconnected before the successful ServiceLink connection is the one causing the problem.

3. Check the suspected ECU.
   - 3.1 Check the resistance and voltage at the ECU connectors. See **Testing the ECUs** in the datalink testing procedures section of this subject.
   - 3.2 Temporarily replace the ECU with an ECU known to be good. If the ICU (or ServiceLink) now lists that ECU, install a new ECU.
4. Check the wires and connectors from the ICU at the connector for the suspected faulty ECU. See **Testing the J1587 Datalink** or **Testing the J1939 Datalink** in the datalink testing procedures section of this subject.
   - 4.1 Check the power supply voltage.
   - 4.2 Check the data signal voltage.
   - 4.3 Check the continuity and resistance to ground. If the readings are outside the acceptable range and are found at several test points, suspect that the datalink has a fault.
5. Determine which branch includes the suspected faulty ECU. Find the connectors and junction blocks that are in series with the suspected faulty ECU.
6. Check the wiring between the branch connector and the ECU and the wiring from the ICU to the branch connector. See **Testing the J1587 Datalink** or **Testing the J1939 Datalink** in the datalink testing procedures section of this subject.
   - 6.1 Check power supply voltage.
   - 6.2 Check the data signal voltage.
   - 6.3 Check the continuity and resistance to ground.
7. Check the ICU. See **Testing the ICU** in the datalink testing procedures section of this subject.
   - 7.1 Check the voltages at the junction block to the ICU.
   - 7.2 Replace the ICU with an ICU known to be good.

Datalink Testing Procedures

The following procedures give the test points and specifications for checking the various types of datalinks, connectors, ECUs and ICUs. Refer to the datalink troubleshooting tables, and the datalink troubleshooting procedures, above, for information on when to test the particular parts of the datalink system.

Testing at the ECUs

1. Make sure that the vehicle battery is charged and the fuses and circuit breakers are good before testing the ECU connectors.
2. The keyswitch must be in the OFF position. Disconnect the ECU datalink circuit at the connector closest to the ECU. Turn the keyswitch to the ON position and check the voltage at the ECU harness connector. See **Table 1** for the acceptable results.
3. Connect the ECU to the datalink connector when the keyswitch is in the OFF position. Turn the keyswitch to the ON position for this test. Touch the probes of the digital multimeter (on the DC voltmeter scale) to the metal terminals of the ECU connector as shown in **Table 1** to test the ECU. Use the AC scale for the voltage tests if the multimeter will not display the rapidly changing DC voltage using the DC scale. If the test results are not within the range shown, replace the ECU and test again.

   NOTE: Voltages in **Table 1** will be varying.

ECU Harness Voltage Tests		
J1587 aDatalink		
Meter (High) Probe	**Meter (Low) Probe**	**Acceptable Meter Reading (VDC)**
ECU Datalink High Terminal	ECU Datalink Low Terminal	1 to 4 VDC (1 to 3V on the AC Scale)

Troubleshooting

ECU Harness Voltage Tests		
J1587 aDatalink		
Meter (High) Probe	**Meter (Low) Probe**	**Acceptable Meter Reading (VDC)**
Battery Positive Post	ECU Datalink High Terminal	6 to 11 VDC *
	ECU Datalink – Terminal	9 to 13.5 VDC *
J1939 Datalink		
Diagnostics Pin C (J1939 High)	Diagnostics Pin D (J1939 Low)	.2 to 5 VDC (.1 to 4V on the AC Scale)
Diagnostics Pin B (BAT High)	Diagnostics Pin C	6 to 11 VDC*
	Diagnostics Pin D	9 to 13.5 VDC*

* If datalink wire connections are reversed, the results are reversed.

Table 1, ECU Harness Voltage Tests

Testing the J1587 Twisted-Pair Datalink

1. Make sure that all fuses and circuit breakers are in good condition.
2. Turn the keyswitch to the OFF position before disconnecting or connecting any part of the datalink system. Disconnect the J1587 connector for the datalink section you are testing.

IMPORTANT: Do NOT disconnect the datalink by disconnecting the engine, frontwall or chassis electrical connectors.

IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1587 resistance tests. Failure to do so may result in inconclusive resistance measurements. The J1939 datalink is not completely inactive with only the ignition off. It may be active even if there appears to be no voltage on the the datalink.

3. Turn the keyswitch to the OFF position. Test the continuity of a J1587 twisted-wire pair by touching the red (positive) probe of a digital multimeter (set to the ohmmeter mode) to the **J1587 High** terminal of the connector. Connect the black (negative) probe to the J1587– wire terminal. See **Table 2** for the results.

   Check the datalink isolation to the vehicle ground by holding one ohmmeter probe on the **J1587 Low** wire and the other probe to a good ground. Perform this test again with the ohmmeter leads reversed. **Table 2** shows the acceptable resistances for these tests.

J1587 Resistance Tests		
Meter (High) Probe	**Meter (Low) Probe**	**Acceptable Meter Reading (Ohms)**
High	Low	1k to 30k Ohms
High	Vehicle Ground	More than 1k Ohms
Low	Vehicle Ground	More than 1k Ohms

Table 2, J1587 Resistance Tests

4. Test the signal voltage on the J1587 twisted pair as shown in **Table 1**. The keyswitch must be in the ON position for the voltage tests. Use the AC scale for the voltage tests if your multimeter will not display the rapidly changing DC voltage using the DC scale.

NOTE: If any voltage reading is a steady 0 VDC or a steady 12 VDC, the ECU or datalink wiring has a fault.

Testing the J1939 Datalink

Use the following five basic steps in the order given to successfully locate J1939 datalink problems. Do not skip steps or tests unless directed to do so.

J1939 Resistance Test

This test checks whether or not both terminating resistors are installed, and ensures that there is a complete circuit from the diagnostic connector through the backbone loop. It does not ensure that branch circuits to each ECU are OK.

Tests in this subject are performed using a digital multimeter set to read ohms.

IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1939 resistance tests. Failure to do so may result in inconclusive resistance measurements. The J1939 datalink is not completely inactive with only the ignition off. It may be active even if there appears to be no voltage on the the datalink.

1. Turn the ignition OFF and disconnect the batteries.
2. Connect the meter leads of a digital multimeter set to read ohms to pins C and D of the 9-pin diagnostic connector and measure the resistance.
3. Reconnect the batteries after the test is completed.

See **Table 3** for test results and possible causes.

J1939 Resistance Test	
Result	**Possible Cause**
60Ω ± 6Ω	The J1939 datalink backbone is intact and both terminating resistors are installed. Go to step 2.
120Ω ± 12Ω	Any of the following: • One of the terminating resistors is missing. • One of the terminating resistors is open. • The circuit may be open anywhere between the terminating resistors.
40Ω ± 4Ω	Three terminating resistors have been installed; one must be removed. There must be one terminating resistor at each end of the backbone for a total of two.
0Ω to 5Ω	**J1939 High** and **J1939 Low** have shorted together somewhere in the system.
Greater than 1000Ω	The most likely cause is an open circuit between the diagnostic connector and the J1939 backbone. It may also be that both terminating resistors are missing or open.
Any other readings	Any of the following: • Incorrect terminating resistor resistance. • Poor or corroded connections. • Short circuit to ground or an open circuit somewhere on the datalink. Go to step 2 to pinpoint the problem.

Table 3, J1939 Resistance Test

ECU Communication Test

The following series of tests check for communication with each ECU connected to the J1939 datalink. If one fails to communicate, pinpoint whether the problem is wiring or an ECU. If all ECUs communicate as they should, J1939 is probably not the problem.

1. **Check whether each ECU connected to the J1939 datalink responds.**

Troubleshooting

1.1 Connect the computer to the diagnostic connector.

1.2 Start the J1939 Datalink Monitor template.

NOTE: The template contains instructions on its use.

1.3 Check whether each ECU that is supposed to be connected to the datalink responds. See **Table 4** for test results and possible causes.

Check whether each ECU connected to the J1939 datalink responds	
Result	**Possible Cause**
All ECUs respond	The J1939 datalink is probably not the problem.
One ECU fails to respond.	Go to step 2.
No ECUs respond	Possible explanations are: • The **J1939 High** and **J1939 Low** pinouts may be reversed at the diagnostic connector, or at any other connector in the system. Check their polarity. • There may be a problem with the PC to vehicle interface. • The entire datalink may be down due to a short to power or short to ground. Go to Step 3 to pinpoint the problem.

Table 4, Check Whether Each ECU Connected to the J1939 Datalink Responds

2. **Check the J1939 datalink wiring to the ECU that does not respond.**

IMPORTANT: The batteries **MUST** be disconnected and the ignition must be **OFF** prior to any J1939 resistance tests.

2.1 Turn the ignition OFF and disconnect the batteries.

2.2 Locate the connector at the ECU in Step 2, Test 1 that did not respond and disconnect it.

2.3 Locate the pins for **J1939 High** and **J1939 Low**. Refer to Freightliner or component supplier literature or wiring diagrams for the specific component.

2.4 Check to make sure that **J1939 High** and **J1939 Low** polarity is correct at the component before proceeding. If not, this is the most likely problem.

2.5 Using a digital multimeter set to read ohms, measure the resistance across the two J1939 datalink pins at the connector to the suspect ECU.

2.6 Reconnect the batteries after the test is completed. See **Table 5** for test results and possible causes.

Check the J1939 datalink wiring to the ECU that does not respond	
Result	**Possible Cause**
60Ω ± 6Ω	The datalink itself is probably not the problem. Make sure that any changeable J1939 parameters for this ECU are set correctly before proceeding. Also, make sure that there is power and ground to the suspect ECU. Go to **step 3** once the following have been confirmed: • J1939 parameters for the ECU (if they can be changed) are correct. • There is power and ground to the suspect ECU.

Check the J1939 datalink wiring to the ECU that does not respond	
Result	**Possible Cause**
Not 60Ω ± 6Ω	There is a problem with the J1939 wiring between the ECU connector and its connection to the J1939 backbone. Repair as necessary.

Table 5, Check the J1939 Datalink Wiring to the ECU That Does Not Respond

3. **Install a test ECU to confirm the problem.**
   - 3.1 Install a test ECU and make sure that all J1939 parameters (if changeable) are set correctly.
   - 3.2 Using the J1939 Datalink Monitor template, check to see if every ECU that is supposed to be connected to the datalink responds. See **Table 6** for test results and possible causes.

Install a test ECU to confirm the problem	
Result	**Possible Cause**
All ECUs respond	The ECU was faulty and the test ECU confirmed this. Replace the ECU.
The ECU still does not respond.	The problem has not been confirmed. Carefully repeat all the diagnostics. If the ECU still does not respond, contact your District Service Manager or the ECU supplier directly for assistance.

Table 6, Install a Test ECU to Confirm the Problem

Test J1939 Voltage for Circuit Faults (Shorts to Power and Ground)

These tests check for shorts to power and shorts to ground on the J1939 datalink.

NOTE: All tests are performed using a digital multimeter set to read voltage.

NOTE: Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition ON, use a digital multimeter to test for voltage at pin B by placing the red (+) lead on pin B and the black (-) lead on a good chassis ground.

1. **Test J1939 High for shorts to power and ground.**
   - 1.1 Turn the ignition ON.
   - 1.2 Touch the red (+) lead to pin B (+12 VDC) and the black (-) lead to pin C (**J1939 High**) of the diagnostic connector. See **Table 7** for test results and possible causes.

Shorts to Power and Ground (J1939 High)	
Result	**Possible Cause**
0 VDC	**J1939 High** is shorted to power. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
12 VDC (battery voltage)	**J1939 High** is shorted to ground. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
Any other reading	**J1939 High** is not shorted to power or ground. Go to step 2.

Table 7, Shorts to Power and Ground (J1939 High)

Troubleshooting

2. **Test J1939 Low for shorts to power and ground.**

   2.1 Turn the ignition ON.

   2.2 Touch the red (+) lead to pin B (+12 VDC) and the black (-) lead to pin D (**J1939 Low**) of the diagnostic connector. See **Table 8** for test results and possible causes.

Shorts to Power and Ground (J1939 Low)	
Result	**Possible Cause**
0 VDC	**J1939 Low** is shorted to power. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
12 VDC (battery voltage)	**J1939 Low** is shorted to ground. Continue to the next test, "Pinpointing Short Circuits on the J1939 Datalink."
Any other reading	**J1939 Low** is not shorted to power or ground. There may be a problem with the vehicle to computer interface. The datalink itself appears to be OK.

Table 8, Shorts to Power and Ground (J1939 Low)

Databus Quick Test

NOTE: All voltages in **Table 1**, except for BAT + and BAT – will be varying.

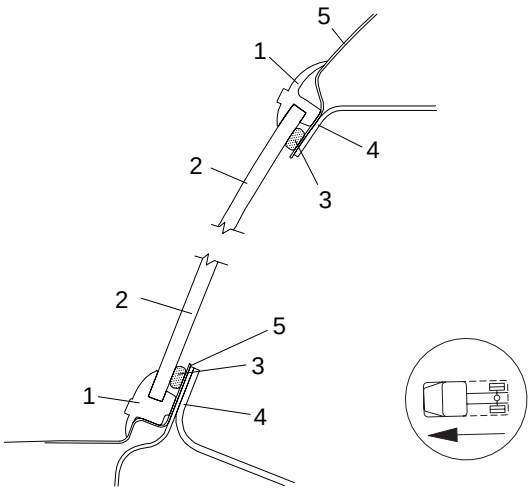
Databus Quick Test				
No.	**Test**	**Red Lead/Black Lead**	**Specification**	**Result**
Battery Connected – Ignition ON				
1	Bat+ to Bat-	Pin B to Pin A	Source Voltage (> 12.4)	
2	J1587+ to J1587–	Pin F to Pin G	1 – 5 VDC (0 – 4 VAC)	
3	Bat+ to J1587+	Pin B to Pin F	6 – 11 VDC	
4	Bat+ to J1587–	Pin B to Pin G	9 – 13.5 VDC	
5	J1939+ to J1939–	Pin C to Pin D	.2 – 5 VDC (.1 – 4 VAC)	
6	Bat+ to J1939+	Pin B to Pin C	6 – 11 VDC	
7	Bat+ to J1939–	Pin B to Pin D	9 – 13.5 VDC	
Ignition OFF – Battery Disconnected at Batteries – NOT Cab Load Disconnect Switch				
8	J1587+ to J1587–	Pin F to Pin G	1k – 30k Ohms	
9	J1587+ to Bat–	Pin F to Pin A	> 1k Ohms	
10	J1587- to Bat–	Pin G to Pin A	> 1k Ohms	
11	J1939+ to J1939–	Pin C to Pin D	55 – 65 Ohms	
12	J1939+ to Bat–	Pin C to Pin A	> 1k Ohms	
13	J1939- to Bat–	Pin D to Pin A	> 1k Ohms	
14	Terminating Resistors	—	110 – 130 ohms	

Table 1, Databus Quick Tests

NOTE: J1939 tests can also be performed on Diagnostic CAN High – Pin H, and Diagnostic CAN Low – Pin J for similar results.

General Information

The encapsulated windshield comes from the manufacturer with an injection-molded polyurethane seal and flange attached all the way around the edges of the windshield glass. There is no need for a separate retainer or moldings. The windshield is held in place on the windshield mask by a bead of urethane adhesive/sealant. The installation is similar to automobile windshields, where the urethane sealant holds the windshield in place and seals out moisture; see **Fig. 1**.



12/11/2001 f820390

1. Injection-Molded Polyurethane Seal and Flange
2. Windshield Glass
3. Urethane Adhesive/Sealant
4. Interior Trim
5. Windshield Mask

Fig. 1, Encapsulated Windshield Installation (cross-sectional view)

See **Specifications 400** for special tools and materials needed to replace a windshield.

Replacement

NOTE: Freightliner recommends Sika Ultrafast, Dow U-400HV, or Bostik® 70-08A adhesive for windshield replacement.

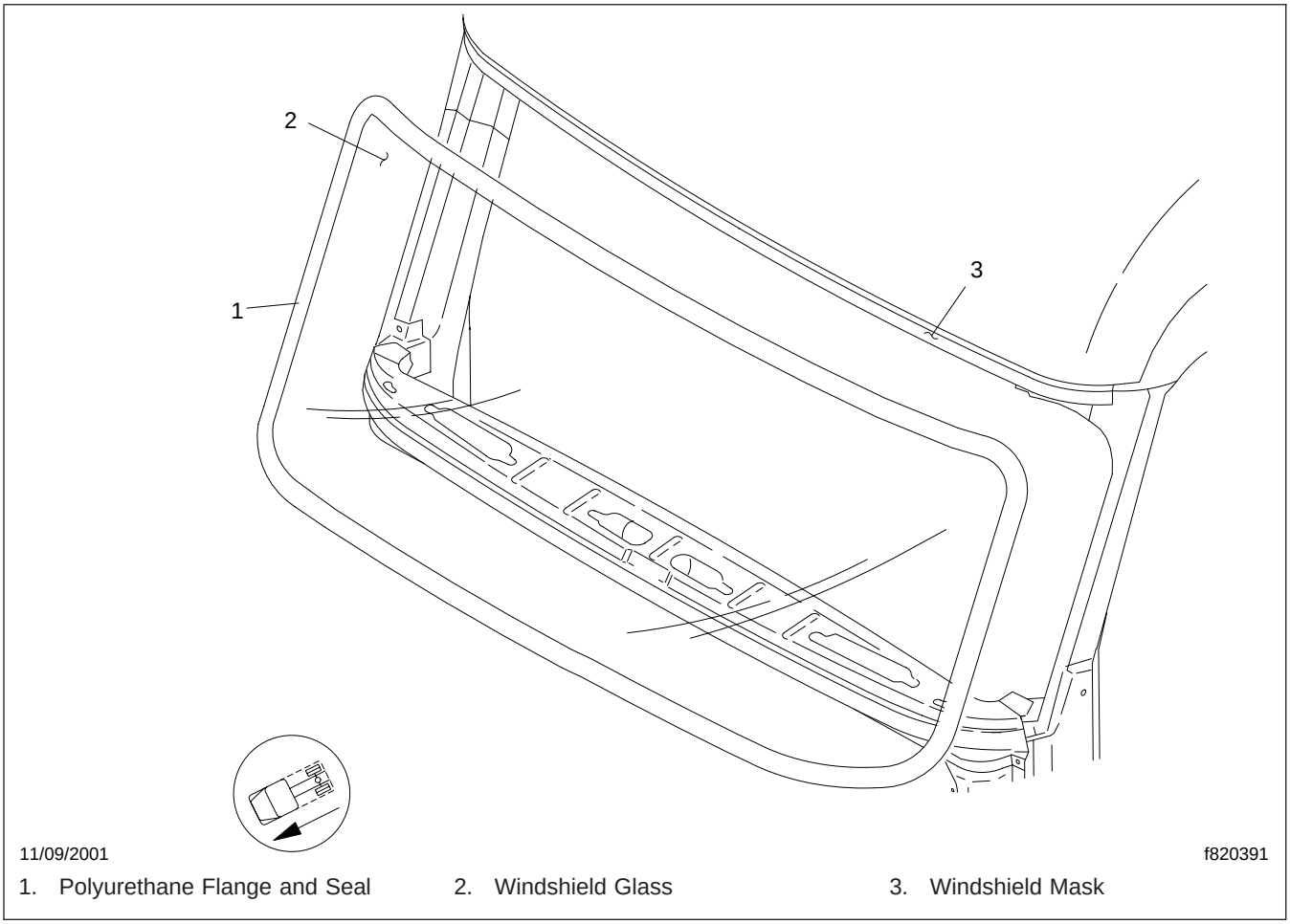
The procedure below specifies Dow adhesives and primers, though other manufacturers' systems can be used. Regardless of the system used, adhere to the adhesive manufacturer's instructions, and use that manufacturer's recommended primers and glass prep solutions for the entire procedure.

NOTE: The following procedure pertains to encapsulated windshields only; see **Fig. 1**.

If the windshield is cracked, carefully inspect the glass, urethane sealant, and the windshield mask to determine the cause. Correct the problem before installing a new windshield. If the underlying cause for the crack is not corrected, the replacement windshield may crack when exposed to high winds, pressure, temperature extremes, or vehicle motion.

NOTE: At least two people are needed to replace a windshield.

1. Apply the parking brakes and chock the tires.
2. Open the windows. Shutting the doors with the windows closed could pressurize the cab and create gaps in the uncured adhesive.
3. Open the hood.



1. Polyurethane Flange and Seal
2. Windshield Glass
3. Windshield Mask

Fig. 1, Windshield Installation (encapsulated windshield)

Windshield Replacement

4. Remove the windshield wiper arms; see **Group 82**.
5. Protect the paint finish and instrument panel by taping paper around the inside and outside of the windshield opening.
6. Lower the door windows, to prevent pressure build-up when closing the doors, which could damage the uncured adhesive seal.
7. Using a suitable knife, make a 90-degree cut into the polyurethane flange surrounding the windshield. Cut off the flange all the way around the windshield.
8. Using a pneumatic cutting tool (**Fig. 2**), a piano wire (**Fig. 3**), or a pull knife (**Fig. 4**), cut through the urethane sealant all around the edges of the windshield glass. See **Fig. 5** for a cross-sectional view.

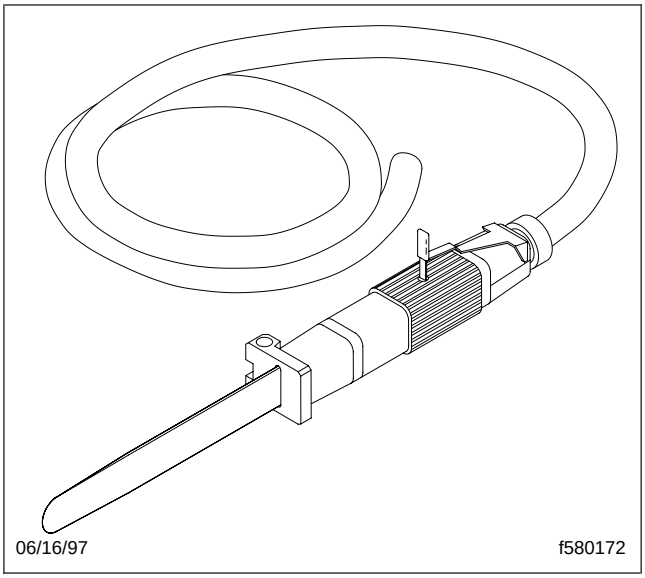
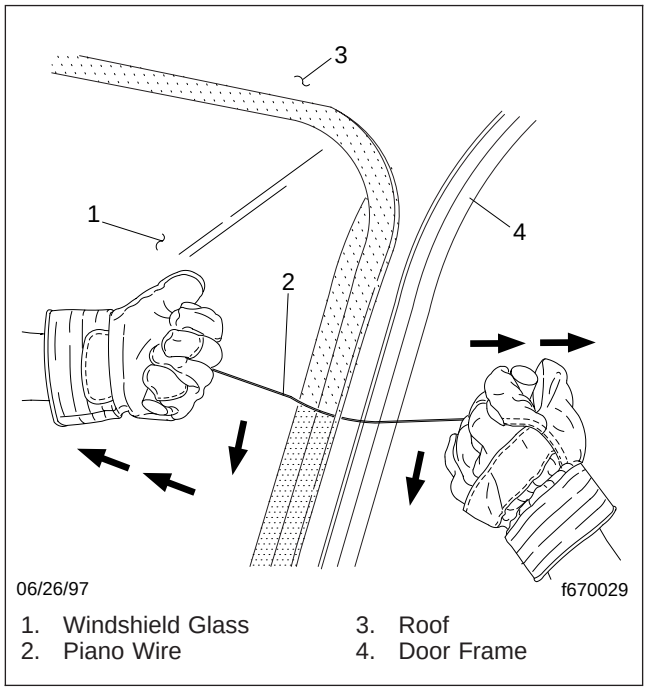


Fig. 2, BTB Pneumatic Cutting Tool

NOTE: To order a BTB pneumatic cutting tool, see **Specifications 400**.

⚠ WARNING

Wear protective gloves and safety glasses when replacing windshield glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.



1. Windshield Glass
2. Piano Wire
3. Roof
4. Door Frame

Fig. 3, Windshield Glass Removal with Piano Wire

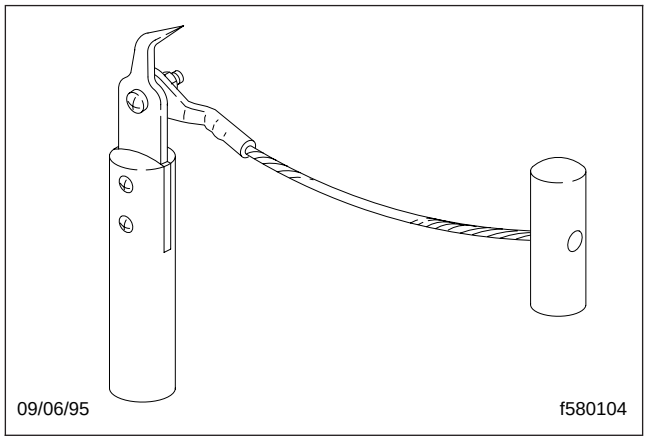
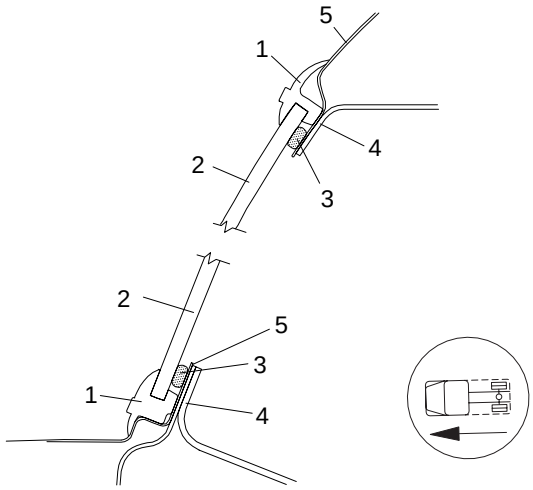


Fig. 4, Typical Pull Knife

9. Carefully remove the damaged windshield glass.
10. Using a BTB pneumatic cutting tool or a sharp knife, trim down the old urethane adhesive/sealant, leaving no more than 1/16 inch (1 to 2 mm) on the windshield mask. Make sure any remaining adhesive has a smooth and even surface.
11. Brush the remaining adhesive and debris from the windshield mask.



1. Injection-Molded Polyurethane Seal and Flange
2. Windshield Glass
3. Urethane Adhesive/Sealant
4. Interior Trim
5. Windshield Mask

Fig. 5, Encapsulated Windshield Installation (cross-sectional view)

12. Check the windshield mask. Apply Betaprime® 5404A Pinchweld and Encapsulation Primer to any bare metal. Allow to dry for a minimum of 6 minutes.

NOTE: Exposed bare metal areas larger than 1/2 inch x 1/2 inch (13 mm x 13 mm) require the use of Betaprime 5201TF Bare Metal Etch Primer.

13. Put the new encapsulated windshield glass on a suitable stand or fixture, with the inside surface of the glass facing up.
14. Clean the bonding surface of the glass with Betaclean GC-800.
15. Apply Betaprime 5500 1-Step Glass/Frit Primer all the way around the edge of the glass to a width of about 1 inch (25 mm). *Do not get any of the primer on the clear glass outside the black band.* Allow a minimum of six minutes for the primer to dry.
16. Holding the sealant applicator at a 90-degree angle to the windshield mask on the cab, apply a uniform and continuous bead of Betaseal U-400HV Adhesive all the way around the edges of the windshield mask. The bead should be a minimum of 3/8 inch (10 mm) thick.

    Keep the spiked edge of the applicator tip against the edge of the mask, and overlap the bead slightly.

IMPORTANT: Do not apply the urethane adhesive/sealant to the windshield glass. Aligning a windshield with adhesive on the glass is very difficult to do without getting the adhesive/sealant on the painted cab surface outside the windshield mask.

17. Attach a suction device to the outside of the windshield. Lift and install the windshield. Align the center of the windshield with the indexing point at the center of the windshield mask. Gently set the windshield in place, then adjust it side-to-side for the best fit. Make sure the lip of the polyurethane flange fits over the sheet metal of the A-pillars.
18. Gently press down on the glass all the way around the bead line to firmly seat the windshield.
19. With a spatula or a paddle, smooth the adhesive flat along the edge of the windshield and remove any excess.
20. Install the wiper arms; see **Group 82**.
21. Clean both sides of the new windshield glass.
22. Remove the protective coverings from the inside and outside of the windshield opening.
23. Close the hood.
24. Refer to the adhesive manufacturer's documentation for cure and drive-away times.

Specifications

See **Table 1** for the materials needed for windshield installation using Dow U-400HV urethane adhesive. The items in **Table 1** are available from your local Dow/Essex dealer.

If using another adhesive, refer to the adhesive manufacturer's instructions for applicable cleaners and primers.

Materials and Tools Needed for Windshield Installation	
Material or Tool	**Part Number**
Betapclean® Glass Cleaner	GC-800
Betaprime® Glass Primer	5500
Betaprime Body Primer	5404A
Betaseal® Adhesive	U-400HV
Betaseal Primerless Auto Glass Adhesive	U-418

Table 1, Materials and Tools Needed for Windshield Installation

See **Fig. 1** and **Fig. 2** for the special tools needed for windshield removal.

To obtain the BTB pneumatic cutting tool (J–43029) contact:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

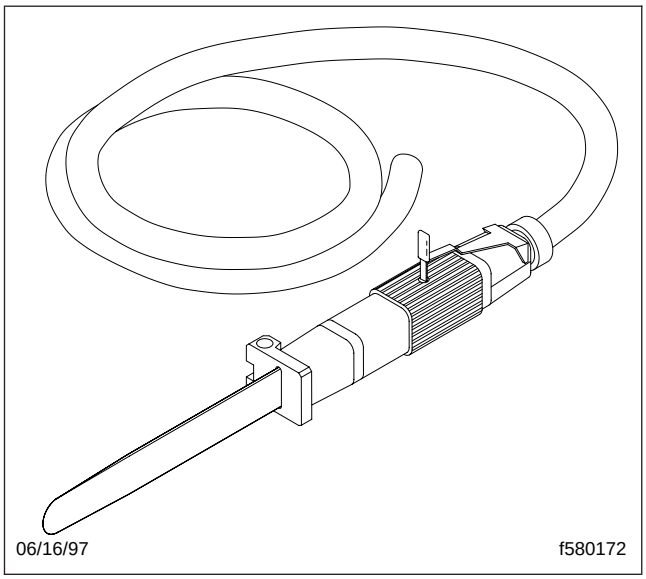


Fig. 1, BTB Pneumatic Cutting Tool (J-43029)

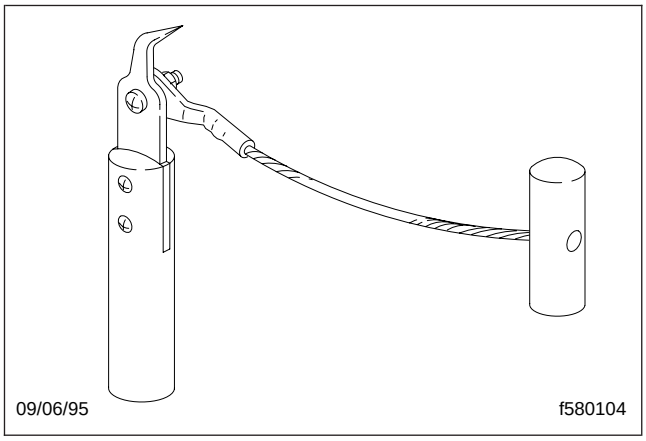


Fig. 2, Typical Pull Knife

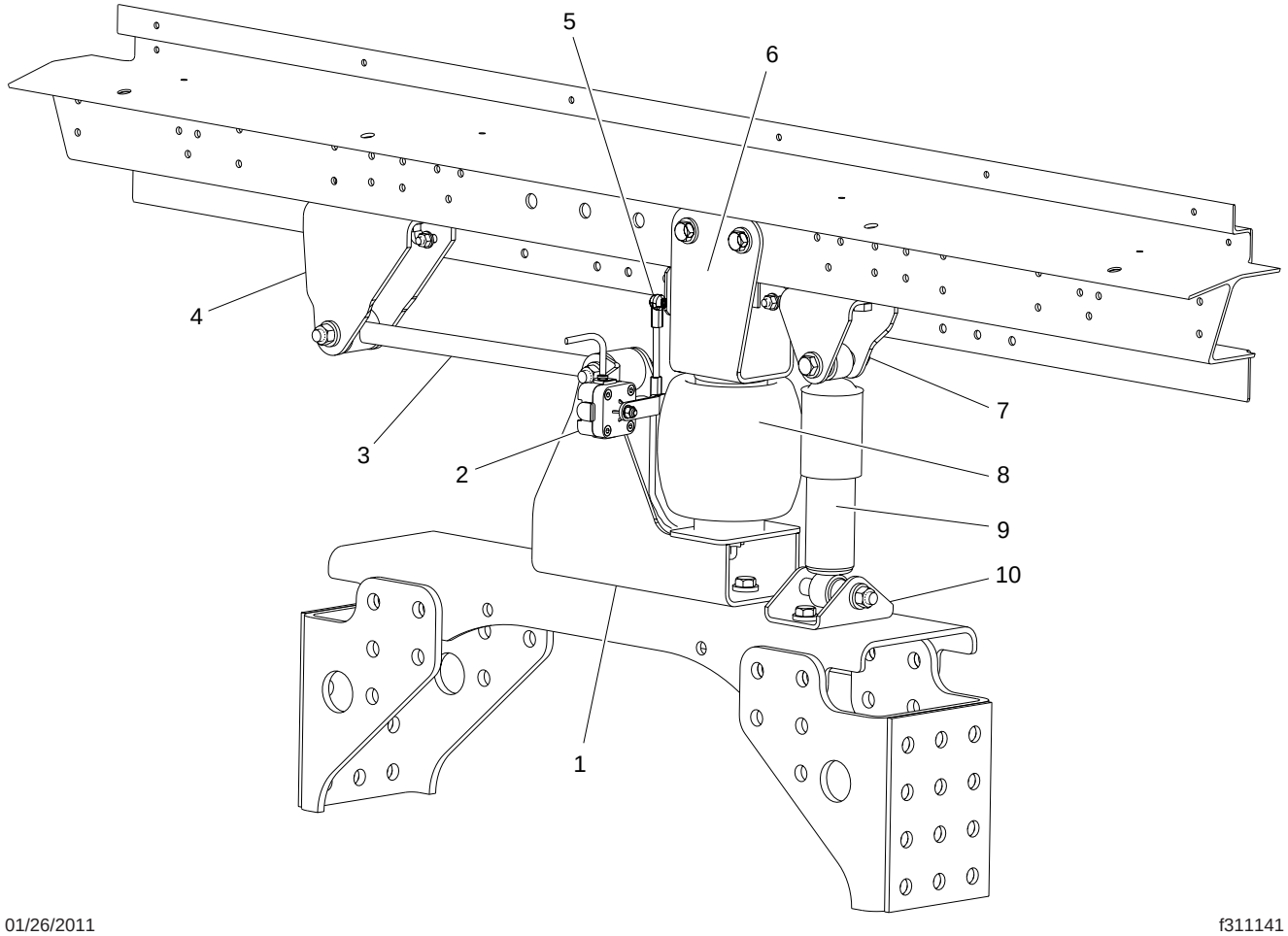
General Information

Cab air-suspension systems consist of an air spring, a height-control valve, a lateral control rod, a shock absorber, and a vertical linkage; see **Fig. 1**.

The cab rear air-suspension system absorbs road shocks better than a solid-mount system, and thus provides a smoother ride for cab occupants and cab-mounted equipment.

Air Spring

The top of the air spring is mounted to a bracket on the cab underbody, and the bottom is mounted to a bracket on a frame rail crossmember. Together with the height-control valve, the air spring compensates for changes in cab load by maintaining the correct cab height at the rear of the cab.



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1. Air Spring Lower Bracket
2. Height-Control Valve
3. Lateral Control Rod
4. Control Rod Cab-Mounted Bracket
5. Vertical Linkage
6. Air Spring Upper Bracket
7. Shock Absorber Upper Bracket
8. Air Spring
9. Shock Absorber
10. Shock Absorber Lower Bracket

Fig. 1, Cab Rear Air Suspension

Height-Control Valve

NOTE: If a leak occurs in the cab air-suspension system, a pressure protection valve (located at the secondary air tank, which supplies the air to the height-control valve) will maintain a minimum pressure of about 65 psi (450 kPa) in the vehicle secondary air system.

All of the air in the cab air-suspension system is admitted through or exhausted from the height-control valve. It mounts on the control rod bracket, which is attached to the frame rail crossmember. The height-control valve has a horizontal control lever, the outboard end of which is connected to a vertical linkage. The upper end of the vertical linkage is attached to a bracket on the cab underbody.

When the load on the cab increases, the dimension between the cab and the crossmember decreases, causing the vertical linkage to push downward on the end of the horizontal control lever. This turns the height-control valve shaft, which activates the height-control valve. Air flows through the valve and into the air spring until the pressure in the spring raises the cab to the correct height. At this height, the control lever and the control shaft are returned to their neutral positions, closing the intake air supply.

When the load on the cab decreases, the rear of the cab rises, causing the vertical linkage to pull up on the end of the horizontal control lever. Turning the height-control valve control shaft in this direction activates an exhaust port in the valve. This allows air pressure in the air springs to decrease until the cab is lowered to the correct height. Again, the control lever and control shaft are returned to their neutral positions, and air flow is stopped.

When the vehicle is in motion, small and abrupt movements of the cab will occur, resulting in small or abrupt movements of the control lever. These movements of the control lever do not activate the height-control valve to correct the cab ride height.

Changes in load that occur when occupants or heavy items are added to or removed from the cab will activate the height-control valve to correct the cab ride height. Also, when the vehicle is moving forward at high speed or in a high headwind, a major change in load occurs from the downforce applied to an optional air shield or air fairing. When these changes in load occur, the cab air-suspension system will correct the cab ride height at the rear of the cab.

Lateral Control Rod

The lateral control rod limits the side-to-side motion of the rear of the cab. One end of the control rod is attached to a bracket on the crossmember, the other to a bracket on the cab underbody.

Shock Absorber

The shock absorber controls the air spring and cab suspension movement, and dampen oscillation in the cab suspension system. It is attached to the rear of the cab and to the crossmember.

Fitting Leakage Repair

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

⚠ WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

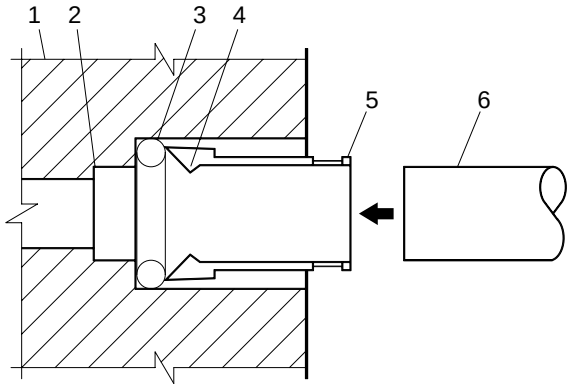
⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
5. Rotate and hold the control lever up until all air is exhausted from the air spring.
6. Push the collar of the quick-connect fitting into the fitting body with a 1/4-inch (7-mm) open-end wrench; see **Fig. 1**. With the collar pushed into the fitting, pull the tubing from the fitting. The fitting should easily release the tubing.

NOTE: Find the mark on the tubing, about 1/4 inch (7 mm) from the end, where the collar clamped the tubing; see **Fig. 2**. If this mark is less than 1/4 inch (7 mm) from the end of the tubing, the fitting was not assembled correctly and could have caused an air leak.

7. Inspect the end of the tubing for paint or debris that could prevent full insertion of the tubing into the fitting. Remove any dirt from the tubing and fitting.
8. Check that the end of the tubing is cut square. If the tubing is cut at an angle, the fitting will not seal correctly; cut the end of the tubing at an angle of 90 degrees.
9. Insert the squared-end of the tubing into the fitting. An initial resistance is felt when the tubing touches the clamping ring section of the collar. Push the tubing past this resistance another 1/4 inch (7 mm) or so until the tubing is fully against the shoulder.



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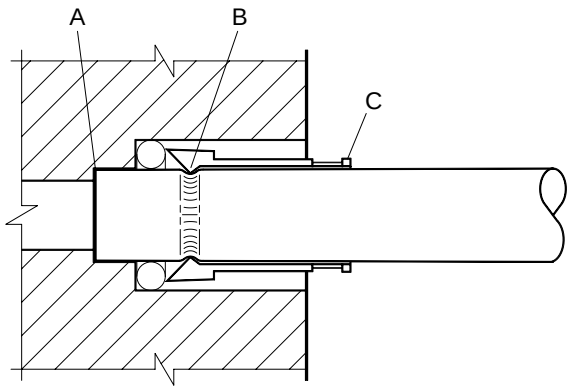
1. Fitting Body
2. Shoulder
3. Release Ring
4. Clamping Ring
5. Collar
6. Nylon Tube

Fig. 1, Parts of the Quick-Connect Fitting



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A. Square end of the tube against the shoulder.
B. The collar clamps the tube here.
C. Push the collar to release the tube.

Fig. 2, Correctly Installed Quick-Connect Fitting

Quick-Connect Fittings

10. Tug on the air tubing to ensure the tubing is clamped in the collar.
11. Align the vertical linkage with the control lever, and install the washer and nut.
12. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Check for air leaks.
13. Remove the blocks that were installed to support the cab.

Height-Control Valve Checking

It is normal to hear air leaking from the height-control valve for as much as 10 minutes after getting out of the vehicle. This air leakage is just the height-control valve exhausting air from the cab suspension air spring to reach the neutral position.

The height-control valves used on the 108SD and 114SD are Barksdale valves. Two methods are available to check the operation of the Barksdale height-control valves. A leak in the valve may be discovered without using a test kit, but a test kit is necessary to determine if the valve has an unacceptable rate of leakage.

Some Barksdale height-control valves have been returned for warranty because the four bolts in the valve housing were overtightened, often, enough to crack the valve housing. These bolts should not be loose, and should not normally require tightening, as there are no serviceable parts in the valve.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

If it is necessary to remove or loosen a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Checking the Height-Control Valve Without Using a Test Kit

WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

1. With the vehicle parked on a level surface, run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine, apply the parking brakes, and chock the tires.
2. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve. This air leakage is the height-control valve exhausting air due to a decreased load on the cab suspension.

3. Disconnect the vertical linkage from the horizontal control lever.
4. Pull the control lever up about 45 degrees for 6 to 8 seconds. If air passes through the valve, that section of the valve is okay.
5. Return the control lever to the neutral position.
6. Push the control lever down about 45 degrees for 6 to 8 seconds. If the air spring inflates, that section of the valve is okay.
7. Return the control lever to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
8. If the valve works as stated in all of the above steps, no further checking is needed. Connect the vertical linkage to the control lever, then tighten the linkage nut.

NOTE: If the valve leaks, go to "Checking the Height-Control Valve Using a Test Kit." Barks-

Height-Control Valve Checking

dale valves have an acceptable leakage rate of 3 cubic inches (50 cc) per minute. You can determine if a leak is acceptable only by using the Barksdale test kit.

Checking the Height-Control Valve Using a Test Kit

⚠ WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

NOTE: The Barksdale field test kit is designed to be used with the height-control valve installed on the vehicle. Refer to **Specifications 400** for information on ordering this Barksdale height-control valve test kit.

1. If not already done, park the vehicle on a level surface and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa).
3. Shut off the engine and wait 5 to 10 minutes for the air suspension system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal, and does not indicate a defective valve.

4. Check the rubber exhaust flapper at the back of the valve housing for leaks. Use a soapy solution.
5. Disconnect the vertical linkage from the control lever.
6. Rotate and hold the control lever up at about 45 degrees to exhaust air from the air springs.
7. Disconnect the air lines from the air spring ports on the height-control valve. Leave the elbow fittings (if equipped) in place. Install a Parker plug into each air spring port (or elbow fitting); see **Fig. 1**.
8. If a flapper is present on the exhaust port of the height-control valve, remove it using needlenose pliers.
9. Clean the surface around the exhaust port, then install the test fitting into the exhaust port. The centering pin on the fitting must align with the slot on the exhaust port. Rotate the test fitting 45 degrees clockwise to lock it in place; see **Fig. 1**.
10. Connect one end of the air hose from the kit to the test connector on the exhaust port, and the other end to the test gauge.
11. Check the height-control valve in the fill mode, as follows.
    - 11.1 Rotate the valve control lever down 45 degrees from the horizontal to the fill position.
    - 11.2 Press the reset button on the test gauge.
    - 11.3 Observe the test gauge for 30 seconds. Refer to **Fig. 2** for the maximum allowable exhaust pressure change vs. inlet pressure.

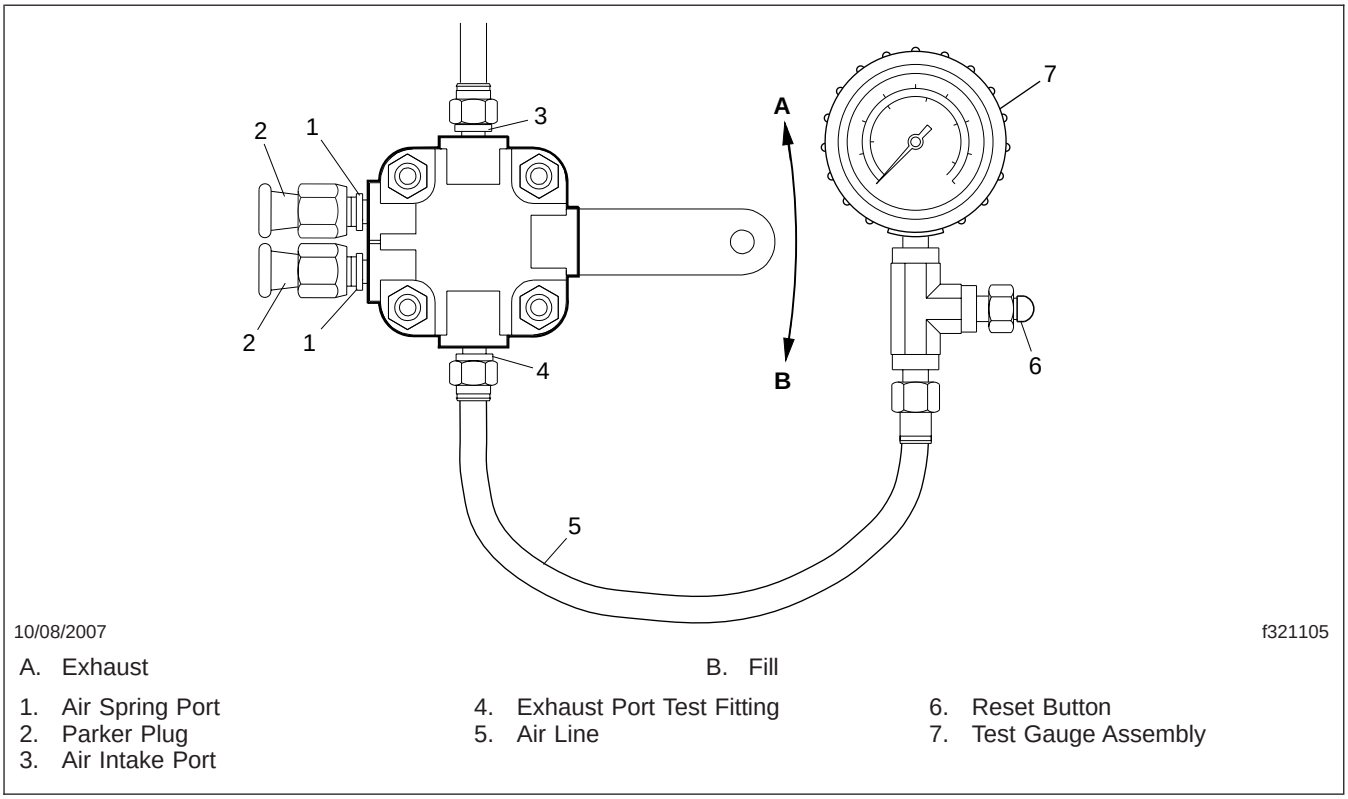
      The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.

      If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

12. Check the height-control valve in the exhaust mode, as follows.
    - 12.1 Rotate the valve control lever up 45 degrees from the horizontal to the exhaust position.
    - 12.2 Press the reset button on the test gauge.
    - 12.3 Observe the test gauge for 30 seconds. Refer to **Fig. 2** for the maximum allowable exhaust pressure change vs. inlet pressure.

      The valve is not working correctly if the gauge pressure reading exceeds the maximum allowable within 30 seconds.



A. Exhaust
B. Fill

1. Air Spring Port
2. Parker Plug
3. Air Intake Port
4. Exhaust Port Test Fitting
5. Air Line
6. Reset Button
7. Test Gauge Assembly

Fig. 1, Test Connections

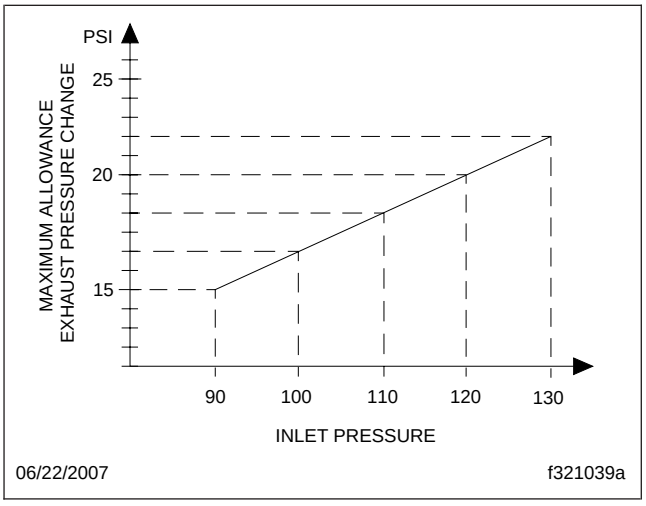


Fig. 2, Inlet Pressure vs. Exhaust Pressure Change in 30 Seconds

If the gauge reads less than the maximum allowable pressure change in 30 seconds, the valve is okay.

NOTE: The test gauge will register the exhausting air. *This does not indicate a defective valve.*

13. Disconnect the test gauge and connector from the valve exhaust port.
14. If the height-control valve is defective, replace it; see **Subject 120**.
15. Install the flapper on the exhaust port by pressing it into place.
16. Remove the two Parker plugs from the air spring ports, and connect the air lines to the air spring ports (or elbow fittings). Connect the vertical linkage to the height-control valve control lever. The ride height will automatically return to the correct position.

Replacement

IMPORTANT: Before replacing the height-control valve, perform the steps in **Subject 110** to see if the height-control valve is actually damaged or just out of adjustment.

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

⚠ WARNING

Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

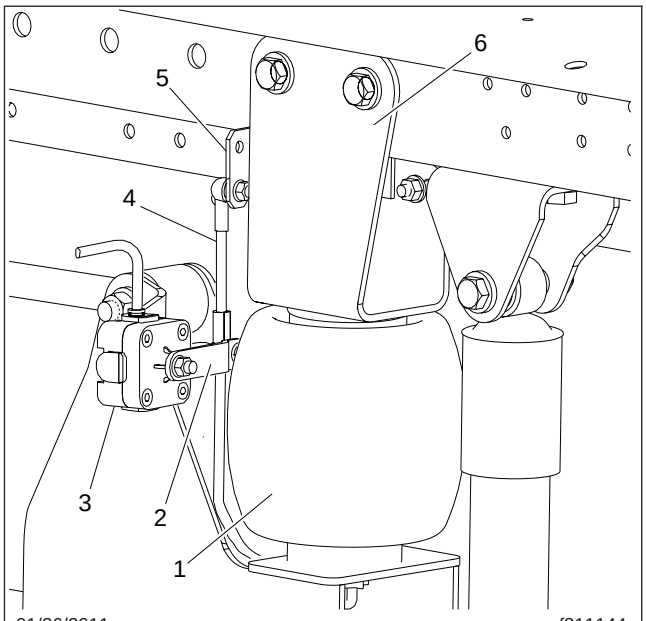
⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the horizontal control lever; see **Fig. 1**.
5. Rotate and hold the horizontal control lever up until all air is exhausted from the air spring.
6. Mark the air tubing to the height-control valve for later reference, then disconnect the tubing.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.



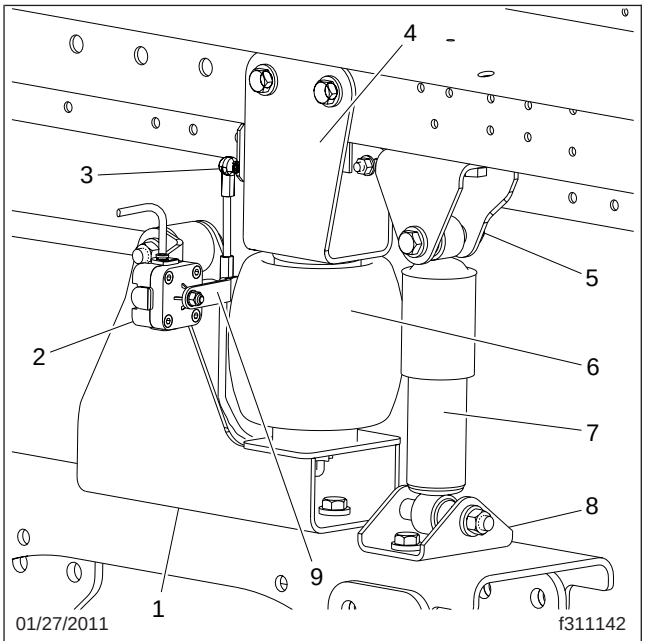
1. Air Spring
2. Horizontal Control Lever
3. Height-Control Valve
4. Vertical Linkage
5. Vertical Linkage Bracket
6. Air Spring Upper Bracket

Fig. 1, Cab Height-Control Valve

7. While holding the height-control valve mounting studs in place with an Allen wrench, remove the nuts and washers that attach the valve to the mounting bracket. Remove the height-control valve.
8. Position the new height-control valve on the height-control bracket. While holding the height-control valve mounting studs in place with an Allen wrench, install the nuts and washers, and tighten 95 lbf·in (1100 N·cm). Do not overtighten.
9. Connect the air tubing to the height-control valve.
10. Align the vertical linkage with the horizontal control lever and install the washer and nut.
11. Start the engine and run it until air pressure builds to at least 100 psi (690 kPa).
12. Check all air tubing and fittings for leaks.
13. Remove the cab supports.

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the shock is removed.
3. Remove the nut, washers, and bolt that attach the shock absorber to the mounting bracket on the cab. See **Fig. 1**.



1. Air Spring Lower Bracket
2. Height-Control Valve
3. Vertical Linkage
4. Air Spring Upper Bracket
5. Shock Absorber Upper Bracket
6. Air Spring
7. Shock Absorber
8. Shock Absorber Lower Bracket
9. Horizontal Control Lever

Fig. 1, Shock Absorber Installation

4. Remove the nut, washers, and bolt that attach the shock absorber to the mounting bracket on the crossmember, then remove the shock.
5. Install the new shock absorber in the lower mounting bracket and install the bolt, washers, and nut. Do not tighten the nut.
6. Position the upper end of the shock absorber in the mounting bracket and install the bolt, washers, and nut.
7. Tighten the upper and lower nuts 45 lbf·ft (61 N·m).
8. Remove the cab supports.

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.

⚠ WARNING

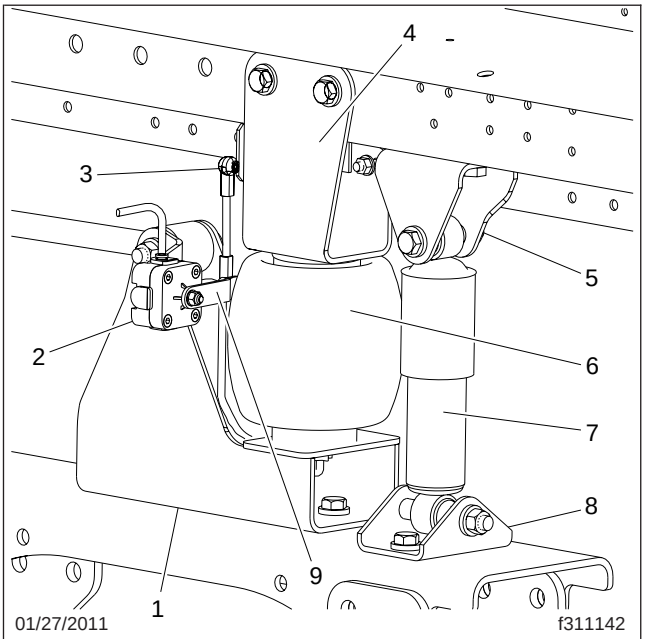
Do not disconnect any air lines in the cab suspension system without first blocking the cab securely. If the cab isn't securely blocked, disconnecting an air line could cause the cab to fall abruptly, possibly resulting in serious injury.

2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the air spring is deflated.
3. Drain all air from the air tanks.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

4. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever; see **Fig. 1**.
5. Rotate and hold the horizontal control lever up until all air is exhausted from the air spring.
6. Disconnect the supply air tubing from the bottom of the air spring. Push in the brass ring at the connection, then pull the air line straight out. If the new air spring will not be installed immediately, cover the open end of the air tubing to prevent dirt or other foreign material from entering.
7. Insert a flat-blade screwdriver between the top of the air spring and the upper mounting bracket, pry the air spring away from the bracket, and pop the air spring tangs loose. Repeat for the bottom of the air spring.
8. Install the new air spring by snapping the bottom of the air spring into the air spring lower bracket, then snapping the top of the air spring into the top bracket.
9. Remove the cover from the air line, then connect it by pushing it into the fitting on the bottom of the air spring. Push the air line all the way in. If it is not pushed all the way in, the connection will leak air. Tug on the air line to seat it completely.
10. Align the vertical linkage with the control lever and install the washer and nut.
11. Start the engine, and run it until air pressure builds to at least 100 psi (690 kPa). Check for air leaks at the air spring.
12. Remove the cab supports.

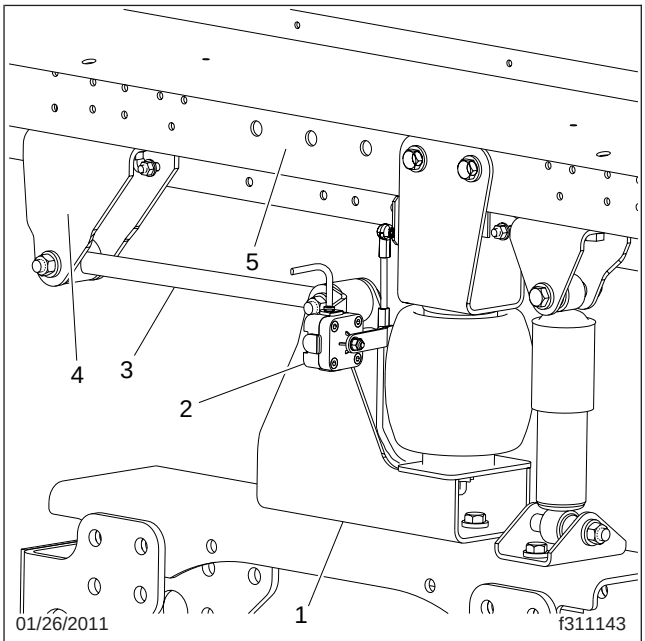


1. Air Spring Lower Bracket
2. Height-Control Valve
3. Vertical Linkage
4. Air Spring Upper Bracket
5. Shock Absorber Upper Bracket
6. Air Spring
7. Shock Absorber
8. Shock Absorber Lower Bracket
9. Horizontal Control Lever

Fig. 1, Air Spring Installation

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Place blocks between the frame and the bottom of the cab, or use jack stands to keep the cab in position when the lateral control rod is removed.
3. Remove the nut, washers, and bolt that attach the lateral control rod to the cab-mounted bracket; see **Fig. 1**.



1. Air Spring Lower Bracket
2. Height-Control Valve
3. Lateral Control Rod
4. Cab-Mounted Bracket
5. Cab Structure

Fig. 1, Lateral Control Rod Installation

4. Remove the nut, washers, and bolt that attach the lateral control rod to the chassis-mounted air spring lower bracket, then remove the lateral control rod.
5. Attach the inboard end of the new lateral control rod to the air spring lower bracket, using the bolt, washers, and nut.
6. Position the outboard end of the lateral control rod in the cab-mounted bracket. Install the bolt, washers, and nut.
7. Tighten the inboard and outboard nuts 45 lbf·ft (61 N·m).
8. Remove the cab supports.

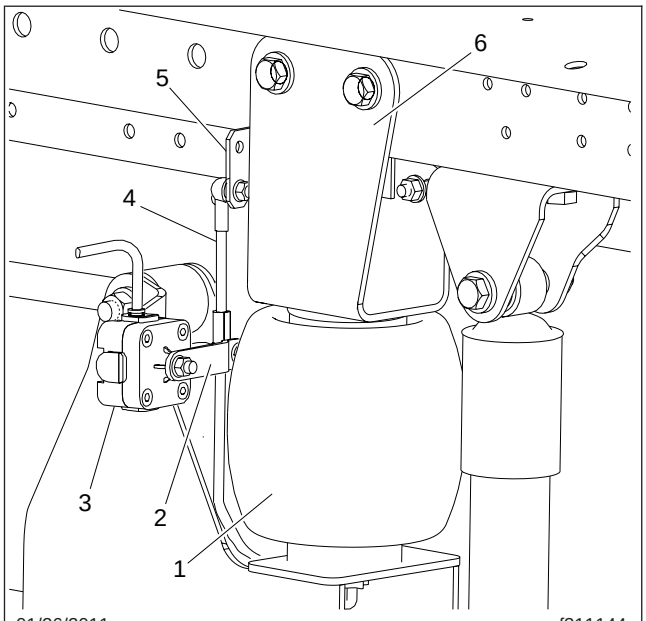
Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa), then shut off the engine.

⚠ WARNING

Do not disconnect the vertical linkage in the cab suspension system without first blocking the cab securely and inserting a pin in the neutral-position hole of the height-control valve and the horizontal control lever. If the cab is not securely blocked, dislodging the pin and moving the control lever could cause the cab to fall or rise abruptly, possibly resulting in serious injury.

3. Place blocks between the frame and the bottom of the cab or use jack stands to keep the cab in position when the air spring is deflated.
4. Insert a 5/32-inch (4-mm) drill bit into the neutral position hole of the height-control valve and horizontal control lever.
5. Disconnect the upper end of the vertical linkage. Depending on the vehicle configuration, it is attached to the cab underbody, or to a vertical linkage bracket on the cab underbody; see **Fig. 1**.
6. Remove the nut and washer that attach the vertical linkage to the horizontal control lever. Disconnect the vertical linkage from the control lever.
7. Align the new vertical linkage between the control lever and the cab underbody. Attach the lower end of the linkage to the control lever, using the nut and washer.
8. Attach the upper end of the vertical linkage to the cab underbody, or to the vertical linkage bracket on the cab underbody.
9. Remove the drill bit or pin from the height-control valve.
10. Remove the cab supports.



1. Air Spring
2. Horizontal Control Lever
3. Height-Control Valve
4. Vertical Linkage
5. Vertical Linkage Bracket
6. Air Spring Upper Bracket

Fig. 1, Cab Height-Control Valve

Checking the Cab Height-Control System for Air Leaks

⚠ WARNING

Keep your hands and all objects away from the area under and around the cab when removing the pressure from the air system. Parts will move as the air is released and can cause personal injury or damage to any objects that are between the moving parts.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

If it is necessary to remove or loosen a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

1. Park the vehicle on a level surface, apply the parking brakes, and chock the tires.
2. Run the engine to build vehicle air pressure to at least 100 psi (690 kPa). Turn off the engine and wait 5 to 10 minutes for the system to equalize.

NOTE: Normal operation of the height-control valve requires a maximum of 10 minutes to settle. Any air leakage during this time is considered normal and does not indicate a damaged valve.

3. Apply a soap-and-water solution to the outside of the air fittings on the height-control valve and on the suspension air springs. Look for bubbles indicating an air leak.
4. If bubbles are seen, check that the air tubing is installed correctly into the fitting; see **Subject 100**.

   If no bubbles are seen, check the height-control valve for air leaks; see **Subject 110**.

Diagnostics and Testing

Air Spring

Inspect the exterior surfaces of the air spring, looking for wear. With the air spring fully inflated, check to see if there is sufficient clearance around the air spring to prevent lines or objects from rubbing against the air spring. Air tubing or cab components that rub against the air spring will cause damage to the air spring. If the air spring is not capable of lifting the cab to its proper ride height, check to see if the shock absorber is damaged. A binding shock absorber will limit the air spring's ability to extend. To clean the air spring, use soap and water.

NOTE: Do not use organic solvents, abrasives, or pressurized steam cleaners to clean the air spring.

Shock Absorber

Inspect the shock body for damage such as bends or dents in the piston. Bends or dents in the shock body will negatively affect the operation of the shock. Inspect the shock body for signs of leaking fluid. Normal operation of the shock will result in some misting of the hydraulic fluid onto the exterior shock body. Large streams of fluid indicate a leak and the shock should be replaced; see **Fig. 1**.

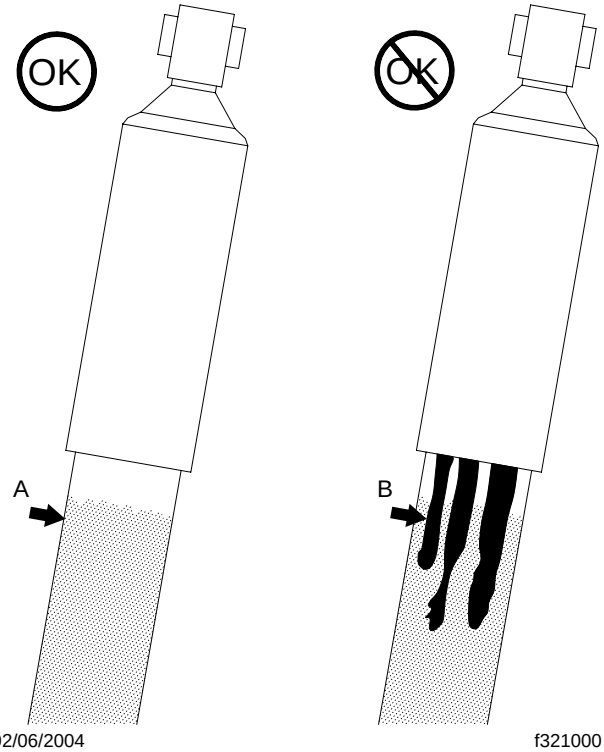
To test the operation of a shock absorber, hold the shock in an upright position and cycle the piston at least five times by pushing the piston up and down. The piston should move evenly throughout each section of the cycle. If the shock does not move evenly

Troubleshooting

when pushed down or pulled up, the shock should be replaced.

Noises such as squeaks, which may be intermittent, may be caused by the valves used to regulate the internal hydraulic fluid. This problem is not repairable and the shock will need to be replaced. Noises from the shock, such as knocking or rattling, may be due to movement between the bushings and mounting brackets. Inspect the bushings or mounting brackets for wear. Repair worn components as necessary. Check the torque of the shock absorber mounting nuts and tighten if necessary.

NOTE: The shock absorber bushings do not require any type of lubrication. Do not attempt to stop bushing noise by lubricating them; grease and mineral-oil-base lubricants will deteriorate the bushing rubber.



A. Dust covered mist (normal).
B. Hydraulic fluid streaks indicating an actual leak.

Fig. 1, Differences Between Misting and Leaking

Torque Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

IMPORTANT: To prevent voiding the warranty on Barksdale height-control valves, note the following:

- Do not overtighten the bolts in the Barksdale height-control valve housing if you detect leaks in the housing. The bolts should not be loose, and should not require tightening. Only if necessary, tighten the valve housing bolts 45 lbf·in (500 N·cm). Any damage to the valve housing will void the warranty.
- Do not attempt to disassemble the Barksdale valve body or the control lever. There are no serviceable parts in the valve, and any disassembly will void the warranty.

NOTICE

When removing or loosening a Barksdale height-control valve from a mounting bracket, always hold the valve-side mounting studs in place with an Allen wrench while loosening or tightening the nuts that attach the valve to the bracket. Because the mounting studs are threaded into the valve body, loosening the nuts without holding the studs can tighten the studs, which can crush the valve body and damage the valve. Conversely, tightening the nuts without holding the studs can back the studs out, causing a separation of the two halves of the valve body, and possibly a leak.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Height-Control Valve Housing Bolts, 1/4–20 * †	—	—	45	500
Height-Control Valve Mounting Locknuts, 1/4–20 * †	—	—	95	1100
Shock Absorber Upper and Lower Nut	45	61	—	—
Lateral Control Rod Upper and Lower Nut	45	61	—	—
Control Lever Screw	—	—	45–50	500–560

* Grade 8 bolts with phosphate- and oil-coated threads, and cadmium-plated, wax-coated grade C locknuts; both used with hardened washers.

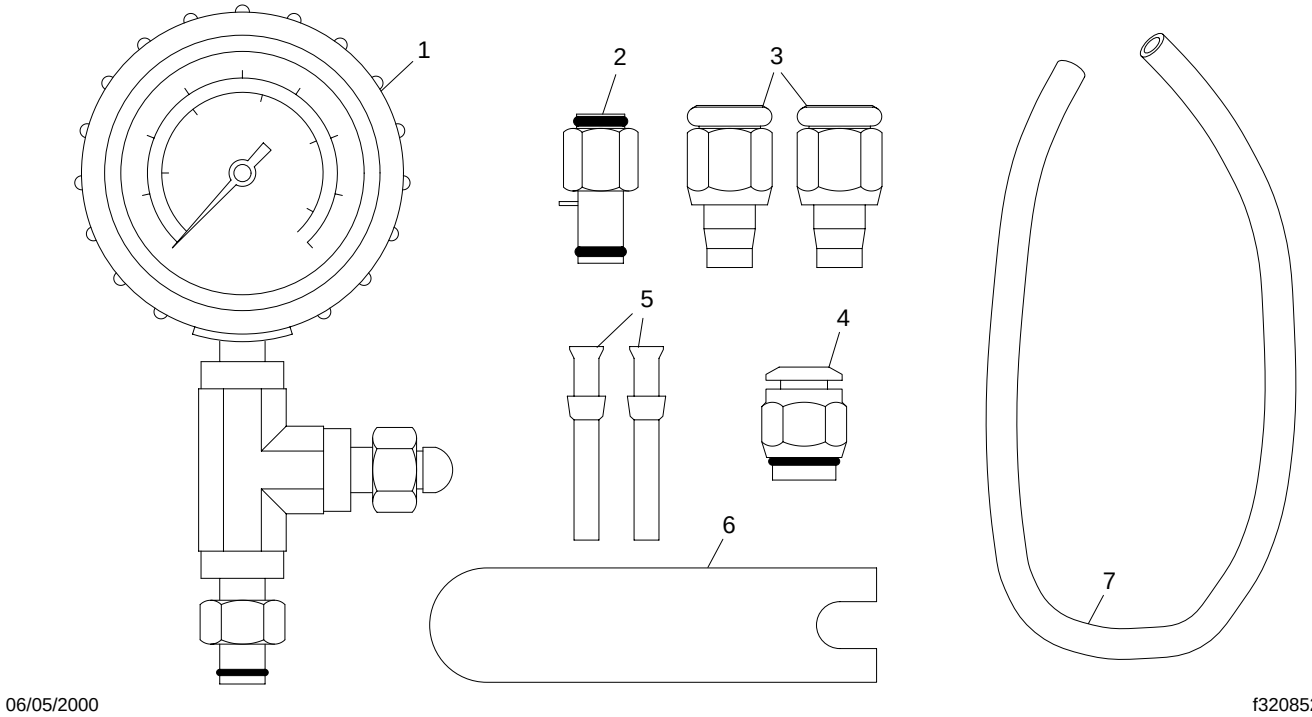
† See the cautionary statements above.

Table 1, Torque Specifications

Special Tools

Use the kit shown in **Fig. 1** to test a Barksdale height-control valve. Test kit BKS KD2264 is available via the Direct Ship program in Paragon.

Specifications

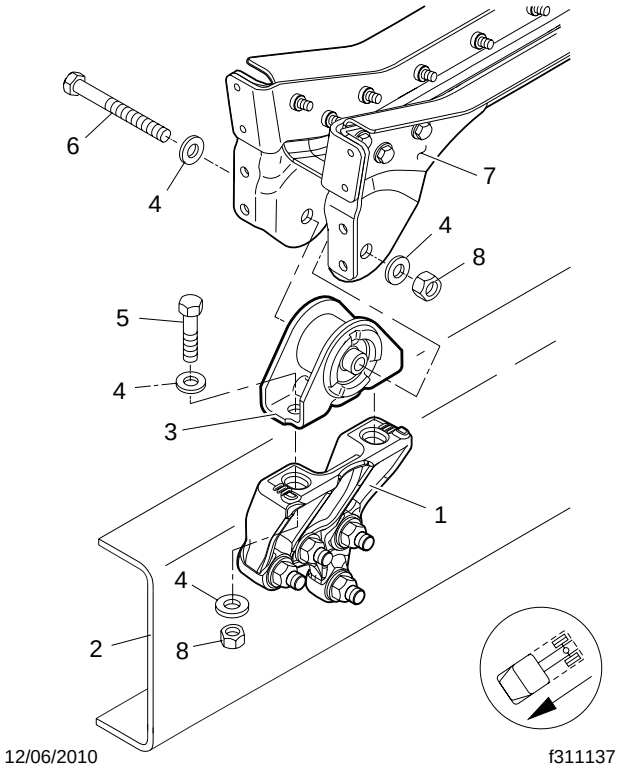


1. Test Gauge Assembly with Reset Button
2. Exhaust Port Test Connector for Cab Suspension Valve
3. Parker Plugs
4. Exhaust Port Test Connector for Chassis Suspension Valve
5. Test Plugs for Cab Suspension Valve
6. Special Tools for Disconnecting Air Line
7. Air Line

Fig. 1, Barksdale Height-Control Valve Test Kit BKS KD2264

General Information

The forward part of the cab is attached to the frame rails with two cab mount isolators. See **Fig. 1**. Each forward cab mount isolator is made of hard rubber, surrounded by a steel bracket. The isolator is attached to a frame rail bracket and the cab underbody.



NOTE: LH shown.

1. Frame-Mounted Bracket
2. Frame Rail
3. Cab Mount Isolator
4. Washer
5. Bolt, 5/8–11 x 2.00
6. Isolator Bolt, 5/8–11
7. Cab Underbody
8. Hexnut, 5/8–11

Fig. 1, Forward Cab Mount Installation (typical)

Forward Cab Mount Replacement

Replacement

1. With the vehicle parked on a level surface, apply the parking brakes and chock the tires.
2. Using a jack, lift up the front of the cab just enough to loosen the isolator bolt. Support the cab with jack stands.

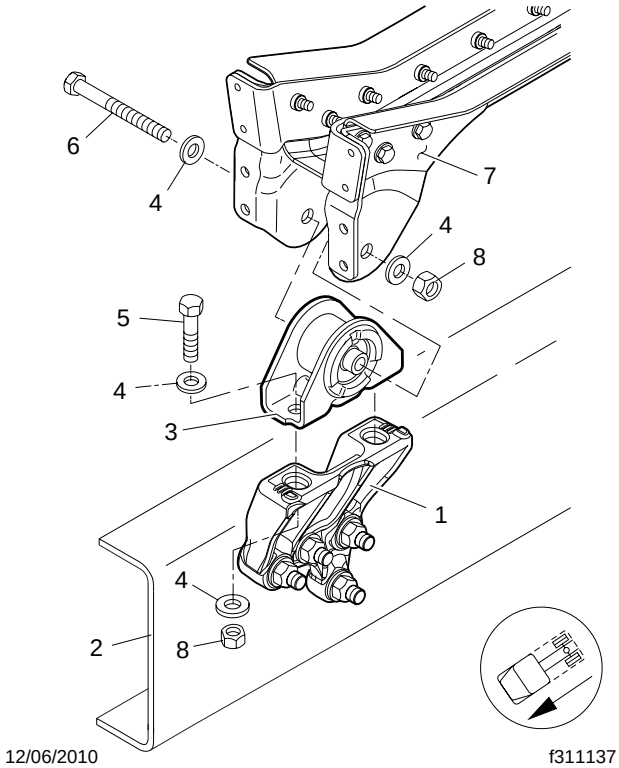
⚠ WARNING

Do not work under the cab when it is supported only by a jack. Use safety stands or other suitable means to firmly support the cab. Jacks can slip, causing the cab to fall, which could result in serious injury or death.

3. Remove the isolator bolt, nut, and washers; see **Fig. 1**.
4. Remove the bolts, nuts, and washers that attach the cab mount isolator to the frame-mounted bracket.
5. Place a new cab mount isolator on the frame-mounted bracket, between the ears of the bracket on the cab underbody. Make sure that the stamped word "OUTSIDE" is facing outboard.

NOTE: If both mounts are replaced, use the alignment marks on the top surface of the frame-mounted brackets to center the cab on the chassis.

6. Attach the cab mount isolator to the bracket on the cab underbody with the isolator bolt, washers, and nut, inserting the bolt from the inboard side. Hand-tighten the nut.
7. Carefully lower the cab.
8. Install the bolts, nuts, and washers that attach the cab mount isolator to the frame-mounted bracket. Tighten the nuts 136 lbf·ft (184 N·m).
9. Tighten the isolator-bolt nut 136 lbf·ft (184 N·m).
10. Remove the jack stands.



NOTE: LH shown.

1. Frame-Mounted Bracket
2. Frame Rail
3. Cab Mount Isolator
4. Washer
5. Bolt, 5/8–11 x 2.00
6. Isolator Bolt, 5/8–11
7. Cab Underbody
8. Hexnut, 5/8–11

Fig. 1, Forward Cab Mount Installation (typical)

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications		
Fastener Description	**lbf·ft**	**N·m**
Cab Mount Isolator-to-Frame-Mounted Bracket Nuts	136	184
Cab Mount Isolator Nut	136	184

Table 1, Torque Specifications

General Information

The exterior mirror unit consists of a rectangular (flat) mirror mounted on a fold-away tubular support loop. A lower square (convex) mirror is mounted on the same support loop, below the main mirror. Both mirrors are mounted in separate housings, and the housings are attached to the support loop, which is mounted to the door. All mirror glass is first surface chrome.

Additional options include electrically powered and heated mirrors. In such cases, the wiring is hidden within the support loop and the mirror housings.

Mirror Assembly

Removal

1. Apply the parking brake and chock the tires.
2. Remove the two screws that attach the support loop upper bracket to the door; see **Fig. 1**.
3. While holding the support loop assembly, remove the four screws that attach the lower bracket to the door.
4. Disconnect any wiring or antenna cables, if present.

Installation

1. Connect any wiring and antenna cables, as applicable.
2. Holding the support loop in position, install the mounting screws finger-tight (two screws on the upper bracket, and four on the lower bracket). See **Fig. 1**.
3. Test the mirror function for movement and heating. If there are problems, check the wiring.
4. Tighten the mounting screws 10 lbf·ft (14 N·m) on both the upper and lower brackets.

Mirror Housing

NOTE: The procedure for removing and installing the convex and flat mirrors are identical.

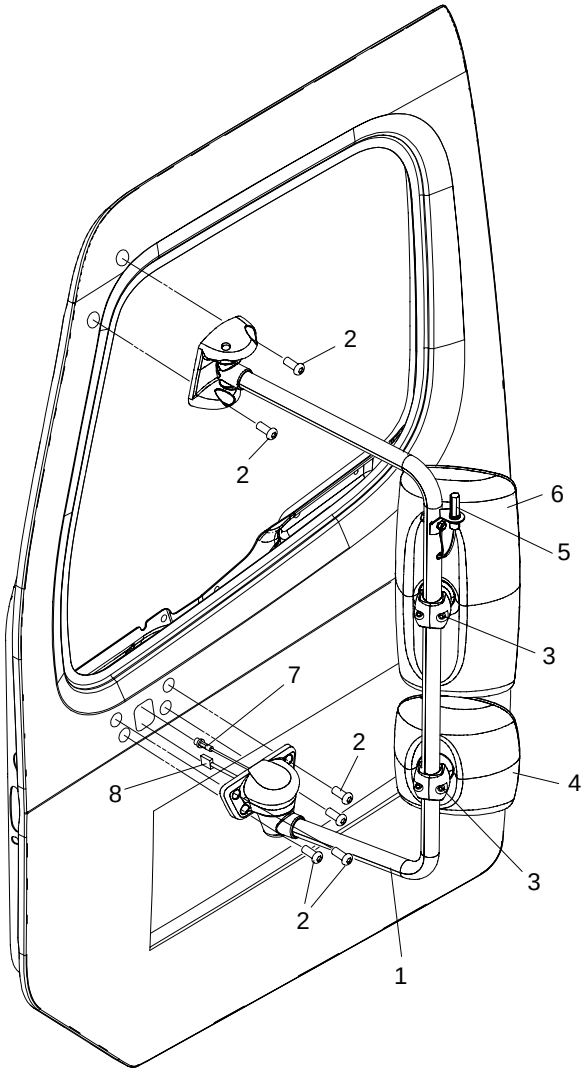
Removal

1. Apply the parking brake and chock the tires.
2. Mark the location of the mirror housing on the support loop; see **Fig. 1**.
3. If equipped with a heated/power mirror, remove the mirror bezel and glass, then disconnect the wiring.
4. Remove the two screws that attach the housing to the support loop. Disconnect any wiring, if present, and remove the housing assembly.

Installation

1. If equipped with a heated/powered mirror, connect the wiring to the mirror, then install the mirror glass and bezel into the mirror housing.
2. As previously marked, position the mirror housing onto the support loop. Install the self-tapping screws finger-tight; see **Fig. 1**.
3. Test the mirror function for movement and heating. If there are problems, check the wiring.
4. Tighten the self-tapping screws 96 lbf·in (1085 N·cm).

Exterior Mirror Removal and Installation



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NOTE: LH shown.

1. Fold-Away Tubular Support Loop
2. Screws, M8
3. Screws, Self-Tapping
4. Square, Convex Mirror Housing
5. CB Radio Antenna Lead (optional)
6. Rectangular, Flat Mirror Housing
7. CB Radio Antenna Cable (optional)
8. Electrical Wiring

Fig. 1, Exterior Mirror Assembly

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Mirror Loop Assembly Mounting Screws, M8	10	14	—	—
Mirror Housing Mounting Screws	—	—	96	1085

Table 1, Torque Specifications

Safety Precautions

⚠ WARNING

Wear protective welding masks and gloves when welding. Failure to do so could result in personal injury, due to the intensity of heat, sparks, and flying debris.

NOTICE

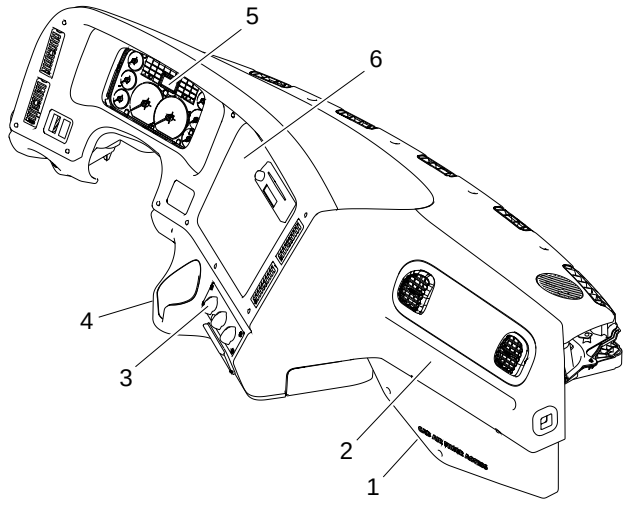
The vehicle is equipped with electronic control units. Serious damage to ECUs and components may result when welding unless the following precautions are taken.

- **Never allow an electronic component to be situated between the ground electrode and the weld site.**
- **Never lay welding cables on, near, or across any electronic component or wiring.**
- **Protect electronic components and wiring near the weld site from heat and splatter.**

1. Apply the parking brakes and chock the tires.
2. From the batteries, disconnect all negative cables first, then the positive cables, and prevent them from making connection with the frame or any other electrically conductive surface.
3. If a supplemental restraint system (SRS) is installed, disconnect it.
4. Disconnect all wiring from electronic control modules near the weld site, including any installed by the customer.
5. Attach the ground electrode as close as possible—within 18 inches (45 cm)—to the weld site. Remove paint, rust, and grease to provide a clean, bare-metal connection for the ground electrode.
6. After welding work is completed, apply touch-up paint to protect the parts.

General Information

The dash tray assembly, attached to the cab front-wall, functions as a support for mounting dash components, and as the ducting assembly for the HVAC system. The dash panels are attached to frame assemblies mounted on the tray assembly, or to the tray assembly itself. The HVAC unit can be accessed by removing the HVAC cover under the passenger's side of the dash. See **Fig. 1**.



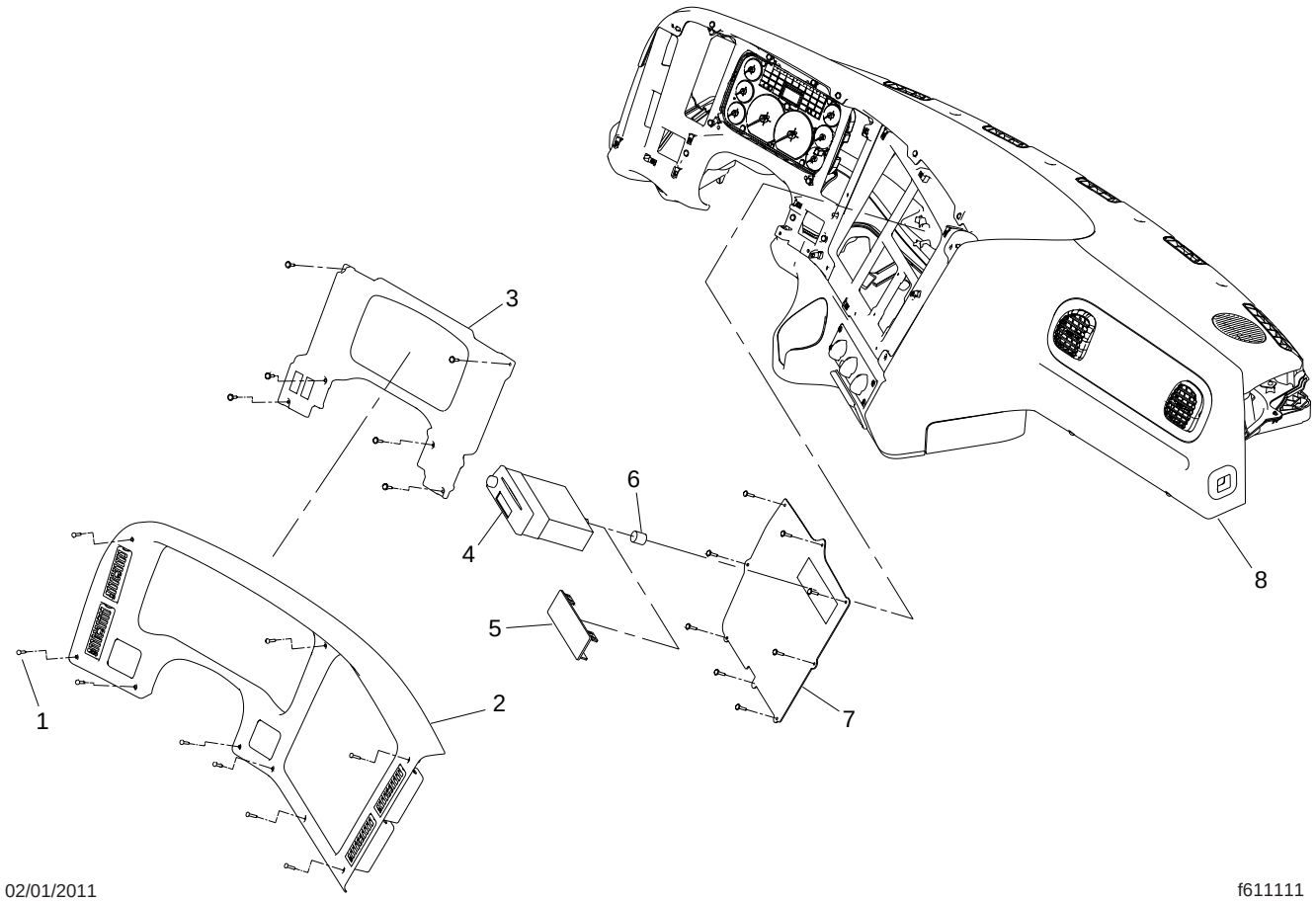
1. HVAC Cover
2. Passenger-Side Dash Panel
3. Climate Control Panel
4. Lower Dash Panel
5. Instrumentation Control Unit (ICU3)
6. Wing Dash Panel

Fig. 1, Dash Panel Layout (typical)

Wing Dash

Removal

1. Apply the parking brake and chock the tires.
2. Disconnect the batteries at the negative terminal.
3. Remove the HVAC lower cover by removing the three screws that hold it in place.
4. Remove the trim plate panel. See **Fig. 1**.
5. Disconnect and remove the radio.
6. Remove the driver-side inner trim panel.
7. Install the wing inner trim panel.
8. Remove the passenger-side dash panel assembly as follows. See **Fig. 2**.
   - 8.1 Remove the screws that hold the panel in place.
   - 8.2 Pry up the upper edge of the dash panel to release the clips from the slots.
   - 8.3 Remove the passenger-side dash panel assembly.
9. Remove the top cover panel by removing the screws that hold it in place.



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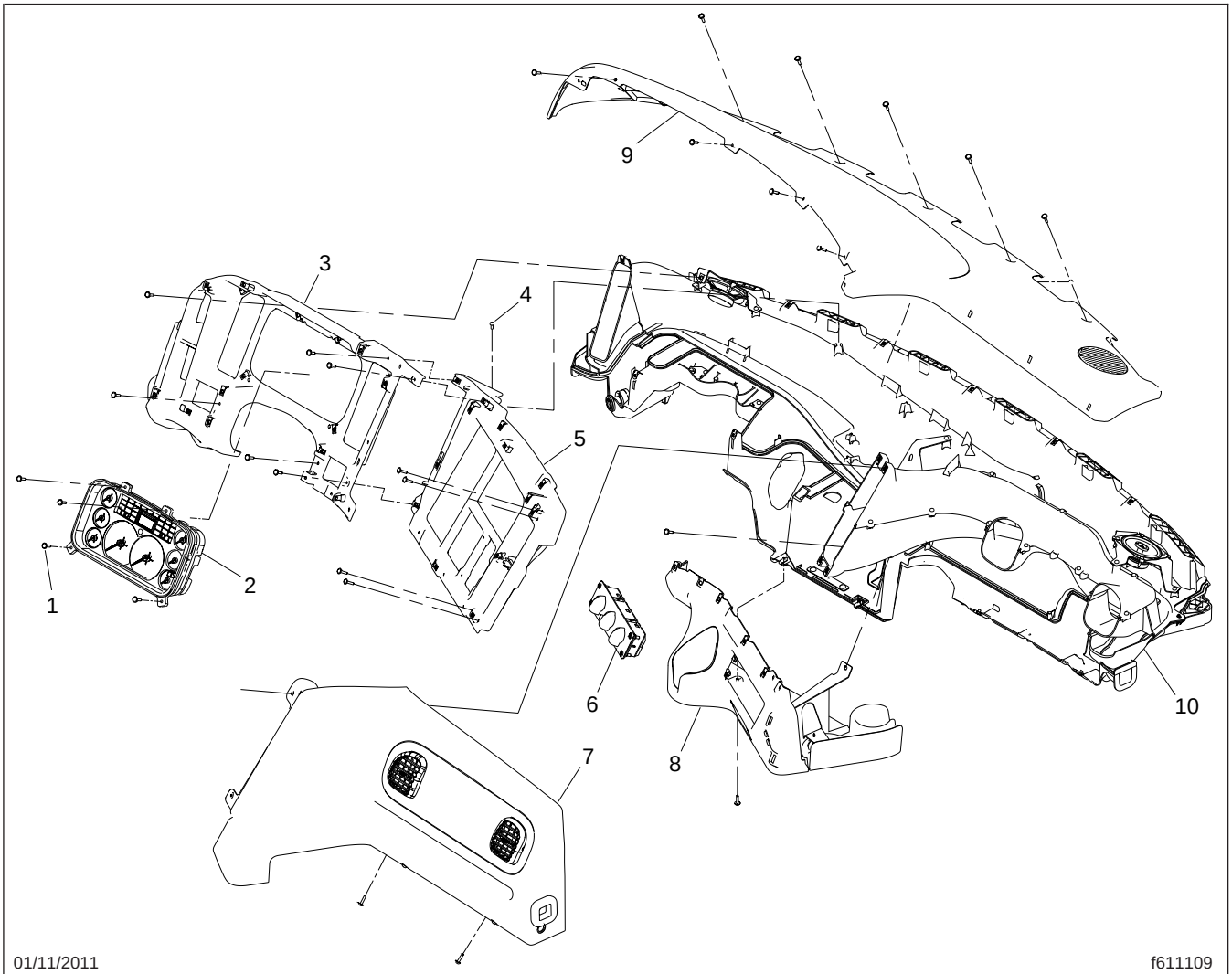
1. Screw with Captive Washer
2. Trim Plate Panel
3. Driver-Side Inner Trim Panel
4. Radio
5. Cover Plate
6. Radio Rear Support Stud
7. Wing Inner Trim Panel
8. Dash Assembly, Partial

Fig. 1, Dash Trim Panels, Wing Dash

Dash Panels Removal and Installation



1. Screw with Captive Washer
2. Instrument Cluster, ICU3
3. Driver-Side Dash Frame Assembly
4. Self-Tapping Screw
5. Wing Dash Frame Assembly
6. HVAC Control Head Assembly
7. Passenger-Side Dash Panel
8. Lower Dash Panel
9. Top Cover Panel
10. Dash Tray Assembly

Fig. 2, Dash Panels, Wing Dash

10. Disconnect the wiring from the instrumentation control unit (ICU3), then remove the screws that hold it in place. Remove the ICU3.
11. Remove the driver-side and wing dash frame assemblies by removing the screws that hold them in place.
12. Remove the HVAC control head assembly by removing the screws that hold it in place. Disconnect the wiring from back of the controls.
13. Remove the lower dash panel as follows.
    13.1 Inside the center HVAC duct, remove the screw that attaches the lower dash panel to the duct and the dash tray assembly.

13.2 Remove the rest of the screws that hold the panel in place.

13.3 Lift the panel out, then disconnect the wiring from the back of the HVAC controls.

13.4 Remove the lower dash panel.

Installation

1. Install the lower dash panel as follows. See **Fig. 2**.

   1.1 Put the lower dash panel in place and connect the wiring to the back of the HVAC controls.

   1.2 Attach the lower dash panel to the dash tray assembly.

   NOTE: Tighten all dash panel screws with captive washers 26 to 34 lbf·in (294 to 384 N·cm).

   1.3 Inside the center HVAC duct opening, install the screw that attaches the lower dash panel to the duct and the dash tray assembly.

2. Connect the wiring to the back of the HVAC control head assembly, then install it in the lower dash panel.
3. Attach the wing frame assembly to the dash tray assembly. Tighten the self-tapping screw (**Fig. 1**, Item 4) that attaches the assembly to the top of the HVAC duct 21 to 23 lbf·in (237 to 260 N·cm).
4. Attach the driver-side dash frame assembly to the dash tray assembly and the wing frame assembly.
5. Connect the wiring to the instrumentation control unit (ICU3), then attach the ICU to the driver-side dash frame assembly.
6. Install the top cover.
7. Install the passenger-side dash panel assembly as follows.

   7.1 Position the panel in place.

   7.2 At the upper edge of the passenger-side dash panel, push the clips into the slots on the top cover.

   7.3 Install and tighten the screws.

8. Attach the driver-side and wing inner trim panels to the the dash panel frame assemblies. See **Fig. 1**.
9. Connect and install the radio.

NOTE: The passenger-side dash panel must be installed before you can install the trim plate panel.

10. Install the trim plate panel.
11. Install the HVAC lower cover. Tighten the screws 26 to 34 lbf·in (294 to 384 N·cm).
12. Connect the batteries.

Flat Dash

Removal

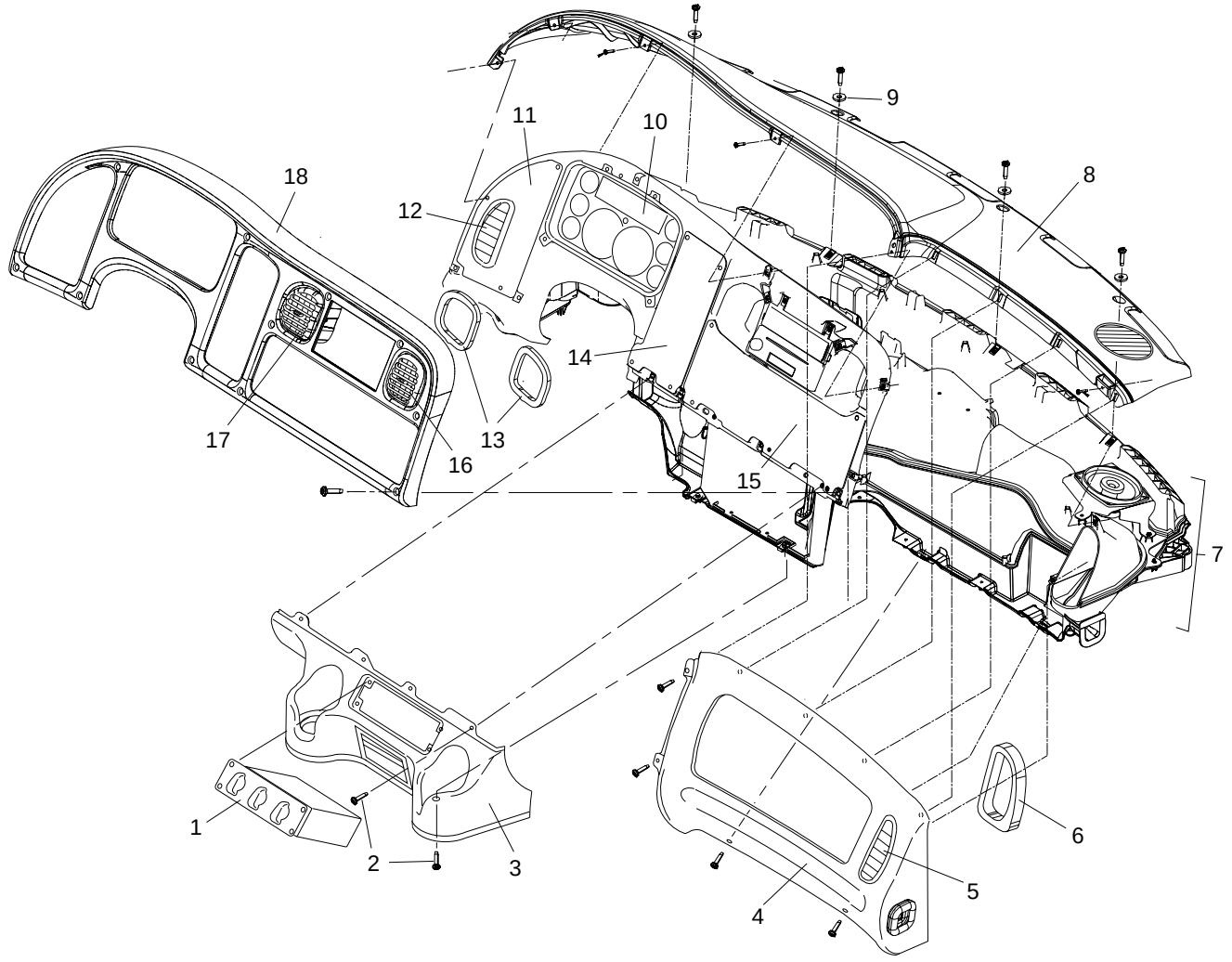
1. Apply the parking brake and chock the tires.
2. Disconnect the batteries at the negative terminal.
3. Remove the HVAC lower cover by removing the three Torx-head screws holding it in place.
4. Remove the HVAC control head assembly by removing the Torx-head screws that hold it in place.
5. Remove the trim plate panel. See **Fig. 3**.
6. Remove the right-hand dash panel assembly as follows.

   6.1 Remove the screws that hold the panel in place.

   6.2 Pry up the upper edge of the dash panel to release the clips from the slots, then remove the panel.

7. Remove the top cover by removing the screws that hold it in place.
8. Remove the cup holder assembly by removing the screws that attach it to the dash tray assembly, and disconnect the wiring from the back of the HVAC controls.
9. Remove the instrumentation control unit (ICU3) from the driver-side dash frame assembly, and disconnect the wiring.
10. Remove the gauge panels from dash frame assembly.

Dash Panels Removal and Installation



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NOTE: HVAC lower cover not shown.

1. HVAC Control Head Assembly
2. Screw with Captive Washer
3. Cup Holder Assembly
4. Right-Hand Dash Panel Assembly
5. Right-Hand Window Outlet Louver
6. Duct Seal
7. Tray Assembly with HVAC Ducting
8. Top Cover
9. Washer
10. Instrument Cluster, ICU 3
11. Gauge Panel
12. Left-Hand Window Outlet Louver
13. Duct Seal
14. Gauge Panel
15. Gauge Panel
16. Right-Hand Dash Outlet Louver
17. Left-Hand Dash Outlet Louver
18. Trim Plate Panel

Fig. 3, Dash Panels, Flat Dash

11. Remove the screws that attach the upper dash frame assmebly to the dash tray assembly. Remove the frame assembly.

NOTE: There is a screw inside each inboard HVAC duct opening that holds the frame assembly to the dash tray assembly.

Installation

1. Attach the upper dash frame assembly to the dash tray assembly. Tighten the two self-tapping screws inside the inboard HVAC duct openings 21 to 23 lbf·in (237 to 260 N·cm).

NOTE: Tighten all dash panel screws with captive washers 26 to 34 lbf·in (294 to 384 N·cm).

2. Attach the gauge panels to the frame assembly.
3. Connect the wiring to the instrumentation control unit (ICU3), then attach the ICU to the driver-side dash frame assembly.
4. Connect the wiring to the back of the HVAC controls, then attach the cup holder assembly to the dash tray assembly.
5. Install the top cover. Tighten the screws 26 to 34 lbf·in (294 to 384 N·cm).
6. Install the right-hand dash panel assembly.
   - 6.1 Put the panel in place.
   - 6.2 At the upper edge of the right-hand dash panel, push the clips into their slots.
   - 6.3 Install and tighten the screws.

NOTE: The right-hand dash panel must be installed before you can install the trim plate panel.

7. Install the trim plate panel.
8. Install the lower HVAC panel. Tighten the screws 26 to 34 lbf·in (294 to 384 N·cm).

Tray Assembly Removal and Installation

Removal

The tray assembly functions as a dash support, wiring harness carrier, and as the ducting assembly for the HVAC system. It is attached to the cab frontwall.

1. Apply the parking brake and chock the tires.
2. Remove all the dash panels; see **Subject 100**.
3. As applicable, remove or disconnect the dash gauges, instruments, and controls.
4. Disconnect the ignition wiring.
5. Tilt the hood.
6. Partially drain the radiator to below the level of the surge tank.
7. Remove the surge tank; see **Group 20**.
8. Separate the bulkhead electrical connector in the engine compartment by loosening the centerbolt. Push the cab end of the wiring harness through the frontwall and into the cab.
9. From inside the cab, mark, then disconnect all the wiring and air lines on the dash. Cut and remove any tie-straps that hold the wiring or air lines in place.
10. Remove the driver-side kick panel and the tread plate, then mark and disconnect the ground wires to the left of, and below the steering column.
11. Remove the upper and lower steering column covers.
12. Disconnect the steering column by removing the four fasteners that hold it to the mounting bracket. Do not disconnect the U-joint. Let the steering wheel and the column rest on the driver's seat.
13. Remove the three fasteners that hold the tray assembly to the steering column mounting bracket.
14. Remove the two fasteners that attach the tray assembly to the top of the HVAC unit.
15. Remove the Christmas-tree fasteners that hold the tray assembly to the wiring harness bracket.
16. Remove the two nuts that hold the tray assembly to the tunnel bracket.
17. From the engine compartment, remove the four fasteners that attach the tray assembly to the frontwall, as follows.
    - 17.1 Remove the fasteners that attach the air cleaner to the mounting bracket and the rain tray. Remove the air cleaner.
    - 17.2 Remove the remaining fasteners that attach the tray assembly to the frontwall.
18. Remove the tray assembly from the cab.

Installation

1. Position the tray assembly in place in the cab, making sure the holes in the tray assembly line up with those in the frontwall.
2. Install the four fasteners that attach the assembly to the frontwall. Do not tighten the fasteners fully until they are all installed, then tighten them 32 to 50 lbf·in (362 to 565 N·cm).
3. Loosely install the fasteners inside the cab. When all are installed, tighten them as follows:
    - three at the steering column bracket—tighten 48 to 64 lbf·in (542 to 723 N·cm)
    - two at tunnel bracket—tighten 32 to 50 lbf·in (362 to 565 N·cm)
    - two on top of the HVAC unit—tighten 26 to 34 lbf·in (294 to 384 N·cm).
4. Install the bulkhead connector harness in the frontwall opening.

   As previously marked, connect the main harness plugs.
5. Attach the steering column to its bracket. Tighten the fasteners 24 to 30 lbf·ft (32 to 40 N·m).
6. Connect the ground wires to the stud below and to the left of the steering column.
7. Secure all the wiring with tie-straps.
8. Connect the ignition wiring.
9. As applicable, route all air lines and wiring through the openings in the dash panel frame assembly.
10. Install and connect the dash gauges, instruments, and controls.
11. Install the dash panels; see **Subject 100**.

Tray Assembly Removal and Installation

12. Install the driver-side kick panel and tread plate.
13. Install the upper and lower steering column covers.
14. From outside the vehicle, install the air cleaner; see **Section 09.01**, Subject 110.
15. Install the surge tank; see **Group 20**.
16. Fill the radiator through the surge tank.
17. Close the hood.
18. Connect the batteries.

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Dash Self-Tapping Screws	—	—	21–23	237–260
Dash Screws with Captive Washers	—	—	26–34	294–384
Dash Tray-to-Frontwall Capscrews	—	—	32–50	362–565
Dash Tray-to-Steering Column Bracket Capscrews	—	—	48–64	542–723
Dash Tray-to-Tunnel Bracket Nuts	—	—	32–50	362–565
Dash Tray-to-HVAC Unit Capscrews	—	—	26–34	294–384
Steering Column Mounting Screws	24–30	32–40	—	—

Table 1, Torque Specifications

Upholstery Panels Removal and Installation

NOTE: Interior components may vary. The following information is intended as a general guideline only.

Headliner

Removal

1. Apply the parking brake and chock the tires.
2. Drain the air tanks.
3. Disconnect the batteries.
4. Remove all items from the overhead storage bins.
5. Pull out the storage bins from the overhead console.
6. Remove the passenger-side grab handle by removing the screws that attach it to the A-pillar.
7. Remove the screw that attaches the top of the passenger-side A-pillar cover to the cab, the remove the A-pillar cover.
8. Remove the two screws from the driver-side A-pillar cover, then pull the bottom of the cover to loosen the clip that attaches it to the cab structure.
9. Remove the three screws that attach each sun visor to the overhead console. Remove the sunvisors.
10. Remove the sun visor inboard retainers.
11. Remove the dome light by popping it out from the upholstery panel, then disconnect the wiring.
12. Remove the coat hooks.
13. Remove the center seat belt anchor (if so equipped) from the rear wall.
14. Remove the Christmas-tree fasteners that attach the headliner to the roof bows. See **Fig. 1**.
15. If so equipped, disconnect the air horn lanyard from its anchor point on the headliner and cab roof structure, then push it up through the slot in the headliner.
16. Remove the Christmas-tree fasteners that attach the headliner to the rear wall upholstery panel.
17. Remove the headliner from the cab.

Installation

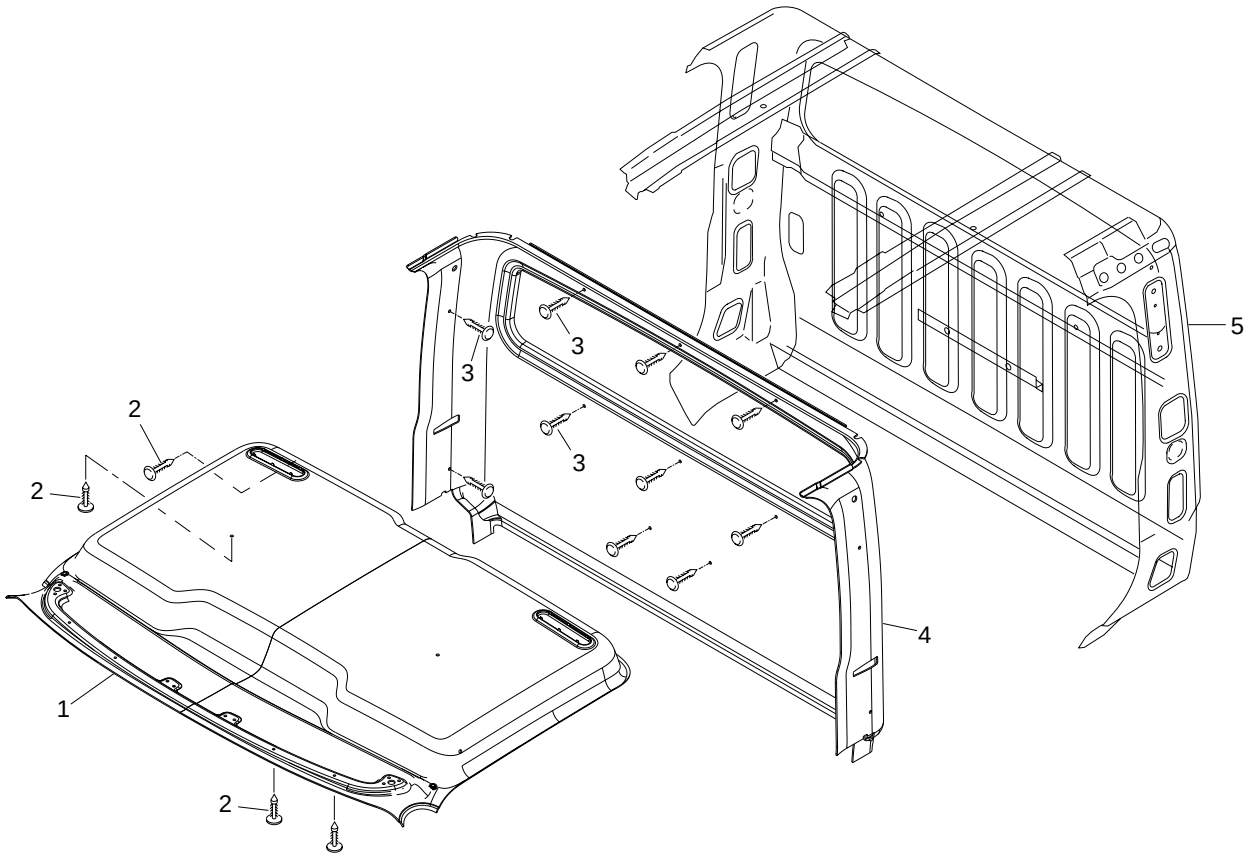
1. With the help of an assistant, position the headliner in place.
2. Using new Christmas-tree fasteners, attach the rear of the headliner to the cab structure at the rear wall.
3. Pull the air horn lanyard out through the slot in the headliner, then attach the lanyard to its anchor point on the headliner and cab roof structure.
4. Install the sun visor inboard retainers.
5. Attach the sun visor outboard brackets to the overhead console.
6. Using new Christmas-tree fasteners, attach the headliner to the roof bows.
7. Attach the center seat belt anchor (if so equipped) to the rear wall.
8. Install the coat hooks.
9. Connect the wiring to the dome light, then install it into the headliner.
10. Install the storage bins in the overhead console.
11. Position the driver-side A-pillar cover on the A-pillar, and secure the lower portion by pushing the Christmas-tree fastener into the hole on the A-pillar. Secure the upper portion with two screws.
12. Position the passenger-side A-pillar cover on the A-pillar, then install a screw through the top hole into the cab structure.
13. Install the passenger-side grab handle on the A-pillar.
14. Connect the batteries.

Rear Wall Upholstery Panel

Removal

1. Apply the parking brake and chock the tires.
2. Drain the air tanks.
3. Disconnect the batteries.
4. Remove the seats; see **Group 91**.

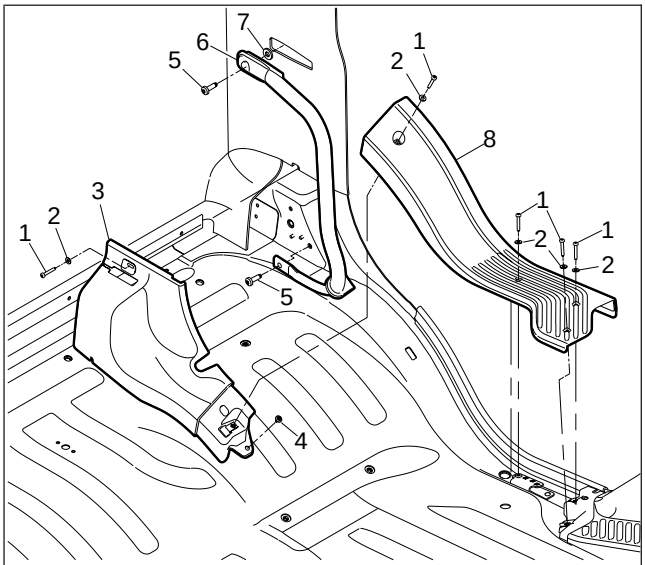
Upholstery Panels Removal and Installation



1. Headliner
2. Christmas-Tree Fastener, Headliner (8 qty.)
3. Christmas-Tree Fastener, Rear Wall Upholstery Panel (12 qty.)
4. Rear Wall Upholstery Panel
5. Cab Structure

Fig. 1, Headliner and Rear Wall Upholstery Panels (typical)

5. Remove the four screws and washers that attach each tread plate to the doorway and the lower B-pillar cover. See **Fig. 2**.
6. On each side of the vehicle remove the screw that attaches the lower B-pillar cover to the doorway, and the screw and washer that attaches it to the B-pillar. Remove the B-pillar cover.
7. Remove the interior B-pillar grab handles.
8. On each side of the cab, pry off the plastic cover on the seat belt upper anchor. Remove the hex-nut, rubber washer, and bushing, then remove the seat belt anchor and the height adjuster (if so equipped).
9. Remove the seat belt retractors.
10. Remove the PDM cover, if so equipped, from the cab rear wall.
11. Remove the seals from the rear edge of each door opening.
12. Remove the headliner. For instructions, see "Headliner" in this subject.
13. Remove the eight Christmas-tree fasteners that attach the rear wall upholstery panel to the rear wall cab. See **Fig. 1**.
14. On each side of the vehicle, remove the two Christmas-tree fasteners that attach the rear wall upholstery panel to the B-pillar.



NOTE: LH shown.

1. Dog Point Screw
2. Flatwasher
3. Lower B-Pillar Cover
4. Self-Tapping Screw
5. Capscrew, M8
6. Grab Handle
7. Washer
8. Tread Plate

Fig. 2, Tread Plate and Lower B-Pillar Cover Installation

15. Pull up the bottom edge of the upholstery panel from behind the lip at the rear edge of the floor mat.
16. Remove the rear wall upholstery panel from the cab.

Installation

1. Position the rear wall upholstery panel in place.
2. Push the bottom edge of the panel down behind the lip on the floor mat.
3. Using new Christmas-tree fasteners, attach the upholstery panel to the cab structure at the rear wall and the B-pillars.
4. Install the headliner; see "Headliner" in this subject.
5. Install the door seals.
6. Install the PDM cover, if so equipped.
7. Install the seat belt retractors. Tighten the mounting screws 35 to 50 lbf·ft (48 to 68 N·m).
8. Install the seat-belt height adjusters (if so equipped) and the seat belt upper anchors. Tighten the mounting screws 35 to 50 lbf·ft (48 to 68 N·m).
9. Install the interior B-pillar grab handles.
10. Install the lower B-pillar covers.
11. Install the tread plates in the doorways.
12. Install the seats; see **Group 91**.
13. Connect the batteries.

Floor Mat

Removal

1. Apply the parking brakes and chock the tires.
2. Disconnect the batteries.
3. Remove the seats and seat belts; see **Group 91**.
4. Remove the four screws and washers that attach each tread plate to the doorway and the lower B-pillar cover.
5. On each side of the vehicle, remove the lower A-pillar cover.
6. *If equipped with a manual transmission,* remove the shift lever boot, rubber mat, and metal cover plate.

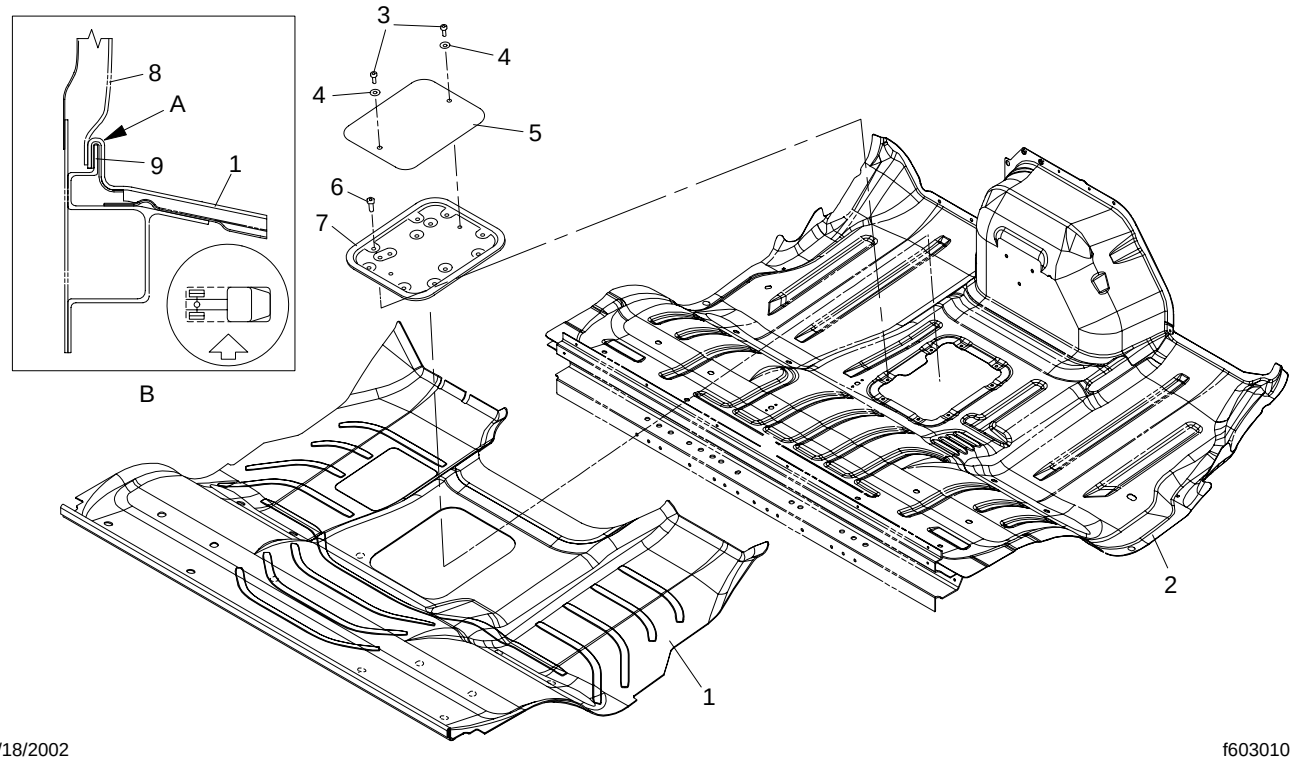
   If equipped with an automatic transmission, remove the rubber mat and metal transmission cover plate. See **Fig. 3**.

NOTE: The transmission ECU is attached to the underside of the metal transmission cover plate. Disconnect the wiring from the ECU before removing the cover plate.

7. Push the bottom of the rear wall upholstery panel in, and lift the rear edge of the floor mat off the top of the metal lip at the rear of the cab deck. See **Fig. 3**. There is a plastic U-channel between the mat and the metal lip.

   Work your way across the width of the cab to remove both the U-channel and the floor mat.
8. Remove the floor mat and the attached insulation from the cab.

Upholstery Panels Removal and Installation



A. Floor fits over this lip.

B. Cross-Sectional View (rear of cab)

1. Floor Mat
2. Cab Deck Structure
3. Capscrew, 1/4–20
4. Washer
5. Rubber Mat
6. Capscrew, M6 (8 qty.)
7. Cover Plate
8. Rear Wall Upholstery Panel
9. Steel Lip (plastic U-channel not shown)

Fig. 3, Floor Mat Installation (equipped with automatic transmission)

Installation

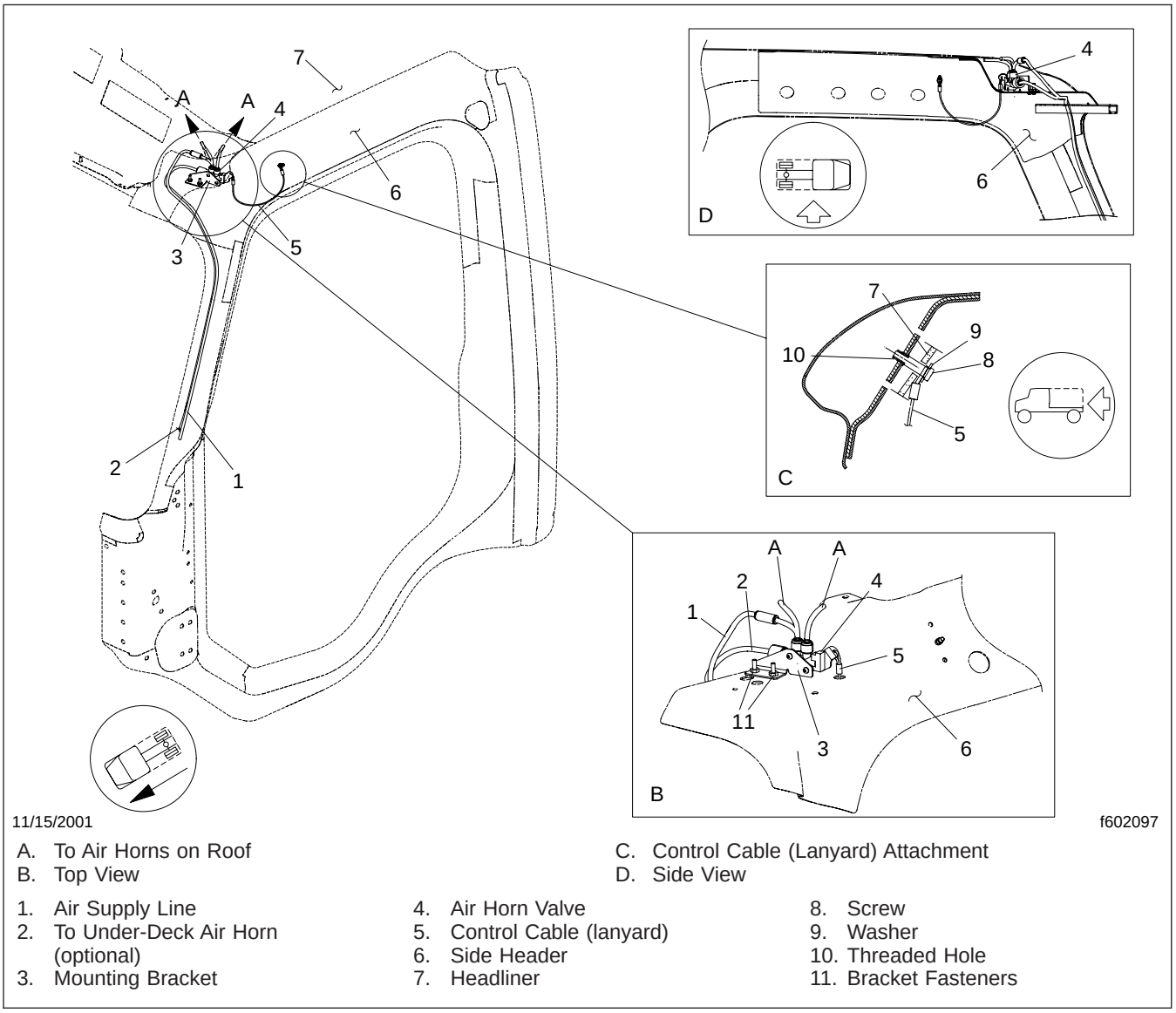
1. Place the floor mat and the attached insulation in place in the cab, then install it and the U-channel over the metal lip along the back wall.
2. *If equipped with an automatic transmission,* connect the wiring to the transmission ECU, then install the transmission cover plate and rubber mat. Tighten the fasteners firmly.

   If equipped with a manual transmission, install the metal cover plate, the rubber mat, and then the shift lever boot.
3. Install the lower A-pillar covers.
4. Install the tread plates in the doorways.
5. Install the seats and the seat belts; see **Group 91**.
6. Connect the batteries.

Air Horn Valve Replacement

Replacement

1. Apply the parking brake and chock the tires.
2. Drain the air supply, and disconnect the batteries.
3. Remove the screw and washer that hold the end of the control cable (lanyard) in place. See **Fig. 1**.
4. Remove the headliner.
5. Mark the air lines for later reference, then disconnect them from the air horn valve.
6. Remove the fasteners that attach the air horn valve to the mounting bracket. Remove the valve.
7. If necessary, disconnect the control cable (lanyard) from the air horn valve.
8. If applicable, connect the control cable (lanyard) to the new air horn valve.



A. To Air Horns on Roof
B. Top View
C. Control Cable (Lanyard) Attachment
D. Side View

1. Air Supply Line
2. To Under-Deck Air Horn (optional)
3. Mounting Bracket
4. Air Horn Valve
5. Control Cable (lanyard)
6. Side Header
7. Headliner
8. Screw
9. Washer
10. Threaded Hole
11. Bracket Fasteners

Fig. 1, Air Horn Valve Installation

Air Horn Valve Replacement

9. Attach the air horn valve to the mounting bracket.
10. As previously marked, connect the air lines to the air horn valve.
11. Install the headliner.
12. Using the screw and washer previously removed, attach the end of the control cable (lanyard) to the side header. Make sure the screw threads into the hole in the steel panel behind the headliner.
13. Connect the batteries.
14. Start the engine, and refill the air supply.
15. Test the horn.

General Information

The bulkhead-style cab door is composed of fully stamped steel inner and outer panels, with large internal steel reinforcements at the hinge/A-pillar, waist, and mirror mount. The primary door seal is mounted on the door assembly. A secondary seal is mounted on the cab around the door opening frame.

The “bulkhead” description refers to the manner in which the door, when closed, seats inside the door opening; the outer panel surface of the door is then flush with the outermost edge of the stamped door opening frame.

The door opens on two discreet, hidden hinges that require no maintenance. The door hinges allow a 65-degree opening. The primary mirror is mounted on the door, which is reinforced at the mount areas.

The wiring for the window, mirror, and courtesy light is routed through an opening on the hinge side of the door.

Most service operations can be done with the door attached to the vehicle. To reduce work time, do not remove the door unless necessary.

NOTICE

Do not attempt to disassemble the door shell. The door panels and reinforcements are assembled using a high-strength adhesive. The heat required to loosen the adhesive can compromise the structural integrity of the door assembly. If the door is structurally damaged, replace the entire door shell.

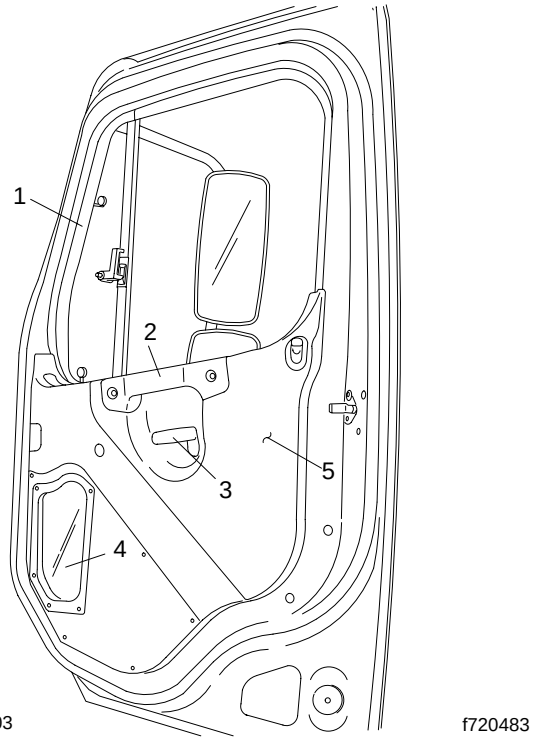
NOTICE

Before performing any electric welding on or near the door, read and comply with the welding precautions in Section 60.04, and disconnect the door wiring harness behind the inner trim panel. Electric currents produced during electric welding can damage various electronic components on the vehicle.

Door Trim Panel Removal and Installation

Removal

1. Apply the parking brake and chock the tires.
2. Using a T40 driver, remove the two mounting screws from the upper and/or lower door-pull handle. See **Fig. 1**.



1. Window Seal
2. Door Pull Handle
3. Interior Release Handle
4. View Window
5. Door Trim Panel

Fig. 1, Cab Door Trim

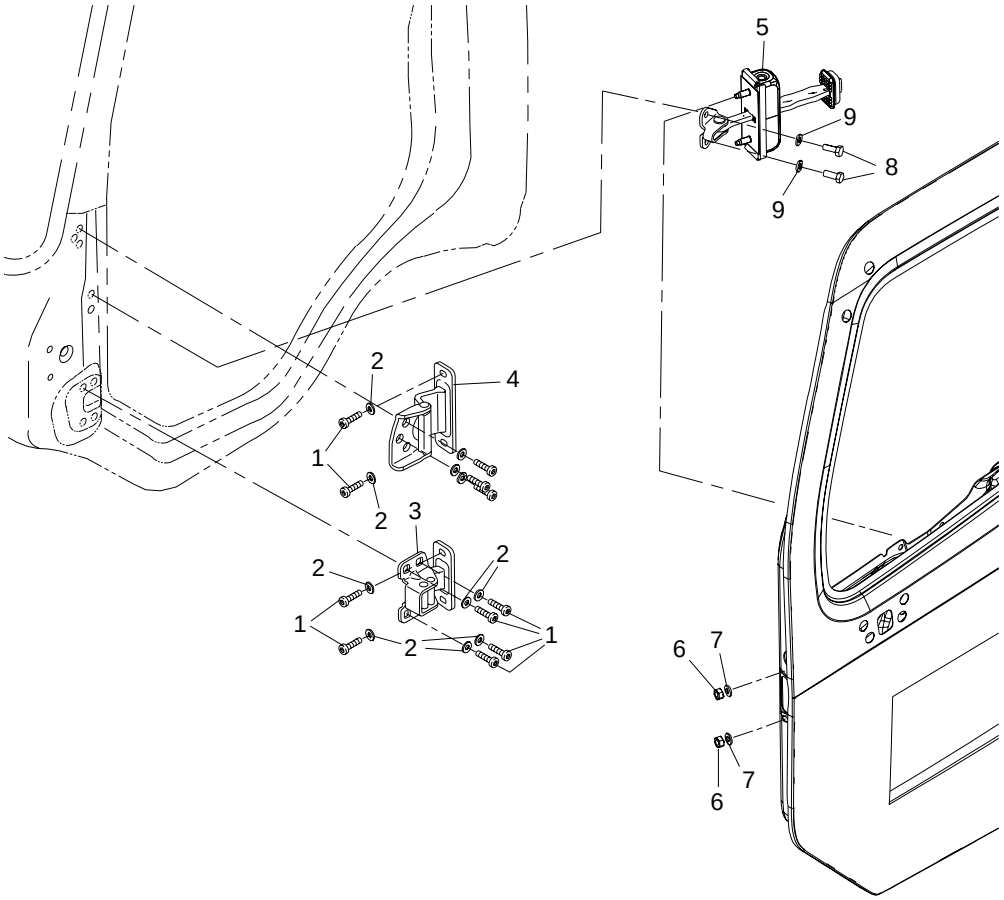
3. For vehicles with manual-crank windows, remove the window-regulator handle.
4. Using a T20 driver, remove the four attaching screws and the lower view-window trim ring, if so equipped.
5. Using a T40 driver, remove the interior door-latch handle.
6. Using a T20 driver, remove the two screws from the forward flange.
7. Pull the trim panel outward from the door to release the snaps, then lift it up and over the lock knob.

Installation

1. Slide the trim panel over the door-lock knob.
2. Position the trim panel in place against the door, then press firmly at the location of each snap-in fastener to ensure that it engages completely.
3. Using a T20 driver, install the two screws in the forward flange of the trim panel.
4. Using a T20 driver, install the four screws and the lower view-window trim ring.
5. Using a T40 driver, install the upper and/or lower door-pull handle. Tighten the screws 11 to 13 lbf·ft (14 to 18 N·m).
6. Install the interior door-latch handle. Tighten the screws 50 to 70 lbf·in (600 to 800 N·cm).
7. If the vehicle has manual-crank windows, install the window-regulator handle.

Removal

1. Apply the parking brake and chock the tires.
2. Lower the window.
3. Disconnect the batteries.
4. Remove the exterior side cowl panel.
5. Remove the door interior trim panel; see **Subject 100**.
6. Disconnect and remove the door wiring harness.
7. If replacing the door, remove any components (e.g. the regulator, latch, handles, connecting rods, or window glass) that will be installed on the replacement door; see the appropriate subjects in this section.
8. Remove the door check assembly as follows. See **Fig. 1**.
   - 8.1 Remove the two capscrews that attach the door check clevis bracket to the cab.
   - 8.2 Remove the two nuts that attach the door check to the edge of the door. Remove the door check assembly from the door.



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1. Capscrews
2. Washers
3. Lower Door Hinge Assembly
4. Upper Door Hinge Assembly
5. Door Check Assembly
6. Hexnut
7. Washer
8. Hexbolts
9. Washer

Fig. 1, Door and Door Check Installation

Door Removal and Installation

CAUTION

Do not attempt to lift the door. The door weighs approximately 110 pounds (50 kg). Lifting or dropping the door could result in personal injury or damage to the door assembly and other components.

9. Using a door support or help from an assistant, support the door frame from its bottom to prevent it from falling or tipping during removal. With the door open and supported, loosen the capscrews that attach the the hinges to the door.

Installation

1. If the door seal has been damaged or is weathered, replace it. For instructions, refer to **Subject 120**.

CAUTION

Do not attempt to lift the door. The door weighs approximately 110 pounds (50 kg). Lifting or dropping the door could result in personal injury or damage to the door assembly and other components.

2. Using a door support or help from an assistant, support the door from its bottom to prevent it from falling or tipping during installation.
3. Install the hinge fasteners. Tighten the capscrews 11 to 13 lbf·ft (14 to 18 N·m).
4. Close the door and check for alignment. Adjust the door if needed; see **Subject 160**.
5. Install the door check assembly as follows.
   - 5.1 Attach the door check to the edge of the door. Tighten the nuts 50 to 70 lbf·in (600 to 800 N·cm).
   - 5.2 Attach the clevis bracket to the cab. Tighten the capscrews 50 to 70 lbf·in (600 to 800 N·cm).
6. If replacing the door, install all components on the door; see the appropriate subjects in this section.
7. Install and connect the door wiring harness.
8. Install the door interior trim panel; see **Subject 100**.
9. Install the exterior side cowl panel.
10. Connect the batteries.
11. If applicable, check that the door electrical components are operating correctly.

Replacement

There are four seals for the cab door (see **Fig. 1**):

- Primary seal
- Secondary seal
- Lower seal
- Rain gutter seal

Primary Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the old seal from the door. It is held in place with double-sided tape and integral retainer clips.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the new primary seal with the lip toward the edge of the door. Make sure the retainer clips are pushed all the way into their holes, and the seal is flat against the surface all the way around. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
6. Close the door and check the seal. Adjust if necessary.

Secondary Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the tread plate at the bottom of the doorway, then loosen up the upholstery panel.
4. Remove the old seal from the cab doorway. It fits over an edge.
5. Using alcohol, clean the surface of any old adhesive or dirt.
6. Install the new secondary seal. Start at the bottom and work your way around. Make sure it is pushed all the way on. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
7. Put the upholstery in place, then install the tread plate.
8. Close the door and check the seal. Adjust if necessary.

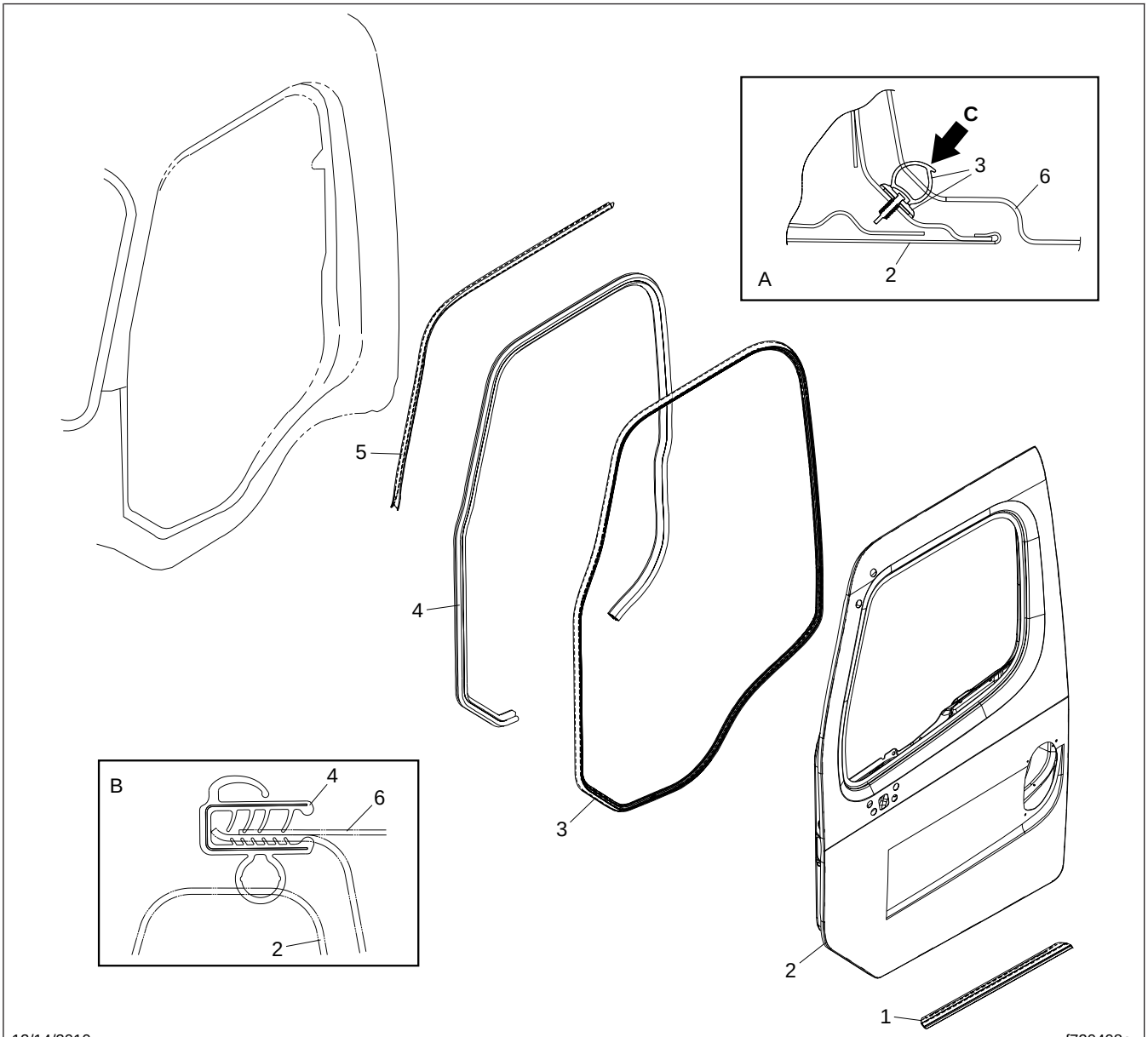
Lower Seal

1. Apply the parking brake and chock the tires.
2. Open the door.
3. Remove the old seal from the bottom of the cab doorway. It is held in place with double-sided tape.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the new lower seal. Make sure it is completely seated. Apply pressure to the areas of the seal that have adhesive tape to seat the seal firmly.
6. Close the door and check the fit. Adjust if necessary.

Rain Gutter Seal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the door.
3. Remove the rain gutter seal from the cab doorway. It is held in place by double-sided tape.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the rain gutter seal. Make sure it is pushed all the way on. Apply pressure to the areas of the gutter that have adhesive tape to seat the gutter firmly.
6. Close the door and check the fit. Adjust if necessary.

Door Seals Replacement



A. Cross-Sectional View of Primary Seal
B. Cross-Sectional View of Secondary Seal
C. Install the primary seal with the lip pointing toward the edge of the door.

1. Lower Seal (installed on the door)
2. Door
3. Primary Seal (installed on the door)
4. Secondary Seal (installed on the cab)
5. Rain Gutter Seal (installed on the cab)
6. Cab

Fig. 1, Door Seals

Replacement

NOTE: The door latches never require lubrication. They come from the manufacturer with lifetime lubrication.

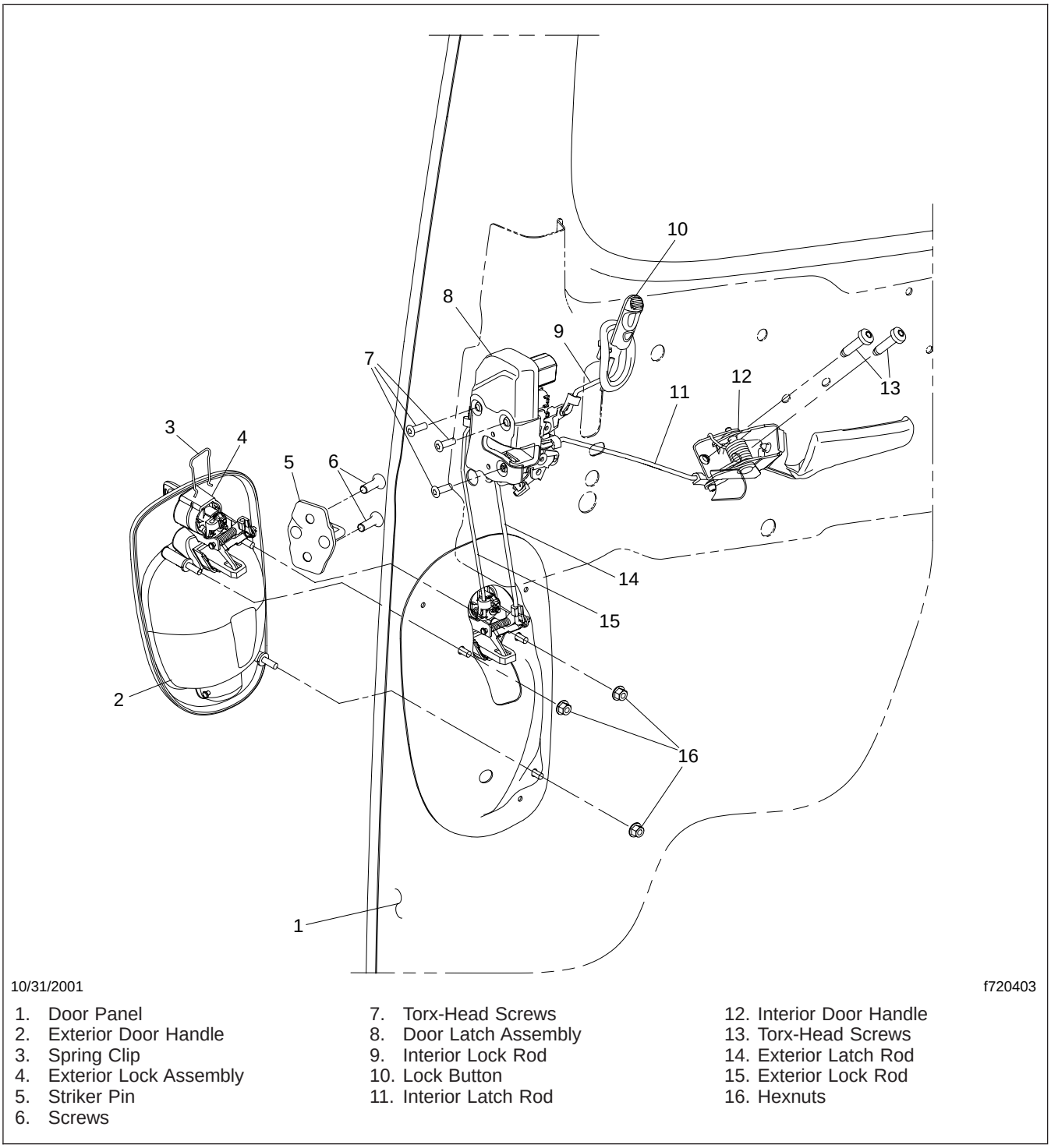
1. Apply the parking brake and chock the tires.
2. Remove the interior trim panel; see **Subject 100**.
3. Peel back the vapor barrier.
4. Disconnect the interior lock rod (**Fig. 1**, item 9) from the door latch assembly.
5. Disconnect and remove the exterior lock rod (item 15), the interior latch rod (item 11), and the exterior latch rod (item 14).
6. At the edge of the door, remove the three screws that attach the latch assembly to the door.
7. Move the latch assembly down to the interior door panel opening, then disconnect the dome light switch wiring from it.
8. Connect the dome light switch wiring to the new latch assembly.
9. Insert the latch assembly inside the door through the door panel opening, move it into position, then, using the three screws, attach it to the door edge. Tighten the screws 50 to 70 lbf·in (600 to 800 N·cm).
10. Connect the interior lock rod to the latch assembly.
11. Connect the exterior lock rod (item 15), and the interior and exterior latch rods (items 11 and 14).

    When connecting the exterior latch rod, make sure the rod length adjustment screw on the latch is loose. Connect the rod to the exterior door handle, then to the latch. When the latch is securely installed, tighten the rod length adjustment screw 15 to 25 lbf·in (170 to 280 N·cm).

NOTE: The colored end of each rod is attached to the latch assembly.

12. Check the rods for correct operation.
13. Install the vapor barrier.
14. Install the interior trim panel; see **Subject 100**.

Door Latch Replacement



1. Door Panel
2. Exterior Door Handle
3. Spring Clip
4. Exterior Lock Assembly
5. Striker Pin
6. Screws
7. Torx-Head Screws
8. Door Latch Assembly
9. Interior Lock Rod
10. Lock Button
11. Interior Latch Rod
12. Interior Door Handle
13. Torx-Head Screws
14. Exterior Latch Rod
15. Exterior Lock Rod
16. Hexnuts

Fig. 1, Door Components

Replacement

NOTE: This procedure is for manual window regulators.

1. Apply the parking brake and chock the tires.
2. Lower the window all the way.
3. Remove the interior trim panel; see **Subject 100**.
4. Peel back the vapor barrier.

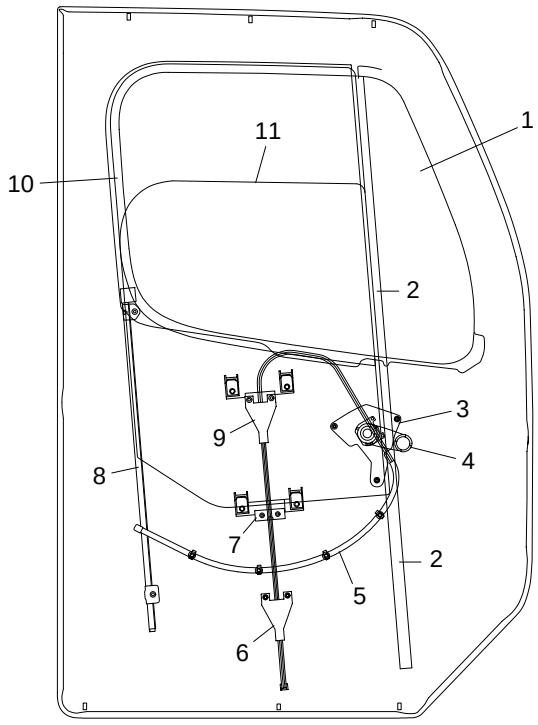
⚠ WARNING

Wear protective gloves and safety glasses when replacing window glass. Gloves will protect your hands from sharp edges, and allow a better grip. Failure to wear gloves and safety glasses when handling glass could result in injury to hands or eyes.

5. Remove the upper and lower screws that attach the glass rear channel to the interior door panel. Let the channel rest at the bottom of the door. See **Fig. 1**.
6. Remove the window seal from the door window opening, as follows.
   - 6.1 Peel back the vent-window seal where it overlaps the door-window seal.
   - 6.2 Pull the door-window seal down and back towards the rear of the cab to remove it. See **Fig. 2**.
7. Raise the window until the regulator-clamp screws can be accessed; see **Fig. 3**.
8. While supporting the glass, loosen the regulator clamps at the bottom edge of the window glass. See **Fig. 4**.
9. Remove the window glass by pulling it up and toward the inside of the door window opening.
10. Lower the new window glass through the inside of the window opening. Support the glass until it rests on the regulator-clamp pads.
11. Install the window seal into the window opening.

NOTE: If replacing the window seal, use 3M™ Strip-Calk 08578 at the joints with the vent window seal to prevent leakage.

12. Carefully raise up the window.



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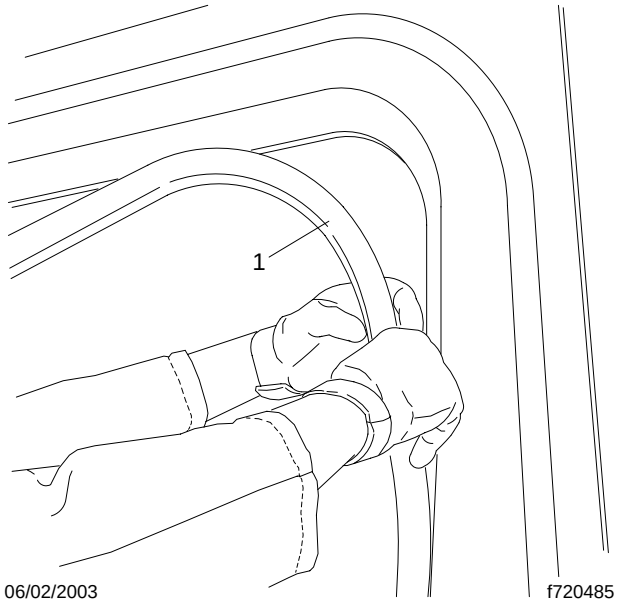
1. Vent Window
2. Window Division Bar
3. Crank Cover-Plate
4. Crank Handle
5. Window Regulator Assembly
6. Lower Run Bracket
7. Window Regulator Clamp Assembly
8. Glass Rear Channel
9. Upper Run Bracket
10. Window Seal
11. Window Glass

Fig. 1, Window Regulator Components

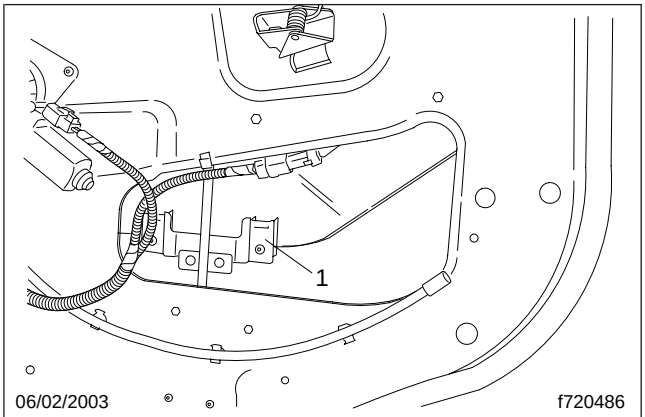
13. Pull up the glass rear channel, making sure the glass edge fits into it. Install the two screws that attach the channel to the door panel. Tighten the screws 60 lbf·in (700 N·cm).
14. Carefully tighten the regulator clamps at the bottom of the window glass. Tighten the clamps 55 to 64 lbf·in (625 to 725 N·cm). *Do not overtighten.*
15. Test the window regulator for smooth operation. The window should raise and lower with no binding.
16. Install the vapor barrier. Reuse the old adhesive to attach the vapor barrier to the door.

Door Window Glass Replacement



1. Window Seal

Fig. 2, Remove/Install the Window Seal

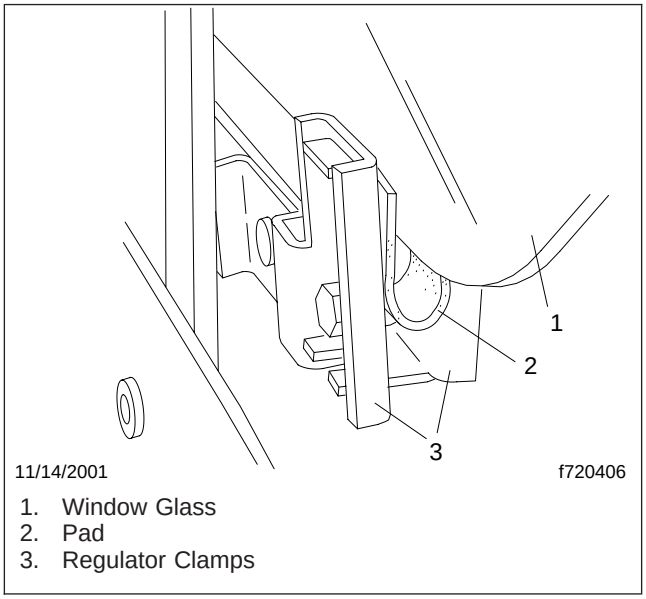


1. Regulator Clamp

Fig. 3, Regulator Clamp

NOTE: If the adhesive does not adhere, use 3M Strip-Calk 08578 as needed to affix the vapor barrier to the door.

17. Install the interior trim panel; see **Subject 100**.



1. Window Glass
2. Pad
3. Regulator Clamps

Fig. 4, Window Glass (bottom edge)

Vent Window Seal Replacement

Replacement

1. Apply the parking brake and chock the tires.
2. Remove the manual window-regulator crank (if so equipped), the door latch handle, the pull handles, the lower view-window trim ring (if so equipped), and the door interior trim panel; see **Subject 100**.
3. Peel back the vapor barrier.
4. Remove the window seal and glass; see **Subject 140**.
5. Remove the vent-window glass.

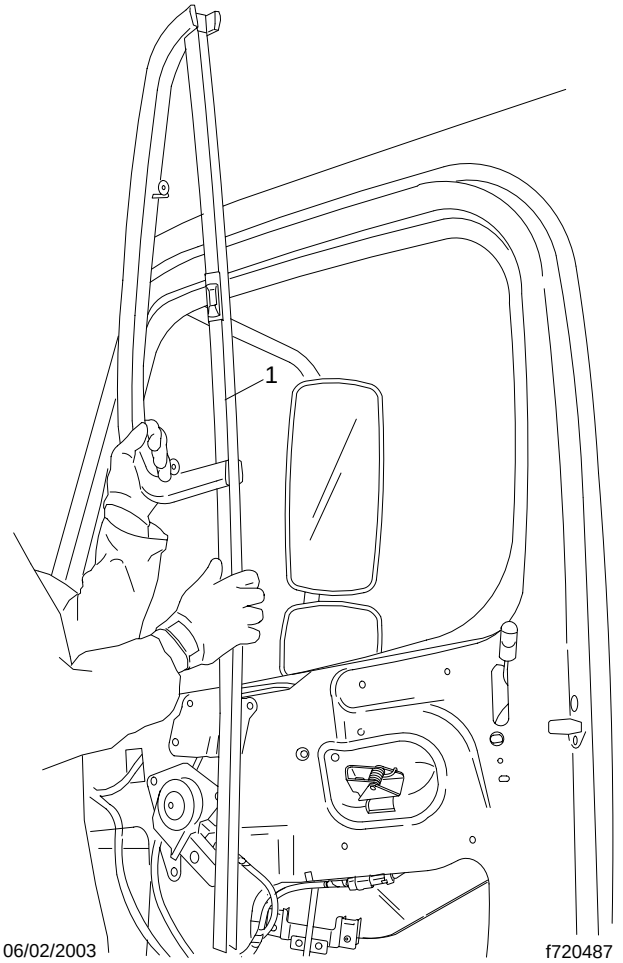
   For an operable vent window, loosen the latch and open the vent window. Remove the two screws that attach the glass to the vent-window frame, and remove the glass.

   For a fixed vent window, starting at the lower front corner apply light pressure against the inside of the glass while carefully prying the seal around the outside of the glass.
6. Remove the vent-window frame assembly as follows.

   6.1 Using a T20 driver, remove the three screws between the door and the front of the vent-window frame assembly.

   6.2 Using a T30 driver, remove the two screws that attach the run channel of the vent-window frame assembly to the door.

   6.3 Pull the vent-window frame assembly up and out of the window opening. See **Fig. 1**.
7. Stretch the top and bottom corners of the seal to release the locking tabs on the seal from the vent-window frame. See **Fig. 2**.
8. Remove the seal from the vent-window frame, carefully pulling it free from around the glass supports.
9. Stretch the new seal over the vent-window glass supports.
10. Apply soapy water to the window seal then press the top corner of the seal into the frame, locking the tabs on the seal into the frame. Work the seal around the frame, using the alignment tabs to position the seal properly. See **Fig. 3**.



1. Vent-Window Frame

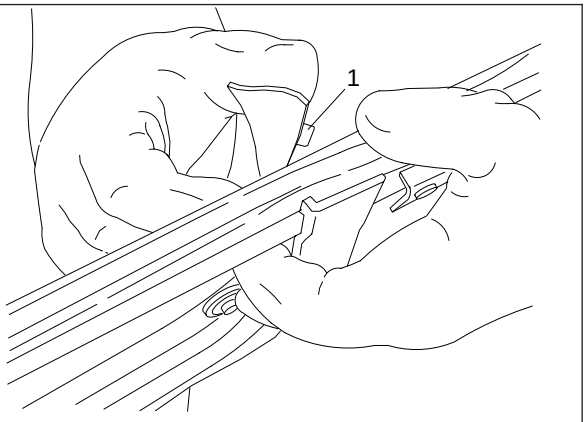
Fig. 1, Remove/Install the Vent-Window Frame Assembly

11. Stretch the bottom edge of the seal and push the locking tabs into the slot in the frame. See **Fig. 2**.
12. Install the vent-window assembly as follows.

    12.1 Slide the run channel through the window opening, then install the vent-window frame in the opening. See **Fig. 1**.

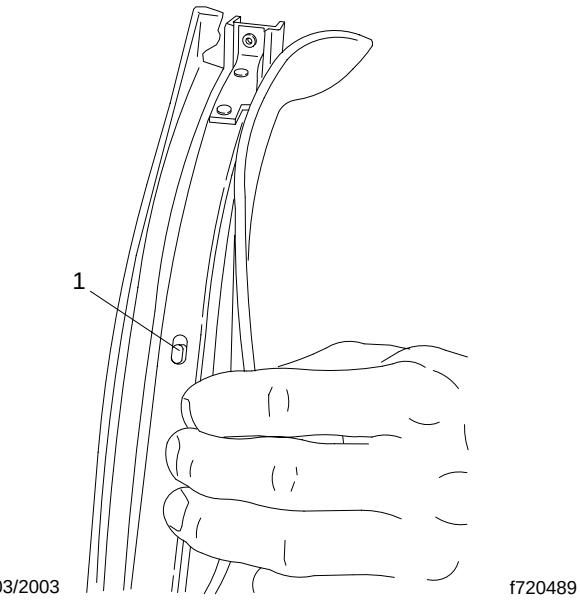
    Overlap the outside of the vent-window seal over the exterior edge of the door. Push the frame assembly forward in the window opening as far as possible.

Vent Window Seal Replacement



1. Tab

Fig. 2, Remove/Install the Vent-Window Seal



1. Alignment Tab

Fig. 3, Install the Vent-Window Seal

12.2 Install the three screws between the door and the vent-window frame. Tighten the screws 36 lbf·in (400 N·cm).

12.3 Using a T30 driver, install the two screws that attach the run channel to the door. Tighten the screws 60 lbf·in (700 N·cm).

12.4 *For an operable vent window,* use the two glass-mounting screws to install the glass in the frame assembly. Torque the screws to 50 to 70 lbf·in (600 to 800 N·cm).

For a fixed vent window, lubricate the inside of the seal with soapy water. From the outside, slide the upper corner of the glass into the seal, then while pushing in on the window, work the seal around the glass.

13. Install the window glass and seal; see **Subject 140**.

14. Install the vapor barrier. Reuse the old adhesive to attach the vapor barrier to the door.

NOTE: If the adhesive does not adhere, use 3M Strip-Calk 08578 as needed to affix the vapor barrier to the door.

15. Install the door interior trim panel, lower view-window trim ring (if so equipped), the pull handles, the door latch handle, and the manual window-regulator crank (if so equipped); see **Subject 100**.

General Information

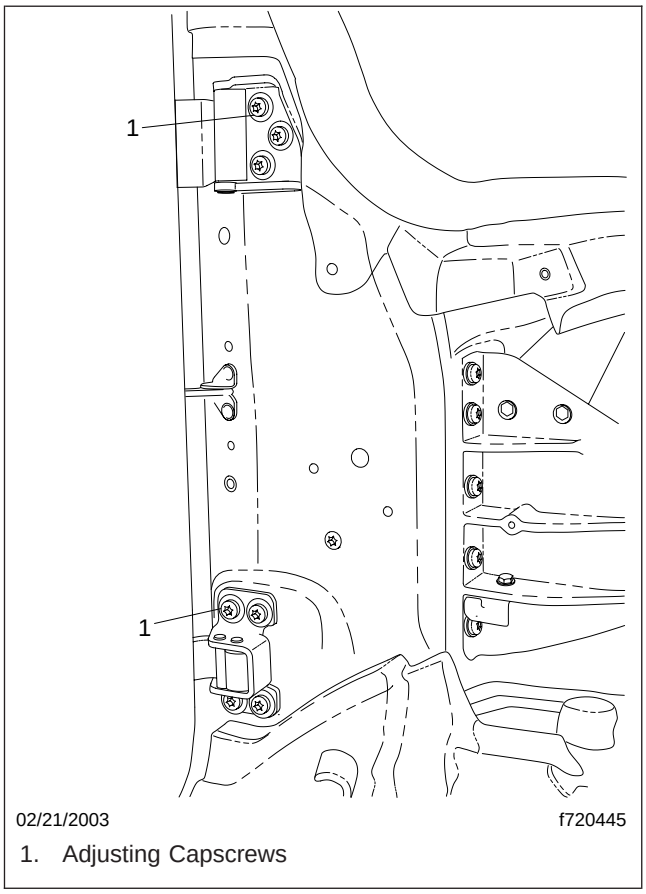
A newly installed door assembly must be adjusted for correct up-and-down, fore-and-aft, and in-and-out positioning relative to the door opening frame. The door assembly should also be adjusted whenever one or more of the following conditions exist (providing the door seal is correctly installed and is in good condition):

- wind or water leaks at the door opening frame
- premature wear of the door seal
- hard closing or opening of the door

The cab portion of the hinge has oversized holes, so that when the capscrews that attach the hinge to the cab (**Fig. 1**) are loosened, the door can be adjusted forward or aft, and up and down within the door opening frame. Slotted holes on the door portion of the hinge (**Fig. 2**) allow for in and out adjustment of the front of the door, and mounting slots for the striker (**Fig. 3**) allow for in and out adjustment of the rear of the door.

Up-and-Down, Fore-and-Aft Adjustment

1. Apply the parking brakes and chock the tires.
2. From outside the cab, check the alignment of the door with the cab door-opening frame. Check that the spaces around the top of the door are uniform. If adjustment is needed, follow the steps below.
3. Remove the cowl side panel.
4. Mark both the vertical and horizontal positions of the latch striker and the hinge before loosening them for adjustment.
5. Loosen the striker, then tighten it just enough to prevent unintentional movement.
6. Loosen the capscrews that attach the hinges to the cab, but keep them tight enough to prevent unintentional movement. See **Fig. 1**.
7. Carefully close the door, then raise or lower it until the gap across the top of the door is about 5/16 inch (8 mm), and the gaps at the front and rear vertical edges of the door are about 3/8 inch (9 mm).

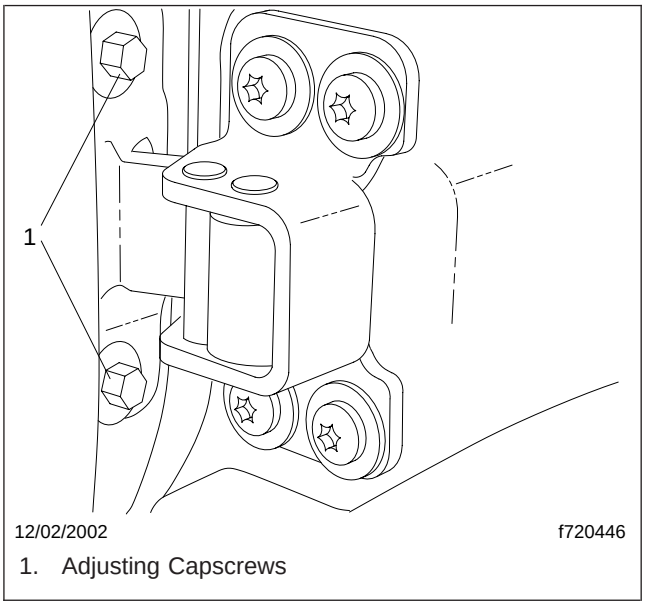


1. Adjusting Capscrews

Fig. 1, Fore-and-Aft and Up-and-Down Adjusting Capscrews on the Cab

8. Without disturbing the positions of the hinges or striker, carefully open and support the door, then tighten the hinge capscrews 11 to 13 lbf·ft (14 to 18 N·m).
9. Open the door and securely tighten the striker. From outside the cab, partially close the door until the latch jaws are about 1 to 2 inches (25 to 50 mm) from the striker. Be sure the striker is horizontal, and centered in the latch jaw when the door is closed. If needed, reposition the striker.
10. Tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m), then close the door and recheck the door alignment.
11. Install the cowl side panel.

Door Adjustment



1. Adjusting Capscrews

Fig. 2, In-and-Out Adjusting Capscrews on the Door

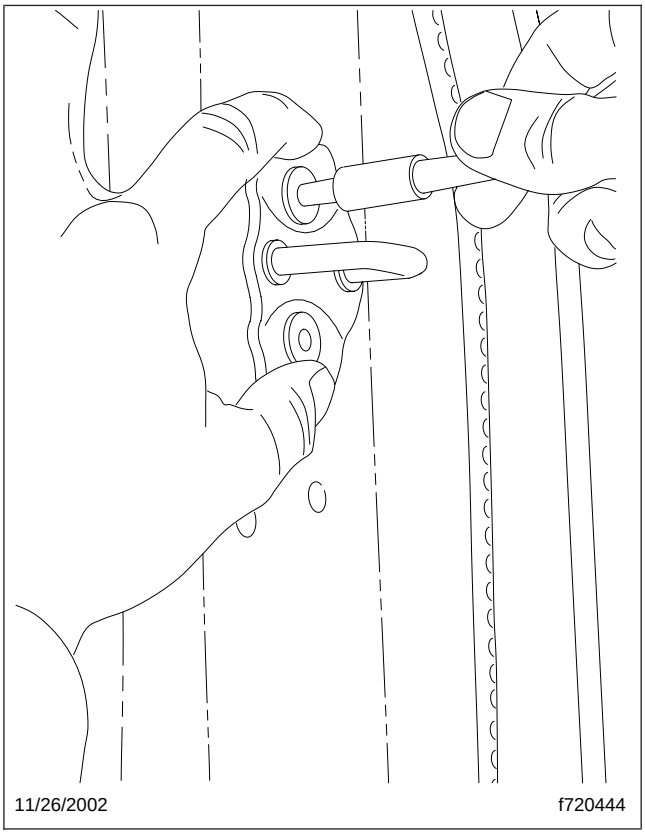


Fig. 3, Striker Adjustment

In-and-Out Adjustment

Poor in-and-out adjustment of the door is often indicated by hard closing of the door, wind and water leaks around the edge of the door, or premature wear of the door seal.

1. With the tires chocked, check the in-and-out adjustment of the door. The outer surface of the door should be flush, within ±3/64 inch (±1 mm), with the surface of the cab skin at *both* its front and rear edges. If adjustment is needed, follow the steps below.
2. If only the rear edge of the door needs adjusting, go to step 6.
3. If the front edge of the door needs adjusting, mark the vertical and horizontal positions of the hinge before loosening them for adjustment.
4. Loosen the capscrews that attach the hinges to the door frame, but keep them tight enough to prevent unintentional hinge movement. See **Fig. 2**.

NOTICE

Do not modify the holes in the hinge to allow for extra adjustment. This could affect the strength of the hinge and damage can result.

5. Carefully close the door, then move the front edge of the door in or out until the outer surface is flush, within ±3/64 inch (±1 mm), with the surface of the cab skin. Be careful not to disturb the up-and-down adjustment.

   If the door cannot be moved sufficiently to bring the upper corner into specified alignment, a shim(s) (part number 18-47661-000) may be added at the lower hinge on the cab side.
6. Without disturbing the positions of the hinges, carefully open and support the door, then tighten the hinge capscrews 11 to 13 lbf·ft (14 to 18 N·m).
7. If the rear edge of the door needs adjusting, mark the vertical and horizontal positions of the latch striker before loosening it for adjustment.
8. Loosen the striker (**Fig. 3**), then tighten it just enough to prevent unintentional movement.
9. Carefully close the door, then move the rear edge of the door in or out until the outer surface

is flush, within ±3/64 inch (±1 mm), with the surface of the cab skin. Be careful not to disturb the up-and-down adjustment.

10. Without disturbing the position of the striker, carefully open the door, then tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m).

NOTE: The striker must be horizontal when tightened.

11. Close the door and recheck the door alignment.

Striker Adjustment

For secure door closure, check the alignment of the latch and striker even if the striker was not loosened.

1. With the tires chocked, partially close the door and make sure that the striker is centered with the latch jaws. Only the center of the striker should contact the latch jaws.
2. Close the door. It should not move up or down as the latch jaws engage the striker.
3. Make sure that the latch jaws will just clear the striker head when the door is closed. If necessary, loosen the striker, then reposition it.
4. Repeat the previous two steps as needed, until the striker is correctly positioned. Tighten the striker screws 11 to 13 lbf·ft (14 to 18 N·m).

NOTE: The striker must be horizontal when tightened.

5. Carefully close the door to the fully latched position (second click). From outside the cab, check the in-and-out, fore-and-aft, and up-and-down positioning of the door.

Window Regulator

To field test a power window regulator, follow the procedure in **Table 1**.

NOTE: Power window regulators are equipped with automatic reset internal thermal protection to prevent motor damage from electrical failure or overuse. Depending on the air temperature, window load, and amount of use, the protection may trip after two or three window cycles. This is normal and is not considered to be a defect. Allow the motor to cool at least 10 minutes to reset the thermal protection before testing.

To field test a manual window regulator, follow the procedure in **Table 2**.

Power Window Regulator Not Working			
Step	**Test Procedure**	**Test Result**	**Action**
1	Check the fuse for the window regulators. Is it open?	Yes	Replace the fuse. Continue troubleshooting for a short in the system.
		No	Go to **step 2**.
2	Check the battery. Is it fully charged?	Yes	Go to **step 3**.
		No	Charge the battery.
3	Remove the interior door panel. Check for battery voltage at the window regulator terminals. With the window rocker switch in the neutral position, connect a voltmeter to the two terminals where the wiring harness connects to the window regulator motor. Is voltage present?	Yes	A shorted switch may have caused the internal circuit protection in the motor to trip. Correct the problem, allow the motor to cool for 10 minutes, then check for voltage again.
		No	Go to **step 4**.
4	With the window rocker switch pushed to the "DOWN" position, check the voltage at the regulator terminals. Also check the voltage with the rocker switch pushed to the "UP" position. What is the voltage reading?	11–15 volts	Go to **step 5**.
		Below 11 or above 15 volts	Check the battery for a full charge, then check the rocker switch for excessive resistance. Repair or replace the switch as needed.
		No voltage	Check the rocker switch for proper function. Replace as needed.
5	Remove the screws that attach the glass to the regulator. Is the glass free to move up and down within the run channels without binding?	Yes	Go to **step 6**.
		No	Adjust the glass run channels, or correct the binding condition. Go to **step 6**.
6	Attach the glass to the regulator, leaving the screws loose so that the glass is free to move slightly from side to side. Test the regulator. Does the regulator work properly with the glass mounting screws loosened?	Yes	Check the regulator mounting alignment, adjust if needed, then tighten the screws. Repeat as necessary.
		No	Go to **step 7**.
7	Test the regulator operation. Does it work properly?	Yes	Troubleshooting is completed.
		No	Replace the window regulator.

Table 1, Power Window Regulator Not Working

Troubleshooting

Manual Window Regulator Not Working or Noisy, Window Glass Binding			
Step	**Test Procedure**	**Test Result**	**Action**
1	Remove the interior door panel to gain access to the window regulator.	—	—
2	Are the regulator mounting screws tight, and is the glass secured to the regulator.	Yes	Go to **step 3**.
		No	Correct any problems and retest.
3	Disconnect the glass from the regulator. Is the glass free to move up and down within the run channels without binding?	Yes	Check that the glass attachment point of the regulator moves when the handle is cranked. If it does not, replace the regulator. Otherwise, go to **step 4**.
		No	Adjust the glass run channels, or correct the binding condition. Go to **step 4**.
4	Connect the glass to the regulator, leaving the screws loose so that the glass is free to move slightly from side to side. Crank the handle. Does the regulator work properly with the glass mounting screws loosened?	Yes	Raise and lower the glass completely, then tighten the glass mounting screws.
		No	Loosen the regulator mounting screws and try to adjust the regulator alignment for proper operation. The glass also may need to realigned after any adjustments to the regulator.
5	Test the regulator operation. Does it work properly?	Yes	Troubleshooting is completed.
		No	Replace the window regulator.

Table 2, Manual Window Regulator Not Working or Noisy, Window Glass Binding

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Interior Door-Pull Handle Screws	11–13	14–18	—	—
Interior Door-Latch Handle Screws	—	—	50–70	600–800
Door Hinge Capscrews, M8	11–13	14–18	—	—
Door Check-to-Door Nuts, M6	—	—	50–70	600–800
Door Check-to-Cab Screws, M6	—	—	50–70	600–800
Latch Assembly Mounting Screws	—	—	50–70	600–800
Exterior Latch Rod Adjustment Screw	—	—	15–25	170–280
Glass Channel Mounting Screws	—	—	60	700
Operable Vent Window Glass-Mounting Screws	—	—	50–70	600–800
Window Regulator Clamp	—	—	55–64	625–725
Vent-Window Frame Mounting Screws	—	—	36	400
Striker Screws	11–13	14–18	—	—

Table 1, Torque Specifications

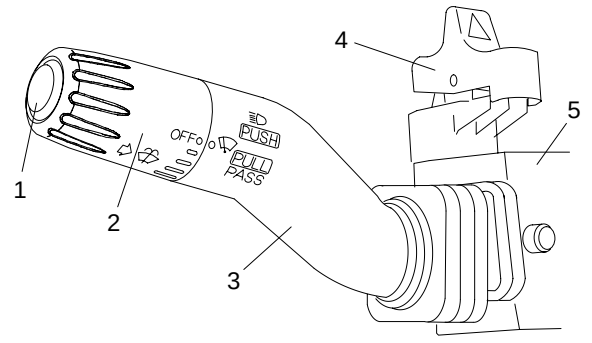
Description

The instrumentation control unit (ICU) monitors wiper control dial and washer switch position and sends this information via J1939 for the Bulkhead Module (BHM). The BHM uses the information to control the windshield wiper motor and the washer pump motor.

Wiper Control Dial

The wiper control dial at the end of the multifunction turn signal switch controls the operation of the wiper. See **Fig. 1**. There are two steady-speed settings, LO and HI, and four delay settings. The delay settings are indicated by four lines of various lengths on the wiper control dial. The longer the length of the line, the shorter the delay between wipes.

Rotate the top of the wiper control dial away from you to turn the wipers on. When the wipers are on, rotate the top of the wiper control dial toward you to turn the wipers off. See **Fig. 2**.



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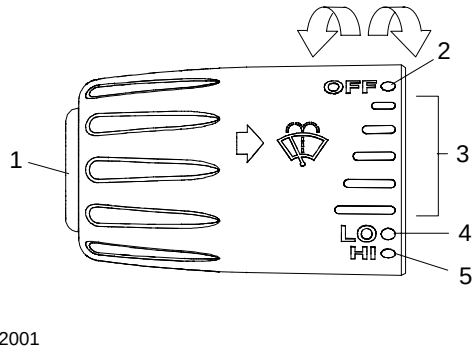
1. Washer Button
2. Wiper Control Dial
3. Turn Signal Lever
4. Hazard Flasher Switch
5. Multifunction Turn Signal Switch Module

Fig. 1, Multifunction Turn Signal Switch

See **Specifications 400** for wiper control dial input/output signals sent to the ICU.

Wiper Motor

The wiper motor is a two-speed motor that runs the wipers at low speed or high speed. For the four intermittent positions, the wipers are pulsed at low speed. There is a short time delay between pulses that varies in duration according to the position of the wiper control dial.



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1. Washer Button
2. Wiper Off Position
3. Wiper Delay Positions
4. Low-speed Wiper Position
5. High-speed Wiper Position

Fig. 2, Wiper/Washer Controls

The BHM controls the wiper motor speed by monitoring three J1939 messages that are received from the ICU. The three messages are:

- wiper on/off message
- wiper low message
- wiper high message

When one of the intermittent speeds is selected, the ICU controls the timing of the wipers by pulsing the wiper on/off and wiper low messages. See **Specifications 400** for the I/O conditions of the wiper motor operation.

The BHM monitors the wiper motor wiring and is capable of detecting a short circuit. Faults detected by the BHM may be reported over the J1939 datalink and can be viewed using ServiceLink®. See **Troubleshooting 300** for possible wiper motor fault conditions.

Washer Pump

The washer pump is operated by a button at the end of the multifunction turn signal lever. To operate the washer, press the button in and hold it in for the length of wash you want. See **Table 1** for a descrip-

tion of the available wash cycles. Unless the wiper control dial is in the high position, wiping triggered by the wash button is done at low speed.

The BHM monitors the washer pump motor wiring and is capable of detecting a short circuit. Faults detected by the BHM may be reported over the J1939 datalink and can be viewed using ServiceLink. See **Troubleshooting 300** for possible washer pump fault conditions.

Washer Fluid Level

If the vehicle is equipped with an optional washer fluid level switch, the BHM will monitor the level of the washer fluid in the fluid reservoir and broadcast this information via a J1939 message. When the BHM sees ground at the washer fluid level input, it sends a J1939 message indicating low washer fluid. The ICU uses this information to illuminate the low washer fluid indicator. If the washer fluid level input is unavailable or in error, the BHM will assume the washer fluid level is low.

Washer Cycles	
Cycle Activation Requirements	**Cycle Description**
Wash button is pressed less than 0.5 second.	Single dry wipe, commonly called a mist wipe.
Wash button is pressed from 0.5 to 1.0 second.	Short wash with three wipes.
Wash button is pressed more than 1.0 second.	Wash continues until the button is released.

Table 1, Washer Cycles

Replacement

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Make sure the wiper blades are parked. If necessary, park them by turning the wipers on and then off.

⚠ WARNING

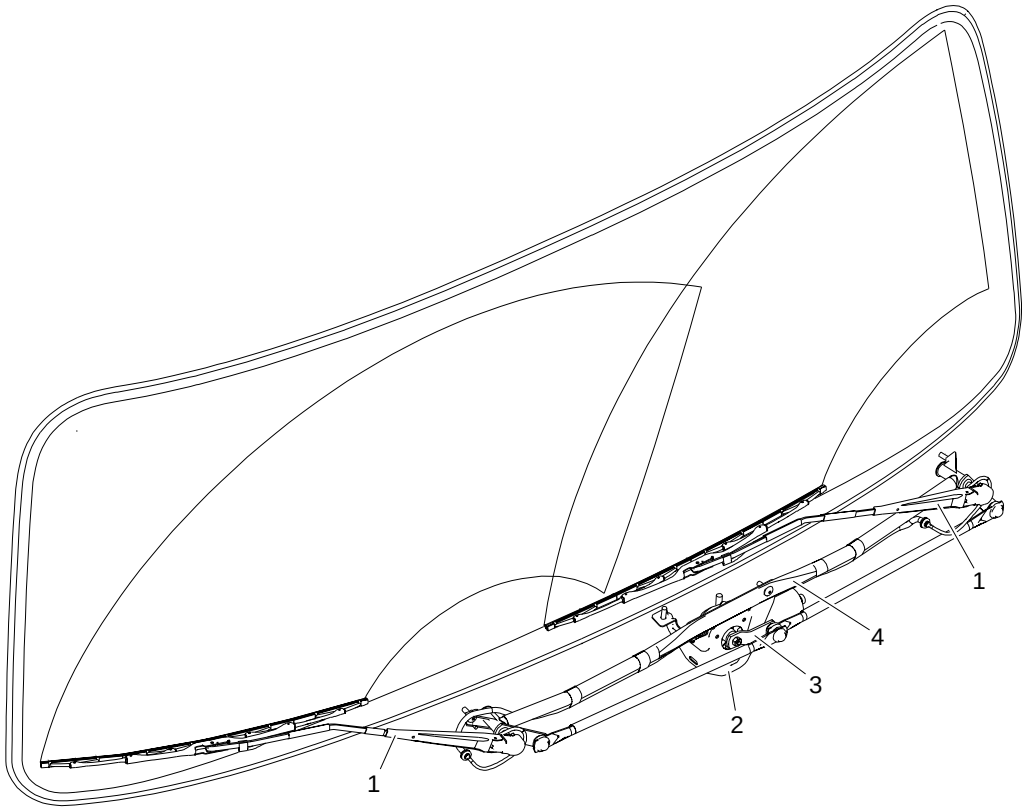
Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

3. Disconnect the batteries.
4. Open the hood.

NOTE: The wiper arms are different lengths. Note which wiper arm belongs on the right and left sides.

5. Remove the wiper arms and washer hoses.
6. Disconnect the wiring harness from the wiper motor and the washer hoses from the linkage assembly.
7. Remove the fasteners that attach the linkage assembly to the cab. See **Fig. 1**.
8. Remove the linkage assembly.
9. Remove the nut and lockwasher that attach the motor lever to the wiper motor. Remove the motor lever.
10. Remove the capscrews that attach the wiper motor to the wiper motor bracket. Remove the wiper motor.
11. Using capscrews, attach the wiper motor to the wiper motor bracket on the new linkage assembly.
12. Inspect the rain tray grommets for wear or damage. Replace if necessary. See **Fig. 2**.
13. Using fasteners, attach the linkage assembly to the cab.
14. Rotate the linkage to the park position. Using a nut and lockwasher, attach the motor lever to the wiper motor. Torque the nut 9 to 12 lbf·ft (12 to 16 N·m).
15. Attach the wiper arms to the wiper pivot shafts in the parked position..
16. Connect the wiring harness to the wiper motor. Attach the washer hoses to the linkage assembly.
17. Connect the batteries.
18. Lower the hood.
19. Remove the chocks from the tires.

Linkage Replacement



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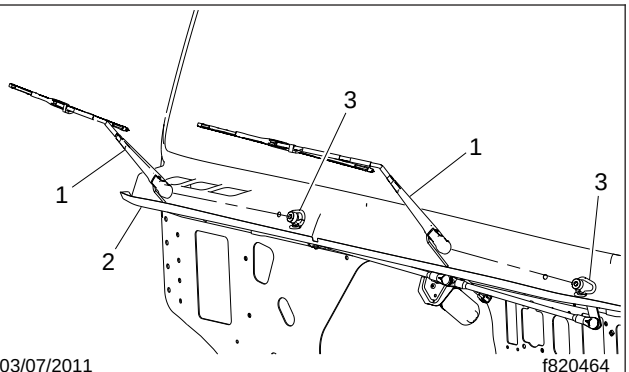
1. Wiper Arm
2. Wiper Motor
3. Motor Lever
4. Linkage Assembly

Fig. 1, Wiper Assembly



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1. Wiper Arm
2. Rain Tray
3. Grommet

Fig. 2, Rain Tray Grommets

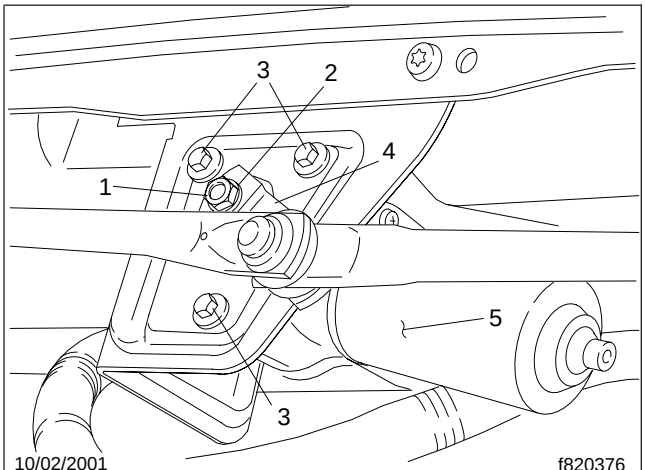
Replacement

1. Turn off the engine, apply the parking brakes, and chock the rear tires.

⚠ WARNING

Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

2. Disconnect the batteries.
3. Open the hood.
4. Remove the nut and lockwasher that attach the motor lever to the wiper motor. See **Fig. 1**. Remove the motor lever.



1. Nut
2. Lockwasher
3. Capscrew
4. Motor Lever
5. Wiper Motor

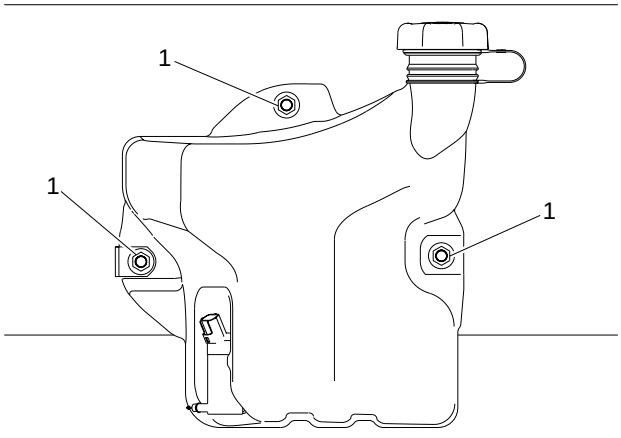
Fig. 1, Wiper Motor Assembly

5. Remove the capscrews that attach the wiper motor to the mounting bracket.
6. Disconnect the wiring harness from the wiper motor. Remove the wiper motor.
7. If the wipers are not in the park position, rotate the linkage so the wipers are in the parked position.
8. Using capscrews, attach the wiper motor to the mounting bracket.
9. Using a nut and lockwasher, attach the motor lever to the wiper motor. Torque the nut 9 to 12 lbf·ft (12 to 16 N·m).
10. Connect the wiring harness to the new wiper motor.
11. Connect the batteries.
12. Lower the hood.

Washer Reservoir Replacement

Replacement

1. Turn off the engine, apply the parking brakes, and chock the rear tires.
2. Disconnect the batteries.
3. Open the hood.
4. Drain the washer reservoir if necessary.
   - 4.1 Place a container under the washer reservoir.
   - 4.2 Remove the washer hose from the pump and attach a hose long enough to reach the container.
5. Remove the wiring harness from the washer reservoir pump.
6. Remove the washer fluid line from the washer reservoir.
7. Remove the pump from the washer reservoir.
8. Remove the three fasteners, nuts, and washers that attach the washer reservoir to the right frame rail in engine compartment. See **Fig. 1** and **Fig. 2**.



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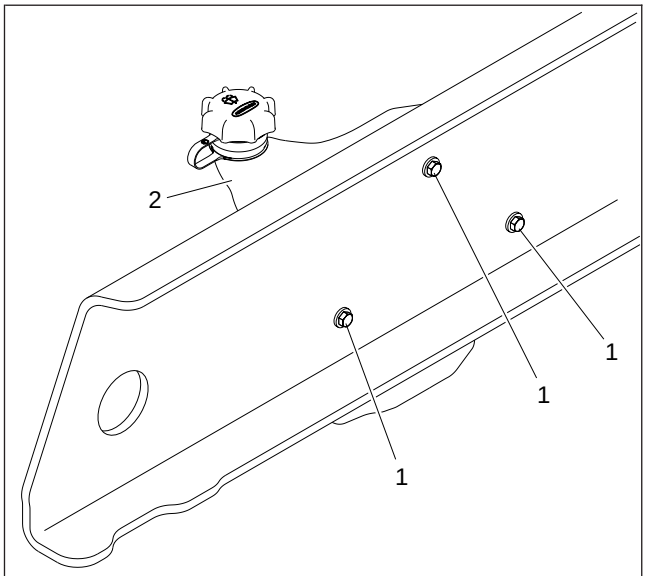
1. Washer Reservoir Fasteners

Fig. 1, Washer Reservoir, Front View

9. Attach the pump to the new washer reservoir.
10. Position the new washer reservoir on the frame rail and install the three fasteners, nuts, and washers. Tighten the nuts securely.



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1. Mounting Nuts
2. Washer Reservoir

Fig. 2, Washer Reservoir, Rear View

11. Attach the wiring harness and washer fluid line to the pump.
12. Transfer the washer fluid to the new reservoir.
13. Close the hood.

Fault Codes

The reference parameters that program the Bulkhead Module (BHM) determine whether a fault code will broadcast for any wiper/washer system fault. Even if the BHM detects a wiper/washer system fault, a fault code may not be transmitted. If the BHM is programmed to transmit wiper/washer system fault codes, they can be viewed through ServiceLink®.

Wiper Motor

Table 1 displays how the BHM handles wiper motor faults.

Washer Pump

Table 2 displays how the BHM handles washer pump faults.

Wiper System Fault Conditions	
Description of Fault	**Action Taken by the BHM**
Ignition switch is in error.	BHM will assume the ignition switch is on, and may transmit a J1939 fault message.
Wiper commutator switch is unavailable or in error.	BHM will assume the wiper commutator switch is in the park position.
J1939 wiper on/off message from the instrumentation control unit (ICU) is unavailable or in error.	BHM may transmit a J1939 fault message.
J1939 wiper low message from the ICU is unavailable or in error.	BHM may transmit a J1939 fault message.
J1939 wiper high message from the ICU is unavailable or in error.	BHM may transmit a J1939 fault message.
Contradictory J1939 messaging between the ICU and BHM.	BHM may transmit a J1939 fault message.
ICU sends an error indicator in any of the J1939 wiper messages to the BHM.	BHM may transmit a J1939 fault message.
BHM fails to receive any five consecutive J1939 wiper messages from the ICU.	BHM may transmit a J1939 fault message.
Short in the wiper motor wiring.	BHM may transmit a J1939 fault message.

Table 1, Wiper System Fault Conditions

Washer Pump Fault Conditions	
Description of Fault	**Action Taken by the BHM**
J1939 washer pump message from the ICU is unavailable or in error.	BHM assumes the J1939 washer pump message is off.
ICU sends an error indicator in the J1939 washer pump message to the BHM.	BHM may transmit a J1939 fault message.
BHM fails to receive five consecutive J1939 washer pump messages from the ICU.	BHM may transmit a J1939 fault message.

Troubleshooting

Washer Pump Fault Conditions	
Description of Fault	**Action Taken by the BHM**
Short in the washer pump motor wiring.	BHM may transmit a J1939 fault message.

Table 2, Washer Pump Fault Conditions

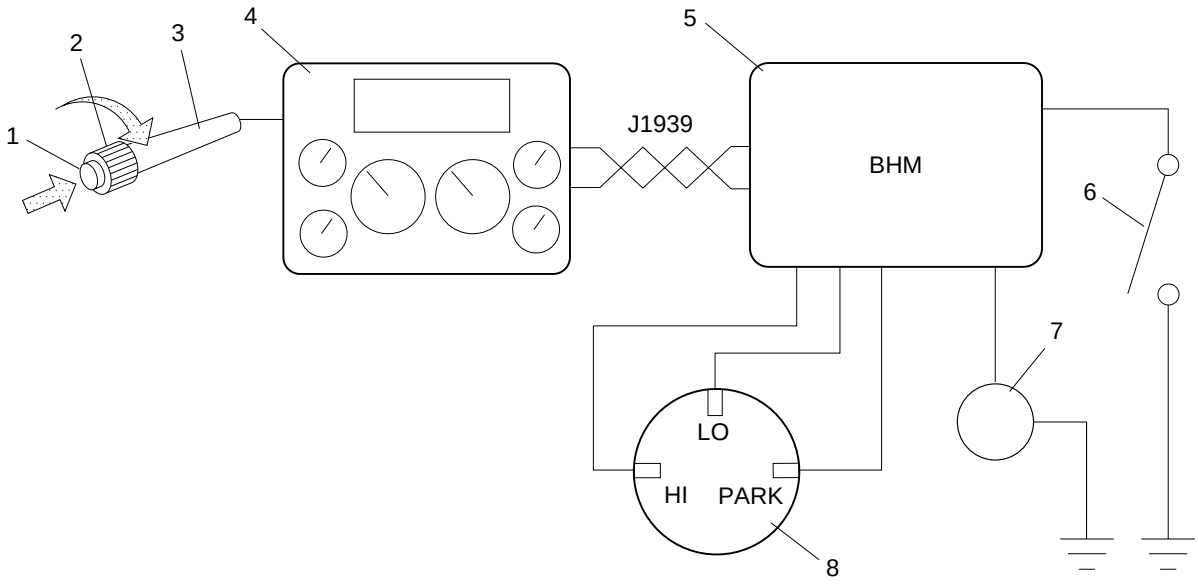
Input and Output Conditions

Table 1 displays the wiper control dial inputs to the ICU and the J1939 message outputs.

Table 2 displays the wiper motor inputs to the BHM and how the BHM reacts to these inputs.

Wiring Diagram

Figure 2 shows a wiring diagram for a typical wiper/washer system. BHM pin identification and circuit colors shown on this diagram may not be representative of every vehicle.



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1. Washer Switch
2. Wiper Control Dial
3. Multifunction Turn Signal Switch
4. Instrumentation Control Unit
5. Bulkhead Module
6. Washer Fluid Level Sensor
7. Washer Pump
8. Wiper Motor

Fig. 1, Wiper/Washer System

Wiper Control Dial Input/Output Conditions					
Inputs to ICU		Outputs from ICU			
Wiper Control Dial Position	Wiper Operation Timing	Ohms	J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message
OFF	Wiper off	Off	Off	Off	24
Intermittent 1	Wipe every 12 seconds	100Ω	Pulsed on	Pulsed on	Off

Specifications

Wiper Control Dial Input/Output Conditions					
Inputs to ICU		Outputs from ICU			
Wiper Control Dial Position	Wiper Operation Timing	Ohms	J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message
Intermittent 2	Wipe every 8 seconds	160Ω	Pulsed on	Pulsed on	Off
Intermittent 3	Wipe every 5 seconds	240Ω	Pulsed on	Pulsed on	Off
Intermittent 4	Wipe every 3 seconds	390Ω	Pulsed on	Pulsed on	Off
LO	Wiper low speed	680Ω	On	On	Off
HI	Wiper high speed	1600Ω	On	Off	On

Table 1, Wiper Control Dial Input/Output Conditions

Wiper Motor Input/Output Conditions				
Inputs to BHM				Output from BHM
Ignition Switch Position	J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message	Wiper Motor Speed
Start/Off	On/Off	On/Off	On/Off	Off
On/Acc	Off	Off	Off	Off
On/Acc	On	On	Off	Low
On/Acc	Off	On	Off	Low*
On/Acc	On	Off	Off	Low*
On/Acc	On	Off	On	High
On/Acc	On	On	On	High*
On/Acc	Off	On	On	High*
On/Acc	Off	Off	On	High*

* This is an error condition. See Troubleshooting 300, for more information concerning fault conditions.

Table 2, Wiper Motor Input/Output Conditions

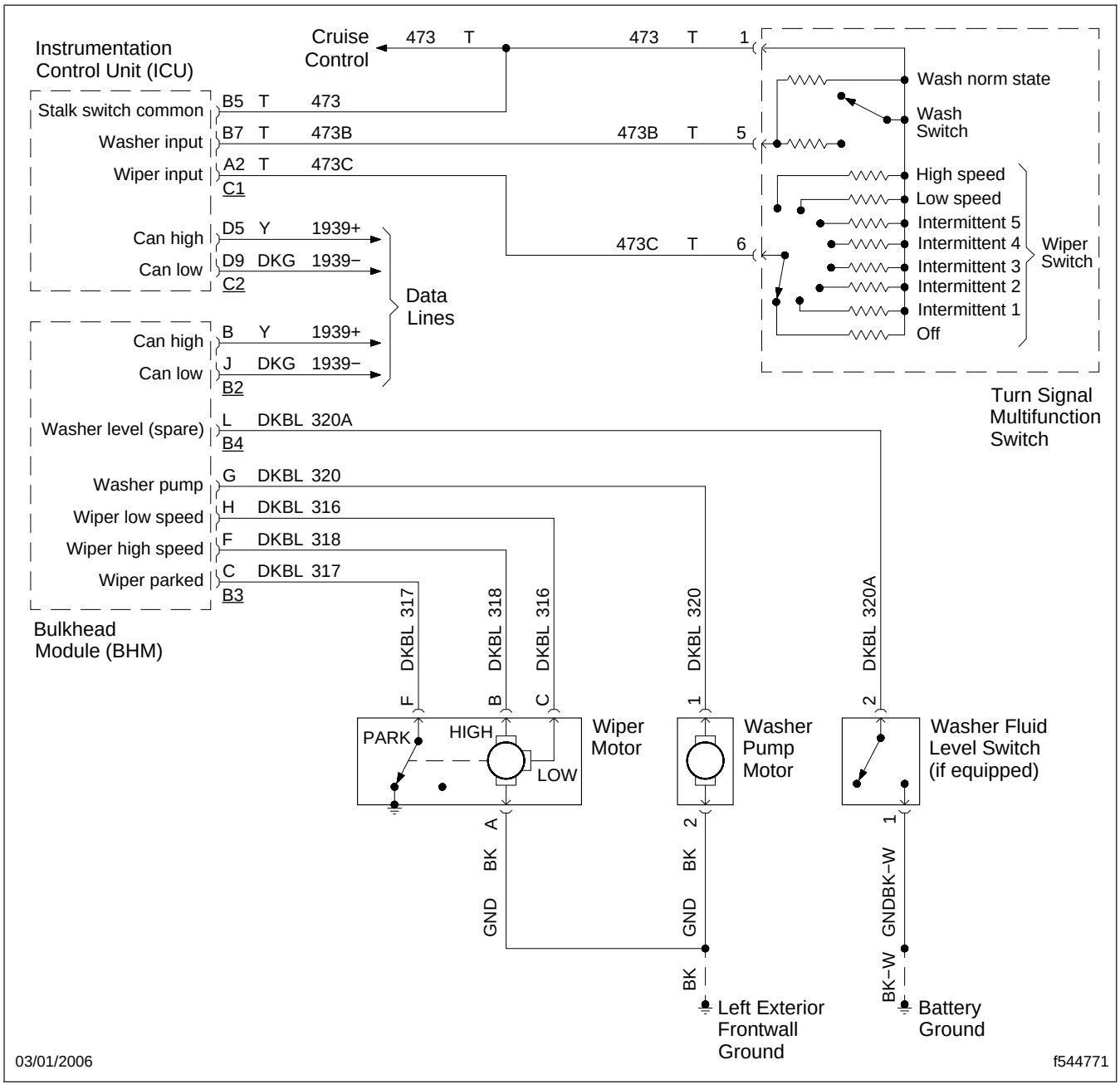


Fig. 2, Wiper/Washer Wiring Diagram

General Diagnostic Overview

A/C cooling problems fit into two basic failure categories, refrigerant or electrical. The goal of this troubleshooting guide is to provide the information necessary to determine what part is causing the problem. We expect the tech to use approved tools and shop practices, symptom driven diagnostics, and warranty component evaluation guides to properly asses component failures. Refer to **www.accessfreightliner.com** for available tool information, service training, and warranty documentation.

For system performance testing, ambient temperature must be above 70°F (21°C) to produce reliable results. In order to quickly determine if your symptoms are refrigerant or electrical, two main tools should be utilized by the technician; ServiceLink and a refrigerant gauge set.

General Diagnostic Procedure

1. Perform the preliminary checks.
2. Perform an initial system inspection.
3. Make a determination about which system is suspected (refrigerant or electrical), and follow the symptoms through to a suspected part.
4. Repair the problem.
5. Verify that all of the refrigerant connections removed during the service are properly sealed using an approved refrigerant leak detector.
6. Verify that the problem has been resolved.

System Overview

The blend air system uses Constant Discharge Temperature Control (CDTC) to regulate the temperature in the vehicle. The CDTC is a closed-loop system that uses the climate control panel settings, the temperature sensors, and various J1587 databus inputs to control and maintain the outlet temperature of the system. The blend air system has an electronically controlled, brushless, direct current (BLDC) blower motor that does not require a resistor block to control the blower speed.

In the blend air system, all air is directed through the evaporator. The amount of air needing to be reheated is controlled by the temperature control door, which directs that amount of air through the heater core.

The cab HVAC assembly consists of a blower motor, evaporator, heater core, CDTC sensor, evaporator temperature sensor, and three electric actuators that drive the air direction control doors. The doors perform the following functions:

- temperature control door—controls how much air is directed through or around the heater core
- air selection mode door—directs airflow to the face, floor, or defrost outlets
- recirculation door—controls the amount of outside air that enters the HVAC unit

The climate control panel contains the microprocessor that controls the system.

The refrigerant system consists of a compressor, condenser, receiver-drier, thermal expansion valve(s), and pressure sensors.

Preliminary Checks

NOTE: Pay attention to the refrigerant system components for evidence of oil seepage and other potential leaks that will be checked during subsequent diagnostic steps.

Before testing the operation of the air conditioning system, check the following items:

1. Inspect the drive belt and mounting fasteners for signs of wear or looseness.
2. Visually inspect the clutch for signs of over heating, damage, or wear. If necessary, check the clutch gap. For instructions, see **Section 83.02**, Subject 140.
3. Check for road debris buildup on the condenser coil fins. Using air pressure and a whisk broom or a soapy spray of water, carefully clean off the condenser. Be careful not to bend the fins.
4. Inspect the fresh and recirculation air filter elements, and inspect the intake-air ducting for debris.
5. With the engine off, and Optimized Idle (if applicable) disabled, turn the compressor drive plate by hand to feel for grinding or harshness inside the compressor.

Initial Inspection

1. Connect refrigerant pressure gauges and ServiceLink to the vehicle.
2. Start the vehicle and select A/C mode and a cold temp setting to request compressor engagement. If the following conditions are met, the clutch should engage.
    - The engine is running at, or above 450 RPM for at least 5 seconds.
    - Refrigerant system high side pressure is above 20 psi (140 kPa). Pressure reading is taken at the binary switch.
    - Refrigerant system high side pressure is below 450 psi (3100 kPa). Pressure reading is taken at the binary switch.
    - Vehicle compressed air system is above 60 psi (414 kPa). Pressure is taken at the dash ECU, and transmitted on the J1587 databus.
    - Evaporator core temperature sensor is reading above 44°F (6.5°C). Temperature is taken in the main heater box, as a direct input to the FCU.
    - The blower feedback from the main HVAC unit is connected, and the signal is meeting the minimum RPM requirements for each knob position.

At this point you should be seeing some indication of a problem, either electrical or refrigerant.

Electrical—If there are any faults that affect the front control unit (FCU) or any of the parallel systems that provide input information to the FCU, or if the system requirements are being met, but the clutch is still not engaging, there may be an electrical problem related to the FCU, or the voltage signal to the compressor.

Refrigerant—If the low side pressure is drawing down far below 20 psi (140 kPa), or if the high side pressure is rising above 450 psi (3100 kPa), there is a refrigerant related problem.

Post-Repair Procedures

After repair work is completed, verify that the repair resolved the problem.

1. Verify that all of the refrigerant connections removed during the service are properly sealed using an approved refrigerant leak detector.
2. Check for fault codes. There should be no active fault codes that indicate the problem still exists.
3. If there is still a problem, repeat the appropriate tests, and make repairs as needed.
4. Verify again.

Refrigerant System Tests

Use the following procedure to evaluate the performance of the air conditioning system. If the system does not operate within the following guidelines, further diagnosis and repair may be necessary. The dash outlet temperature will fluctuate during each clutch cycle, and the temperature reading should be taken at the lowest value.

1. Park the vehicle out of direct sunlight, shut down the engine, and chock the tires.
2. Open the hood and leave the hood open for the entire test.
3. Open the driver and passenger doors and leave the doors open for the entire test.
4. Note the current ambient air temperature.

NOTE: High relative humidity reduces cooling and could increase the dash outlet temperatures, and high-side system pressures.

5. Using the ambient air temperature readings noted in the previous step, find the temperature/pressure specifications in **Table 1** that best match your ambient conditions.
6. Connect the test gauges to the high and low side service ports.
7. Place a thermometer in the center dash outlet.

NOTE: EPA10 and owner-set idle limits may prevent the warm-up run from continuing without occasional throttle inputs.

8. Start the engine and run the A/C for 15 minutes.
9. Set the engine speed to 1500 rpm and engage the engine fan.
10. Set the cab climate control panel to the following settings:
    - air selection switch to face mode
    - air conditioning on
    - blower speed switch to high
    - temperature control switch to full cold
    - recirculation switch off
11. Allow the system to stabilize at least five minutes or until the dash outlet temperature has reached a minimum, then compare the system values to the information in **Table 1**. The results should be close to those listed, but minor discrepancies are not a guarantee that the system has a refrigerant system problem.

    Possible causes of refrigerant system complaints:

    - Too much oil - High high-side pressure, poor heat rejection at the condenser
    - Too much refrigerant - High high-side pressure, good cooling
    - Not enough refrigerant - Low high-side pressure, low low-side pressure, poor cooling
    - Debris in the system - thermal expansion valve (TXV) plugged or uncontrollable, compressor turns hard, receiver/dryer is icing
    - Contaminated or incorrect refrigerant - Very inconsistent system pressures and duct temps

Day Cab with TitanX Condenser						
Ambient Air Temp.	**Humidity (approximate)**	**Dash Outlet Temperature (approximate)**	**Service Port Pressures**		**A/C Compressor Status**	**A/C Compressor Status Comments**
			High: psi (kPa)	**Low: psi (kPa)**		
70°F (21°C)	Low 25%	41–44°F (5–7°C)	79–96 (545–662)	9–40 (62–276)	Cycling	On 5 sec; Off 8 sec
	Med 50%	44–47°F (7–8°C)	80–102 (552–703)	10–45 (69–310)	Cycling	On 6 sec; Off 6 sec
	High 70%	45–52°F (7–11°C)	89–110 (614–758)	10–51 (69–352)	Cycling	On 6 sec; Off 6 sec

Refrigerant System Tests

Day Cab with TitanX Condenser						
Ambient Air Temp.	Humidity (approximate)	Dash Outlet Temperature (approximate)	Service Port Pressures		A/C Compressor Status	A/C Compressor Status Comments
			High: psi (kPa)	Low: psi (kPa)		
80°F (27°C)	Low 25%	40–44°F (12–16°C)	90–114 (634–896)	9–39 (83–386)	Cycling	On 8 sec; Off 6 sec
	Med 50%	40–45°F (4–7°C)	95–116 (655–800)	14–38 (97–262)	Cycling	On 2 minutes 30 sec; Off 4 sec
	High 70%	44°F (7°C)	119 (820)	16 (110)	On	On steady
90°F (32°C)	Low 25%	45–48°F (7–9°C)	118–133 (814–917)	8–27 (55–186)	Cycling	On 2 minutes; Off 6 sec
	Med 50%	51°F (11°C)	135 (931)	15 (103)	On	On steady
	High 70%	58°F (14°C)	140 (965)	16 (110)	On	On steady
100°F (38°C)	Low 25%	42°F (6°C)	170 (1172)	20 (138)	On	On steady
	Med 40%	52°F (11°C)	176 (1213)	22 (152)	On	On steady
	High 50%	57°F (14°C)	178 (1227)	22 (152)	On	On steady

Test conditions:

- engine at 1500 rpm
- engine fan locked on
- fresh air mode
- blower speed on high, about 13.5 vdc
- cab doors open
- hood open
- parked out of direct sunlight
- no wind speed or less than 5 mph (8 km/h)
- stabilize at each point

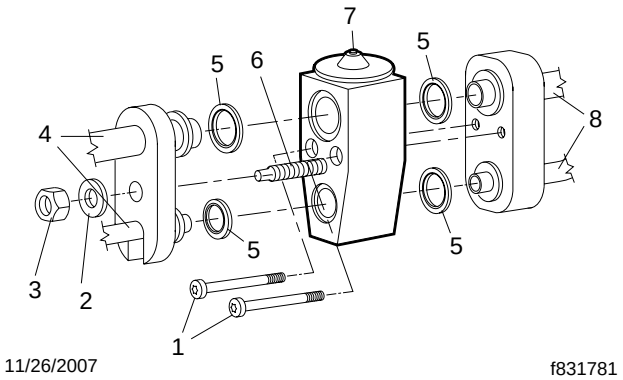
Table 1, Day Cab with TitanX Condenser

Thermal Expansion Valve Testing

General

The thermal expansion valve (TXV) (see **Fig. 1**) is a controlling device that regulates the flow of refrigerant into the evaporator. It is actuated by changes in evaporator pressure and the superheat of the refrigerant gas leaving the evaporator. Superheat is defined as any temperature of a gas above the boiling point for that liquid. For example, when a refrigerant liquid boils at a low temperature of 40°F (4.5°C) in the evaporator and then the refrigerant gas increases in temperature, superheat has been added. If this refrigerant changed from a liquid to a gas or vapor at 40°F (4.5°C) and then the refrigerant vapor increased in temperature to 50°F (10°C), then it has been superheated by 10°F (6.5°C). The refrigerant entering the evaporator is metered at a rate that matches the amount of refrigerant being boiled off in the evaporator. In addition to metering refrigerant, the TXV also provides a pressure drop in the system, separating the high-pressure side of the system from the low-pressure side. To operate properly, the TXV must have a steady flow of liquid refrigerant supplied to it by the high side of the system. Issues such as an excessively low refrigerant charge, or contaminants in the system can interrupt this flow of liquid to the valve. In these cases, symptoms may surface making it seem as if the valve is inoperative or plugged. These symptoms can include poor performance, low low-side pressures (even a vacuum) ,etc. Before replacing a TXV, it is important to verify that there are no contaminants in the system and that the refrigerant charge is correct, by performing a refrigerant identification and thorough leak check of the entire system. The TXV is often incorrectly replaced as the primary failed part, but is rarely the cause of a performance issue. In rare instances the power element of the TXV can lose its charge, reducing the range of the TXV, but there is no other situation that can be considered a failure of the TXV. Due to the

similarity of symptoms that these root causes have on A/C performance, proper diagnosis is essential to making the correct repairs to the A/C system.



1. Screw (2)
2. Washer
3. Nut
4. Refrigerant Lines to J-Block
5. Seal
6. Stud
7. Thermal Expansion Valve
8. Refrigerant Lines to Evaporator

Fig. 1, Thermal Expansion Valve Installation

Diagnostics

To determine if the TXV is functioning, watch the low-side pressure while the compressor is engaged. The influence from the TXV modulating can be seen as the low-side gage needle "wags." As the load on the system changes from ambient conditions, the TXV may not wag as much, and care must be taken to prevent false diagnosis. If a TXV failure is suspected, connect the gage set to the properly charged refrigerant loop, and run the compressor. Watch for the low-side gage needle to wag, indicating that the TXV is working. Depending on the load, the low-side pressure may progress from moderate to high, but the needle will simultaneously wag as the average pressure changes.

Leak Detection

General

The information in this section is intended to convey a general method of leak detecting that should be used to enhance the usefulness of a leak detector being used in accordance with operator's instructions provided by the manufacturer. A technician should not attempt to perform leak detection without reading and understanding the owner's manuals for the tools being used, and should expect to review those instructions from time to time, to ensure the proper method continues to be used. The process described here was developed using the published list of recommended tools and warranty evaluation guides as a basis for the expectations for repair competence. The only way to confirm that a refrigerant leak exists is by finding a failed or damaged component. A UV flashlight and goggles can be used to provide an indication of a leak, but a approved electronic leak detector must be used to confirm the existence of a leak, and approximate the leak rate. The connections used for A/C refrigerant are intended to seal properly, but given the high level of sensitivity provided by current leak detecting equipment, the detector may indicate a leak even though the connection meets the design specifications. To balance this, the "Acceptable Leak Rates by Component" table in **Specifications, 400** contains the qualifying leak rates for the components used on these vehicles. The leak rates, in oz/yr, correspond to the sensitivity values required for all detectors that meet the SAE J2791 functional specifications. By switching between the sensitivity levels, it is possible to discern between leaks of varying sizes and qualify each potential leak. It is expected that a leak rate relates to each component, as it arrives at the factory, but the Mini-Stato seals that connect the components together are specified separately. Additionally, due to the possible difficulty of distinguishing between two minor leaks at a multi-port connection, the leak rate for two Mini-Stato seals should be considered a condemning value if it is not completely clear which seal is leaking.

Method

IMPORTANT: The refrigerant system should be warmed up from completion of the initial inspection, but the engine is off.

1. Shut down the engine.
2. Before testing for compressor leaks, blow shop air near the compressor shaft seal to clear any refrigerant that may have collected.
3. Install the caps before testing the service ports.

4. Minimize the amount of wind blowing through the test area, as this will make small leaks harder to find.
5. Set the detector on the most sensitive setting.
6. Start at a point along the refrigerant loop, and methodically follow the refrigerant path, test all around O-ring connections and crimped ends until you reach the starting point.
7. When the detector indicates a suspected leak, move it away from the suspect area, then re-check to the location after the detector has cleared.
    - If the detector continues to indicate a leak, adjust the sensitivity of the detector to match the designed leak specifications shown in "Acceptable Leak Rates by Component" Table, in **Specifications, 400**, and retest the suspected area to confirm the leak.
    - Mark any confirmed leaks, then change the sensitivity back to high and continue checking the system.
8. After the entire system has been checked, recover the refrigerant, investigate each leak point to determine what component failed, and how, then repair the leak.
9. Recharge the refrigerant system, then use the electronic leak detector to confirm that each connection opened during the repair is sealed within the design specifications provided in the "Acceptable Leak Rates by Component" table in **Specifications, 400**.

Denso A/C Compressor Pressure Test

NOTE: This test is meant to be performed after a failure has been repaired, which may have caused damage to the compressor due to low refrigerant or oil levels. Compressors cause refrigerant to flow through the system by creating a pressure differential, high and low pressures. The compressor pressure test must be performed with the refrigerant system discharged, and the refrigerant lines disconnected.

If the A/C system is experiencing a low "high side" pressure, or a high "low side" pressure, test the performance of the compressor as follows.

1. Place your thumb over the suction port of the compressor and slowly rotate the compressor. An even suction should be felt as the compressor is turned.
2. Place your thumb over the discharge port and slowly rotate the compressor. An even pressure should be felt as the compressor is turned.
3. If an uneven pressure is felt on either the suction or discharge port while turning the compressor, internal damage has occurred, and the compressor will not perform properly.

Electrical Component Checking

Blower Motor Circuit Tests

The blower motor power and ground are supplied directly to the blower motor assembly. The blower speed is controlled by the fan switch on the control module (climate control panel). The control module sends a pulse width modulated (PWM) signal to the blower motor. The frequency of this signal is 2000 Hz. The pulse width varies with the fan switch selection.

The protection modes for the blower motor are as follows:

- Reverse Voltage Protection—The motor will not operate if the polarity of the motor leads, circuits 98F and ground, are reversed.
- Current Protection—If the motor exceeds the maximum limit, the speed will be reduced until the current is within the limits (23.5A maximum).
- Temperature Protection—If the motor's internal temperature sensor senses that the temperature is too high, the blower speed is reduced to 1000 rpm to reduce the load on the motor and a comparison is made between the sensor reading and the maximum limit. If the temperature is still too high, the blower speed is further reduced to the minimum value of approximately 500 rpm and a temperature comparison is made to the maximum. If, after the second comparison, the temperature is still too high, the motor will shut down until it has cooled sufficiently.

Perform the tests in **Table 1** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the blower motor passes the tests in **Table 1** and the blower still does not operate properly, check the blower motor. To quickly check for normal operation, set the fan switch to high and listen for a change in the sound of the blower near the HVAC unit while pressing the recirculation button on and off. The blower will be louder when recirculation is enabled.

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

The A/C compressor clutch is controlled by the control module (climate control panel). When the control module determines that the A/C compressor is required, it grounds the A/C request input to the bulkhead module (BHM). When the BHM receives the A/C request signal from the climate control panel, it will apply power to the A/C clutch output when the following conditions are met:

- engine has been running more than 5 seconds;
- battery voltage is greater than 9.25V;
- low air pressure warning is not active on the ICU;
- A/C clutch has not been engaged in the previous 15 seconds.

NOTE: The **A/C clutch cycle timer strategy** is implemented differently, depending on BHM software versions. With BHM software version 6.1, the total A/C clutch cycle time (on + off time) is a minimum of 15 seconds. This ensures that the A/C compressor does not cycle more than four times per minute. With BHM software versions 6.4 and 6.5, the minimum compressor off time is 15 seconds. This means the total cycle time (on + off time) will always exceed 15 seconds. This, too, ensures that the A/C compressor does not cycle more than four times per minute.

The BHM sends power to energize the A/C clutch. A binary switch is wired into this circuit, which will prevent the compressor clutch from engaging if the refrigerant pressure is too high or too low.

When **all** of the following conditions are met, the control module will send the A/C request signal to the bulkhead module:

- The air selection switch is in one of the A/C or defrost settings, or the recirculation mode is on.
- The fan switch is on any setting other than OFF.

Electrical System Tests

Blower Motor Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
main power to blower motor	battery switch ON (if equipped) key OFF blower motor connector removed	Measure between pin 4 of blower motor connector and negative battery post.	12V*	Check fuse F2 in the PDM under the hood. If the fuse is blown, check for shorted wiring or a damaged blower motor. Check for an open in circuit 98F.
blower motor ground circuit	battery switch ON (if equipped) key OFF blower motor connector removed	Measure between pin 3 of blower motor connector and the positive battery post.	12V*	Check for an open in blower motor ground circuit.
PWM signal from control module	battery switch ON (if equipped) key ON, engine off blower motor connector connected change the fan (blower) speed setting on the control module and observe frequency using the digital multimeter (DMM)	Backprobe pins 4 and 5 of the blower motor connector, harness side (DMM set to measure frequency).	0 Hz fan off 0 Hz fan on high 2000 Hz all other speeds	Check circuit 338H. Check control module.
voltage drop (power circuit)	battery switch ON (if equipped) key ON, engine off all connectors connected fan (blower) speed on high	Backprobe pin 4 at the blower motor connector, other lead on positive battery post.	less than 0.5V	Locate high resistance or open in circuit 98F.
voltage drop (ground circuit)	battery switch ON (if equipped) key ON, engine off all connectors connected fan (blower) speed on high	Backprobe pin 3 at the blower motor connector, other lead on negative battery post.	less than 0.5V	Locate high resistance or open in blower motor ground circuit.
blower motor current draw	battery switch ON (if equipped) key ON, engine off all connectors connected fan (blower) speed on high	Use current clamp around circuit 98F or blower motor ground wire.	less than 23.5A	Check blower motor.

* The voltage should be approximately the same as the battery voltage.

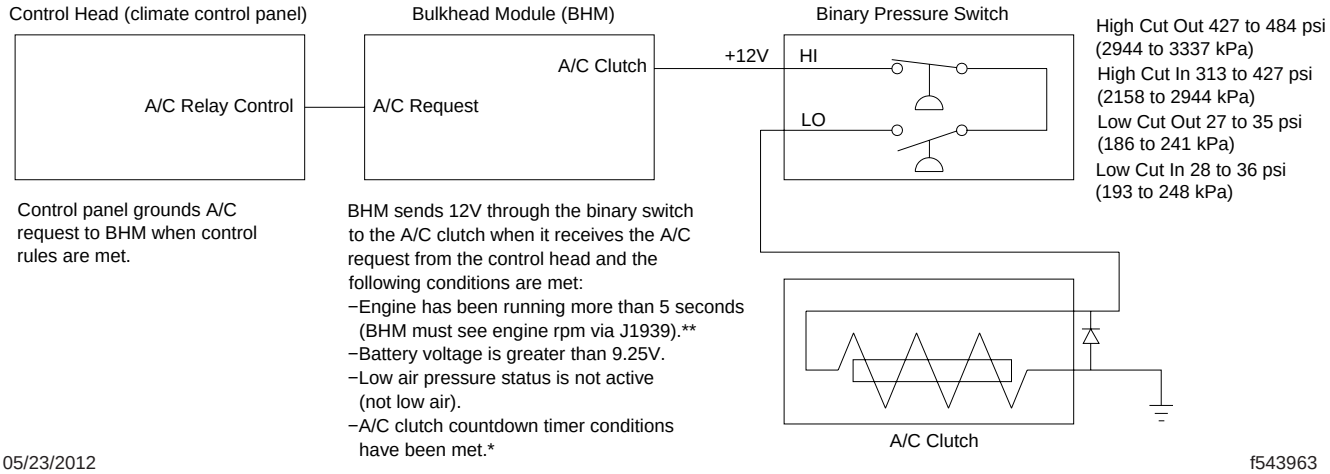
Table 1, Blower Motor Circuit Tests

- The evaporation sensor temperature is above 40.1°F (4.5°C).

When these conditions exist, the control module sends the A/C request signal to the bulkhead module. See **Fig. 1**.

NOTE: The A/C signal will remain active until the evaporator sensor reaches 38.3°F (3.5°C), the fan is turned off, or the air selection switch is taken out of defrost or A/C mode.

See **Table 2** for the A/C clutch circuit tests. Perform the tests in **Table 2** in the sequence presented. The



*See **A/C clutch cycle timer strategy** note above.
NOTE: Binary pressure switch positions indicate little or no system pressure.

Fig. 1, A/C Clutch Control Circuit

directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check.

NOTE: If these tests pass and the A/C clutch still will not engage, check the following—

- make sure that the air system does not have an active low air pressure warning;
- make sure that the battery voltage to all BHM inputs is above 9.25V;
- make sure that the engine speed is available (make sure it registers on the tachometer).

Recirculation

Recirculation Mode

Recirculation mode allows the driver to choose between fresh air or recirculated air moving through the HVAC system. When recirc mode is selected, all of the air through the front HVAC unit is recirculated within the cab, except when the unit is in partial recirc mode, which is explained in "Partial Recirc Mode."

Using the recirculation mode prevents dusty or smoky air from entering the cab and provides better air conditioning performance since the cab air is already cooled and less humid than outside air. Humidity holds a lot of heat.

Partial Recirc Mode

After recirc mode has been on for 20 minutes, the system enters partial recirc mode to introduce a controlled amount of fresh air to the cab. This prevents the air from becoming stagnant if left in recirc mode. The recirc door partially opens to one of two partially open positions depending on vehicle speed. When the vehicle is stopped or moving very slowly, the recirc door opens to its widest partially open position. When the vehicle is moving at slow to moderate speeds, the recirc door opens to its most narrow partially open position. Pressing the recirc button again resets the 20-minute timer and the system goes into full recirc again.

Actuator Stepper Motors–Temperature, Recirc, and Mode

The actuator stepper motors are used to precisely position the temperature control, recirc, and air selection mode doors within the HVAC unit. The motors can operate in both forward and reverse direction. The motor direction and position is controlled by the FCU.

Electrical System Tests

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement				
Test	**Conditions**	**Test Point/Method**	**Good Result**	**What to Do if Test Fails**
A/C request input	key ON, engine ON air selection switch in one of A/C settings fan (blower) speed on any setting but OFF connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to see if the A/C request is seen by the BHM	ServiceLink/Datalink Monitor NOTE: Make sure the Datalink Monitor template is **not** in Test Mode. The control module should request A/C. This will cause the "A/C Request" annunciator on the template to indicate that the request is on. If the annunciator does not indicate that a request for A/C is received, check the settings on the control module before proceeding with "What to Do if Test Fails."	A/C request is received by the BHM	Perform the "Evaporator Probe Circuit Tests." Check wiring between the control module and the bulkhead module. Check for an open circuit. Check the control module. Check the bulkhead module. Try to manually ground the A/C request input while observing the template to confirm.
A/C clutch circuit*	key ON, engine OFF connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to manually actuate the A/C clutch output	ServiceLink/Datalink Monitor NOTE: Put the template in "Test Mode" and actuate the A/C clutch by selecting the button for "Clutch On." You should hear a distinct click when the clutch engages. The A/C clutch annunciator (BHM to clutch) should turn on when the output is energized. If this annunciator indicates that the output is on but the clutch does not engage, then the problem is in the A/C clutch circuit and not with the BHM. If the A/C clutch annunciator does not indicate that the output is energized when the output is turned on and the clutch does not engage, then the problem is with the BHM.	A/C clutch should engage	Check continuity across the binary switch. If the circuit is open, check if the refrigerant pressure is within operating range of the binary switch. (Refrigerant pressure may be very low or too high.) If pressures are okay, replace binary switch. Check for faulty wiring. Check for faulty A/C clutch ground circuit. Check for faulty A/C clutch coil (coil resistance should be 3Ω ±0.5Ω). Check for faulty BHM (see note in Test Point/Method column).

* Circuit faults with the A/C clutch output may generate bulkhead module fault codes.

Table 2, A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

Actuator Stepper Motor Test Procedures

Temperature Blend Door Actuator Circuit Tests

The temperature blend door actuator controls the amount of air that is routed through the heater core. The temperature blend door actuator is controlled by the temperature control switch on the control module (climate control panel). The control module senses the door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control module to the sensor.

The target position is based on the temperature control switch setting and internal control module algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired temperature setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The temperature blend door should move from one extreme position to the other when turning the temperature control switch from cold to hot or from hot to cold.

Follow the tests in **Table 3** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the temperature blend door actuator passes the tests in **Table 3** and the actuator still does not operate properly, check for mechanical problems with the actuator.

Temperature Blend Door Actuator Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
actuator motor drive circuit	key ON, engine OFF temperature blend door actuator connector removed fan (blower) switch on low change temperature setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the temperature blend door actuator connector.	9V+ for about 1 second*	Check wiring between control module and temperature blend door actuator. If wiring is okay, replace the control module.
actuator position sensor reference voltage circuit	key ON, engine OFF temperature blend door actuator connector removed	Measure between pin 7 of the temperature blend door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key ON, engine OFF temperature blend door actuator connector removed	Measure between pin 8 of the temperature blend door actuator connector and the battery positive post.	12V*	
actuator position sensor feedback signal circuit	key ON, engine OFF all connectors connected	Backprobe pins B11 and B5 at control module connector.	0.50V (full hot) to 4.00V (full cold)†	Check wiring between control module and temperature blend door actuator.‡ If wiring is okay, replace the actuator.‡

* The voltage should be approximately the same as the battery voltage.

† Values are approximate.

‡ It is assumed that reference voltage and ground circuits are functioning.

Table 3, Temperature Blend Door Actuator Circuit Tests

Air Distribution Door Actuator Circuit Tests

The air distribution (mode) door actuator controls the direction the air is routed through the HVAC ducts in the cab. The air distribution door actuator is controlled by the air selection switch on the control module (climate control panel). The control module senses the air distribution door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control module to the sensor.

The target position is based on the air selection switch setting and internal control module algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired air selection setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The air distribution door should move from one extreme position to the other when turning the air selection switch from the far left to the far right or from the far right to the far left.

Follow the tests in **Table 4** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the air distribution door actuator passes the tests in **Table 4** and the actuator still does not operate properly, check for mechanical problems with the actuator. To quickly check for normal operation, feel for air flowing from the correct outlet in each air selection setting.

Air Distribution Door Actuator Circuit Tests

Test	Conditions	Test Point	Good Result	What to Do if Test Fails
actuator motor drive circuit	key ON, engine OFF air distribution door actuator connector removed fan (blower) speed on low change the air selection setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the air distribution door actuator connector.	9V+ for about 1 second*	Check wiring between control module and air distribution door actuator. If wiring is okay, replace the control module.
actuator position sensor reference voltage circuit	key ON, engine OFF air distribution door actuator connector removed	Measure between pin 10 of the air distribution door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key ON, engine OFF air distribution door actuator connector removed	Measure between pin 8 of the air distribution door actuator connector and the battery positive post.	12V*	

Air Distribution Door Actuator Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
actuator position sensor feedback signal circuit	key ON, engine OFF all connectors connected	Backprobe pins B10 and B5 at control module connector.	0V (far right) to 5V (far left)	Check wiring between control module and air distribution door actuator.† If wiring is okay, replace the actuator.†

* The voltage should be approximately the same as the battery voltage.

† It is assumed that reference voltage and ground circuits are functioning.

Table 4, Air Distribution Door Actuator Circuit Tests

Recirculation Door Actuator Circuit Tests

The recirculation door actuator controls the source of the air, fresh or recirculated, that is routed through the HVAC ducts in the cab. The recirculation door actuator is controlled by the recirculation button on the control module (climate control panel).

The control rules for the recirculation mode are as follows:

- The recirculation mode is not available in the defrost settings.
- The default at power-up is fresh air unless the fan switch is in the OFF position. When the fan switch is in the OFF position, the recirculation mode is the default mode, but the LED is not illuminated.
- When the recirculation mode is enabled, it will remain on until one of the following occurs:
  - – the air selection switch is moved to a defrost mode;
  - – the recirculation button is pressed;
  - – the ignition is cycled;
  - – 20 minutes have passed and the recirculation timer has expired.

NOTE: The system enters partial recirculation mode for five minutes, then resumes full recirculation mode for 20 minutes. This cycle repeats as long as the system remains in recirculation mode.

The control module senses the recirculation door position by reading the feedback voltage from the actuator position sensor. The feedback voltage will be less than the 5V reference voltage sent by the control module to the sensor.

The target position is based on the recirculation button setting and internal control module algorithms. The desired position is considered reached when one of the following conditions is true, although this does not necessarily mean that the position actually corresponds to the desired recirculation button setting (for example, if the actuator movement is limited due to an obstruction).

- The actuator feedback position has been reached.
- The actuator is stalled for more than 1 second; the actuator feedback position does not change for more than 1 second.
- The target position corresponds to an end stop and an additional 1 second extra drive in the same direction (to guarantee sealing) has been performed.

The recirculation door should move from one extreme position to the other when the recirculation button is pressed on and then pressed off.

Perform the tests in **Table 5** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check. If the recirculation door actuator passes the tests in **Table 5** and the actuator still does not operate properly, check for mechanical problems with the actuator. To quickly check for normal operation, set the fan switch to high and listen for a change in the sound of the blower near the HVAC unit while pressing the recirculation button on and off. The blower will be louder when recirculation is enabled.

Electrical System Tests

Recirculation Door Actuator Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
actuator motor drive circuit	key ON, engine OFF recirculation door actuator connector removed fan (blower) speed on low change the recirculation setting while observing the digital multimeter (DMM)	Measure across pins 5 and 6 of the recirculation door actuator connector.	9V+ for about 1 second*	Check wiring between control module and recirculation door actuator. If wiring is okay, replace the control module.
actuator position sensor reference voltage circuit	key ON, engine OFF recirculation door actuator connector removed	Measure between pin 10 of the recirculation door actuator connector and the battery negative post.	5V	
actuator position sensor reference ground circuit	key ON, engine OFF recirculation door actuator connector removed	Measure between pin 8 of the recirculation door actuator connector and the battery positive post.	12V*	
actuator position sensor feedback signal circuit	key ON, engine OFF all connectors connected	Backprobe pins A11 and B5 at control module connector.	0.8V (recirc. on) to 4.7V (recirc. off)	Check wiring between control module and recirculation door actuator.† If wiring is okay, replace the actuator.†

* The voltage should be approximately the same as the battery voltage.

† It is assumed that reference voltage and ground circuits are functioning.

Table 5, Recirculation Door Actuator Circuit Tests

Evaporator Temperature Sensor

General Information

The evaporator temperature sensor is located on the evaporator. The sensor input to the FCU is used to control the A/C compressor in order to prevent evaporator freezing. The sensor has a negative temperature coefficient (NTC), which means that its resistance decreases as temperature increases.

Evaporator Probe Circuit Tests

The evaporator temperature sensor is a resistive element, where the resistance increases as the temperature decreases. The control module (climate control panel) uses this sensor to determine the evaporator temperature. The control module uses the temperature information to determine if the A/C compressor should be engaged or not in order to prevent the evaporator core from freezing. As refrigerant flows through the evaporator, condensation will form on the surface of the evaporator. If this condensation freezes because the evaporator temperature is too low, airflow will be restricted through the core and poor cooling will result. The control module will shut off the compressor when the evaporator temperature is near the point where freezing may occur. See **Table 6** for evaporator probe temperature versus resistance values.

Perform the tests in **Table 7** in the sequence presented. The directions under the column "What to Do if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the specified repair or check.

Evaporator Probe Temperature/Resistance	
Temperature: °F (°C)	**Resistance: ohms**
-40 (-40)	92757
-22 (-30)	48790
-4 (-20)	26757

Evaporator Probe Temperature/Resistance	
Temperature: °F (°C)	**Resistance: ohms**
14 (-10)	15252
32 (0)	9000
50 (10)	5485
68 (20)	3443
86 (30)	2221

Evaporator Probe Temperature/Resistance	
Temperature: °F (°C)	**Resistance: ohms**
104 (40)	1468
122 (50)	993.2

Table 6, Evaporator Probe Temperature/Resistance

Evaporator Probe Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
evaporator temperature probe	key OFF, engine OFF sensor probe removed and disconnected fill a cup with ice then add water to make an ice-water bath NOTE: use mostly ice and allow time for temperature to stabilize at 32°F (0°C) place the tip of the evaporator probe in the ice-water bath for 5 minutes before testing—leave the tip immersed while taking the resistance measurement—be sure the meter reading is stable before noting the final measurement	Measure across pins on the temperature probe.	for pre-1-8-07: 16,000 to 16,730Ω at 32°F (0°C) — for 1-8-07 on: 8910 to 9090Ω at 32°F (0°C)	Replace temperature probe.
evaporator temperature probe circuit test	battery switch ON (if equipped) key ON, engine OFF sensor probe installed, but connector is disconnected	Measure across temperature probe connector terminals.	5V	Check for an open in circuits 338K and 338GP. If wiring is okay, replace the control module.

Table 7, Evaporator Probe Circuit Tests

Fault Codes

If the A/C clutch is not working, use ServiceLink to check for fault codes. Use **Table 1** to diagnose A/C clutch engagement issues, and **Table 2** to diagnose backlighting problems. Refer to **Table 3** and **Table 4** for a description of the fault codes.

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement				
Test	**Conditions**	**Test Point/Method**	**Good Result**	**What to Do if Test Fails**
A/C request input	key ON, engine ON air selection switch in one of A/C settings fan (blower) speed on any setting but OFF connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to see if the A/C request is seen by the BHM	ServiceLink/Datalink Monitor NOTE: Make sure the Datalink Monitor template is **not** in Test Mode. The control module should request A/C. This will cause the "A/C Request" annunciator on the template to indicate that the request is on. If the annunciator does not indicate that a request for A/C is received, check the settings on the control module before proceeding with "What to Do if Test Fails."	A/C request is received by the BHM	Perform the "Evaporator Probe Circuit Tests." Check wiring between the control module and the bulkhead module. Check for an open circuit. Check the control module. Check the bulkhead module. Try to manually ground the A/C request input while observing the template to confirm.
A/C clutch circuit*	key ON, engine OFF connect ServiceLink and use the "A/C Clutch Function" Datalink Monitor template to manually actuate the A/C clutch output	ServiceLink/Datalink Monitor NOTE: Put the template in "Test Mode" and actuate the A/C clutch by selecting the button for "Clutch On." You should hear a distinct click when the clutch engages. The A/C clutch annunciator (BHM to clutch) should turn on when the output is energized. If this annunciator indicates that the output is on but the clutch does not engage, then the problem is in the A/C clutch circuit and not with the BHM. If the A/C clutch annunciator does not indicate that the output is energized when the output is turned on and the clutch does not engage, then the problem is with the BHM.	A/C clutch should engage	Check continuity across the binary switch. If the circuit is open, check if the refrigerant pressure is within operating range of the binary switch. (Refrigerant pressure may be very low or too high.) If pressures are okay, replace binary switch. Check for faulty wiring. Check for faulty A/C clutch ground circuit. Check for faulty A/C clutch coil (coil resistance should be 3Ω ±0.5Ω). Check for faulty BHM (see note in Test Point/Method column).

* Circuit faults with the A/C clutch output may generate bulkhead module fault codes.

Table 1, A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

Fault Code Driven Diagnosis

Backlighting Circuit Tests				
Test	**Conditions**	**Test Point**	**Good Result**	**What to Do if Test Fails**
backlighting circuit ground test	battery switch ON (if equipped) key OFF, engine OFF control module connector disconnected	Measure between pin B8 of the control module connector and the positive battery post.	12V*	Check for an open in the control module ground circuit.
backlighting power test	battery switch ON (if equipped) key OFF, engine OFF control module connector disconnected headlight switch ON	Measure voltage between pins A2 (positive lead) and B8 (negative lead) on the control module connector while toggling the dimmer switch between full dim and full bright.	voltage should be about 1.2V at full dim and 10.8V at full bright	Check circuit 29A for an open/short. If okay, refer to **Group 54** for further diagnosis.
backlighting pulse width modulated (PWM) signal test	battery switch ON (if equipped) key OFF, engine OFF control module connector disconnected headlight switch ON	Measure frequency between pins A2 and B8 on the control module connector.	400 Hz	Check circuit 29A for an open/short. If okay, refer to **Group 54** for further diagnosis.

* The voltage should be approximately the same as the battery voltage.

Table 2, Backlighting Circuit Tests

J1587 Fault Codes, HVAC (bulkhead module related) MID 164				
MID	**SID**	**FMI**	**Fault Description**	**Action**
164	057	05	A/C clutch output open circuit (low current)	Check circuit 98A for an open circuit. Check binary switch; it may be open. If open, check for low or high refrigerant pressure. Also check the switch itself. Check A/C clutch coil for an open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for a short to ground.

Table 3, J1587 Fault Codes, HVAC (bulkhead module related) MID 164

J1939 Fault Codes, HVAC (bulkhead module related) Source Address (SA) 33				
SA	**SPGN**	**FMI**	**Fault Description**	**Action**
33	1550	05	A/C clutch output open circuit (low current)	Check circuit 98A for an open circuit. Check binary switch; it may be open. If open, check for low or high refrigerant pressure. Also check the switch itself. Check A/C clutch coil for an open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for a short to ground.

Table 4, J1939 Fault Codes, HVAC (bulkhead module related) Source Address (SA) 33

Symptom Troubleshooting Tables

Problem — No Fresh Air (nonrecirculation mode)

Problem — No Fresh Air (nonrecirculation mode)	
Possible Cause	**Remedy**
Mechanical problem with the recirculation door actuator.	Inspect the recirculation door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Recirculation Door Actuator Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	
The blower motor is in protection mode.	Refer to "Blower Motor Circuit Tests" in **Subject 330** for diagnosis.

Problem — Warm Airflow When the Air Conditioner is On; A/C is Not Working; or Poor Performance of A/C

Problem — Warm Airflow When the Air Conditioner is On; A/C is Not Working; or Poor Performance of A/C	
Possible Cause	**Remedy**
Low refrigerant charge in the system.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full charge of refrigerant.
Too much refrigerant in the system.	Evacuate the system, then add a full charge of refrigerant.
Moisture in the system.	If moisture is in the system, ice crystals may form and block the flow of refrigerant at the expansion valve or other places in the system. Recover the refrigerant, replace the receiver-drier, evacuate the system, and add a full charge of refrigerant.
The refrigerant compressor is not working.	The refrigerant charge is low or high.
	The refrigerant compressor clutch or drive belt needs repair or replacement.
	Refer to "A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement" in **Subject 330** for diagnosis.
Ice has formed on the evaporator coil.	Defrost the evaporator coil before resuming operation of the air conditioner. Refer to "Evaporator Probe Circuit Tests" in this subject for diagnosis.
Temperature blend door actuator is not working.	Refer to "Temperature Blend Door Circuit Tests" in **Subject 330** for diagnosis.
	Mechanical problem with temperature blend door actuator.
Blockage in A/C system such as lines, evaporator, condenser, or expansion valve.	Remove the blockage.
The blower motor is in protection mode.	Refer to "Blower Motor Circuit Tests" in **Subject 330** for diagnosis.
The evaporator probe isn't working or is out of range.	Refer to "Evaporator Probe Circuit Tests" in **Subject 330** for diagnosis.

Problem — Low-Side Pressure Too Low

Problem — Low-Side Pressure Too Low	
Possible Cause	**Remedy**
The expansion valve is not working.	Check the expansion valve for blockage and function. Blockage may be due to moisture causing ice formation.

Symptom Driven Diagnosis

Problem — Low-Side Pressure Too Low	
Possible Cause	**Remedy**
There are line or component restrictions.	Remove the restrictions.
The refrigerant charge is low.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full refrigerant charge.

Problem — High-Side Pressure Too High

Problem — High-Side Pressure Too High	
Possible Cause	**Remedy**
Airflow through the condenser is restricted.	Check for and remove dirt or debris in front of the condenser and radiator.
	Check the engine fan operation.
There is an internal restriction in the condenser indicated by ice buildup on the condenser or a cool spot on the line from the condenser to the receiver-drier.	Replace the condenser. If compressor failure recently occurred, the blockage may be due to debris from a failed compressor.
Air is in the refrigerant.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier if necessary, and add a full charge of refrigerant.
The engine is overheated.	Check the engine cooling system.
Restriction in the compressor discharge line.	Replace the line.

Problem — Compressor Runs Continuously

Problem — Compressor Runs Continuously	
Possible Cause	**Remedy**
Low refrigerant charge in the system.	Perform a leak test. Repair any leaks, evacuate the system, replace the receiver-drier, and add a full charge of refrigerant.
The evaporator probe isn't working.	Refer to "Evaporator Probe Circuit Tests" in **Subject 330** for diagnosis.

Problem — Little or No Heat

Problem — Little or No Heat	
Possible Cause	**Remedy**
Low engine coolant.	Check coolant level. If low, check for source of leak and repair as necessary.
Plugged heater core.	Flush or replace the heater core as necessary.
Engine thermostat is not working.	Check to see if the engine thermostat is stuck open. Refer to **Section 20.00, Subject 300** for diagnosis.
Engine fan on all the time.	Refer to **Group 20** for diagnosis.
Mechanical problem with temperature blend door actuator.	Inspect the temperature blend door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Temperature Blend Door Actuator Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	

Problem — Water or Liquid Leaking from the Air Conditioner

Problem — Water or Liquid Leaking from the Air Conditioner	
Possible Cause	**Remedy**
The drain tubes are plugged.	Clean the drain tubes.
Heater core is leaking.	Leak test and replace the heater core if necessary.

Problem — Recirculation Mode Not Working

Problem — Recirculation Mode Not Working	
Possible Cause	**Remedy**
Air selection switch is set to full or partial defrost.	Recirculation mode is not available in any of the defrost settings. This is not a problem.
Mechanical problem with the recirculation door actuator.	Inspect the recirculation door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Recirculation Door Actuator Circuit Tests" in **Subject 330** for diagnosis.
The recirculation door actuator is not working.	
The control module is not working.	

Problem — Air Selection Switch Not Working

Problem — Air Selection Switch Not Working*	
Possible Cause	**Remedy**
Mechanical problem with the air distribution door actuator.	Inspect the air distribution door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Air Distribution Door Actuator Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	

* Not able to control where the air is directed.

Problem — No Cool Vent Air on a Heater-Only System

Problem — No Cool Vent Air on a Heater-Only System	
Possible Cause	**Remedy**
Mechanical problem with the temperature blend door actuator.	Inspect the temperature blend door actuator for obstructions or mechanical damage. Correct as necessary.
Problem with the wiring.	Refer to "Temperature Blend Door Actuator Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	

Problem — No Backlighting on the control module

Problem — No Backlighting on the control module	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Backlighting Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	

Symptom Driven Diagnosis

Problem — Blower Not Working

Problem — Blower Not Working	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Blower Motor Circuit Tests" in **Subject 330** for diagnosis.
The control module is not working.	
A fuse is blown.	
The blower motor is not working.	

Specifications

Acceptable Leak Rates by Component	
Component	**Acceptable Leak Rates**
J-Block Body	0.25 oz/yr and greater condemns these components
Evaporators (main and auxiliary)	
Condenser	
Receiver Dryer (Body)	
Lines/Hoses	
Capped Charge Ports	
Mini-Stato seal (1 - when the leak can be tied to a single seal)	
Mini-Stato seals (2 - when the leak cannot be tied to a single seal)	0.50 oz/yr and greater condemns these components
Compressor (shaft seal, housing, etc.)	
TXV (Power Valve and Super Heat Cap)	
Sensor/Switches (O-ring and crimped body connections)	

Table 1, Acceptable Leak Rates by Component

Heating, Ventilation and Air Conditioning (HVAC) System General Description

Stated simply, the air conditioning system operates by circulating refrigerant between two heat transfer units. The unit in the cab absorbs heat from the air in the cab, and the one in front of the radiator gets rid of the heat from the cab, into the outside air. Both units consist of coiled tubing, covered with fins so they transfer heat most efficiently.

The heat transfer unit in the cab is called the evaporator. It is mounted in the dashboard, next to the blower fan. It absorbs heat out of the air in the cab and transfers it to the refrigerant, which carries the heat away. The other heat transfer unit, called the condenser, is usually mounted low in the front end of the vehicle. Hot refrigerant from the evaporator circulates to it, and gives off the stored heat to the air being pulled in by the engine cooling fan and the vehicle's forward movement.

Inside the cab, the blend air heating, ventilating, and air conditioning (HVAC) system uses a brushless blower motor to circulate temperature-controlled air through the cab. The rate of airflow is controlled by a multi-speed fan switch.

The temperature control switch on the climate control panel sets the desired temperature in the cab.

The air selection switch on the control panel controls ducting air from the blower through the cab. On vehicles with air conditioning, a recirculation button on the control panel allows the driver to recirculate the air in the cab and prevent fresh outside air from entering the system.

Recirculation mode helps to warm or cool the cab more quickly, but the cab tends to build more humidity and fog the windows in recirculation mode. Allowing fresh air to enter the system and circulate helps defog the cab. After 20 minutes in recirculation mode, the system automatically enters partial recirculation mode for five minutes, to bring some fresh air into the cab. After five minutes in partial recirculation mode, the system will automatically resume full recirculation for another 20 minutes. The full and partial recirculation cycle will repeat as long as the system remains in recirculation mode. If the recirculation button is pressed when the system is in either recirculation mode, recirculation mode will be canceled. There may be a slight change in the sound within the cab as the system goes into, and out of, partial recirculation mode.

Description of Components

Actuator

The actuator is a combined motor and gearbox which drives the levers and doors within the HVAC assembly. Movement of the levers and doors is controlled by the settings on the climate control panel. A proportional feedback signal is returned from each actuator to the control panel to provide current position information. There are three actuators on the HVAC assembly: a temperature blend actuator, a recirculation actuator, and an air distribution actuator.

Binary Switch

A binary switch disengages the refrigerant compressor clutch, to protect the compressor from harmful operating conditions. It performs two functions.

- If refrigerant system pressure falls too low, the binary switch disengages the compressor clutch. This happens when falling pressure drops below 25.6 to 31.2 psig (177 to 215 kPa). Normal compressor operation resumes when the pressure rises to 25.7 to 34.3 psig (177 to 236 kPa).
- If the refrigerant system pressure rises above 426.5 to 483.5 psig (2941 to 3334 kPa), the binary switch shuts off the compressor clutch. When system pressure falls back to 313 to 426 psig (2158 to 2937 kPa), the compressor resumes operation.

Blower Motor

The brushless blower motor forces air through the HVAC evaporator, and through the duct work into the cab.

Climate Control Panel (control head)

The fan switch, air selection switch, and the temperature control switch are mounted on the climate control panel, which is also called the control head. On HVAC systems with air conditioning, the air recirculation button is mounted on the climate control panel.

General Information

The climate control panel is controlled by a microprocessor and backlit with LEDs (light-emitting diodes).

Condenser

In the condenser, the hot refrigerant gas coming from the compressor turns back into liquid. As it condenses to liquid, the refrigerant gives off the heat it has carried out of the cab. The heat goes out through the condenser tubing and cooling fins, to the air currents created by the engine fan and vehicle movement.

Evaporator

Because the evaporator is an area of low pressure in the system, the boiling point of the refrigerant falls, which helps it absorb heat from the tubing walls and fins of the coils. As it absorbs heat, liquid refrigerant quickly boils and turns into a gas.

As heat is absorbed through the outside surfaces of the evaporator, air passing over the unit loses its heat to these cooler surfaces. Moisture in the air condenses on the outside of the evaporator and drains off as water, dehumidifying the air in the cab.

Evaporator Probe

The temperature of the evaporator is monitored by a variable resistance temperature probe. As the temperature of the evaporator increases, the temperature probe resistance decreases. The evaporator temperature probe is connected to the control head, which controls operation of the refrigerant compressor through the bulkhead module in order to prevent the evaporator core from freezing. When the evaporator temperature reaches 38.3°F (3.5°C), the control head sends a message to the bulkhead module to disengage the refrigerant compressor clutch. The refrigerant compressor will not resume operation until the temperature has risen above 40.1°F (4.5°C).

Expansion Valve

The expansion valve divides the high and low pressure areas of the refrigerant system. high pressure liquid refrigerant from the receiver-drier passes through the expansion valve, and moves into the low pressure area of the evaporator.

The expansion valve proportions the flow rate of refrigerant according to the rate of evaporation in the evaporator. If the amount of liquid in the evaporator drops off, the temperature of the gas going to the compressor rises. This causes a sensor tube in the expansion valve to react to the temperature changes, which causes an orifice in the valve to open or close. Through the orifice, liquid refrigerant is metered into the evaporator.

Fan Cycling Switch

Located on the receiver-drier, the fan cycling switch sends a ground signal to the ECM (electronic control module) to keep the fan turned off, and takes away the ground to engage the fan. The fan will come on if the refrigerant pressure is greater than 300 ±10 psi (2070 kPa ±70 kPa). The fan turns off when the pressure drops below 250 ±10 psi (1725 kPa ±70 kPa).

Heater Core

The heater core is a convoluted tube covered with fins. When the water valve is open, warm engine coolant flows through the heater core tube, heating the tube and fins. The blower motor blows air through the finned tube and into the cab, to heat the cab.

Receiver-Drier

The receiver-drier is a reservoir and filter for liquid refrigerant. It also removes water and acids from the refrigerant. The water-absorbing material (desiccant) in the unit helps stop blockages caused by moisture forming in the expansion valve and other parts of the system.

Refrigerant

Refrigerant is the chemical that absorbs heat from the air in the cab and release it to the air outside the cab.

During compressor operation, refrigerant constantly changes from a gas to a liquid, then back to a gas, depending on whether it is absorbing heat (boiling) in the low pressure evaporator, or releasing absorbed heat in the high pressure condenser.

Refrigerant Compressor

"Heat" in the low pressure gas of the evaporator does not feel warm to the touch, because liquid refrigerant boils at a temperature much lower than the temperature at which water turns to ice. By touch,

the "heated" gas in the coils is very cold. As a result, there is the problem of how to remove heat from subfreezing gas using outside air that may be higher than 100°F (38°C).

With a refrigerant compressor, low pressure gas from the evaporator can be squeezed into a much smaller space. When the gas is compressed, the heat it contains becomes concentrated. In this way, the gas is made hotter than the outside air without adding heat.

If the system pressure rises above 550 ± 50 psi (3792 ± 345 kPa), a pressure relief valve will vent, disengaging the compressor clutch until the pressure drops to 400 psi (2758 kPa).

A second purpose of the compressor is to move refrigerant through the system.

Definition of Terms

Refer to the following terms for a better understanding of the heater and air-conditioning system.

Air Conditioner A system used to control the temperature, humidity, and movement of air in the cab.

Air Cylinder Air-operated device used to open or close vents through which air is pushed into the cab by the blower.

Ambient Air Temperature The temperature of air around an object or the outside temperature.

Binary Switch This switch disengages the refrigerant compressor clutch to protect the compressor from harmful operating conditions.

Blower Motor A blower motor forces air through the HVAC assembly and through the duct work.

Blower Resistor Block Assembly Inline resistors that control the amount of voltage going to the blower motor. By controlling the voltage, you can control the fan speed.

Boiling Point The temperature at which a liquid changes to a gas. The boiling point varies with pressure.

Bulk Charging Use of large containers of refrigerant for charging a refrigerant system. Normally used for charging empty systems.

Charge A specific amount of refrigerant or oil by volume or weight. Also the act of placing an amount of refrigerant or oil into the air conditioning system.

Clutch Cycling Switch (Thermostatic Switch) Engages or disengages the compressor depending on changes in evaporator temperature.

Condensate Water taken from the air, which forms on the outer surface of the evaporator.

Condenser A heat exchanger that is used to remove heat from refrigerant, changing it from a high pressure hot gas to a high pressure warm liquid. Typically the condenser is mounted in front of the radiator.

Contaminants Anything other than refrigerant or refrigerant oil in the system. Usually means water, dirt, or air in the system.

Dehumidify To remove water from the air at the evaporator.

Dehydrate To remove all traces of moisture from the refrigerant system. This process occurs during evacuation.

Desiccant A drying agent used in the receiver-drier to remove moisture and maintain an extremely dry state.

Discharge Line Connects the refrigerant compressor outlet to the condenser inlet.

Discharge Pressure High-side pressure, or condensing pressure, of the refrigerant being discharged from the compressor.

Discharge Service Valve A device that allows high-side pressure to be checked and other service operations to be performed. This valve is located between the receiver-drier and the expansion valve.

Drive Pulley A pulley attached to the front of the engine crankshaft. It drives the compressor clutch pulley with a belt.

Duct A passageway for the transfer of air from one point to another.

Evacuate To place a high vacuum in the refrigeration system to remove air, and dehydrate, or remove traces of moisture.

Evaporate A change of state from a liquid to a gas.

Evaporator A component in which liquid refrigerant changes to a gas after it absorbs heat from the air. Also removes some moisture from the cab air.

Expansion Valve A device that causes a pressure-drop of the refrigerant and also regulates its flow.

General Information

Flooding A condition caused by too much liquid refrigerant going into the evaporator. Usually caused by an expansion valve that is stuck open.

Flushing A process of passing liquid refrigerant through an air conditioner component to remove dirt and water from the part. Liquid refrigerant removes heavy contamination, such as gritty dirt and large dirt buildup.

Freeze-Up Failure of a unit to operate properly because of ice forming at the expansion valve orifice or on the evaporator.

Heater Core A part of the heating system through which hot engine coolant flows to provide heat to the cab, or to adjust the temperature produced by the air conditioner.

Humidity The amount of water vapor in the air.

Hydraulic Lock The return of liquid refrigerant to the compressor, which could destroy the unit.

Leak Detector Any device used to detect refrigerant leaks in a refrigerant system.

Liquid Line high pressure liquid refrigerant is carried back to the evaporator from the condenser by the liquid line to repeat the evaporation/condensation cycle.

Liquid Pressure Pressure of refrigerant in the liquid line from the condenser to the expansion device.

Low Head Pressure High-side pressure that is lower than normal due to a system problem.

Low Suction Pressure Low-side pressure that is lower than normal due to a system problem.

Magnetic Clutch An electrical coupling device used to engage or disengage the compressor.

Manifold Designed to control refrigerant flow for system test purposes. It is used with manifold gauges.

Manifold Gauge A calibrated instrument used for measuring system pressures.

Manifold Gauge Set A manifold that is complete with gauges and charging hoses and is used to measure or test pressure.

Micron A metric unit of length equal to one-millionth of a meter. This unit of measure is used to measure vacuum drawn from a refrigerant system by a vacuum pump.

Nitrogen A colorless, odorless, dry, inert gas.

Opacity A measure of contamination of refrigerant oil in the compressor. Fresh refrigerant oil is clear; when contaminated, it appears cloudy or may have fine particles held in suspension.

Overcharge Too much refrigerant or oil in the system.

Polyalkylene Glycol (PAG) A highly refined synthetic oil used in R–134a air conditioning systems.

PSIA Pounds per square inch, absolute pressure. Pressure exerted by the air at sea level. Atmospheric pressure is usually measured with a mercury barometer.

PSIG Gauge pressure, relative to the local atmosphere. At sea level, 0 PSIG is about 14.7 PSIA, which is standard atmospheric pressure. But in Denver, which is at about 5000 feet altitude, standard atmospheric pressure and PSIG are about 12.5 PSIA. It is possible to have a negative gauge pressure, indicating a vacuum.

Receiver-Drier A combination desiccant, filter, and storage container for liquid refrigerant.

Recovery Removal of the refrigerant from the air conditioning system.

Recycling Removal of contaminants and moisture from R–134a using a recovery and recycling station.

Refrigerant–134a (R–134a) The cooling agent used in automotive air conditioning systems. The chemical name for R–134a is tetrafluoroethane.

Refrigerant Compressor A device used to draw low pressure refrigerant gas from the evaporator and squeeze it into a high-temperature, high pressure gas. A second purpose of the compressor is to move refrigerant through the system.

Refrigeration Cycle The complete circulation of refrigerant through an air conditioning system, accompanied by changes in temperature and pressure.

Relative Humidity The actual water content of the air in relation to the total water the air can hold at a given temperature.

Sensor A temperature- or pressure-sensing unit that is used to sense air temperatures or pressures, and provide a control voltage for operation of automatic temperature control units.

Suction Line The line connecting the evaporator outlet to the compressor inlet.

Suction Pressure Compressor inlet pressure or the system's low-side pressure.

Suction Service Valve A device that allows low-side pressure to be checked and other service operations to be performed. This valve is located between the evaporator and the compressor.

Suction Side The low pressure area of the system, extending from the expansion valve to the compressor inlet.

Thermistor A vacuum pressure sensor that is used to measure, in microns of mercury, the internal system vacuum level after evacuation.

Thermostatic Vacuum Gauge A high-vacuum gauge sensitive to pressures ranging from atmospheric pressure to less than 1 micron of mercury, with scales reading from 25,000 microns to 1 micron of mercury.

Thermostatic Switch A temperature-sensitive switch used to control system temperature and prevent evaporator freeze-up. It does this by controlling the compressor's clutch operation.

Undercharge A system low on refrigerant resulting in lack of cooling and possible compressor damage.

Vacuum Refers to pressure that is less than atmospheric pressure.

Vacuum Pump A mechanical device used to evacuate and create a high vacuum in the refrigerant system.

Vacuum Pump Oil Water soluble oil used in some vacuum pumps to absorb moisture from the refrigerant system.

Vapor The gaseous state of a material.

Principles of Operation

In a blend air system, the heater core is always filled with hot water. Air enters the HVAC assembly through the blower and blows through the evaporator. If the refrigerant compressor is engaged, the air is cooled by moving the heat from it into the evaporator, where the refrigerant absorbs the heat and carries it away. The temperature blend doors then direct the air through or around the heater core, depending on the climate control settings. The temperature blend doors are used to blend the correct amount of cold and hot air to reach the desired temperature.

The temperature blend, air distribution, and recirculation levers and doors are controlled by actuators.

Air Conditioner

When the air conditioner is on, the compressor squeezes the refrigerant into a high-pressure, high-temperature gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid. After it is compressed, refrigerant gas passes out of the discharge port of the compressor and on to the condenser.

At the condenser, air passing over the fins absorbs heat from the hot refrigerant gas. As the gas cools, it changes back to a liquid. The liquid moves to the receiver-drier, which filters it and removes traces of moisture and acids.

From the receiver-drier, liquid refrigerant moves to the expansion valve, which meters the flow into the evaporator and acts as a boundary between the high- and low-pressure sides of the system. The metered release of the expansion valve greatly drops the pressure of the liquid, causing it to expand. The pressure drop lowers the boiling point of the refrigerant and causes it to evaporate quickly, as it absorbs heat from air passing over the evaporator. The resulting cool air is forced into the cab by the blower. The heated refrigerant gas is drawn back into the compressor where the cycle is repeated.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves. When refrigerant gas or liquid contacts leather, the leather will stick to your skin.

⚠ WARNING

Use care to prevent refrigerant from touching your skin or eyes because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come in contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

⚠ WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion that could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, charged, and leak tested. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following guidelines:

- Keep the oil free of contaminants.
- Do not expose the air conditioning system or the PAG oil container to air for more than five minutes. PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use.
- Use care when handling. Spilled oil could damage painted surfaces, plastic parts, and other components such as drive belts.
- Never mix PAG oil with other types of refrigerant oil.

Replacement

IMPORTANT: Daimler Trucks North America LLC does not recommend the use of any type of coolant system sealer or leak stop product.

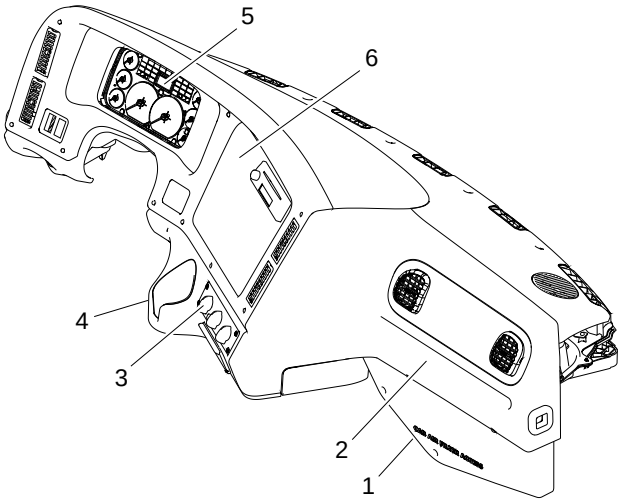
1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals or at the battery shutoff switch.
3. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 100.
4. Remove the surge tank. For instructions, see **Section 20.01**, Subject 120.
5. Remove the Torx® capscrew that attaches the coolant line seal to the heater core. Remove the coolant lines from the heater core.
6. Remove the following dash panels inside the cab. See **Fig. 1**. For instructions, see **Section 60.05**.
   - HVAC cover
   - lower dash panel
   - right-hand dash panel
7. Remove the capscrews that attach the temperature blend actuator to the HVAC assembly and remove the temperature blend actuator. See **Fig. 2**.
8. Remove the capscrews that attach the HVAC wiring harness to the HVAC assembly.
9. If the original heater core is being replaced, use a sharp utility knife to cut within the groove on the heater core access panel. Remove and discard the heater core access panel. See **Fig. 3**.

   If there is a heater core service cover in front of the heater core, remove the service cover.

⚠ WARNING

Failure to wear protective gloves could result in serious skin cuts due to the sharp edges on the heater core fins.

IMPORTANT: A small amount of antifreeze may be present in the heater core. Protect the interior of the vehicle to prevent any damage from an antifreeze spill.



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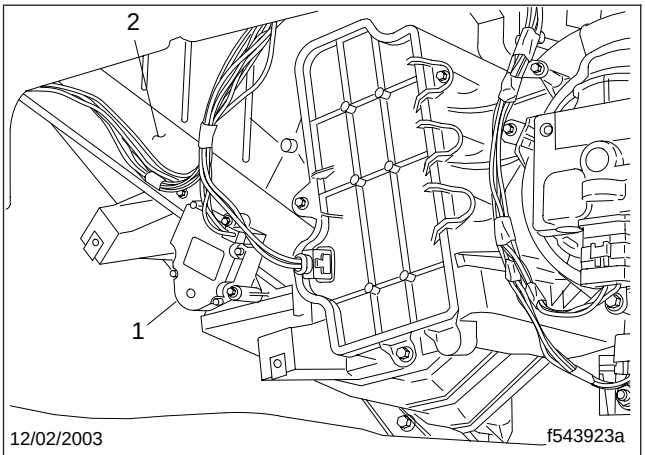
1. HVAC Cover
2. Passenger-Side Dash Panel
3. Climate Control Panel
4. Lower Dash Panel
5. Instrumentation Control Unit (ICU3)
6. Wing Dash Panel

Fig. 1, Dash Panels



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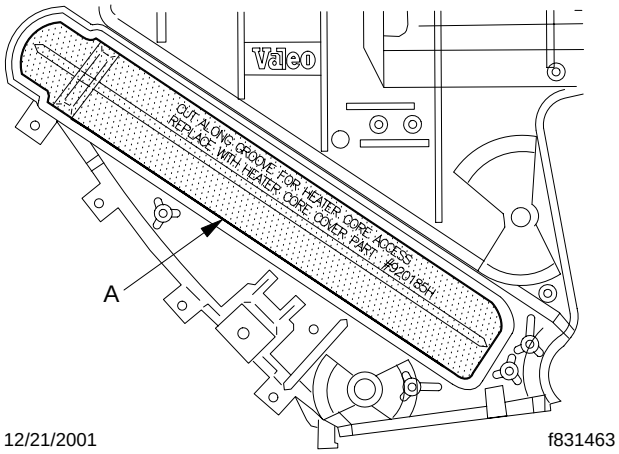
1. Temperature Blend Actuator
2. Heater Core Service Cover

Fig. 2, HVAC Assembly

10. Wearing protective gloves, remove the heater core and drain any remaining coolant from the heater core.
11. Remove any debris or coolant that may be in the heater core housing.

Heater Core Replacement



A. Cut within the groove on the heater core access panel.

Fig. 3, Heater Core Access Panel

12. Wearing protective gloves, install a new heater core in the HVAC assembly.

NOTICE

Do not overtorque the capscrew. Overtorquing the capscrew may crack the heater core.

13. Using a Torx capscrew, attach the coolant lines to the heater core. Tighten the capscrew 30 lbf·in (340 N·cm).
14. Attach the heater core service cover to the HVAC assembly.
15. Using capscrews, attach the HVAC wiring harness to the heater core service cover, securing both the wiring harness and the cover.
16. Using capscrews, attach the actuator to the heater core service cover and the HVAC assembly.
17. Install the dash panels. For instructions, see **Section 60.05**.
18. Install the surge tank. For instructions, see **Section 20.01**, Subject 120.
19. Install the air cleaner. For instructions, see **Section 09.01**, Subject 100.
20. Connect the batteries at the negative terminals or at the battery shutoff switch.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.

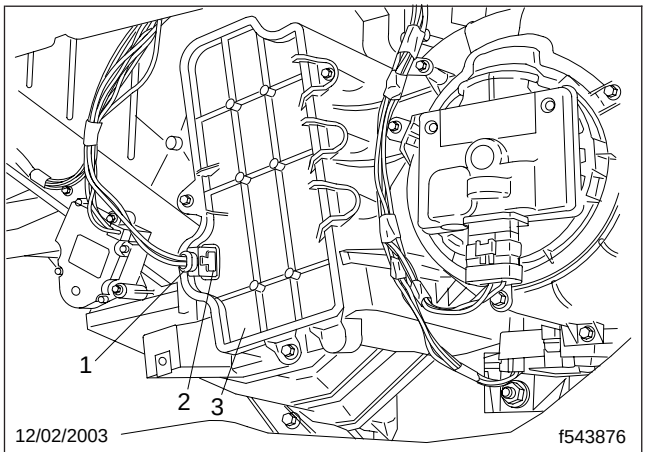
⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 100.
5. Remove the surge tank. For instructions, see **Section 20.01**, Subject 120.
6. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

7. Remove the capscrews that attach the expansion valve to the evaporator lines.
8. Remove the lower HVAC cover inside the cab. For instructions, see **Group 60**.
9. Rotate the evaporator probe counterclockwise and pull the evaporator probe out of the evaporator service cover. See **Fig. 1**.
10. Remove the capscrews that attach the evaporator service cover to the HVAC assembly. Remove the evaporator service cover.
11. Remove the filter and the evaporator.
12. Remove the expansion valve from the evaporator.
13. Make sure the new evaporator is covered with the evaporator liner and the evaporator grommet is installed on the evaporator.



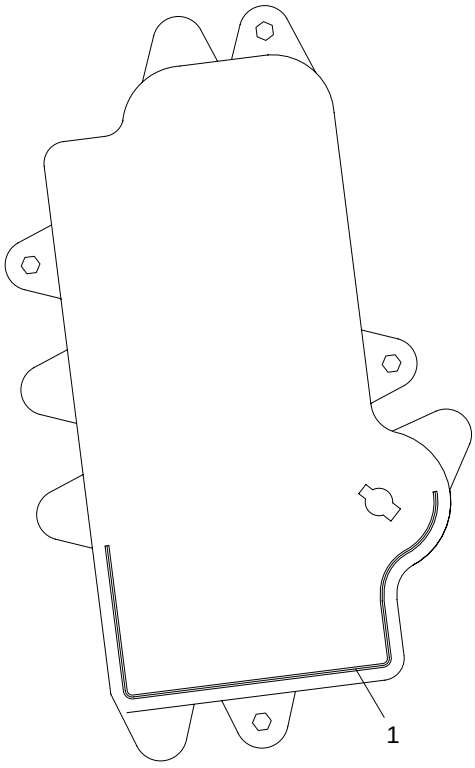
1. Evaporator Probe Wiring Harness
2. Evaporator Probe
3. Evaporator Service Cover

Fig. 1, Evaporator Probe and Service Cover

14. Uncap the evaporator lines.
15. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the evaporator lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
16. Using capscrews, install the expansion valve on the evaporator lines. Tighten the capscrews 35 lbf·in (395 N·cm).
17. Install the evaporator in the HVAC assembly.
18. Uncap the refrigerant lines.
19. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
20. Connect the refrigerant lines to the expansion valve. Tighten the capscrew on the retaining plate 14 to 16 lbf·ft (19 to 22 N·m).
21. Remove the condensate seal from the lower portion of the evaporator service cover, and install a new condensate seal in the same location on the service cover. See **Fig. 2**.
22. Using capscrews, attach the evaporator service cover to the HVAC assembly.

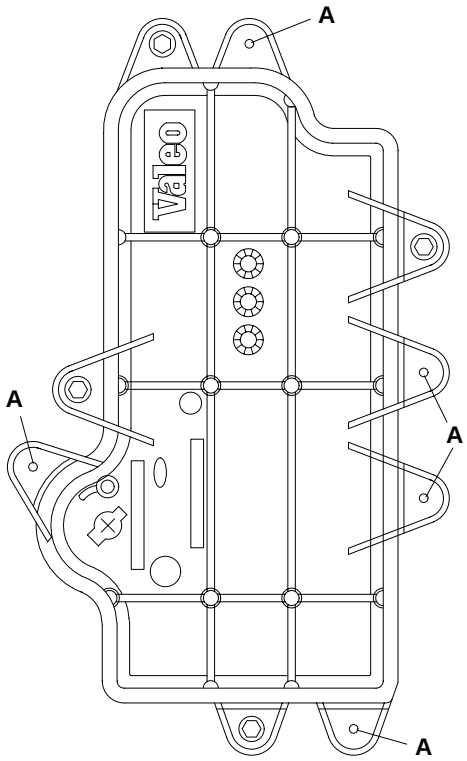
    If a tapped hole that is used to mount the evaporator service cover to the HVAC assembly becomes stripped, drill a new hole in one of the alternative mounting locations on the HVAC assembly. Use a 1/4-inch (6-mm) drill bit to make a new tapped hole. See **Fig. 3**.

Evaporator Replacement



1. Condensate Seal

Fig. 2, Evaporator Service Cover



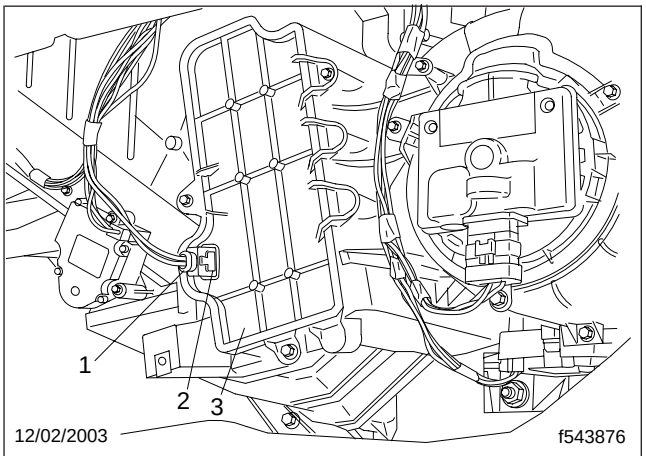
A. Drill a tapped hole in any of these alternative mounting locations.

Fig. 3, Evaporator Service Cover

23. Install the evaporator probe in the evaporator service cover.
24. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
25. Install the surge tank. For instructions, see **Section 20.01**, Subject 120.
26. Install the air cleaner. For instructions, see **Section 09.01**, Subject 100.
27. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220** of this section. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.01**, Subject 130.
28. Return the hood to the operating position.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Press the metal retainer on the wiring harness connector to disconnect the wiring harness from the evaporator probe. See **Fig. 1**.



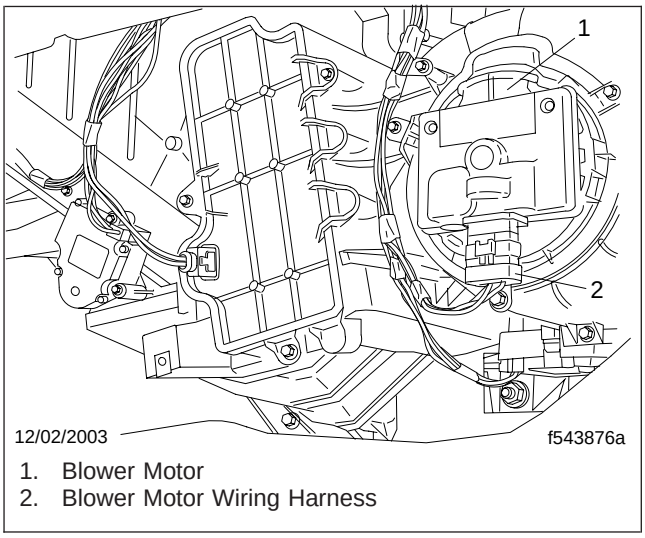
1. Evaporator Probe Wiring Harness Connector
2. Evaporator Probe
3. Evaporator Service Cover

Fig. 1, Evaporator Probe

4. Rotate the evaporator probe counterclockwise and pull the evaporator probe out of the evaporator service cover.
5. Install a new evaporator probe in the evaporator service cover.
6. Attach the wiring harness to the evaporator probe.
7. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the lower HVAC cover. For instructions, see **Group 60**.
4. Disconnect the wiring harness from the blower motor. See **Fig. 1**.



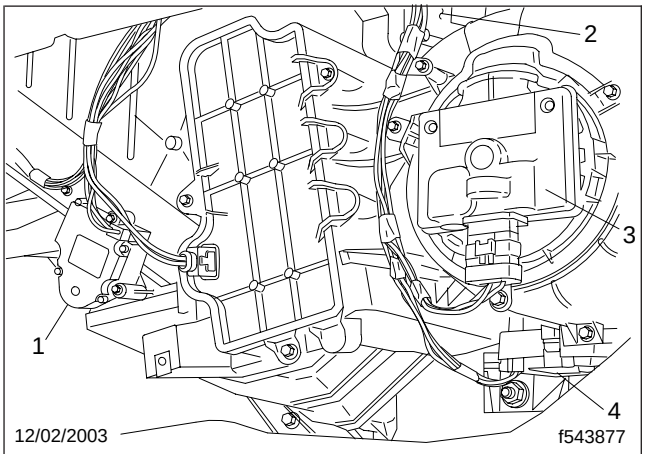
1. Blower Motor
2. Blower Motor Wiring Harness

Fig. 1, Blower Motor

5. Remove the capscrews that attach the blower motor to the HVAC assembly and remove the blower motor.
6. Using capscrews, install the new blower motor on the HVAC assembly.
7. Attach the wiring harness to the blower motor.
8. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
9. Connect the batteries.

Temperature Blend Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the temperature blend actuator. See **Fig. 1**.



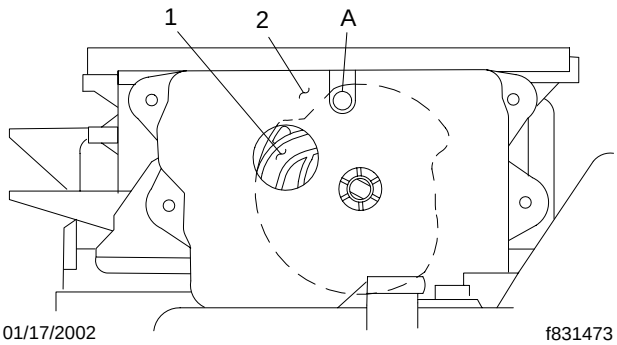
1. Temperature Blend Actuator
2. Air Distribution Actuator
3. Blower Motor
4. Recirculation Actuator

Fig. 1, Actuators

4. Remove the capscrews that attach the actuator to the HVAC assembly and remove the actuator.
5. Using capscrews, install the new actuator on the HVAC assembly. Make sure that the actuator is correctly aligned on the door extension.
6. Attach the wiring harness to the temperature blend actuator.
7. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
8. Remove the chocks from the tires.

Air Distribution Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the air distribution actuator. See **Fig. 1**.
4. Remove the capscrews that attach the actuator to the mounting plate and remove the actuator.
5. Before installing a new actuator, rotate the cam behind the mounting plate so that the alignment hole in the cam is aligned with the hole in the HVAC assembly. See **Fig. 2**.



A. Align the hole in the cam with the hole in the HVAC assembly.

1. Cam
2. Mounting Plate

Fig. 2, Cam Alignment for the Air Distribution Actuator

IMPORTANT: If the alignment hole in the cam is not aligned with the hole in the HVAC assembly, the actuator could be installed with the cam 180 degrees from the correct position. Incorrect alignment of the cam will prevent the air distribution doors from operating correctly.

6. Using capscrews, install the new actuator on the mounting plate. Make sure that the actuator is correctly aligned on the door extension.
7. Attach the wiring harness to the air distribution actuator.
8. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.
9. Remove the chocks from the tires.

Actuator Replacement

Recirculation Actuator Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 60**.
3. Disconnect the wiring harness from the recirculation actuator. See **Fig. 1**.
4. Remove the tread plate cover. See **Fig. 3**.

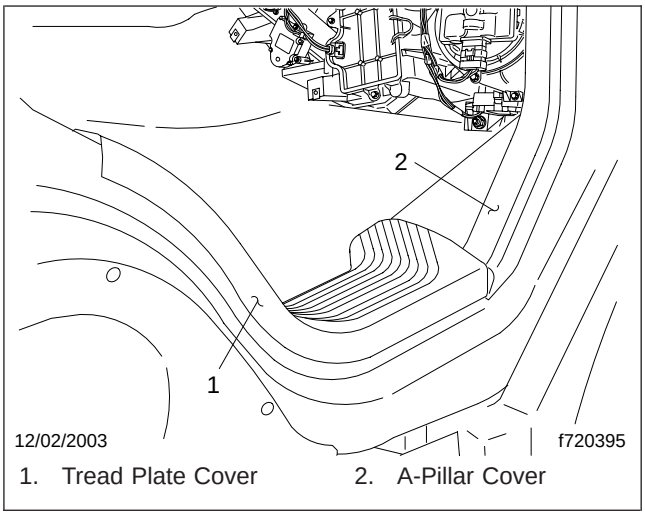


Fig. 3, A-Pillar and Tread Plate Covers

5. Remove the A-pillar cover.
6. Remove the capscrews that attach the actuator to the HVAC assembly and remove the actuator.
7. Using capscrews, install the actuator on the HVAC assembly. Make sure that the actuator is correctly aligned on the door extension.
8. Attach the wiring harness to the recirculation actuator.
9. Attach the A-pillar cover to the cab floor.
10. Attach the tread plate cover to the cab floor.
11. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 60**.

Heater and Air Conditioner Assembly or Heater Assembly Replacement

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.

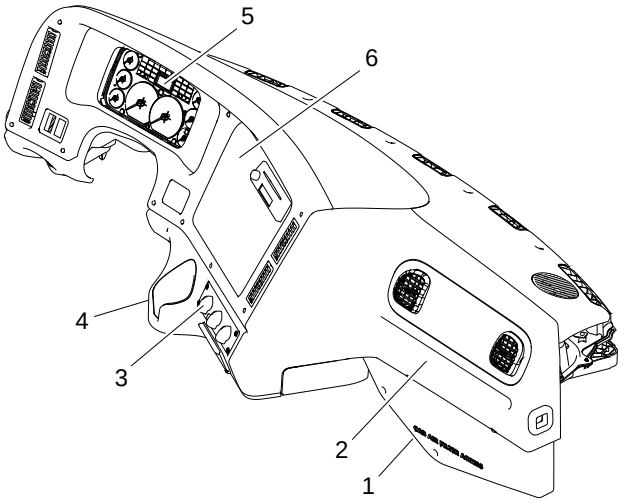
⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

5. If equipped with an air conditioner, recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
6. Remove the Torx® capscrew that attaches the coolant line seal to the heater core and remove the coolant lines.
7. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through the refrigerant lines since shop air is wet (humid).

8. Remove the following dash panels inside the cab. See **Fig. 1**. For instructions, see **Section 60.05**.
   - HVAC cover
   - lower dash panel
   - right-hand dash panel
9. Disconnect the two HVAC wiring harnesses.
10. Remove the capscrews, nuts, and washers that attach the heater and air conditioner assembly or heater assembly to the dash and frontwall and remove the assembly.



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1. HVAC Cover
2. Passenger-Side Dash Panel
3. Climate Control Panel
4. Lower Dash Panel
5. Instrumentation Control Unit (ICU3)
6. Wing Dash Panel

Fig. 1, Dash Panels

11. Using capscrews, nuts, and washers, attach the new heater and air conditioner assembly or heater assembly to the dash and frontwall. Tighten the capscrews 72 to 96 lbf·in (810 to 1080 N·cm). Tighten the nuts 18 to 19 lbf·ft (24 to 26 N·m).
12. Connect the two HVAC wiring harnesses.

NOTE: Do not lubricate the Mini Stat-O-Seals prior to installation.

13. Replace the Mini Stat-O-Seals on the refrigerant lines with new ones.
14. Using a capscrew, attach the refrigerant lines to the expansion valve. Tighten the capscrew on the retaining plate 14 to 16 lbf·ft (19 to 22 N·m).
15. Attach the coolant lines to the heater core. Tighten the capscrew 30 lbf·in (340 N·cm).
16. Install the dash panels. For instructions, see **Section 60.05**.
17. Connect the batteries.
18. If equipped with an air conditioner, evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**.

Heater and Air Conditioner Assembly or Heater Assembly Replacement

19. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.
20. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.

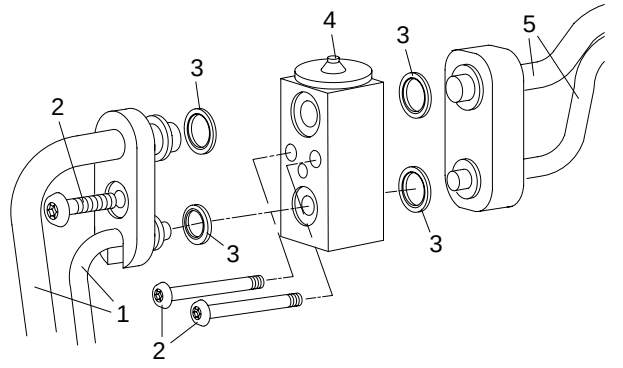
Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Remove the air cleaner. For instructions, see **Section 09.01**, Subject 110.
5. Remove the surge tank. For instructions, see **Section 20.01**, Subject 130.
6. Remove the capscrew that attaches the refrigerant lines to the expansion valve and remove the refrigerant lines. Quickly cap the refrigerant lines. See **Fig. 1**.



1. Refrigerant Line
2. Capscrew
3. Mini Stat-O-Seal
4. Expansion Valve
5. Evaporator Line

Fig. 1, Expansion Valve

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

7. Remove the capscrews that attach the expansion valve to the evaporator lines and remove the expansion valve. If the evaporator lines will be exposed to air for more than five minutes, cap the evaporator lines.
8. If the evaporator lines were capped, uncap the lines.
9. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the evaporator side of the expansion valve. Do not lubricate the Mini Stat-O-Seals prior to installation.
10. Using two capscrews, attach the expansion valve to the evaporator lines. Tighten the capscrews 35 lbf·in (395 N·cm).
11. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate the Mini Stat-O-Seals prior to installation.
12. Attach the refrigerant lines to the expansion valve. Tighten the capscrew on the retaining plate 14 to 16 lbf·ft (19 to 22 N·m).
13. Install the surge tank. For instructions, see **Section 20.01**, Subject 130.
14. Install the air cleaner. For instructions, see **Section 09.01**, Subject 110.
15. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220** of this section.
16. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.02**, Subject 130.
17. Return the hood to the operating position.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

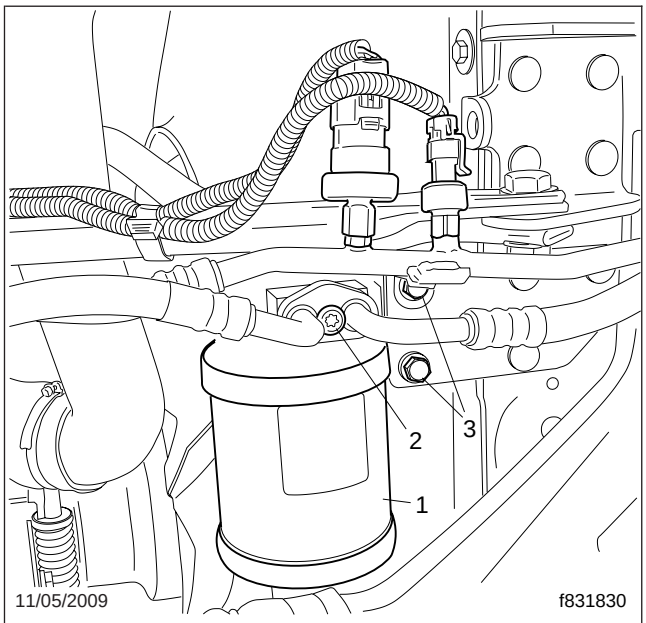
4. Disconnect the refrigerant lines from the receiver-drier. Quickly cap the refrigerant lines.
5. Remove the nuts from the receiver-drier mounting studs. Remove the receiver-drier. See **Fig. 1**

IMPORTANT: If the desiccant cartridge inside the receiver-drier has fallen apart, flush the system and replace the expansion valve and the refrigerant compressor (desiccant matter can't be removed from these parts). A cartridge may fall apart from too much moisture in the system, because of poor evacuation of the system, or lack of maintenance.

6. Install a new receiver-drier on the mounting plate. Tighten the nuts 11 to 15 lbf·ft (15 to 20 N·m)
7. Uncap the refrigerant lines.

NOTE: Do not lubricate Mini Stat-O-Seals prior to installation.

8. Replace the Mini Stat-O-Seals on the refrigerant lines with new ones.
9. Connect the refrigerant lines to the receiver-drier. Tighten the capscrew on the retaining plate 14 to 16 lbf·ft (19 to 22 N·m).



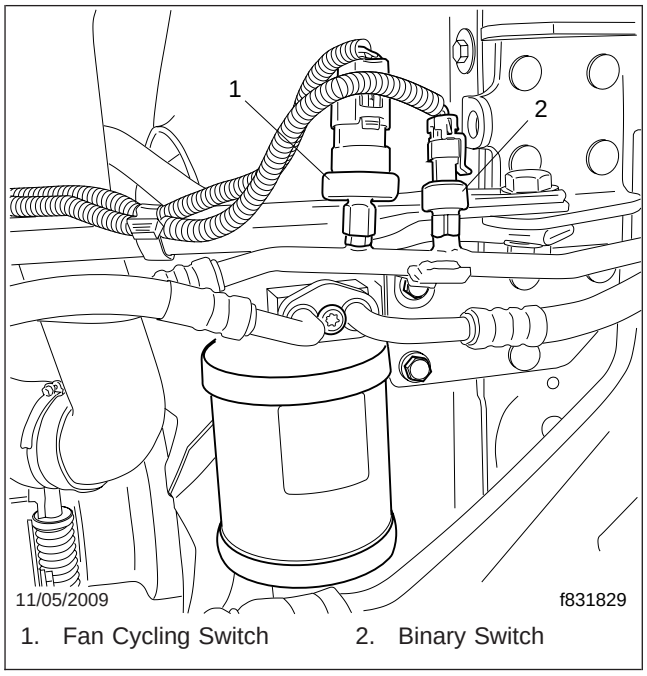
1. Receiver-Drier
2. Retaining Plate Capscrew
3. Mounting Capscrew

Fig. 1, Receiver-Drier Installation

10. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**.
11. Be sure to add refrigerant oil to the compressor to replace that which is lost when the system is recovered. See **Section 83.02**, Subject 130.
12. Return the hood to the operating position.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Disconnect the wiring harness from the binary switch. See **Fig. 1**.



1. Fan Cycling Switch 2. Binary Switch

Fig. 1, Binary Switch Installation (typical)

4. Remove the binary switch.
5. Install a new binary switch. Tighten 60 to 72 lbf·in (678 to 813 N·cm).
6. Connect the wiring harness to the binary switch.
7. Return the hood to the operating position.

Condenser Removal and Installation

Removal

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the capscrews that attach the grille to the hood. Remove the grille.
3. Open the hood.

⚠ WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

4. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.

IMPORTANT: Under no circumstances should the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

5. Disconnect the refrigerant lines from the condenser. Quickly cap the condenser inlet and outlet ports if the condenser will be reinstalled and cap the refrigerant lines.
6. Remove the fasteners that attach the condenser to the charge air cooler or to the mounting brackets. Remove the condenser.

Installation

1. Position the condenser on the charge air cooler or the mounting brackets. Install and tighten the fasteners 84 to 108 lbf·in (950 to 1220 N·cm).
2. Uncap the inlet and outlet ports on the condenser and uncap the refrigerant lines.

NOTE: Do not lubricate Mini Stat-O-Seals prior to installation.

3. Replace the Mini Stat-O-Seals on the refrigerant lines.
4. Connect the refrigerant lines to the condenser. Tighten the bolt on the retaining plate 14 to 16 lbf·ft (19 to 22 N·m).
5. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220** of this section.
6. Add refrigerant oil to the compressor to replace that which is lost in the old condenser. For instructions, see **Section 83.02**, Subject 130.
7. Return the hood to the operating position.
8. Using capscrews, attach the grille to the hood.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the capscrews that attach the climate control panel to the cup holder panel. Pull the control panel away from the cup holder panel.
3. Disconnect the wiring harness from the control panel.
4. Connect the wiring harness to the new control panel.
5. Using capscrews, attach the control panel to the cup holder panel.

WARNING

Before doing any of the work below, read the information in Safety Precautions 100. Failure to read and understand the safety precautions, and to take necessary precautions against the dangers involved when working with refrigerant, could lead to serious personal injury.

Required Equipment

You will need equipment to accomplish the following tasks:

- Identification—The machine must be able to verify the purity of the refrigerant in the refrigerant system and check for the presence of hydrocarbon-based refrigerants or other unapproved refrigerants.
- Leak Detection—The tool must meet the J2791 specifications in order to maximize the usefulness of the diagnostic information.
- Recovery—The machine must be able to fully recover the refrigerant from the refrigerant system according to the SAE J-2788 standards.
- Evacuation—Ideally, the machine should have a vacuum pump rated at 6 cfm. Vacuum pump maintenance intervals set by the manufacturer must be followed to maintain performance and reduce system contamination.
- Charging—The scale used in charging should be accurate to SAE J-2788 standard.
- Flushing—Adaptors for the compressor(s), expansion device(s), and receiver-drier should be purchased or fabricated to flush the system with refrigerant.

Refrigerant Identification

IMPORTANT: Always use a refrigerant identifier before hooking up any equipment to the refrigerant system. This practice will protect your tools and ensure that you are not held responsible for an improper repair.

1. Using a high-quality refrigerant identifier and the manufacturer's instructions, attach the identifier to the vehicle and perform the test.
2. If the vehicle passed the test, it is safe to recover the refrigerant.
3. If the vehicle failed the test due to an excessive amount of noncondensable gas, recover the refrigerant system, then purge the recovery tank of the noncondensable gas.
4. If the vehicle failed the test due to the presence of a hydrocarbon-based refrigerant or a refrigerant other than R–134a, **do not recover the refrigerant into the general-use machine.** To change the refrigerant, remove the existing refrigerant into a separate container. **Refrigerant must be recycled by a qualified recycling center.** It is best to refer the customer to the place where the vehicle was last serviced.

Leak Detection

There are two approved methods for finding refrigerant leaks; UV dye, and electronic leak detection. In either case, the electronic leak detector should be used to confirm the leak exists, and recheck the connection after the repair has been completed.

UV Dye

All Freightliner refrigerant systems contain UV dye for improved leak detecting. Use a UV flashlight and glasses, according to the manufactures' instructions to quickly inspect the refrigerant loop where ever it is possible to see the parts of the system. After noting all the potential leaks, use the electronic leak detector to confirm the existence of a leak.

Electronic Leak Detectors

Use an approved refrigerant leak detector (see the recommended tool list at accessfreightliner.com) and follow the manufacturers instructions. Operators should also be familiar with the list of "false trigger" chemicals provided by each manufacturer. Utilize the leak rate table in **83.00, Specifications 400**, to determine how severe each leak is.

Recovery

The recovery process removes most of the refrigerant charge in the system.

1. Turn off the engine, apply the parking brakes, chock the tires, and open the hood.

2. Remove the caps from the suction and discharge service valves.
3. Identify the refrigerant using the "Refrigerant Identification" procedures.
4. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery and charging machine hoses to the valves.

IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

5. Follow the refrigerant recovery and charging machine manufacturer's instructions, and recover all of the refrigerant from the refrigerant system.

IMPORTANT: Always comply with all federal and local regulations regarding refrigerant recovery and disposal. You may be subject to substantial penalties for improper procedures.

6. Measure the oil recovered during the recovery process. The refrigerant system will have to be filled with the same quantity of new refrigerant oil. If the system is contaminated with moisture, all of the compressor oil must be replaced with clean oil. If the system is heavily contaminated with desiccant or grit, replace the compressor, expansion valve, and receiver-drier, and flush the condenser and evaporator(s). After the system is charged, check its performance, to ensure that the heat exchangers are not plugged.

Evacuating

The main purpose in evacuating the refrigerant system is to remove noncondensable gases (NCG), such as nitrogen and air. The secondary purpose is to boil off free water molecules. You can boil and remove water from the air conditioning system by lowering the system pressure to a vacuum, to cause the moisture to vaporize at normal ambient temperatures. A vacuum pump can reduce the pressure in the system. Since the pressure is lowest at the pump, NCG and water vapor are pulled out of the system. This process is called evacuation or dehydration.

Measuring Vacuum

Vacuum should be measured with an electronic thermistor vacuum gauge, which is designed for use with high-vacuum pumps and can accurately read as low as 100 microns. This gauge can have an analog scale, or a digital display.

The location of the vacuum gauge will affect the reading. The closer to the vacuum source, the lower the reading will be. Follow the manufacturer's instructions for proper use of the vacuum gauge.

If the pressure will not stabilize, it indicates a leak. If it stabilizes at a vacuum that is too high, for example 1500 microns Hg, there is probably moisture in the system, and more evacuation is required.

The ability to hold a vacuum is only an indication that there are not any leaks that are present *under a vacuum*. The system still may leak when it is under positive pressure, so a pressure leak test must be performed in addition.

Maintaining an Oil-Lubricated Vacuum Pump

Maintenance is important for a high-vacuum pump. The PAG oil must be changed at regular intervals to prevent moisture buildup, which will cause decreased pump performance and eventual pump failure.

Pumping down, for extremely wet air conditioning systems, can completely saturate the pump oil, in which case, the oil must be replaced.

NOTICE

Flush the vacuum pump every fourth time it is used, and before storing for long periods of time. Acid will form and corrode the pump, if water-laden oil remains in the pump for an extended period.

PAG vacuum pump oil is extremely water soluble. This helps the pump reach a high vacuum, by absorbing water and sealing the pump.

Use only specified vacuum pump oil as a lubricant. Do not use any solvent or any other oil. Clean oil should be run through the pump until it runs out clear. Oil should be added to the fill level indicated on the pump. Check the oil level before each use.

Evacuation Procedure

1. The system refrigerant must have been recovered, and the refrigerant compressor filled with the correct amount of refrigerant oil. Replace the receiver-drier if the system conditions require it.

2. Make sure the vacuum pump has been properly maintained.
3. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery and charging machine hoses, or a vacuum pump, to the valves.

IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

4. Follow the refrigerant recovery and charging machine manufacturer's instructions, and evacuate the refrigerant system.
5. Using a 6-cfm pump, the system should be evacuated a minimum of 10 minutes. Evacuate the system for a longer period of time if using a smaller pump. Make sure that the vacuum level reaches a point where water would boil and does not go back toward zero, then proceed with charging and leak testing the system.

Flushing

Flushing removes moisture-laden oil and some contamination, such as dirty oil and some particles. When a part is flushed, liquid refrigerant is forced through it. The liquid picks up the contaminants and flushes them out. The only approved flushing agent is R-134a refrigerant.

Whether to flush or replace a part depends on how much contamination there is, as previously described.

Normally, the system always has pressure in it. Some loss of refrigerant from one season to the next is normal, and does not mean that the system is dirty. If refrigerant parts show signs of internal corrosion and grit, the system is contaminated.

If the system is contaminated with moisture, flush all sections of the system. Then replace the compressor and the receiver-drier prior to evacuating and charging the system.

If the system is heavily contaminated or if desiccant has circulated through the system, replace the receiver-drier, expansion valve(s), and the compressor.

Flush the system in segments to lessen the chance of blowing deposits against a port.

Backflush the system in the opposite direction of refrigerant flow.

Flushing parts with refrigerant, requires a refrigerant recovery and charging machine, and all the adaptors for each section to be flushed.

Flushing Procedure

Method 1

NOTE: Use this method when the recovery and charging machine is equipped with a flush cycle.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter and follow the instructions from the manufacturer of the recovery and charging machine to perform the flush. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Remove the adaptors and bypass devices and install the expansion device(s), the compressor, and a new receiver-drier.
5. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
6. Charge the system with refrigerant and check the system performance.

Method 2

NOTE: Use this method when two recovery and charging machines are available.

1. Recover the refrigerant from the air conditioning system.
2. Disconnect both ends of the line or part(s) being flushed. Tightly cap the lines to the rest of the system.

NOTE: You must remove the expansion device(s), receiver-drier, and compressor(s) when flushing. These components must be removed and bypassed when performing a system flush.

3. Install the flushing adaptors and an inline filter. When flushing the entire system, use an adaptor that fits where the compressor was located, and backflush.
4. Charge the part with 2 pounds (0.9 kg) of refrigerant or the system with 5 pounds (2.3 kg) of refrigerant, then recover the refrigerant with a second machine. It is desirable to start the recovery slightly before the charge cycle is done, since this helps to push fluid through the system. Repeat the process several times until you think that all the oil has been removed.
5. Remove the adaptors and bypass devices and install the expansion device(s), the compressor(s), and a new receiver-drier.
6. If installing the existing compressor, remove the oil in it and replace the oil with new oil. New compressors may or may not have a full charge of oil.
7. Charge the system with refrigerant and check the system performance.

Oil Balancing

General Information

Compressors require refrigerant oil to function. When the air conditioning system is operating, some of the oil leaves the compressor and is circulated through the system with the refrigerant. The refrigerant oil cannot leave the system except when there is a leak, the refrigerant is recovered, or when a system part is replaced. It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner, and cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system.

IMPORTANT: Refrigerant oil is hygroscopic (attracts moisture from its surroundings), and must not be exposed to the moisture that is present in the air. New oil must be from a container that has not been opened or that has been tightly sealed since its last use.

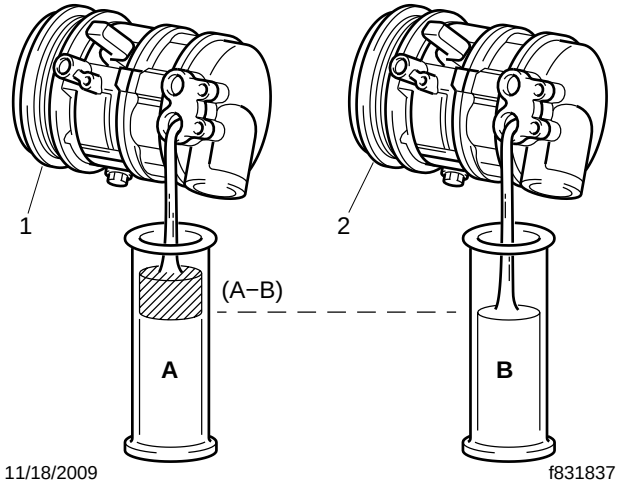
Tubing, funnels, or other equipment used to transfer the oil must be very clean and dry. When handling refrigerant oil:

- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

Compressor Oil Balancing

Replacement refrigerant compressors are supplied with some refrigerant oil. If the air conditioning system has been flushed, the system will need a complete new charge of oil. If the system has not been flushed, use the following procedures to adjust the oil level, when a new compressor or other system component has been installed. The type of oil required depends on the brand of compressor used on the system. See **Section 83.02, Subject 130** for details about how the total system volume is determined. See PartsPro MOD 700 to determine the oil type and vehicle specific oil quantities.

1. Drain the remaining oil from the compressor into a clean graduated container, and note the amount. See **Fig. 1**.
2. Make note of the total volume of oil recovered from the recovery machine and the compressor.
3. Drain the oil from new compressor into a clean calibrated container, and compare the two quantities of oil.
4. Add only the amount of oil removed during recovery and from the old compressor to the system.



1. New Compressor 2 Old Compressor

Fig. 1, Oil Balancing

5. Add the new compressor oil as described in the supplier specific compressor service section of the workshop manual.

System Oil Balancing

After repairs are finished, refer to **Table 1** and use the following equation to determine the quantity of refrigerant oil that needs to be added to the system.

[Quantity Recovered] + [Quantity for All Replaced Components] = [Quantity Added to the System]

Table 1 provides the quantities of oil that need to be added to the system for each component that was replaced. Add the quantities listed in the table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less. Inject the calculated oil volume at the high-side pressure port during the refrigerant charging process.

Refrigerant Oil Quantities for Replaced Components	
Add the quantities listed in this table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.	
Component	**Quantity oz (mL)**
High Pressure Line (main A/C)	1 (30)
Low Pressure Line (main A/C)	2 (59)
High Pressure Line (auxiliary A/C)	1 (30)

Refrigerant Oil Quantities for Replaced Components	
Add the quantities listed in this table for each component that was replaced. Use the sum of the quantities or 6 fl oz (177 mL), whichever is less.	
Component	**Quantity oz (mL)**
Low Pressure Line (auxiliary A/C)	3 (89)
Condenser	1 (30)
Evaporator (main A/C)	3 (89)
Evaporator (auxiliary A/C)	2 (59)
Receiver-Drier	3 (89)
Minor Leak at Connector Only	0.5 (15)
Major Leak at Connector Only	2 (59)

Table 1, Refrigerant Oil Quantities for Replaced Components

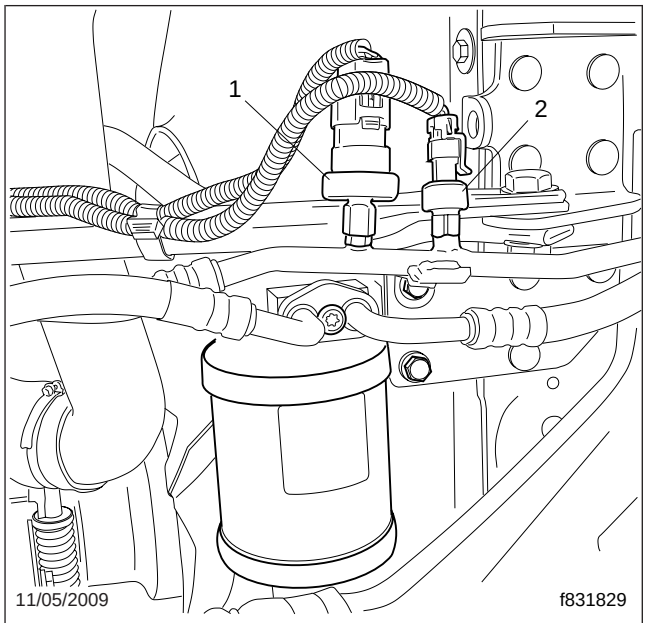
Charging

NOTE: Before charging, the system must be recovered and evacuated with the recovery and charging machine connected to the service and discharge port connections.

1. Obtain enough refrigerant to fully charge the system. To determine the amount of refrigerant needed to fully charge the system, read the Air Conditioner label on the vehicle.
2. Charge the system on the high side following the refrigerant recovery and charging machine manufacturer's instructions.
3. While the compressor is engaged, check the duct temperature and operating pressures at the suction and discharge ports. Compare the temperature and pressures to those in in **Section 83.00, Troubleshooting**. If the operating pressures are not acceptable, see **Section 83.00, Troubleshooting**, for troubleshooting procedures.
4. Disconnect the hoses.
5. Shut down the engine.
6. Recover the refrigerant that is in the hoses.

Replacement

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Disconnect the wiring harness from the fan cycling switch. See **Fig. 1**.



1. Fan Cycling Switch 2. Binary Switch

Fig. 1, Switch Location (typical)

4. Remove the fan cycling switch.
5. Install a new fan cycling switch. Tighten 60 to 72 lbf·in (678 to 813 N·cm).
6. Connect the wiring harness to the fan cycling switch.
7. Return the hood to the operating position.

Refrigerant

WARNING

R–134a is the only refrigerant that is approved for use on Freightliner vehicles. Several companies offer less expensive, hydrocarbon-based refrigerant, such as propane and methane. Use of these refrigerants will void the warranty on the air conditioning system, cause damage to the air conditioning system, and possibly result in personal injury or property damage. Leaking air conditioning systems charged with hydrocarbon-based refrigerants pose a serious risk of fire or explosion under the hood, or inside the passenger compartment. No vehicle built by Freightliner Trucks can be safely charged with hydrocarbon-based refrigerants, regardless of what the refrigerant supplier states.

When servicing an air conditioning system, always use a refrigerant identifier to ensure that the system has not been charged with something other than R–134a. This should be standard practice since there is no way to tell what services have been previously performed. Identification by service technicians will help to avoid the risk of explosion and help to guard against contamination of equipment when refrigerant is recovered and recycled.

Refrigerant recovery/charge stations can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
1-800-328-6657

The vehicle's refrigerant charge level is printed on a sticker in the engine bay, on the right side of the vehicle. If the sticker is missing, check Group 83 in PartsPro (module/subgroup 700) for the proper sticker and charge information, using the vehicle's serial number.

Refrigerant Oil

IMPORTANT: Using the wrong refrigerant oil in the HVAC system will prevent proper lubrication, and may cause early failure of system components. Always verify that the correct oil is being used in the system. Order Denso PAG oil (ND-8OIL, P/N DII LA446963 0040) from your local Freightliner parts distribution center, it is the only acceptable oil to use in a system with a Denso compressor.

Torque Specifications

Table 1 shows torque specifications for Stat-O-Seal assembly bolts.

Stat-O-Seal Assembly Bolt Torque Specs	
HVAC Component	**Torque: lbf·ft (N·m)**
Refrigerant Compressor	14–16 (19–22)
Condenser	14–16 (19–22)
Receiver-Drier	14–16 (19–22)
Expansion Valve (to lines to receiver-drier)	14–16 (19–22)
Expansion Valve (small screws to evaporator lines)	35 lbf·in (395 N·cm)
Evaporator	14–16 (19–22)
Junction Block	14–16 (19–22)

Table 1, Stat-O-Seal Assembly Bolt Torque Specs

General Information

The main purpose of the refrigerant compressor is to draw low-temperature, low-pressure refrigerant gas from the evaporator and squeeze it into high-temperature, high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid at high ambient temperatures. A second purpose of the compressor is to move refrigerant through the air conditioning system.

Safety Precautions

Whenever repairs are made to any air conditioner parts that hold R–134a refrigerant, you must recover, purge or flush (if contaminated), evacuate, charge, and leak test the system. In a good system, refrigerant lines are always under pressure and you should disconnect them only after the refrigerant charge has been recovered (discharged) at the service valves.

Refrigerant R–134a is safe when used under the right conditions. Always wear safety goggles and non-leather gloves while recovering, evacuating, charging, and leak testing the system. Do not wear leather gloves; when refrigerant gas or liquid contacts leather, the leather will stick to your skin.

⚠ WARNING

Use care to prevent refrigerant from touching your skin or eyes, because liquid refrigerant, when exposed to the air, quickly evaporates and will freeze skin or eye tissue. Serious injury or blindness could result if you come into contact with liquid refrigerant.

Refrigerant splashed in the eyes should be rinsed with lukewarm water, not hot or cold. Do not rub the eyes. Apply a light bandage and contact a physician right away.

Refrigerant splashed on the skin should be rinsed with lukewarm water, not hot or cold. Do not rub the skin. Apply a light coat of a nonmedicated ointment, such as petroleum jelly. Contact a physician right away.

R–134a refrigerant does not burn at ambient temperatures and atmospheric pressure. However, it can be combustible at pressures as low as 5.5 psig (139 kPa absolute) at 350°F (177°C) when mixed with air concentrations that are greater than 60 percent.

⚠ WARNING

R–134a air conditioning systems should not be pressure tested or leak tested with compressed air. Combustible mixtures of air and R–134a may form, resulting in a fire or explosion, which could cause personal injury or property damage.

Always work in an area where there is a constant flow of fresh air when the system is recovered, evacuated, and charged. R–134a vapors have a slightly sweet odor that is difficult to detect. Frequent leak checks and air monitoring equipment are recommended to ensure a safe working environment.

IMPORTANT: When servicing an R–134a air conditioning system, use only service equipment certified to meet the requirements of SAE J2210 (R–134a recycling equipment). The equipment should be operated only by qualified personnel who are familiar with the recycling station manufacturer's instructions.

Because of its very low boiling point, refrigerant must be stored under pressure. To prevent the refrigerant containers from exploding, never expose them to temperatures higher than 125°F (52°C).

On R–134a refrigerant systems, polyalkylene glycol (PAG) oil is used in the compressor. When handling PAG oil, observe the following:

- keep the oil free of contaminants
- do not expose the air conditioning system or the PAG oil container to air for more than 30 minutes; PAG oil has a high moisture absorption capacity and the oil container should be immediately sealed after each use
- use care when handling: spilled oil could damage painted surfaces, plastic parts, and other components (drive belts)
- **never** mix PAG oil with other types of refrigerant oil

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

Pre-Service Checks

NOTE: Compressor problems usually show in one of four ways: abnormal noise, seizure, leakage, or low discharge pressure. Resonant compressor noises are not causes for alarm; irregular noise or rattles are likely to be caused by broken parts. To check for seizure, de-energize the magnetic clutch and see if the drive plate can be turned. If it won't turn, the compressor has seized.

Make the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Check the drive belt and mounting:
   - 1.1 On the drive belt, look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. See the drive belt section in **Group 01** for instructions.
   - 1.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the torque value in the torque specifications table under **Specifications 400**. Repair or replace cracked or damaged brackets.
   - 1.3 Check the tension of the compressor drive belt. See the drive belt section in **Group 01** for instructions.
2. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.
3. Check for road debris build-up on the condenser coil fins. Using air pressure and a whiskbroom or a solution of soap and water, carefully clean the condenser; be careful not to bend the fins.

NOTE: For other possible causes of air conditioner problems, see **Section 83.00**, *Heater and Air Conditioner Troubleshooting* and the applicable fan clutch section in **Group 20**.

Refrigerant Compressor Removal and Installation

⚠ WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

Removal

1. Apply the parking brakes, and chock the tires.
2. Raise the hood.
3. Begin recovery of the refrigerant from the air conditioning system; for instructions, see **Section 83.01, Subject 220**.
4. Turn off the engine.
5. Remove the drive belt. Do not pry or roll the belt off the pulleys. See the drive belt section in **Group 01** for instructions.
6. Disconnect the wiring harness from the compressor.

NOTICE

Under no circumstances should the ports on the compressor or the refrigerant lines remain uncapped for longer than five minutes. Water and dirt can damage the refrigerant system. Do not blow shop air through refrigerant lines since shop air is wet (humid).

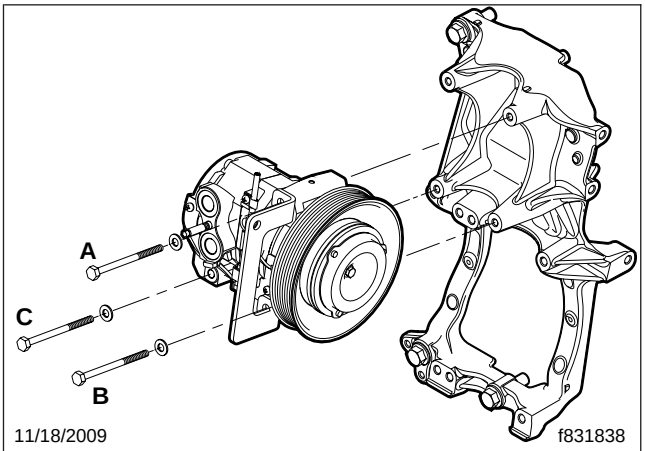
7. After the refrigerant has been fully recovered, remove the capscrews that attach the refrigerant lines and retaining plate(s) to the compressor. Remove the refrigerant lines and the retaining plates. Remove and discard the Mini Stat-O-Seals. Cap the discharge and suction ports and the refrigerant lines.
8. Being careful not to spill any refrigerant oil, remove the capscrews and washers that attach the refrigerant compressor to the engine, and remove the compressor.

Installation

IMPORTANT: A new compressor is filled with refrigerant oil and nitrogen gas. The oil quantity is printed on a label attached to the compressor.

When installing a new compressor on the vehicle, gently release the nitrogen gas from the discharge side of the compressor.

1. Adjust the refrigerant oil level in the compressor; for instructions, see **Subject 130**.
2. Position the compressor on the mounting bracket and install the capscrews and washers. Tighten 15 to 19 lbf·ft (21 to 26 N·m) in the sequence shown in **Fig. 1**.



Tighten A, then B, then C.

A. Front Top
B. Front Bottom
C. Rear

Fig. 1, Tightening Sequence (typical installation shown)

3. Uncap the discharge and suction ports and the refrigerant lines. Check the refrigerant lines and the discharge and suction ports. They must be clean and free of nicks, gasket residue, and other foreign material.
4. Install new Mini Stat-O-Seals on the refrigerant lines.
5. Attach the refrigerant lines to the compressor. Tighten the capscrew 14 to 16 lbf·ft (19 to 22 N·m).
6. Connect the wiring harness to the compressor.
7. Install the drive belt.
8. If installing a new compressor, or if the system was without any refrigerant pressure before repairs were started, replace the receiver-drier; for instructions, see **Section 83.01, Subject 180**.

Refrigerant Compressor Removal and Installation

9. Evacuate, charge, and leak test the refrigerant system; for instructions, see **Section 83.01, Subject 220**.
10. Return the hood to the operating position.

WARNING

Before doing any of the work below, read the information under Safety Precautions 100. Failure to read the safety precautions and to be aware of the dangers involved when working with refrigerant, could lead to serious personal injury.

General Information

Denso compressors require ND-8 PAG refrigerant oil. When the air conditioning system is operating, refrigerant oil can leave the compressor and circulate through the system with the refrigerant, but the refrigerant oil cannot leave the system except when there is a leak, when the refrigerant is recovered, or when a system part is replaced.

It is important that the air conditioning system has the correct amount of refrigerant oil for proper operation. Too little oil will result in compressor failure. Too much oil will degrade the performance of the air conditioner, and cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil, from the charging machine, must be measured in order to know how much oil must be returned to the system. When a system component is replaced, a quantity of new oil equal to the recovered oil plus the oil coating the inside of the component must be returned to the system. New oil must be from a container that has not been opened or that has been tightly sealed since its last use. Tubing, funnels, or other equipment used to transfer the oil must be very clean and dry.

When handling refrigerant oil:

- Be sure that the oil is free of water, dust, metal powder, and other foreign substances;
- Do not mix the refrigerant oil with other types or viscosities of oil;
- Quickly seal the oil container after use. Refrigerant oil absorbs moisture when exposed to the air for any period of time.

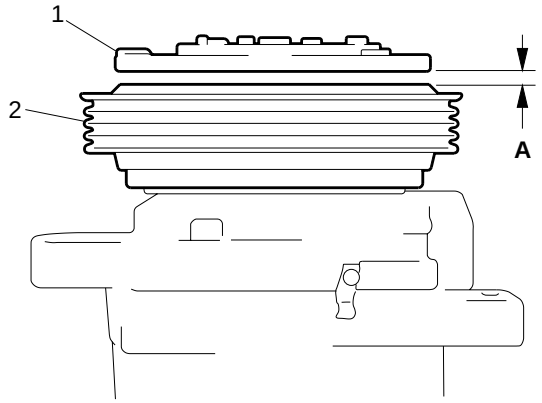
Order Denso PAG oil (ND-8OIL, P/N DII LA446963 0040) from your local Freightliner parts distribution center, it is the only acceptable oil to use in a system with a Denso compressor.

Denso Total System Oil Volume

Denso refrigerant compressors are supplied with approximately 4.5 oz. of ND-8 oil, but the vehicle configuration affects the total charge volume. If a complete new oil charge is required, the amount will be determined by the volume stated in the new compressor literature, and the volume listed in PartsPro. The two amounts will be combined to give the total oil charge required. If a complete new oil charge is not required, use the oil balancing info in **Section 83.01, Subject 220**.

Clutch Assembly Removal, Inspection, and Installation

The clutch should be replaced if it is worn. Before replacing the clutch, check the air gap at three equally spaced points around the perimeter. The air gap should be at least 0.014 in (0.35 mm), and no greater than 0.024 inch (0.60 mm). The gap must be greater than 0.024 inch (0.60 mm) at all three points for the clutch to need replacing. See **Fig. 1**.



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Check at three equally spaced points.
A. 0.014 to 0.024 in (0.35 to 0.60 mm)
1. Hub Sub-Assembly
2. Magnetic Clutch

Fig. 1, Checking the Clutch Clearance

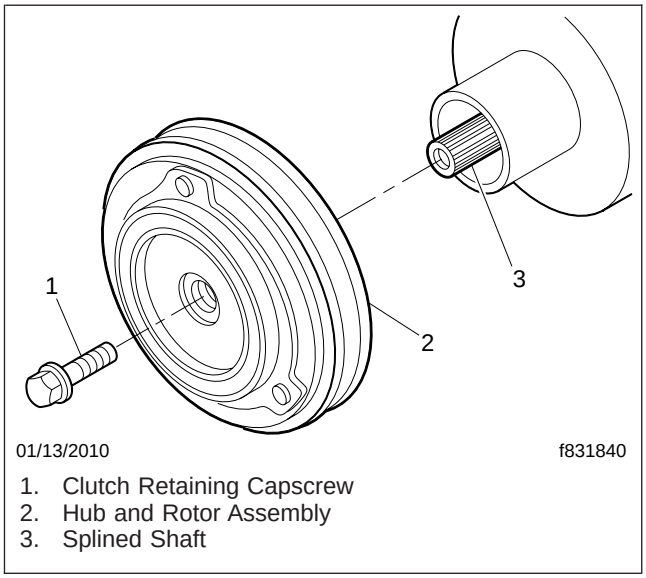
Removal

The hub is secured with a bolt (splined shaft is used for connection with compressor).

1. Remove the compressor from the vehicle. For instructions, see **Subject 110**.
2. Remove the clutch retaining capscrew from the compressor shaft. See **Fig. 2**.
3. Remove the shims from the pressure plate. NOTE: Save the air gap shims for reassembly.

NOTE: If the rotor cannot be removed easily, tap the rotor lightly with a plastic hammer, then remove it from the compressor shaft being careful not to damage the pulley when tapping on the rotor.

4. Using snap ring pliers, remove the snap ring, then remove the rotor. Discard the snap ring. See **Fig. 3**.



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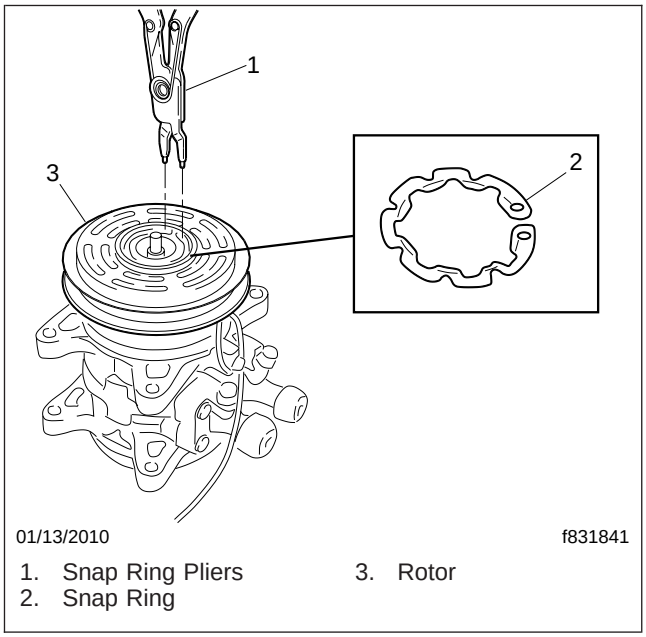
1. Clutch Retaining Capscrew
2. Hub and Rotor Assembly
3. Splined Shaft

Fig. 2, Removing the Retaining Capscrew



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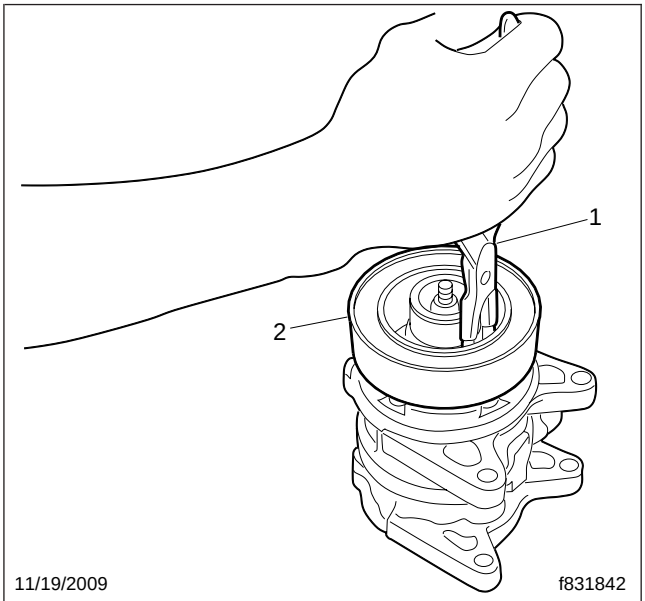
1. Snap Ring Pliers
2. Snap Ring
3. Rotor

Fig. 3, Rotor Removal

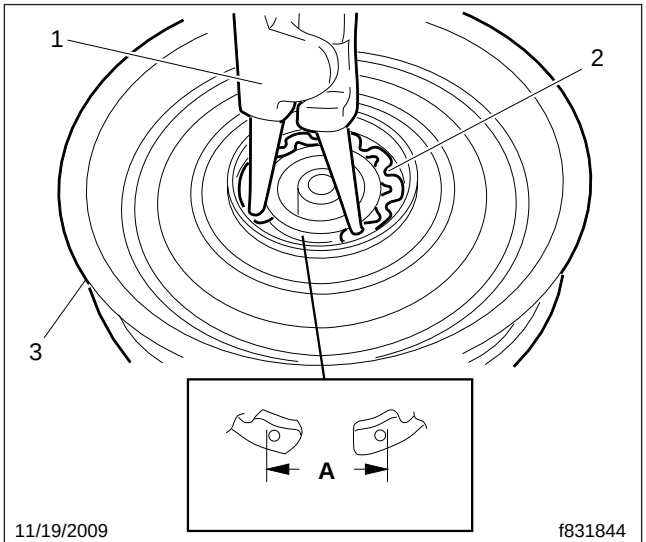
5. Using snap ring pliers, remove the snap ring, then remove the stator. Discard the snap ring. See **Fig. 4**.

Clutch Assembly Removal, Inspection, and Installation



1. Snap Ring Pliers
2. Stator

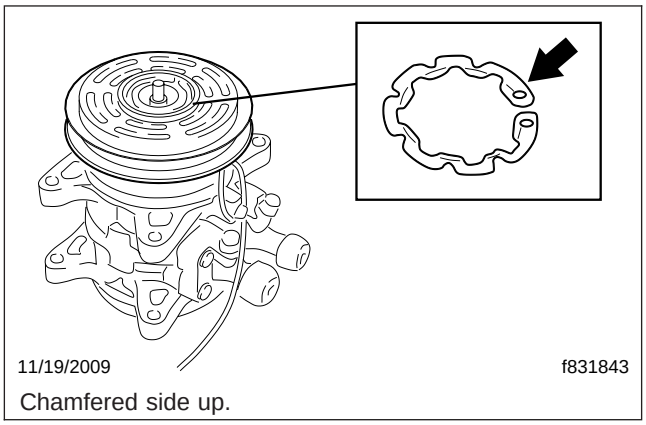
Fig. 4, Stator Removal



A. Do not exceed 1.2 in (30.9 mm).

1. Snap Ring Pliers
2. Snap Ring
3. Rotor

Fig. 5, Snap Ring Installation



Chamfered side up.

Fig. 6, Snap Ring Installation

Inspection

After the magnetic clutch is disassembled, inspect each component and decide whether they can be reused. Refer to **Table 1** for clutch inspection and recommended action.

Installation

NOTICE

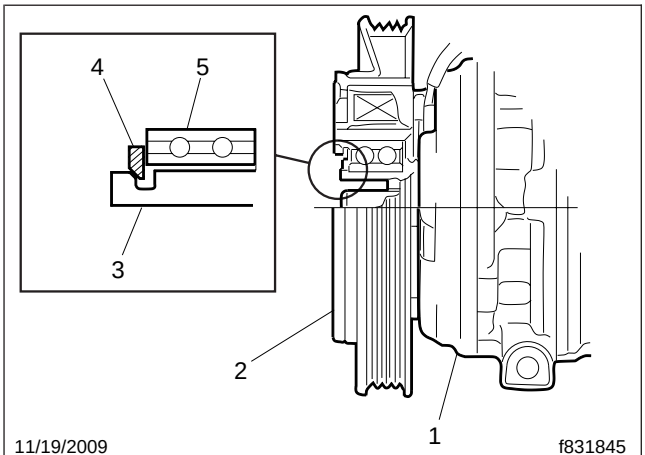
Excessive opening of the snap rings may weaken the fixing force of the snap ring. Maximum allowed opening must not exceed 1.2 in (30.9 mm). See Fig. 5.

1. Align the stator to the compressor housing by positioning the index pin into its indexing hole/slot.

IMPORTANT: The snap ring must be installed with the chamfered side facing up. See **Fig. 6**.

2. Secure the stator with a new snap ring. Make sure the snap ring is fully seated. See **Fig. 7**.
3. Install the rotor to the compressor and secure it with a new snap ring.
4. Temporarily install the hub to verify the gap clearance. See **Fig. 1**.
5. Check the air gap. The air gap between the hub and rotor should be 0.014 to 0.024 in (0.35 to 0.60 mm). Check the clearance at 3 locations.
6. Set the air gap clearance between the pressure plate and rotor by adding or removing compressor shaft shims so that the air gap clearance is within the specified range and distance.

Clutch Assembly Removal, Inspection, and Installation



1. Compressor
2. Clutch Assembly
3. Compressor Shaft
4. Snap Ring
5. Bearing

Fig. 7, Seating the Snap Ring

7. Install the clutch retaining capscrew in the compressor shaft. Tighten 15 to 19 lbf·ft (21 to 26 N·m)

8. After the clutch is assembled, turn the rotor by hand to verify it does not contact either the pressure plate or stator.

Magnetic Clutch Inspection		
Part Name	**Check Point and Expected Damage**	**Action**
Hub	Dislocation or peeling of rubber.	Replace or Repair
	Roughness, burn, rust, slip or extreme wear on mating surface.	Replace
Rotor	Play, unusual sound, rust, insufficient grease or seizure of bearing.	
	Roughness, burn, rust, slip or extreme wear on mating surface.	
Stator	Burn, wire breakage or layer short circuit of stator coil. Resistance of stator coil at 68°F (20°C) (2.8 to 3.2 ohms)	
	Damage of deformation of rotor (pulley) groove(s).	

Table 1, Magnetic Clutch Inspection

Specifications

Special tools can be purchased from the following independent suppliers:

Classic Tool Design
31 Walnut St.
New Windsor, NY 12553
845-562-8700

Mastercool USA Inc.
One Aspen Drive
Randolph, NJ 07869
(973) 252-9119

Torque Values		
Description	**Torque**	
	lbf·in (N·cm)	**lbf·ft (N·m)**
Compressor Mounting Fasteners	—	15–19 (21–26)
Clutch Retaining Capscrew	—	15–19 (21–26)
Clutch Lead Wire Clamp Screw	132 (1500)	—

Table 1, Torque Values

General Information

The hoods on the 108SD and 114SD vehicles are made of fiberglass, using the spray-up process.

The materials used in fiberglass spray-up hoods are a combination of glass filaments, resin (the binder), catalysts (to initiate the cure), and weather resistance additives. The filaments of pure glass provide strength, dimensional stability, and heat resistance. The resin is a liquid plastic that hardens when combined with another substance, the catalyst. The resin acts as a binder to hold the filaments together; it supplies only a limited amount of additional strength to the structure.

Several reinforcing members and an air intake plenum are bonded to the engine side of the hood.

Hood Mounting and Components

The front of the hood assembly is mounted on pivot brackets. The hood pivot and tilt-assist mechanisms allow the hood to be tilted forward for vehicle service. In the closed position, the rear of the hood is supported by brackets attached to the cab front wall. The hood rear support brackets hold the hood in the correct position for operation. The rear of the hood is held in place with latches, one on each side. The front hood-hinge pivots are adjustable fore-and-aft and side-to-side. The rear hood support brackets are adjustable up-and-down only.

The tilt-assist mechanism used on the 108SD and 114SD consists of two spring struts, attached to the hood and brackets on the frame rail assemblies.

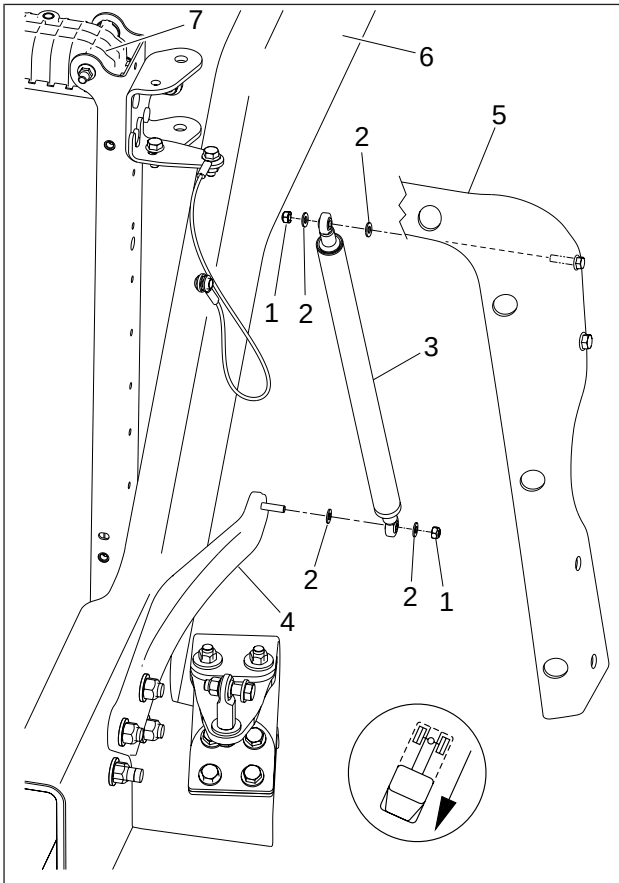
The stationary grille is mounted to brackets on the charge air cooler. An optional bezel is attached around the grille opening of the hood.

The hood is equipped with a headlight assembly on each fender, and air intake grilles on both sides of the hood. Optional access doors (butterfly hatches) allow under-hood servicing without the need to tilt the hood.

Hood Removal, Installation, and Adjustment

Removal

1. Apply the parking brakes and chock the tires.
2. Open the hood until it is balanced over the hood pivots.
3. With an assistant holding the hood balanced over the hood pivots, remove the tilt-assist spring struts by removing the fasteners that secure the struts to the frame assembly and the hood; see **Fig. 1**.



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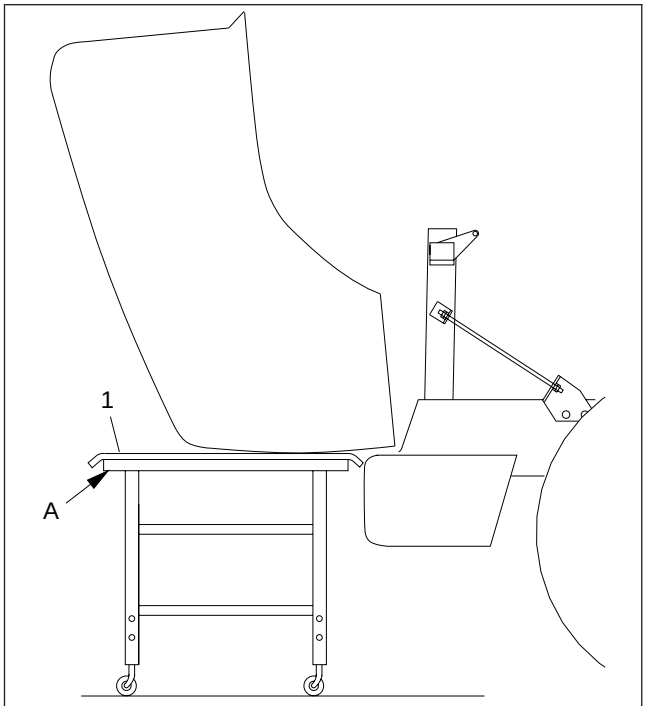
NOTE: LH shown. Hood panel not shown for clarity.

1. Locknut
2. Flatwasher
3. Strut
4. Hood Pivot Support Bracket
5. Hood
6. Frame Rail Assembly
7. Radiator

Fig. 1, Spring Strut Installation

4. Place a support between the floor and the front of the hood; see **Fig. 2**.

   The support should be as wide and as long as the front of the hood, and should be the same height as the lowest edge of the hood. Place cardboard, carpet, rags, or other padding on top of the support to protect the hood.



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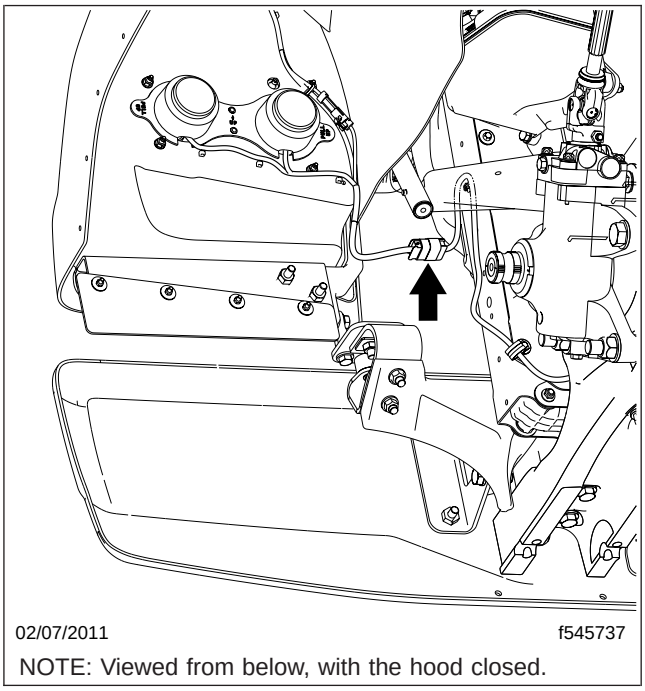
A. The top of the support should be at same height as the lowest edge of the hood.

1. Cardboard, Carpet, or Furniture Pad

Fig. 2, Supporting the Hood

5. On each side of the vehicle, disconnect the wiring harness between the chassis and the hood; see **Fig. 3**.
6. Lower the hood until it is balanced over the pivots, to relieve tension on the check cables. Have an assistant hold the hood in this position.
7. Disconnect the check cables from the brackets on the radiator; see **Fig. 4**.
8. Carefully tilt the hood onto the support.

Hood Removal, Installation, and Adjustment



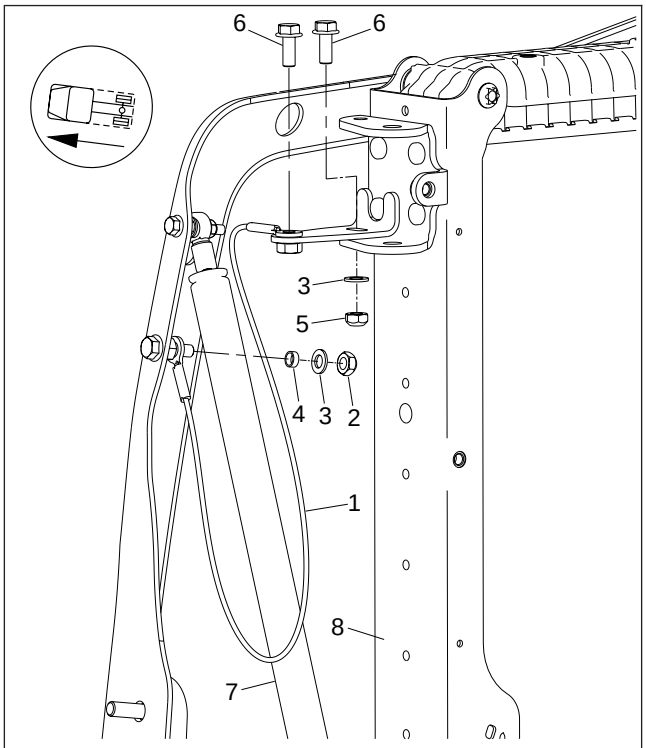
NOTE: Viewed from below, with the hood closed.

Fig. 3, Hood Wiring Harness Connector (LH shown)

9. Remove the hood-hinge pivot bolts. For a vehicle with a forward frame extension (FFE), see **Fig. 5**. For a non-FFE vehicle, see **Fig. 6**.
10. Remove the hood from the vehicle by carefully rolling or sliding the hood support away from the vehicle; do not try to lift the hood.

Installation

1. With the tires chocked, move the support and hood into alignment with the front of the vehicle. Do not try to lift the hood.
2. Align the holes of the hood pivot brackets with the rod-end pivots. Install the hood-pivot bolts. Install the washers and nuts. Tighten the nuts 128 to 162 lbf·ft (173 to 219 N·m). For a vehicle with forward frame extension (FFE), see **Fig. 5**. For a non-FFE vehicle, see **Fig. 6**.
3. Lower the hood until it is balanced over the pivots, then have an assistant hold the hood in this position.
4. Connect the check cables to the brackets on the radiator; see **Fig. 4**. Tighten the nuts 60 lbf·in (680 N·cm).



NOTE: LH shown. Hood panel not shown for clarity.

1. Hood Check Cable
2. Locknut
3. Flatwasher
4. Bushing
5. Restraint Cable Bracket
6. Flange Bolt
7. Spring Strut
8. Radiator

Fig. 4, Hood Check Cable Installation

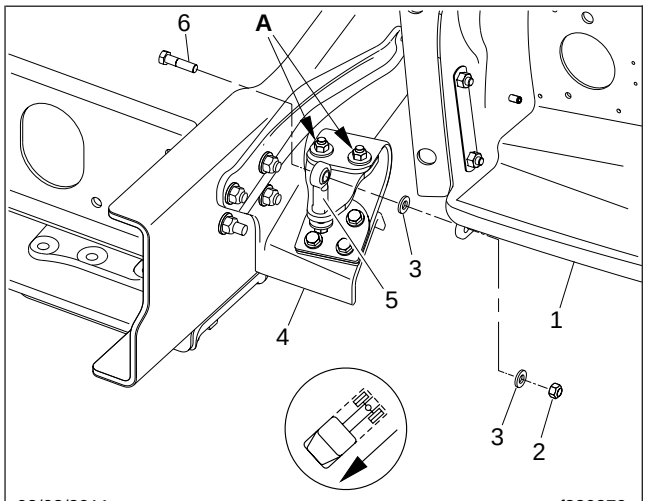
5. Install the tilt-assist spring struts on the frame assembly and the hood. Tighten the nuts 15 to 19 lbf·ft (20 to 26 N·m). See **Fig. 1**.
6. Connect the wiring harness on the left side of the vehicle; see **Fig. 3**.

Adjustment

NOTE: If the vehicle has had damage to the chassis, the frame must be straightened before adjusting the hood.

1. Drive the vehicle back and forth to settle the frame and suspension. Park the vehicle on a flat, level surface. Shut down the engine, apply the parking brakes, and chock the tires.

Hood Removal, Installation, and Adjustment



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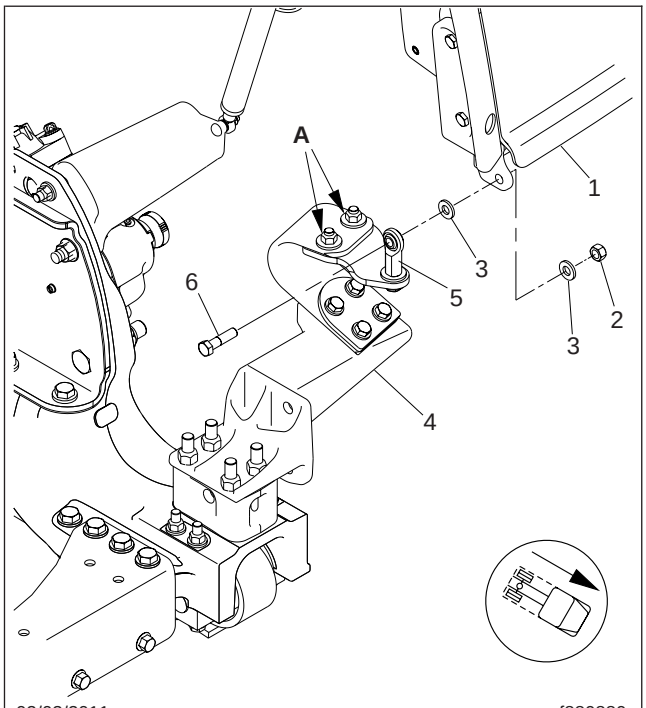
NOTE: LH shown.

A. Loosen to adjust hood fore-aft alignment.

1. Hood
2. Pivot Hexnut
3. Washer
4. Hood Pivot Support Bracket
5. Hood Pivot, Rod-End
6. Pivot Bolt

Fig. 5, Hood Hinge Installation, FFE

2. With the hood in the operating position, and both hood latches latched, determine whether hood adjustment is necessary.
   - The character lines of the hood and cab should line up.
   - The gap between the rear edge of the hood and the side cowl panel should be uniform on both sides of the vehicle.
   - The gap between the rear vertical edge of the hood and the front outer vertical edge of the cowl should be between 3/4 and 1 inch (19 to 27 mm).
3. To adjust the hood fore-and-aft at the front, loosen, but do not remove, the two nuts on each side of the hood that attach the hood pivot adapter plate to the hood hinge. For a vehicle with forward frame extension (FFE), see **Fig. 5**. For a non-FFE vehicle, see **Fig. 6**. After adjustment, tighten the nuts 57 to 72 lbf·ft (77 to 98 N·m).
4. To adjust the rear of the hood up-and-down on each side of the hood, loosen, but do not remove, the two fasteners that attach the hood rear locator to the hood rear support bracket. See **Fig. 7**. After adjustment, tighten the fasteners 23 to 29 lbf·ft (31 to 40 N·m).



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NOTE: LH shown.

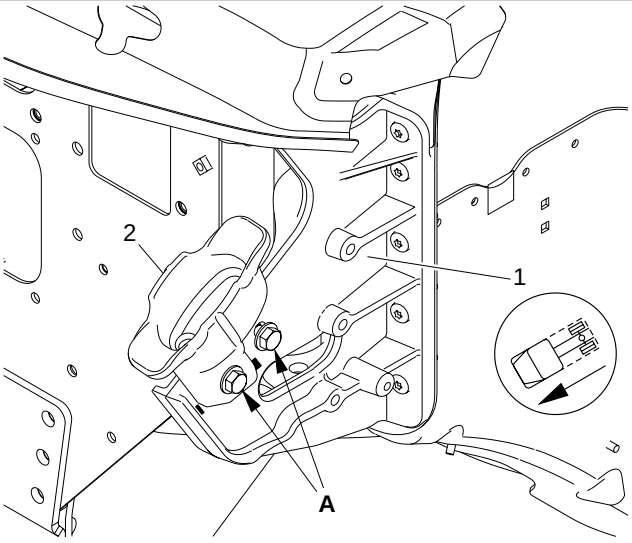
A. Loosen to adjust hood fore-aft alignment.

1. Hood
2. Pivot Hexnut
3. Washer
4. Hood Pivot Support Bracket
5. Hood Pivot, Rod-End
6. Pivot Bolt

Fig. 6, Hood Hinge Installation, Non-FFE

5. Close and latch the hood.

Hood Removal, Installation, and Adjustment



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A. Loosen to adjust the hood up-and-down alignment.

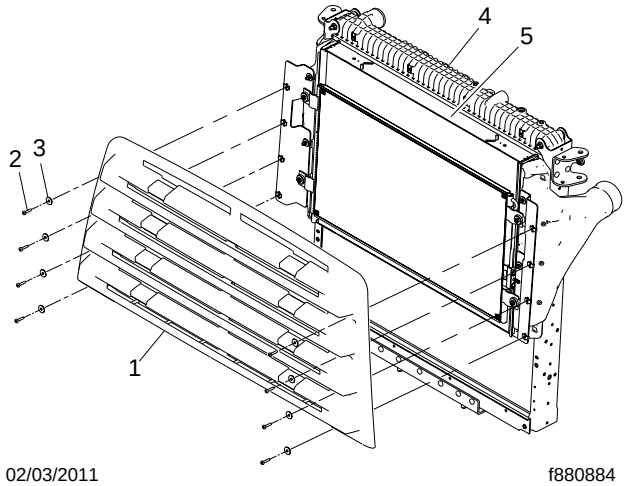
1. Hood Rear Support Bracket
2. Hood Rear Locator

Fig. 7, Hood Rear Support (LH shown)

Grille Removal and Installation

Removal

1. Apply the parking brakes and chock the tires.
2. Remove the M6 screws and flatwashers that attach the grille to the brackets on the charge air cooler. Remove the grille. See **Fig. 1**.



1. Grille
2. Screw, M6
3. Washer
4. Radiator
5. Charge Air Cooler

Fig. 1, Grille Installation

3. If it is necessary to remove the hood surround bezels, do so as follows. See **Fig. 2**.
   - 3.1 From inside the grille opening, remove the four locknuts and isolators that attach the center bezel to the hood.
   - 3.2 From inside each side of the grille opening, remove the three locknuts and isolators that attach each side bezel to the hood.
   - 3.3 Pull the center bezel loose from the hood. Adhesive strips secure the aft edges of the bezels to the hood surface.
   - 3.4 Pull both side bezels loose from the hood.
   - 3.5 If the center bezel is being replaced, remove the nameplate.

Installation

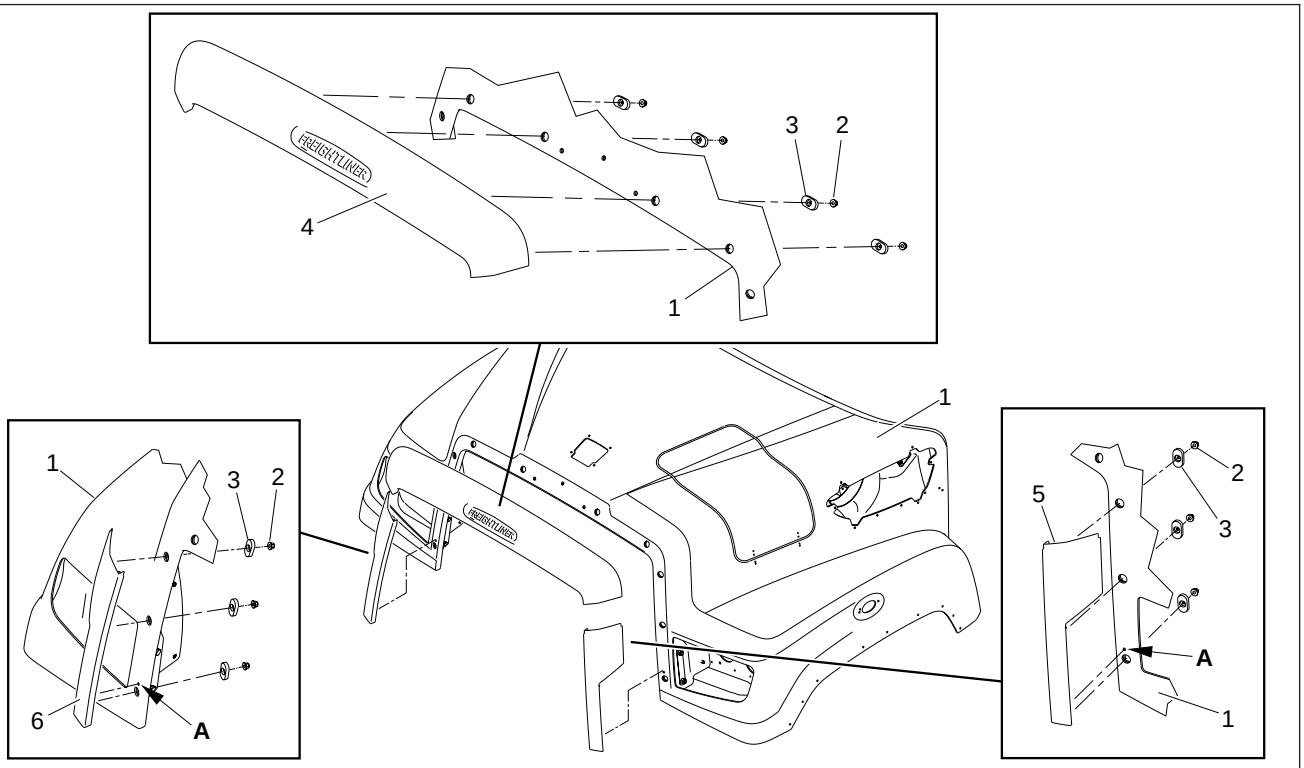
1. Install the hood surround bezels (if removed) as follows. See **Fig. 2**.
   - 1.1 If new bezels are being installed, install the nameplate on the new center bezel, then remove the backing from the adhesive strips on the underside of the bezels.

     If the original bezels are being installed, remove the old adhesive, then clean the surface under the aft edges of the bezels with rubbing alcohol. Allow to dry, then install new double-sided strips to the aft edges.
   - 1.2 Clean the bonding surface on the hood with a 50:50 mixture of isopropyl alcohol, wipe, and allow to dry completely.
   - 1.3 Test for proper alignment of the side bezels before removing the backing from the adhesive strips. Align the locator pin on the bezel with the hole on the hood skin, then rotate the bezel until the side tab on the bezel touches the hood skin.

   NOTE: It is necessary to install the side bezels before installing the center bezel.

   - 1.4 Remove the backing from the side bezel adhesive strips, then position the bezels.
   - 1.5 Install the three locknuts and isolators for each side bezel. Tighten the nuts 55 to 72 lbf·in (620 to 810 N·cm).
   - 1.6 Test for proper alignment of the center bezel, then remove the backing from the adhesive strips.
   - 1.7 Install the four locknuts and isolators. Tighten the nuts 55 to 72 lbf·in (620 to 810 N·cm).
   - 1.8 Apply firm pressure to the bezels over the adhesive strips to ensure good adhesion to the hood surface.
2. Using the screws and flatwashers, attach the grille to the brackets on the charge air cooler. Tighten the screws 50 to 55 lbf·in (560 to 620 N·cm).

Grille Removal and Installation



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A. Align the locator pin on the bezel with the hole in the hood.

1. Hood
2. Flanged Locknut, M6
3. Isolator
4. Center Bezel
5. Side Bezel, LH
6. Side Bezel, RH

Fig. 2, Bezel Installation

Safety Precautions

⚠ WARNING

Before performing any fiberglass repairs, read and comply with the following warnings and precautions. Observe any additional precautions given by the manufacturers of the repair materials used.

- All of the raw materials used in repairing fiberglass are harmful to the eyes and could cause blindness. Wear goggles or other protective eye shields to reduce the chances of repair material contacting your eyes. If repair material contacts eyes, rinse with plenty of water (15 minutes), and call a doctor.
- Fiberglass repair materials can be skin irritants. Do not allow the materials to contact skin. Wear protective gloves made from the following recommended materials: butyl rubber, nitrile rubber, polyvinyl alcohol. If the repair material contacts skin, wash with soap and water.
- Some fiberglass repair materials are toxic. Perform repairs in a well ventilated area. If ventilation is not adequate, wear appropriate respiratory protection.
- Most of the materials involved in fiberglass repair and cleanup are flammable. Do not perform repairs in areas where exposed (or stored) flammable liquids may contact an open flame or any burning material.
- When grinding or sanding fiberglass surfaces, wear goggles or other protective eye shields, and appropriate respiratory protection. Do not breathe grinding dust or particles, otherwise irritation may occur.

Hood Repair

⚠ WARNING

Before starting any hood repair procedures, read the safety precautions in Subject 120. Failure to be aware of the hazards in using fiberglass repair materials could result in serious and long-term health problems.

General Information

The 108SD and 114SD hood is an assembly of the one-piece hood outer shell and inner reinforcing members bonded together with a structural adhesive; see **Fig. 1**.

If a joint between two parts has separated and there is no damage at the joint area, the parts can be rebonded. Or, if a part is damaged and its adjoining parts are not damaged, the damaged part can be separated from the hood and new or used parts can be bonded in place. A section of a part can be replaced as long as the section does not include a joint between two parts. Fenders and headlight reinforcements are available as replacement parts or for use in section replacements. If the damage is such that the parts cannot be replaced, or a section replacement cannot be done, replace the entire hood assembly.

For minor surface cracks (cracks that do not go through the laminate), see "Surface Damage Repair."

For cracks that go through the laminate, or for large damaged areas, see "Structural Damage Repair."

For section replacement, or to rebond parts, see "Hood Component Rebonding."

Because fiberglass dust can shorten the life of electrical units, air-powered tools are preferred for frequent use.

NOTE: Store fiberglass repair adhesives in a cool, dry, well ventilated area that is out of direct sunlight. Do not store adhesive syringes on their sides. Storing the syringes in the upright or upside down position allows any air that enters the syringe to accumulate at either end, instead of throughout the syringe.

Surface Damage Repair

Surface damage refers to scratches, chips, or nicks on the outer surface of the hood or half-fender. Use the following instructions to repair surface damage:

1. Clean the area with xylene, acetone, or an equivalent grease- and wax-removing solvent. Inspect the area closely.
2. Using 220-grit or finer sandpaper, remove all of the paint around the damaged area to a distance of about 1-1/2 inches (4 cm). See **Fig. 2**.
3. Using an air nozzle, blow off all dust.
4. Apply Ashland Pliogrip 7775L self-leveling urethane adhesive over the non-coated area and spread a thin layer using a squeegee applicator. Cover the entire damaged area, overlapping onto the painted surface. Leave a crowned excess of adhesive, slightly higher than the painted surface.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

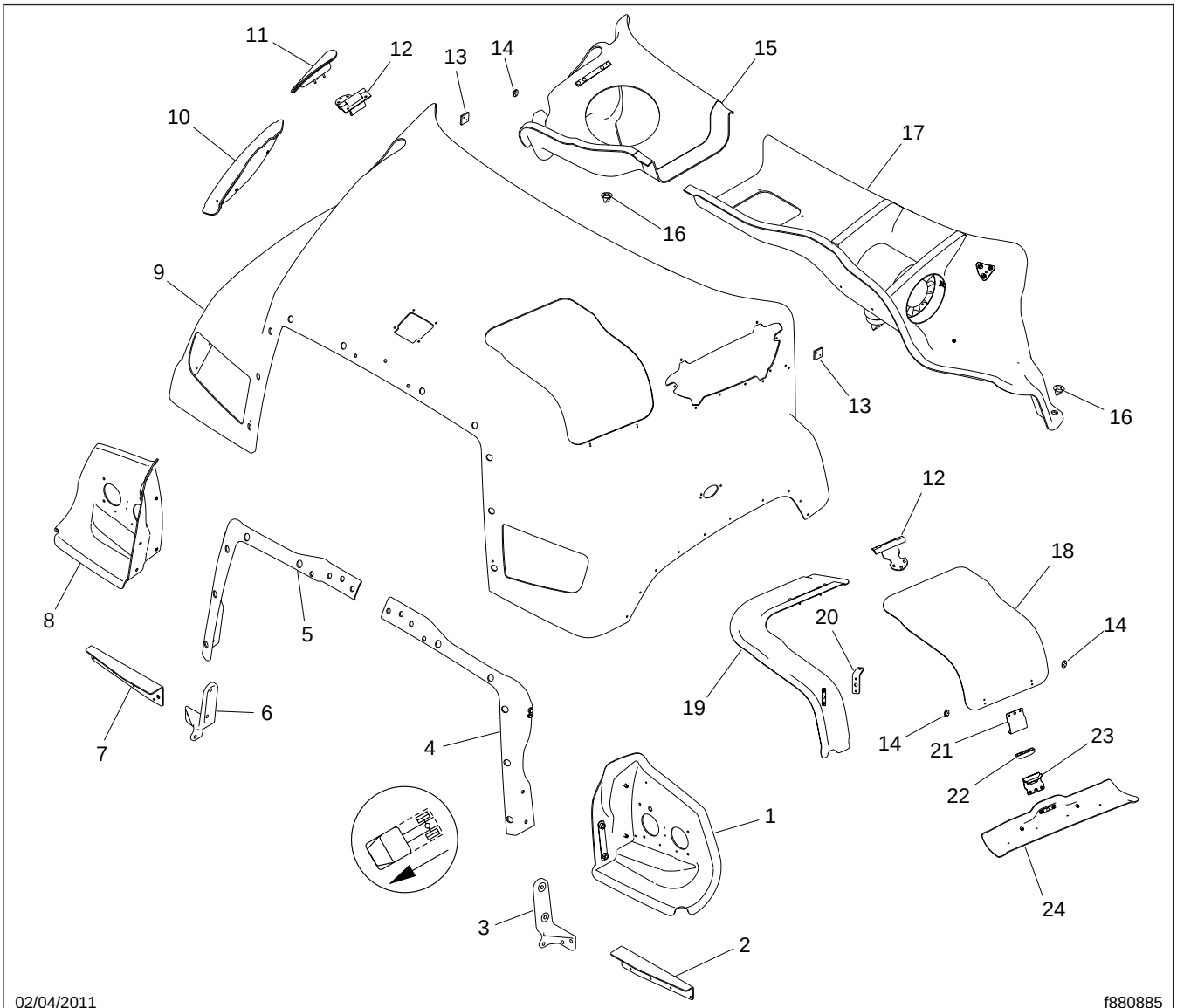
5. After the adhesive dries (about 50 minutes), sand it with a hand-held disc pad. Use 320-grit or finer sandpaper. Feather the edges of the fill so there are no visible sharp edges.
6. Clean the area with compressed air. Mask the area, then spot prime and paint it. Use Sherwin Williams BB–11 black conductive primer. See **Group 98** for spot-painting instructions.

Structural Damage Repair

The Preform FRP (fiberglass reinforced plastic) hood consists of a one-piece hood and fender assembly. Inner reinforcements are bonded to the engine-side of the hood with a structural adhesive. See **Fig. 1**. If the hood is damaged, determine which parts are affected.

If there is damage to any of the reinforcements, the damage is not repairable. For example, if the grille area of the hood is damaged so badly that the reinforcement bonded inside the grille area is also damaged, replace the entire hood assembly.

Hood Repair



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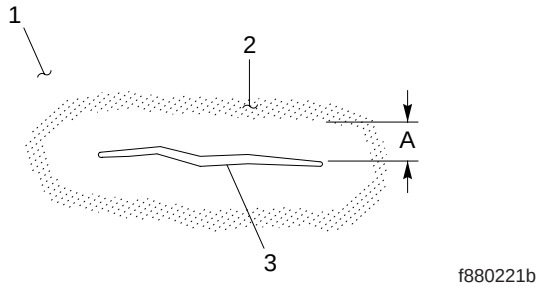
1. Headlamp Reinforcement, LH
2. Grille Opening Lower Reinforcement, LH
3. Hood Pivot Hinge, LH
4. Grille Opening Upper Reinforcement, LH
5. Grille Opening Upper Reinforcement, RH
6. Hood Pivot Hinge, RH
7. Grille Opening Lower Reinforcement, RH
8. Headlamp Reinforcement, RH
9. Outer Hood Panel
10. Hood Side Reinforcement, RH
11. Access Door Panel, RH
12. Access Door Hinge Assembly, RH
13. Backing Plate
14. Latch Reinforcement Plate
15. Air Intake Plenum Reinforcement, RH
16. Drain Plug
17. Air Intake Plenum Reinforcement, LH
18. Access Door Panel, LH
19. Access Door Reinforcement
20. Prop Rod Catch Bracket
21. Access Door Stop Bracket
22. Access Door Bearing Block
23. Access Door Stop Bracket
24. Access Door Reinforcement

Fig. 1, Hood Assembly Components



A. Remove paint and primer 1-1/2 inches (4 cm) around the damaged area. Use 220-grit or finer sandpaper.

1. Paint
2. Primer
3. Scratch

Fig. 2, Damaged Area with Paint and In-Mold Coating Removed

If a joint between two reinforcements, or between a reinforcement and the hood skin, has separated and there is no damage at the joint area, the parts can be rebonded. Or, if a part of the hood skin is damaged and its adjoining reinforcement(s) aren't damaged, the reinforcement can be separated from the damaged part, the damaged part can be patched, and the reinforcement(s) rebonded in place.

If a half-fender has a small crack or hole, it can be repaired; if it has a puncture or large fracture, it must be replaced.

For rebonding parts, see "Hood Reinforcement Rebonding."

For damage in the form of a crack or small hole, see "Crack or Small Hole Repair."

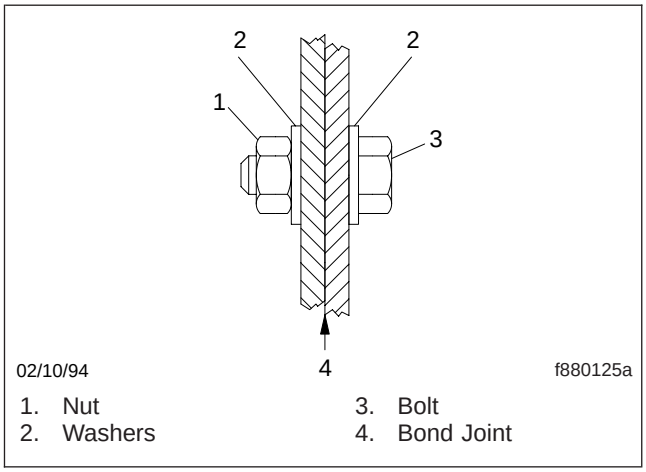
For larger damaged areas, see "Puncture or Large Fracture Repair."

Hood Reinforcement Rebonding

1. If rebonding a joint that has partially separated, completely separate the reinforcement from the hood using a heat gun and putty knife. Remove as much of the old adhesive as possible. The heat gun will soften the adhesive and allow it to be peeled off the FRP.

   If the parts cannot be separated, work folded medium-grit sandpaper or a section of a steel hacksaw blade between the two surfaces to remove the old adhesive.

2. Scuff the surfaces with 80- to 220-grit sandpaper.
3. Clean the surfaces to be bonded with Ashland 6036 solvent or methylene chloride. Inspect the area closely to be sure all of the old adhesive, dirt, water, grease, and oils are removed.
4. If replacing a large part, align the part on the hood and clamp it in place. Drill holes through the bonding surfaces and install clamping bolts in the holes. Use two washers, one on each side of the joint. See **Fig. 3**. There should be enough clamping bolts to hold the hood in place and keep the bonding surfaces together, or at least one bolt every 12 to 18 inches (30 to 45 cm). Remove the part for application of adhesive.



1. Nut
2. Washers
3. Bolt
4. Bond Joint

Fig. 3, Clamping Bolt at Bond Joint

5. Following the manufacturer's instructions, use enough adhesive to bond the parts together. Use Ashland Pliogrip urethane cartridge materials 7773 or 7779.

NOTE: When using Ashland Pliogrip 7773 or 7779, insert the two tubes of adhesive into the applicator and dispense a 3/8-inch (10-mm) diameter bead of uniform green-colored adhesive at the bonding surface. Discard any adhesive that does not show this uniform green color.

6. Within three and one half minutes (7773) or within 10 minutes (7779) of applying the bead, align the part on the hood and clamp it firmly in place. If it is a large part, install the clamping bolts. Tighten the clamps or clamping bolts just enough to ensure that a uniform amount of pressure is applied along the seam. Ideally, the adhe-

Hood Repair

sive should be compressed to form a bondline one inch (25 mm) wide and 0.030 inch (0.76 mm) thick. This thickness can be ensured by sprinkling 0.030 inch (0.76 mm) glass beads into the adhesive before mating the parts.

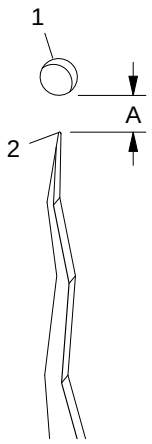
7. Before it cures, remove any excess adhesive that squeezes out the edges of the bond.
8. Remove the clamps after the adhesive has cured for 30 minutes (7773) or for 60 minutes (7779).
9. If holes were drilled for clamping bolts, repair them using the instructions under "Crack or Small Hole Repair."
10. If necessary, prime and paint the repair area using the instructions under "Surface Damage Repair."

Crack or Small Hole Repair

A crack (fracture) or small hole through the laminate requires repair with a fiberglass-reinforced patch.

1. Examine the damage to the hood or half-fender. Apply hand pressure all around the damaged area to check for any concealed damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.
3. Clean the damaged area on both sides of the hood or half-fender with xylene, acetone, or equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. If repairing a crack, use a 1/8-inch (3-mm) diameter bit to drill a hole completely through the uncracked laminate 1/8 inch (3 mm) from each end of the crack, to prevent the crack from lengthening. See **Fig. 4**.
5. On the engine side of the hood (or underside of the half-fender), use a router bit (on a grinder or a drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the damage. Taper the outside edge of the ground area. See **Fig. 5**.

   If repairing a crack, grind outward to the drilled hole at the end of the crack, but not beyond. See **Fig. 6**, Ref. A.



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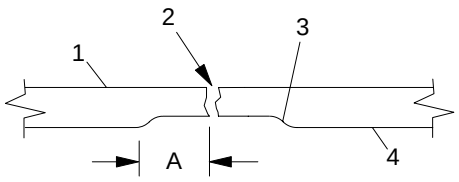
A. 1/8 inch (3 mm)

1. Drilled 1/8-inch (3-mm) Hole
2. End of Crack

Fig. 4, Drilling a Hole to Prevent the Crack From Lengthening



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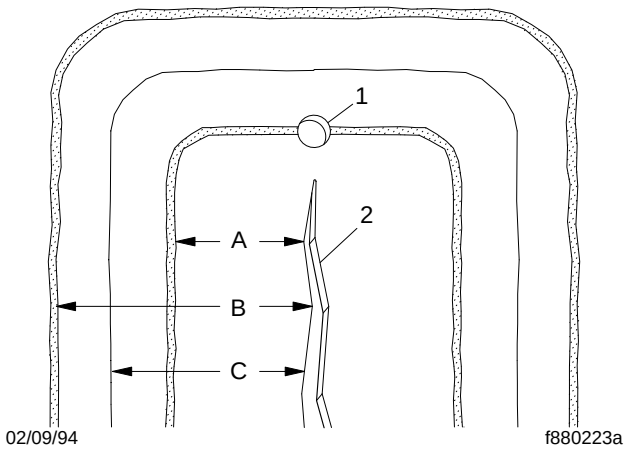
A. Grind a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward in all directions from the damaged area.

1. FRP
2. Crack
3. Slight Taper
4. Engine Side of Hood (or underside of half-fender)

Fig. 5, Recessed Area (cross-sectional view)

6. Use 80- to 220-grit sandpaper to scuff an area at least one inch (25 mm) away from the fracture on all sides. Be sure to scuff thoroughly, since this will give the patch a surface to which it can stick. See **Fig. 6**, Ref. B.
7. Blow the dust away with compressed air and wipe the area with a clean cloth.



A. Use a router to grind away a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward from the damage. If repairing a crack, don't grind past the hole drilled at the end of the crack.
B. Use 80- to 220-grit sandpaper to scuff the area one inch (25 mm) around the damage.
C. Cut the fiberglass cloth to fully cover the damage, and overlay about 3/4 inch (20 mm).

1. Hole
2. Crack

Fig. 6, Preparing the Damaged Area on the Engine Side of the Hood

8. If necessary, align the panel sections on both sides of the crack, using weights or clamps to re-establish the original panel profile.
9. With a razor-blade knife, cut a section of woven fiberglass cloth to fully cover the crack and to overlay about 3/4 inch (20 mm). See **Fig. 6**, Ref. C.
10. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

11. Lay the cut section of fiberglass cloth on the repair area, centered over the damage. Using a fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.
12. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.
13. After two to five minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, mate the FRP parts to be bonded within one to four minutes after dispensing the adhesive.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after five minutes when the adhesive has set.

14. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface if required.
15. Repair the damage on the outside surface of the hood or half-fender, using the instructions in "Surface Damage Repair." Prime and paint both surfaces, using the instructions in **Group 98**.

Puncture and Large Fracture Repair (Section Replacement)

If a half-fender has a puncture or large fracture, replace the half-fender.

On very large damaged areas (for example, structural damage on the side surface of the hood covering an area of a square foot or more) it may be easier to do a section replacement rather than make a patch. Fenders and headlight reinforcements may be used in section replacements. Also, a second damaged hood with the needed section intact may be available as scrap.

IMPORTANT: A matching piece from another 108SD or 114SD vehicle hood must be used for section replacement. Use of any other material may not allow the necessary bonding for the repair.

1. Push in on the area immediately surrounding and underneath the damaged area to determine the extent of damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.

Hood Repair

3. Clean the damaged area on both sides of the hood with xylene, acetone, or an equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. Using a sabre saw, cut out a large, straight-sided panel containing the damaged area. See **Fig. 7**, Ref. A.

   If the damage extends to a joint where a reinforcement is bonded to the hood, completely separate the reinforcement with a heat gun and putty knife before cutting. See "Hood Reinforcement Rebonding" for instructions.
5. From a scrap hood, cut a section replacement panel from the same area, only slightly larger than the cut-out in the damaged hood. See **Fig. 7**, Ref. B. Then, trim the section replacement to fit both the size and contour of the original cutout.

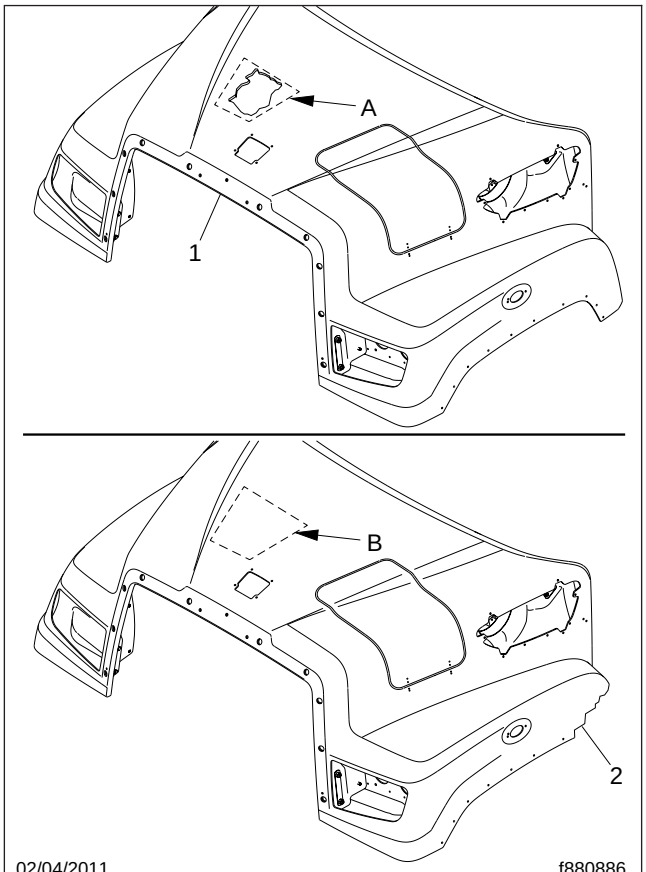
   If the damage is next to a headlight reinforcement, but doesn't include the reinforcement, remove the headlight reinforcement from the replacement section (scrap hood), not the damaged hood.
6. After the trimming is completed, sand the edges to allow a 1/16- to 1/8-inch (2- to 3-mm) gap around the cutout.
7. On the engine side of the hood, use a router bit (on a grinder or drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the cutout area. See **Fig. 8**, Ref. A.

   Also, grind 1/2 inch (13 mm) inward from all edges on the engine side of the section replacement. See **Fig. 8**, Ref. C.

   Slightly taper the outside edge of the ground area on the hood and the inside edge of the ground area on the section replacement. See **Fig. 9**, Ref. 3.
8. Use 80- to 220-grit sandpaper to scuff an area at least one inch (25 mm) out from all sides of the cutout area. See **Fig. 8**, Ref. B.

   Also, scuff at least one inch (25 mm) in from all sides of the section replacement. See **Fig. 8**, Ref. D.

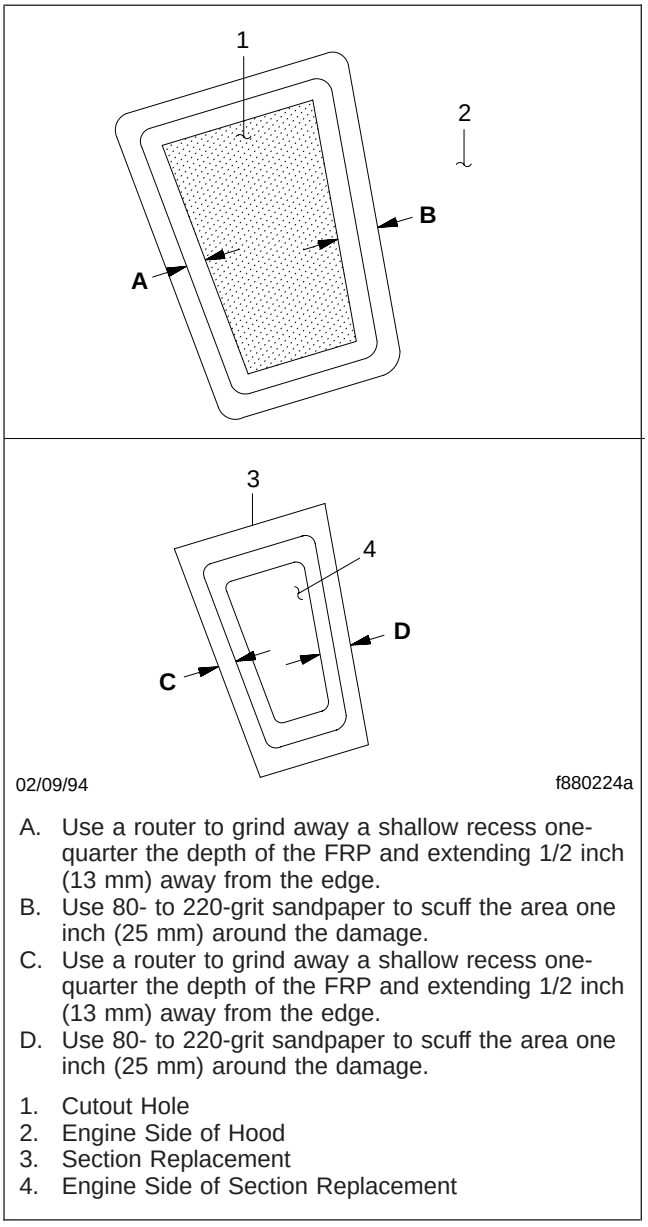
   Scuff thoroughly, since this will give the section replacement a surface to which it can stick. Be sure to completely sand off any undercoating sprayed on these areas.
9. On the outer sides of both the cutout and the section replacement, bevel the edges about 45 degrees. See **Fig. 10**.
10. Gently feather the outer painted surfaces back about 1/2 inch (13 mm) beyond the edges of the repair areas (on both the cutout and the section replacement), using 220-grit or finer sandpaper.
11. Blow the dust away with compressed air, and wipe the area with a clean cloth.



A. Remove this area.
B. Use as a section replacement for damaged hood.

1. Damaged Hood
2. Scrap Hood

Fig. 7, Section Replacement of a Damaged Fiberglass Hood



A. Use a router to grind away a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) away from the edge.
B. Use 80- to 220-grit sandpaper to scuff the area one inch (25 mm) around the damage.
C. Use a router to grind away a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) away from the edge.
D. Use 80- to 220-grit sandpaper to scuff the area one inch (25 mm) around the damage.

1. Cutout Hole
2. Engine Side of Hood
3. Section Replacement
4. Engine Side of Section Replacement

Fig. 8, Preparing the Section Replacement and Hood Cutout on the Unexposed Side

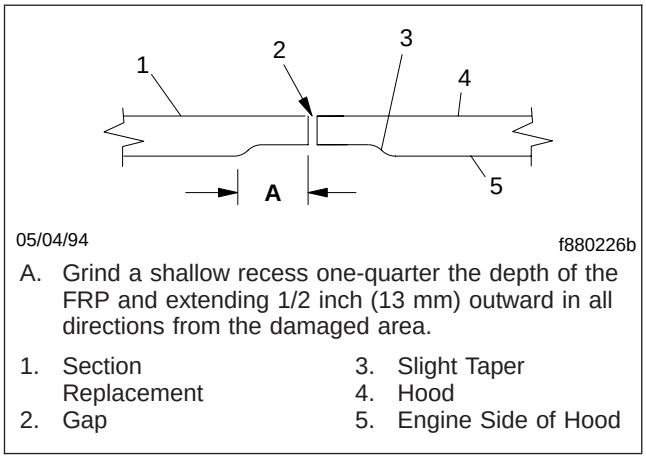
12. If the section replacement is close enough to an edge, use clamps to temporarily secure it during the repair.

    If the replacement is too far from an edge to use clamps, use bond strips. See **Fig. 11**.

    12.1 Cut some scrap FRP into strips. Make enough strips to hold the section replacement in position; about one every six inches (15 cm). If the surface of the replacement panel is contoured or curved, use many small bond strips; larger strips could deform the curves.

    12.2 On the engine side of the repair, use 220-grit sandpaper to scuff sand the areas on the hood and section replacement panels where you plan to bond the strips.

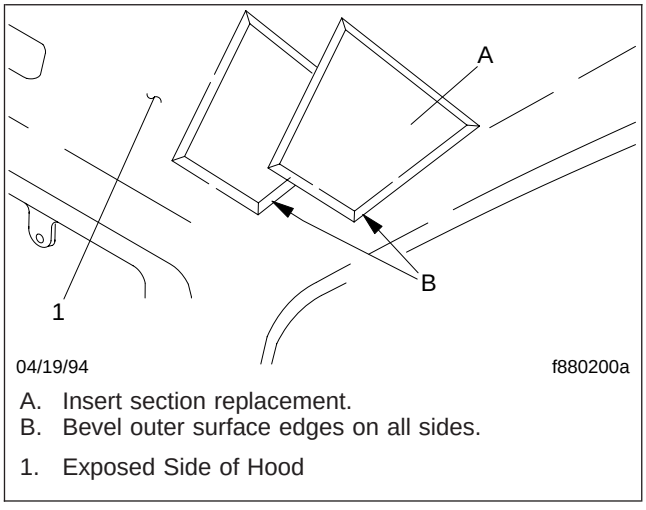
    12.3 If a joint between the hood and a reinforcement was separated for the repair, rebond the joint. See "Hood Reinforcement Rebonding" for instructions.



A. Grind a shallow recess one-quarter the depth of the FRP and extending 1/2 inch (13 mm) outward in all directions from the damaged area.

1. Section Replacement
2. Gap
3. Slight Taper
4. Hood
5. Engine Side of Hood

Fig. 9, Cutout Area (cross-sectional view)

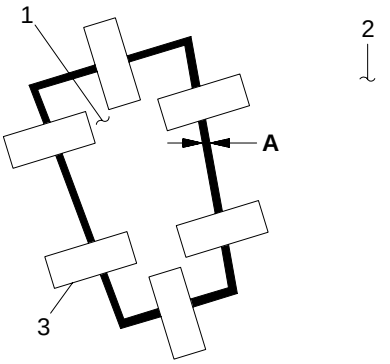


A. Insert section replacement.
B. Bevel outer surface edges on all sides.

1. Exposed Side of Hood

Fig. 10, Areas to be Beveled

Hood Repair



A. Gap of 1/16 inch to 1/8 inch (2 to 3 mm)

1. Section Replacement
2. Engine Side of Hood
3. Bond Strip

Fig. 11, Securing the Section Replacement to the Hood Using Bond Strips

12.4 Holding the section replacement in position, bond the strips to both hood and replacement panels in the area already scuffed. Use Ashland Pliogrip 7773 to bond the strips.

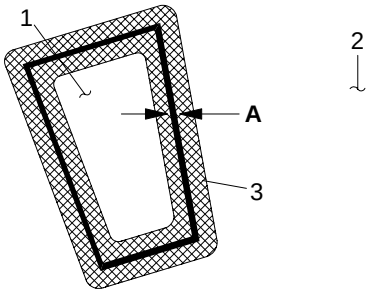
NOTE: When using Ashland Pliogrip 7773, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

12.5 After the adhesive has hardened, use 80- to 220-grit sandpaper to scuff the bond strips.

12.6 Blow the dust away with compressed air, and wipe the area with a clean cloth.

13. With a razor-blade knife, cut sections of woven fiberglass cloth to fully cover the gap between the cutout and the section replacement, all the way around the damaged area. The cloth should overlay about 3/4 inch (20 mm) on both sides of the gap. See **Fig. 12**.
14. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.



NOTE: The fiberglass cloth should overlay about 3/4 inch (20 mm) on both sides of the gap.

A. Gap of 1/16 inch to 1/8 inch (2 to 3 mm)

1. Section Replacement
2. Engine Side of Hood
3. Fiberglass Cloth

Fig. 12, Overlaying the Gap with Fiberglass Cloth

15. Use a plastic or metal device to spread a thin layer of adhesive over the scuffed area.
16. Lay the cut sections of fiberglass cloth on the repair area, centered over the damage. Using a fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.
17. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.
18. After two to five minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, the FRP parts to be bonded should be mated within one to four minutes after the adhesive is dispensed.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after five minutes when the adhesive has set.

19. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface, if desired.

20. Repair the damage on the outside surface of the hood and paint the surface on both sides, using the instructions in "Surface Damage Repair."

Torque Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.04**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Hood Pivot-Bolt Nuts	128–162	173–219	—	—
Check Cable Nuts	—	—	60	680
Tilt-Assist Strut Mounting Nuts	15–19	20–26	—	—
Hood Pivot Adapter Plate Nuts	57–72	77–98	—	—
Hood Rear Locator Fasteners	23–29	31–40	—	—
Hood Surround Bezel Nuts	—	—	55–72	620–810
Grille Mounting Screws	—	—	50–55	560–620

Table 1, Torque Specifications

Repair Tools, Materials

Surface Damage

Required tools and materials:

- Xylene, acetone, or equivalent solvent
- 220- or finer grit sandpaper
- 320- or finer grit sandpaper
- Hand-held disc pad
- Self-leveling adhesive [1]
- Applicator squeegee
- Primer [2]

Structural Damage

Section Replacement (Punctures and Large Fractures)

Required tools and materials:

- Scrap FRP from a damaged hood
- Xylene, acetone, or equivalent solvent
- Saber saw
- Router bit
- Razor-blade knife
- Woven fiberglass cloth
- Clamps
- 80- to 220-grit sandpaper
- 220- or finer grit sandpaper
- 320- or finer grit sandpaper
- Hand-held disc pad
- Adhesive for bonding strips (if needed) [3]
- Self-leveling adhesive [1]
- Applicator squeegee
- Primer [2]

Crack or Small Hole

Required tools and materials:

- Xylene, acetone, or equivalent solvent
- 1/8-inch diameter drill bit

[1] Use Ashland Pliogrip 7775L self-leveling urethane adhesive. 7775L has no sag resistance and, therefore, is useful for filling cracks and channels, and for bonding glass-fiber reinforcing fabrics. Ashland products are available through Freightliner dealers. See **Table 2** and **Table 3**.

[2] Use Sherwin Williams BB–11 black conductive primer. Contact your local Sherwin Williams automotive paint distributor to purchase this primer.

[3] Ashland Pliogrip 7773 or 7779 adhesives are recommended for this application, but 7771 and 7770 may be substituted. A heat gun may be used to speed curing times. Ashland products are available through Freightliner dealers. See **Table 2**.

Specifications

- Router bit
- Razor-blade knife
- Woven fiberglass cloth
- 80- to 220-grit sandpaper
- 220- or finer grit sandpaper
- 320- or finer grit sandpaper
- Hand-held disc pad
- Self-leveling adhesive [1]
- Applicator squeegee
- Primer [2]

Hood Component Rebonding

Required tools and materials:

- Solvent [4]
- 80- to 220-grit sandpaper
- Clamps, clamping bolts with washers
- 0.030" (0.76 mm) diameter glass beads
- Adhesive [3]
- Primer [2]
- Heat gun
- Putty knife, hacksaw blade

NOTE: Ashland Pliogrip 7700 and 8000 Series adhesives and accessories are available through Freightliner dealers and PDCs. The 7700 Series adhesives are two-part urethane adhesives, specially formulated and packaged for repair of hoods and other fiber-reinforced plastics. Adhesive 7775L is a self-leveling mixture that is appropriate when a surface filler or glass fabric reinforcement repair is required. The 8000 Series adhesives are also two-part urethane adhesives, available for those who prefer to use these earlier-generation adhesives. Descriptions, working times, and curing times (sanding and repainting) for the various adhesives are shown below in **Table 2** and **Table 4**. Ashland adhesive accessories are listed in **Table 3** and **Table 5**.

NOTE: All of the adhesives develop the same bonding strength; specific adhesives may be preferred to change working times.

NOTE: All working and curing times correspond to an ambient temperature of 73°F (23°C) in the workplace; humidity level will NOT affect working or curing times.

IMPORTANT: While a heat gun may be used to speed adhesive curing time, do not overheat the adhesive. The maximum allowable temperature is 180°F (82°C).

Working and Curing Times for 7700 Series Adhesives

Description	Part Number	Working Time in Minutes	Curing Time in Minutes	Curing Time in Hours
Adhesive, two 1.7 oz (50 ml) cartridges, 3.4 oz (100 ml)	ACA 7771	1.5	10.0	—
Adhesive, two 1.7 oz (50 ml) cartridges, 3.4 oz (100 ml)	ACA 7773	3.5	30.0	—
Adhesive, two 10 oz (300 ml) cartridges, 20 oz (600 ml)	ACA 7773 300	3.5	30.0	—
Adhesive, two 1.7 oz (50 ml) cartridges, 3.4 oz (100 ml)	ACA 7775L	5.0	50.0	—
Adhesive, two 1.7 oz (50 ml) cartridges, 3.4 oz (100 ml)	ACA 7779	10.0	—	1.0
Adhesive, two 10 oz (300 ml) cartridges, 20 oz (600 ml)	ACA 7779 300	10.0	—	1.0
Adhesive, two 1.7 oz (50 ml) cartridges, 3.4 oz (100 ml)	ACA 7770	35.0	—	2.5–3.0
Adhesive, two 10 oz (300 ml) cartridges, 20 oz (600 ml)	ACA 7770 300	35.0	—	2.5–3.0

Table 2, Working and Curing Times for 7700 Series Adhesives

[4] Use Ashland 6036 primer or methylene chloride. Contact Ashland Merchandising Group, telephone (419) 289–9588, to purchase this primer.

Specifications

7700 Series Accessories	
Description	**Part Number**
Manual Applicator Gun for 10 oz (300 ml) Cartridges	ACA TS526C
1/4" Mixing Nozzles for 1.7 oz (50 ml) Cartridges (100/box) *	ACA 583 238
Pneumatic Applicator Gun for 10 oz (300 ml) Cartridges	ACA TS525
3/8" Mixing Nozzles for 10 oz (300 ml) Cartridges (100/box) *	ACA F 771072

* These are additional mixing nozzles. Each adhesive cartridge comes with two mixing nozzles.

Table 3, 7700 Series Accessories

Working and Curing Times for 8000 Series Adhesives				
Description	**Part Number**	**Working Time in Minutes**	**Curing Time in Minutes**	**Curing Time in Hours**
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8104	4	30	—
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8110	10	—	1
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8145	50	—	5–8

Table 4, Working and Curing Times for 8000 Series Adhesives

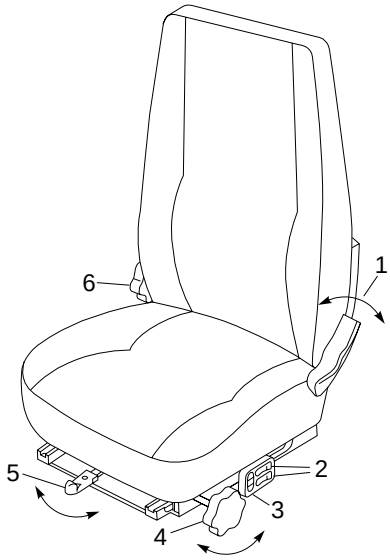
8000 Series Accessories	
Description	**Part Number**
Pneumatic Applicator Gun for 12 oz (355 ml) Cartridges	ACA 582 2241
3/8" Mixing Nozzles for 8000 Series Cartridges (100/box) *	ACA F 771072

* These are additional mixing nozzles. Each adhesive cartridge comes with two mixing nozzles.

Table 5, 8000 Series Accessories

General Information

Bostrom T-Series air suspension seats offer weight/height adjustment, infinite adjustment Parabar II® lumbar support, and a fore-and-aft roller-track isolator system. See **Fig. 1**.



1. Back Rest Tilt Lever
2. Lumbar Support Switches (optional)
3. Height Adjustment Switch
4. Seat Cushion Tilt Knob
5. Fore-and-Aft Seat Adjustment and Isolator Lever
6. Lumbar Support Knob (optional)

Fig. 1, Bostrom T-Series Air Suspension Seat

For complete operating instructions, refer to **Chapter 6** in the *108SD and 114SD Driver's Manual* or the seat manufacturer's operating manual.

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Adjust the seat to the maximum height.
3. Remove the suspension shroud (if equipped) from the seat base.
4. To secure the seat suspension in the extended position, bind the two cross-rods together with a large tie strap, at either the top or bottom of the fully extended scissor arms.

NOTE: If the seat is removed for a suspension rebuild (**Subject 150**), use a spacer block instead of tie straps to secure the seat in the extended position.

5. Release the air pressure from the seat air spring.

CAUTION

Do not remove the seat without first draining the seat air spring, and holding the seat suspension extended by securing the cross-rods together at either the top or bottom of the fully extended scissor arms. If the seat suspension is not properly secured, the seat could lower unexpectedly, pinching a hand or finger between the suspension parts, resulting in personal injury.

6. Drain the vehicle air reservoirs.

WARNING

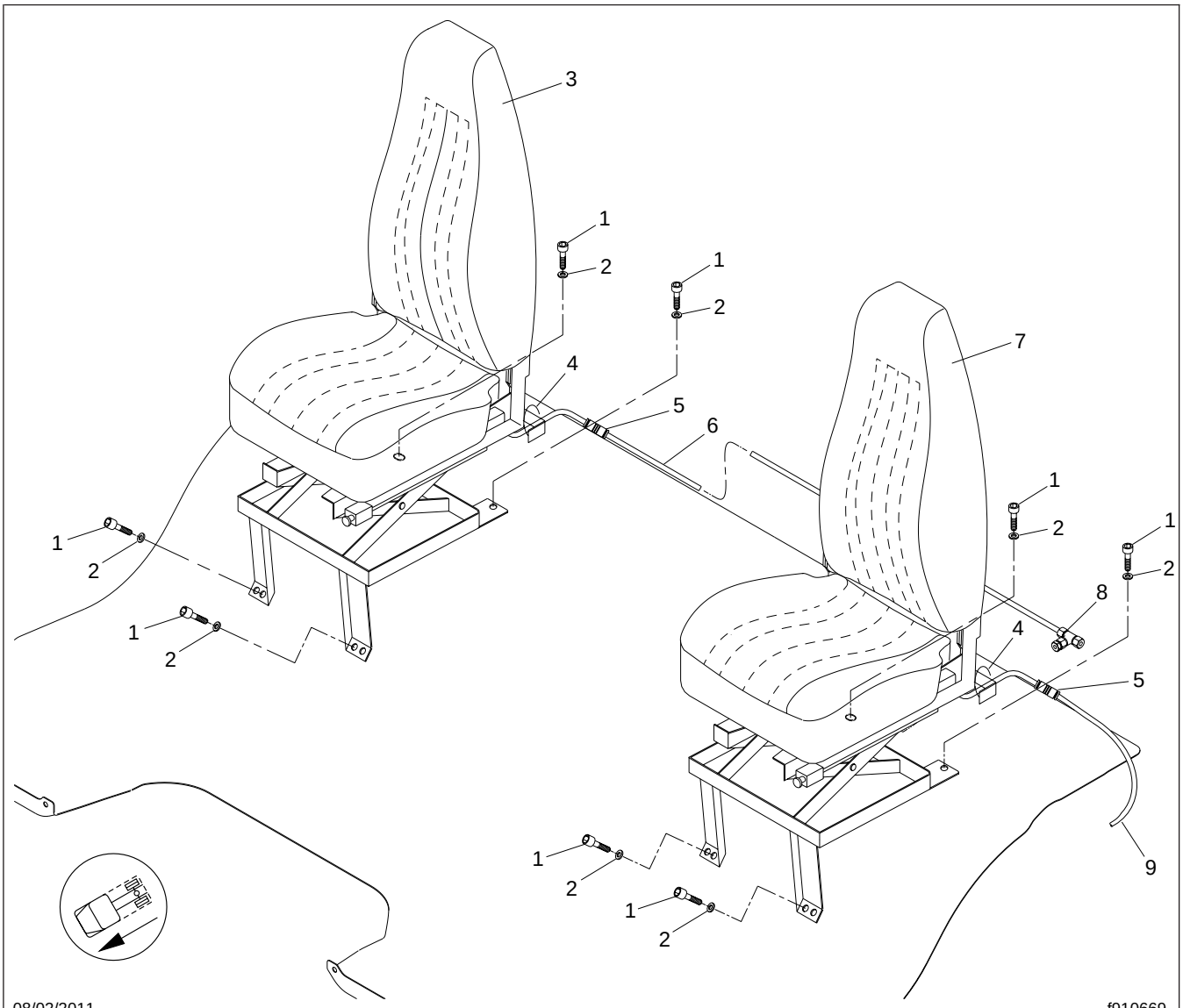
Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

7. If equipped with a seat heater, disconnect the power supply from the seat.
8. Disconnect the air valve air supply hose.
9. Remove the capscrews that attach the seat belt and tether belts to the intermediate-connection-point (ICP) bar.
10. Remove the capscrews and washers that attach the seat to the cab deck. Remove the seat from the cab. See **Fig. 1**.

Installation

1. Position the seat on the cab deck. Insert the capscrews through the washers and the seat base. See **Fig. 1**. Tighten the capscrews 25 to 29 lbf·ft (34 to 39 N·m).
2. Attach the seat belt and tether belts to the intermediate-connection-point (ICP) bar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
3. Attach the air valve air supply hose.
4. If equipped with a seat heater, plug in the power supply to the seat.
5. Start the engine and allow the air reservoirs to fill. Adjust the seat to its maximum height, then remove the tie strap that binds either the top or bottom cross-rods together.
6. Install the suspension shroud (if equipped) on the seat base.

Seat Removal and Installation



1. Capscrew
2. Washer
3. Passenger Seat
4. Cable Tie
5. Union
6. Air Line (with passenger suspension seat only)
7. Driver Seat
8. Tee (with passenger suspension seat only)
9. Air Supply Line

Fig. 1, Seat Installation

Air Spring Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the seat from the vehicle; see **Subject 100**.
3. If not already done, secure the seat suspension in the extended position by binding the two cross-rods together with a large tie strap, at either the top or bottom of the fully extended scissor arms.

⚠ WARNING

Do not remove the seat without first draining the seat air spring, and holding the seat suspension extended by securing the cross-rods together at either the top or bottom of the fully extended scissor arms. If the seat suspension is not properly secured, the seat could lower unexpectedly, pinching a hand or finger between the suspension parts, resulting in personal injury.

4. Release the air pressure from the air spring.

⚠ WARNING

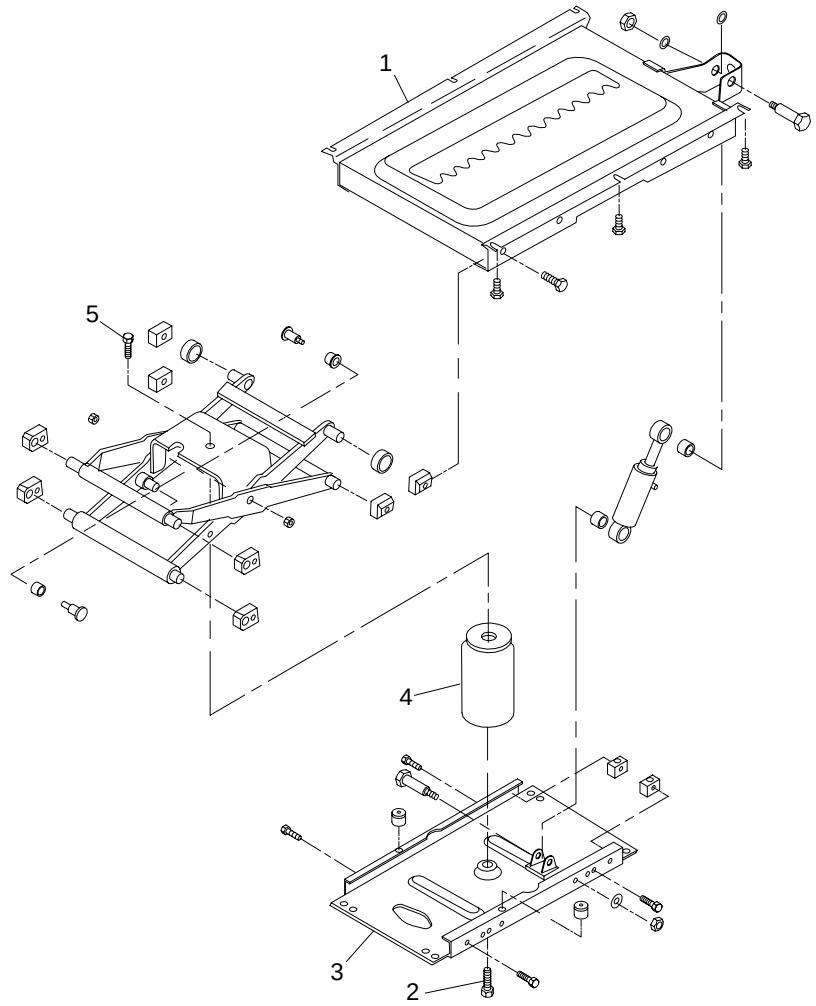
Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

5. Disconnect the air line from the air spring by loosening the air fitting while pulling the air line out of the fitting.
6. Remove the top and bottom capscrews from the air spring. Remove the air spring from the suspension. See **Fig. 1**.

Installation

1. Position the air spring in place so the fitting at the bottom of the air spring is toward the back of the seat. See **Fig. 1**.
2. Install the top capscrew. Tighten the capscrew 60 to 84 lbf·in (680 to 950 N·cm).
3. Install the bottom capscrew. Tighten the capscrew 24 to 48 lbf·in (270 to 540 N·cm).
4. Connect the air line to the fitting in the air spring by pushing the tube into the fitting.
5. Install the seat in the vehicle; see **Subject 100**.

Air Spring Removal and Installation



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1. Upper Frame
2. Bottom Capscrew
3. Base
4. Air Spring
5. Top Capscrew

Fig. 1, Seat Air Spring Installation

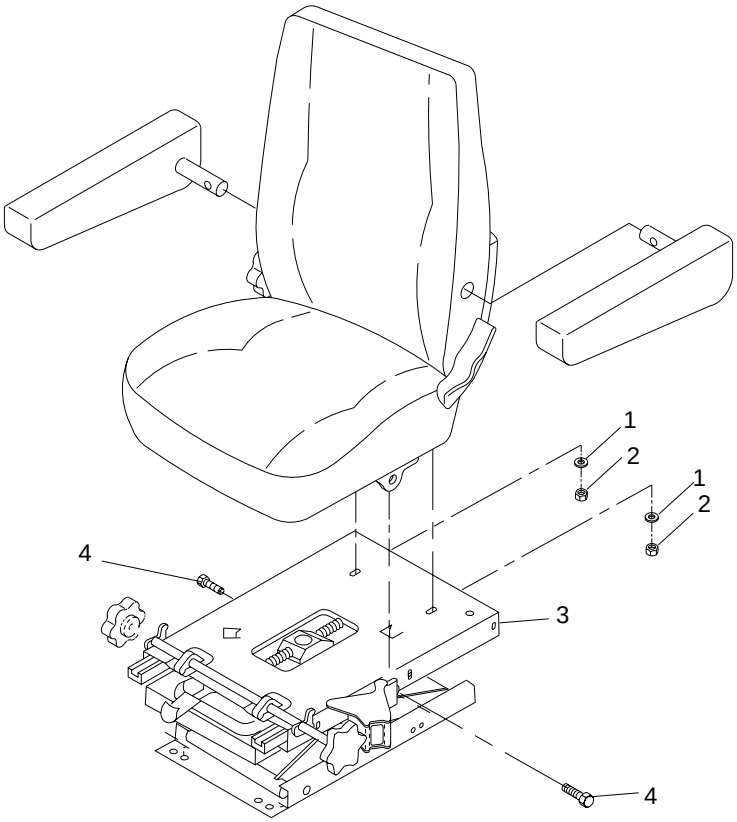
Seat/Back Assembly Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Adjust the seat/back assembly to the most rearward position
3. Remove the two nuts and flatwashers from the underside of the channel assembly. See **Fig. 1**.
4. Remove the two shoulder bolts from the channel assembly.
5. Disconnect the air lines to the lumbar supports.
6. Remove the seat/back assembly.

Installation

1. Place the seat/back assembly onto the channel assembly. See **Fig. 1**.
2. Connect the air lines to the lumbar supports.
3. Install the two shoulder bolts in the channel assembly.
4. Install the two nuts and flatwashers in the underside of the channel assembly.



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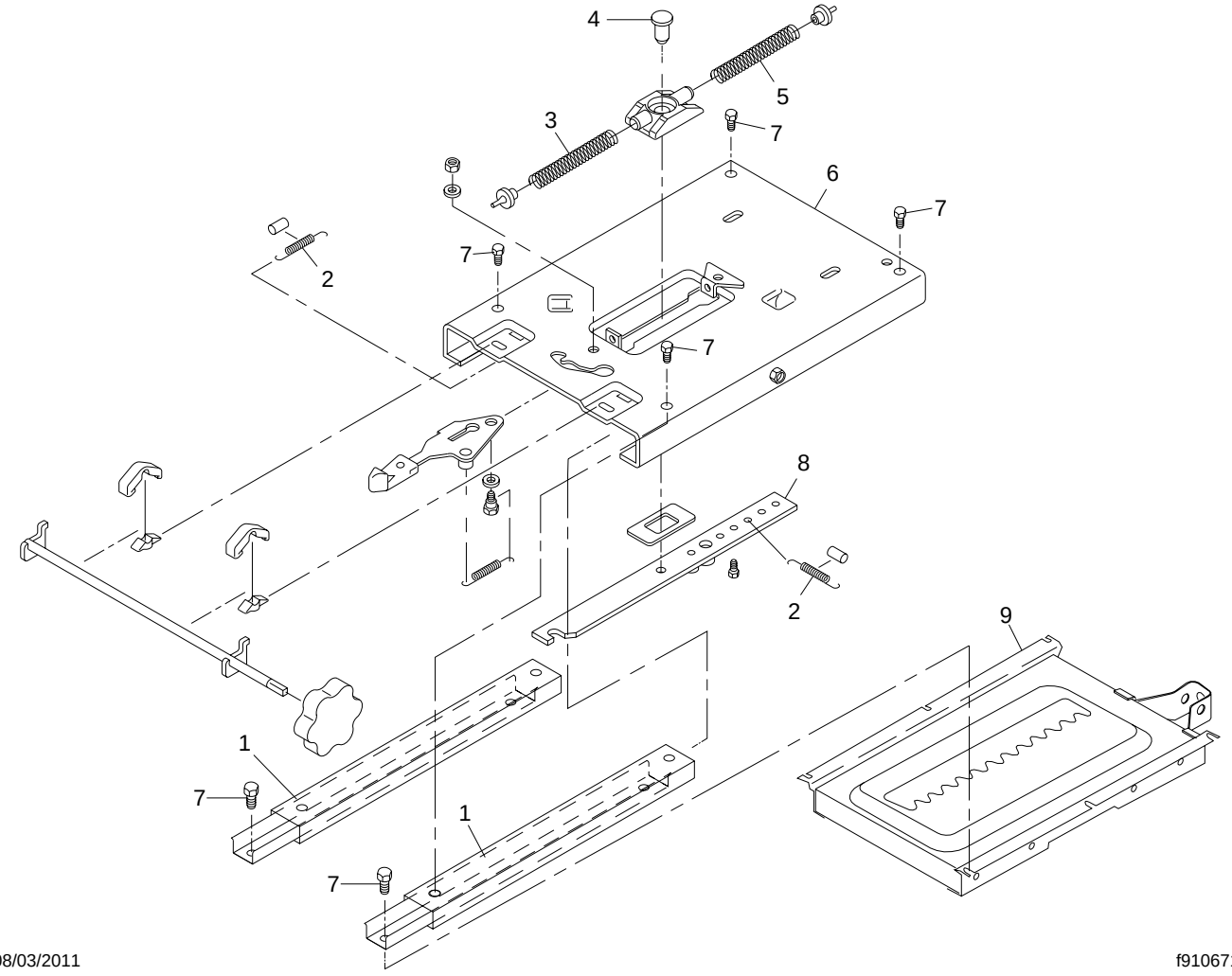
1. Flatwasher
2. Nut
3. Channel Assembly
4. Shoulder Bolt

Fig. 1, Seat/Back Assembly Installation

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the seat/back assembly; see **Subject 120**.
3. Move the isolator assembly to the rear. Remove the front screws and nuts that attach the rails to the upper frame. See **Fig. 1**.
4. Using care, move the isolator assembly to the front. Remove the rear screws and nuts that attach the rails to the upper frame.
5. Remove the screws that attach the rails to the isolator assembly.
6. Remove and install one slide rail at a time.
7. Using new screws, attach the slide rails to the isolator assembly.



1. Slide Rail
2. Spring
3. Front Isolator Spring
4. Pivot Bolt
5. Rear Isolator Spring
6. Isolator Assembly
7. Capscrew
8. Latch Bar
9. Upper Frame

Fig. 1, Slide Rail Installation

Slide Rail Replacement

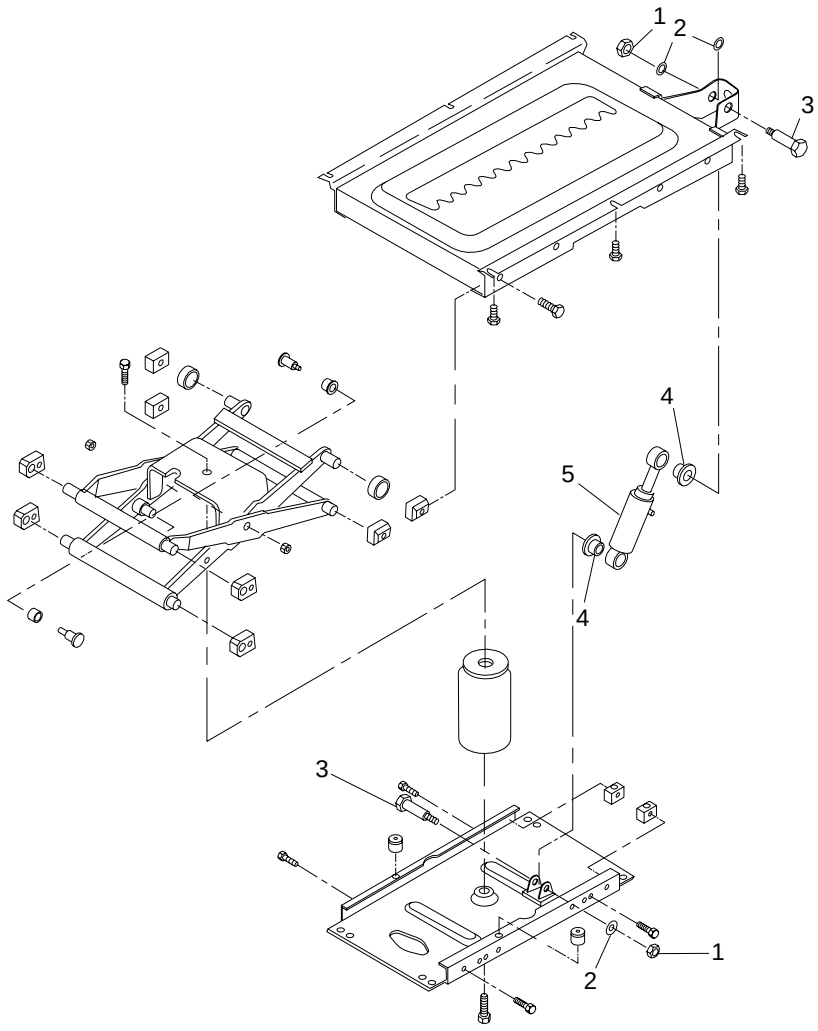
8. Using new screws and nuts, attach the slide rails to the upper frame.
9. Install the seat/back assembly; see **Subject 120**.

Damper Removal and Installation

Removal

NOTE: The seat/back assembly does not need to be removed.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the suspension shroud (if equipped) from the seat base.
3. Adjust the seat to the maximum height.
4. Move the isolator assembly to the fully forward position to provide access to the damper assembly.
5. Remove the shoulder bolts, hexnuts and washers at the top and bottom of the damper. Remove the damper. See **Fig. 1**.



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1. Hexnut
2. Washer
3. Shoulder Bolt
4. Bearing
5. Damper

Fig. 1, Damper Installation

Damper Removal and Installation

Installation

1. Install the new damper with the flanges of the bearings to the outside of the suspension. See **Fig. 1**.
2. Install the shoulder bolts, washers, and hexnuts at the top and bottom of the damper.
3. Install the suspension shroud (if equipped) on the seat base.

Suspension Rebuild—Bearing/Slide Block Removal and Installation

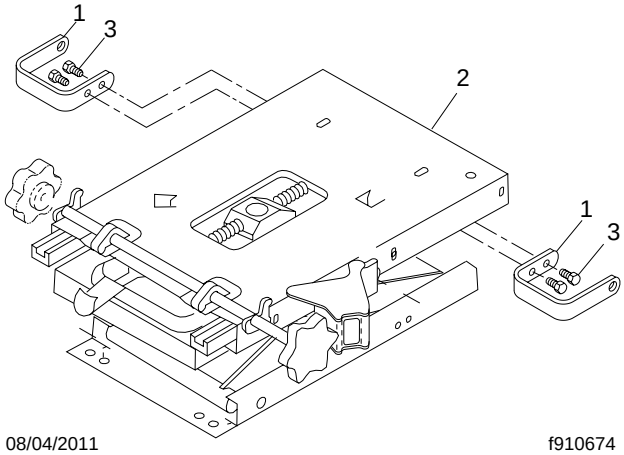
Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.

⚠ WARNING

Air lines under pressure can whip dangerously if disconnected under pressure. Drain all air from the air tanks before disconnecting air lines. Disconnecting pressurized air lines can cause personal injury and/or property damage.

2. Bleed all air from the supply line. Disconnect the air supply line from the seat.
3. Remove the seat from the vehicle; see **Subject 100**.
4. With the seat suspension secured in the extended position with a spacer block, use the air valve to exhaust all air from the air spring.
5. Remove the seat/back assembly; see **Subject 120**.
6. Remove the ICP brackets. See **Fig. 1**.



1. ICP Bracket
2. Seat Suspension
3. Capscrew

Fig. 1, ICP Brackets

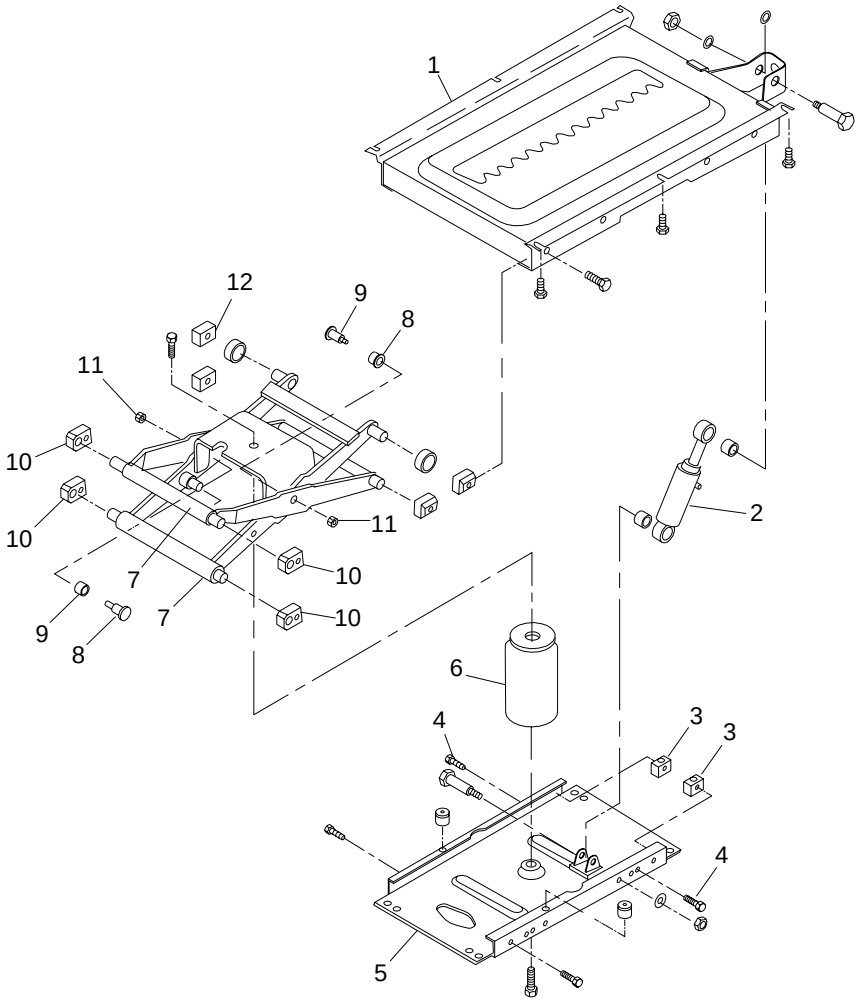
7. Remove the air spring. See **Subject 110**.
8. Remove the damper. See **Subject 140**.
9. Remove the capscrews from the upper front bearing blocks. See **Fig. 2**.
10. Remove the capscrews from the lower rear stop blocks.
11. Remove the isolator assembly by lifting and sliding it forward until the bearing blocks can be removed from the cutouts in the channels on the upper frame. Then slide the channel rearward until the slide blocks can be removed.
12. Remove the capscrews from the lower front bearing blocks.
13. Slide the lever assemblies forward until the bearing blocks can be removed from the channels on the base. Then slide the lever assemblies rearward until the slide blocks can be removed from the channels.
14. Remove the shoulder bolts and nuts from the pivots of the lever assemblies and inspect the bolts. If the bolts are worn, replace them.

Installation

1. Replace the bearings at the pivots on the lever assembly by pushing out the old bearings and pressing in the new bearings. The flange of the bearings should be on the outside of the lever assembly. See **Fig. 2**.
2. Install the shoulder bolts and nuts into the pivots of the lever assemblies. Tighten the bolts 16 to 20 lbf·ft (22 to 27 N·m).
3. Install new bearing blocks, spacers and slide blocks on the levers with the beveled surfaces outward. Slide the levers with blocks into the channel on the base assembly. Tighten the capscrews 23 to 27 lbf·ft (30 to 37 N·m).
4. Slide the isolator assembly over the blocks. Line up the capscrews with the bearing blocks. Tighten the capscrews 23 to 27 lbf·ft (30 to 37 N·m).
5. Manually move the suspension up and down to make sure there are no clearance problems.
6. Block the suspension up with a spacer block placed between the base riser and the upper frame.
7. Install the air spring; see **Subject 110**.
8. Install the damper; see **Subject 140**.
9. Install the ICP brackets.
10. Install the seat/back assembly; see **Subject 120**.

Suspension Rebuild—Bearing/Slide Block Removal and Installation

11. Install the seat in the vehicle; see **Subject 100**.



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1. Upper Frame
2. Damper
3. Stop Block
4. Capscrew
5. Base
6. Air Spring
7. Slide Lever Assembly
8. Shoulder Bolt
9. Bearing
10. Bearing Block
11. Nut
12. Slide Block

Fig. 2, Seat Suspension

Specifications

For fastener torque values, see **Table 1**.

Torque Values		
Description	**Torque: lbf·in (N·cm)**	**Torque: lbf·ft (N·m)**
Seat Mounting Capscrews	—	25–29 (34–39)
Seat/Tether Belt-to-ICP Bar Capscrews	—	35–45 (48–61)
Airspring Bottom Capscrew	60–84 (680–950)	—
Top Airspring Capscrew	24–48 (270–540)	—
Pivot Shoulder Bolt	—	17–19 (22–27)
Slide Block Capscrews	—	23–27 (30–37)
Bearing Block Capscrews	—	23–27 (30–37)

Table 1, Torque Values

General Information

WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Although the three-point seat belts installed in Freightliner vehicles appear similar to the seat belts used in passenger cars, there are some important differences that can affect service life:

- A heavy truck can travel more miles in a year than a car might go in its lifetime.
- There is more movement in a truck seat belt system, especially with air ride seats.
- Trucks often operate in more severe environments than cars, such as gravel pits, cement plants, and grain elevators, where the belts are exposed to abrasive dirt and dust.

Because of these factors, truck seat belt systems need to be inspected regularly to ensure that they are in proper condition; see **Subject 100**.

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

Inspection

⚠ WARNING

Inspect and maintain seat belts. When any part of a seat belt system needs replacement, the entire seat belt must be replaced, both retractor and buckle side. Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire vehicle seat belt system must be replaced before operating the vehicle. Do not attempt to modify the seat belt system; doing so could change the effectiveness of the system. Failure to replace worn or damaged seat belts, or making any modifications to the system, may result in personal injury or death.

Seat belts have a finite life which may be much shorter than the life of the vehicle. Regular inspections and replacement as needed are the only assurance of adequate seat belt security over the life of the vehicle.

1. Check the web for fraying, cuts, or extreme or unusual wear, especially near the buckle latch plate and in the D-loop guide area.
2. Check the web for extreme or unusual dirt or dust, and for severe fading from exposure to sunlight.
3. Check the buckle and latch for operation and for wear or damage.
4. Check the Komfort Latch or the Sliding Komfort Latch (if equipped) for function and cracks or other damage.
5. Check the upper seat belt mount on the door pillar for damage.
6. Check the web retractor for function and damage.
7. Check the mounting bolts for tightness, and tighten any that are loose.

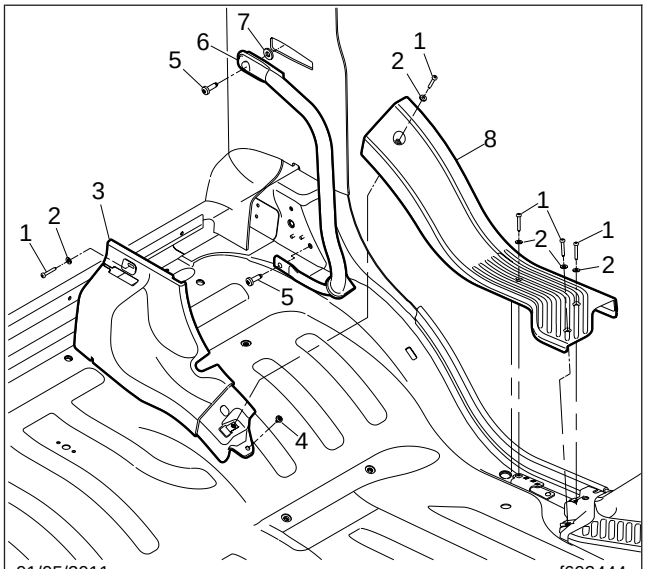
Seat Belt System Replacement

IMPORTANT: When any part of a seat-belt system needs replacement, the entire seat-belt system must be replaced—both the retractor side and the buckle side and, if equipped, both tether belts.

Any time a vehicle is involved in an accident, and the seat belt system was in use, the entire seat-belt system must be replaced before operating the vehicle.

Air Suspension Seat

1. Apply the parking brakes and chock the tires.
2. Remove the tread plate and the lower B-pillar cover, as follows.
   - 2.1 Remove the four screws and washers that attach the tread plate to the doorway and the lower B-pillar cover; see **Fig. 1**.
   - 2.2 Remove the screw that attaches the lower B-pillar cover to the doorway, and the screw and washer that attaches it to the B-pillar. Remove the B-pillar cover.
3. Disconnect the seat and tether belts from the seat by removing the capscrew from each end of the intermediate-connection-point (ICP) bar; see **Fig. 2**. Remove and discard the buckle side of the seat belt.
4. Remove the capscrews that attach the tether belts to the cab deck. Remove and discard the tether belts.
5. Remove the screw that attaches the seat-belt retractor to the lower B-pillar.
6. Remove the capscrews that attach the height adjuster to the upper B-pillar. Remove and discard the retractor side of the seat belt.
7. Install the height adjuster of the new seat belt on the upper B-pillar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
8. Install the seat-belt retractor on the lower B-pillar. Tighten the screw 35 to 45 lbf·ft (48 to 61 N·m).
9. Attach the angle brackets of the new tether belts to the cab floor. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
10. On both sides of the seat, first place the tether bracket against the ICP bar, then place the seat-belt bracket on top of the tether bracket. Insert the capscrew through the brackets into the ICP bar. Tighten both capscrews 35 to 45 lbf·ft (48 to 61 N·m).
11. Install the lower B-pillar cover and the tread plate.



NOTE: LH shown.

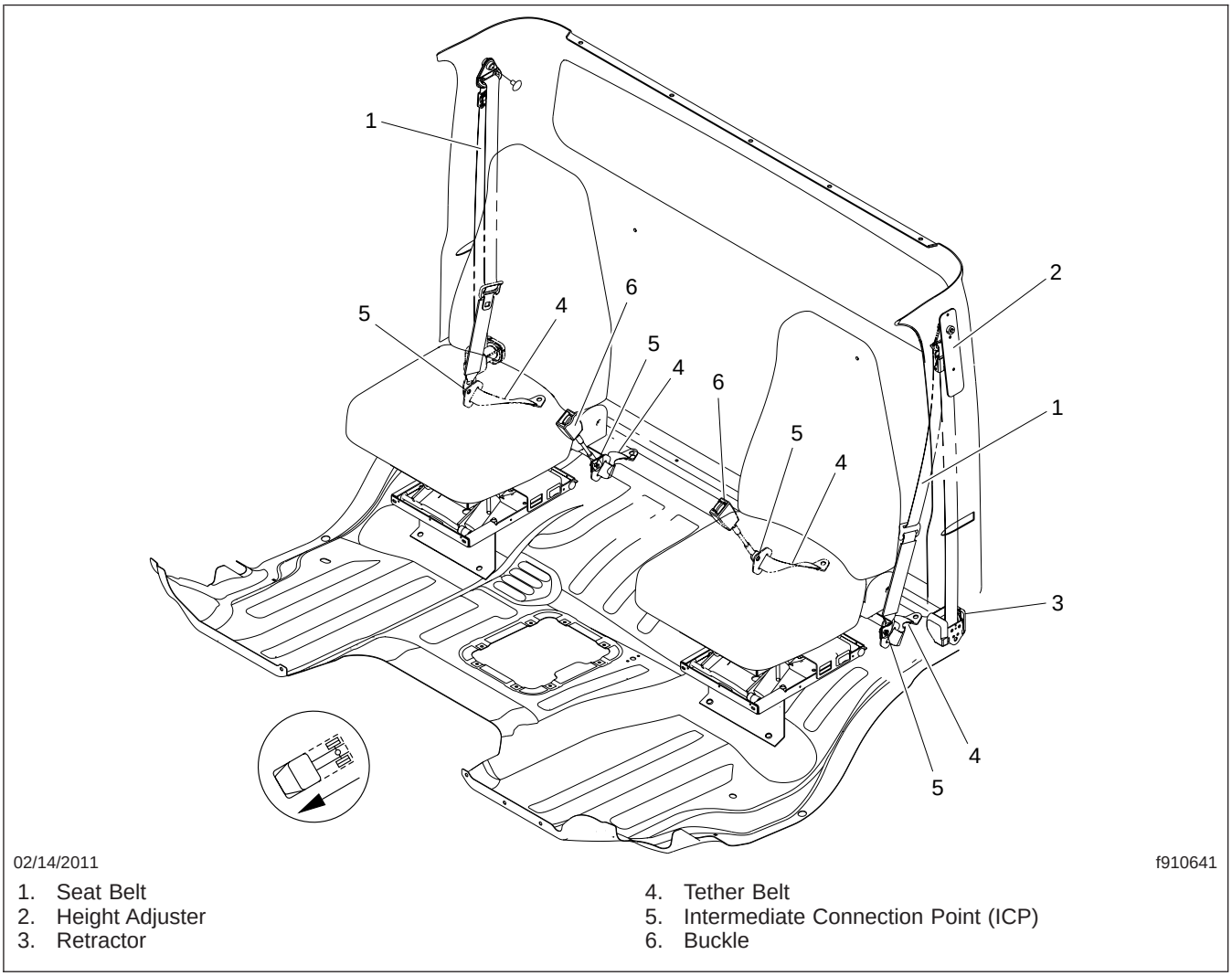
1. Dog Point Screw
2. Flatwasher
3. Lower B-Pillar Cover
4. Self-Tapping Screw
5. Capscrew, M8
6. Grab Handle
7. Washer
8. Tread Plate

Fig. 1, Tread Plate and Lower B-Pillar Cover Installation

Static Seat

1. Apply the parking brakes and chock the tires.
2. Remove the tread plate and the lower B-pillar cover, as follows.
   - 2.1 Remove the four screws and washers that attach the tread plate to the doorway and the lower B-pillar cover; see **Fig. 1**.
   - 2.2 Remove the screw that attaches the lower B-pillar cover to the doorway, and the screw and washer that attaches it to the B-pillar. Remove the B-pillar cover.

Seat Belt System Replacement



1. Seat Belt
2. Height Adjuster
3. Retractor
4. Tether Belt
5. Intermediate Connection Point (ICP)
6. Buckle

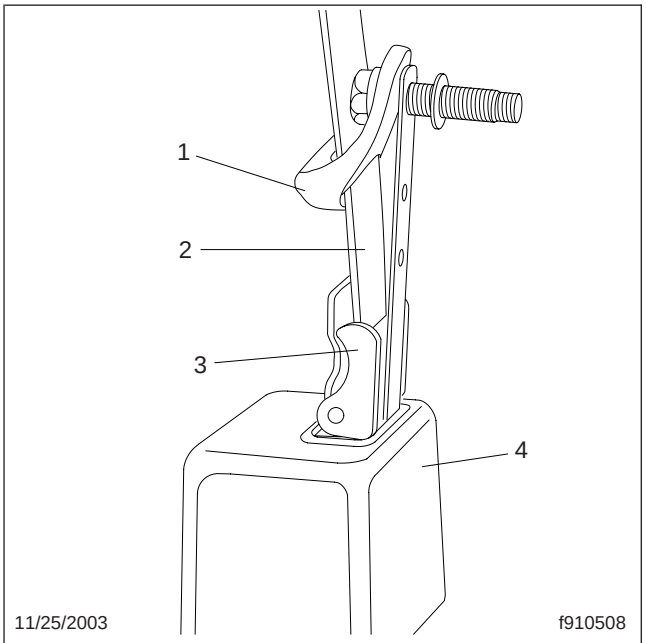
Fig. 2, Seat Belt Installation, Air Suspension Seats (typical)

3. Remove the capscrews that attach the seat-belt brackets to the cab deck. Remove and discard the buckle-side of the seat belt.
4. Remove the screw that attaches the seat-belt retractor to the lower B-pillar.
5. Remove the capscrews that attach the height adjuster to the upper B-pillar. Remove and discard the retractor side of the seat belt.
6. Install the height adjuster of the new seat belt on the upper B-pillar. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
7. Install the seat-belt retractor on the lower B-pillar. Tighten the screw 35 to 45 lbf·ft (48 to 61 N·m).
8. Attach both seat-belt brackets to the cab deck. Tighten the capscrews 35 to 45 lbf·ft (48 to 61 N·m).
9. Install the lower B-pillar cover and the tread plate.

Unlocking an Installed Retractor

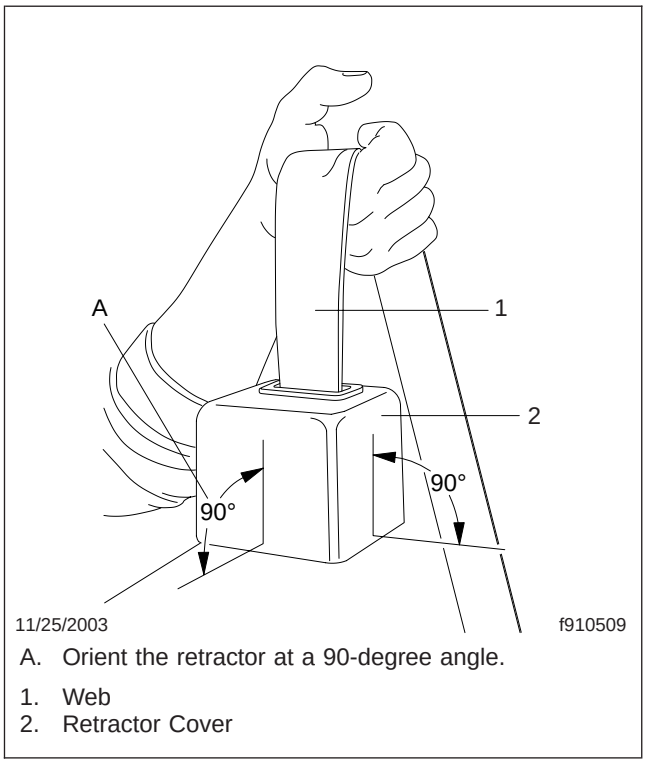
Seat belt retractors can lock up, preventing the webbing from being extracted. This condition, known as reverse lock-up, is caused by excessive webbing spooling into the retractor before installation in the vehicle.

1. Apply the parking brakes and chock the tires.
2. Verify that the retractor is mounted in the 90-degree position, as shown in **Fig. 1**.
3. Firmly grasp the web close to the retractor; see **Fig. 2**.
4. Pull on the web with enough force to tighten the web onto the spool. The retractor should unlock when tension is released and least 1/2 inch (12.7 mm) of the web is allowed to retract back into the retractor.



1. Web Guide Loop
2. Web
3. Komfort Latch®
4. Retractor Cover

Fig. 1, Retractor in the 90-Degree Position



A. Orient the retractor at a 90-degree angle.

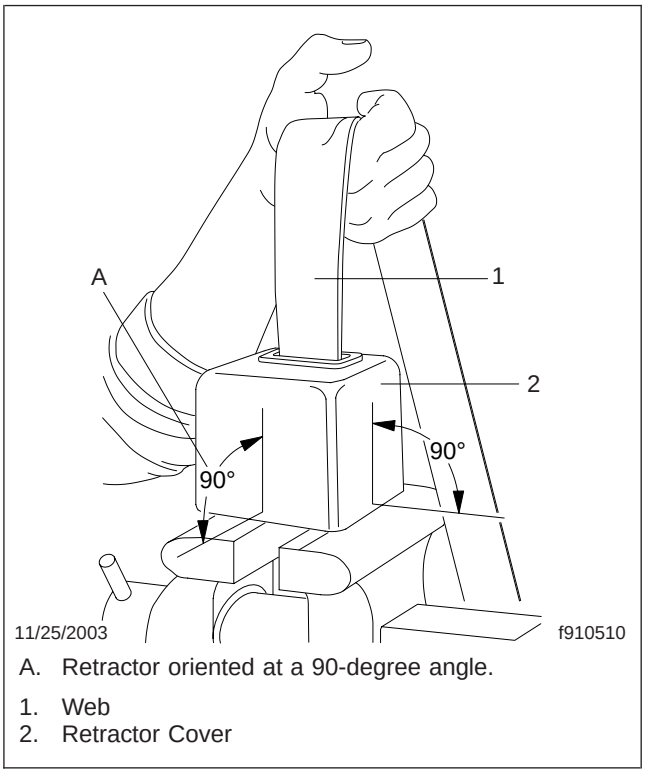
1. Web
2. Retractor Cover

Fig. 2, Firmly Grasp the Webbing

Unlocking an Uninstalled Retractor

1. Clamp the retractor in a vice at a 90-degree angle; see **Fig. 3**.
2. Pull on the web with enough force to tighten the web onto the spool.
3. Release the web. This allows 1/2 inch (12.7 mm) of the webbing to feed back into the retractor storage housing and unlock the retractor.
4. Pull all the webbing out of the retractor, and allow only 12 to 15 inches (304 to 381 mm) to retract. Lock the Komfort Latch on the web; see **Fig. 4**.

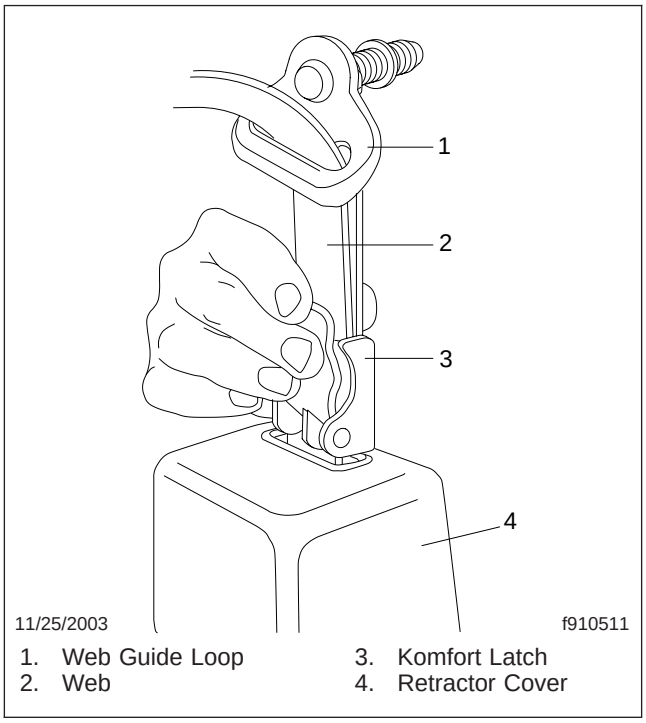
Seat Belt Retractor Unlocking



A. Retractor oriented at a 90-degree angle.

1. Web
2. Retractor Cover

Fig. 3, Place the Retractor in a Vice



1. Web Guide Loop
2. Web
3. Komfort Latch
4. Retractor Cover

Fig. 4, Lock the Komfort Latch

Specifications

Unless listed in **Table 1**, tighten all fasteners using the torque specifications found in **Section 00.01**.

Torque Specifications				
Fastener Description	**lbf·ft**	**N·m**	**lbf·in**	**N·cm**
Height Adjuster Mounting Screws	35–45	48–61	—	—
Seat Belt Retractor Mounting Screw				
Tether Belt Angle Bracket Screws				
Intermediate-Connecting-Point (ICP) Bar Screws				

Table 1, Torque Specifications

General Information

Freightliner Trucks currently applies DuPont® single-stage Imron Elite EA (also called Elite SS) or two-stage (base coat and clear coat) Imron Elite EB (also called Elite BC) high-solids polyurethane enamel on the vehicle cab at the factory.

Black standard urethane or Imron Elite EA is used on the vehicle chassis. The chassis includes the frame, hubs, running gear, and any components attached to the frame. Aluminum fuel tanks are not painted.

To meet the air quality regulations imposed by the EPA and local jurisdictions, these products contain lower levels of volatile organic compounds (VOCs) than earlier types (916Y, Centari®, and Imron), and are formulated free of lead and chrome.

The procedures in this section are for use with DuPont products. Unless otherwise noted, all products are manufactured by E. I. du Pont de Nemours and Company, Inc. Obtain approval from a Freightliner Regional Office for use of topcoats produced by other manufacturers.

Color-Matching

The recommended aftermarket paints for color-matching factory-applied paint are as follows:

- Use Imron 5000 or Elite EA for cabs that were factory-painted single-stage Elite EA.
- Use Imron 6000 or Elite EB for cabs that were factory-painted two-stage Elite EB.
- Use Imron 5000 or Elite EA for the chassis.

To ensure proper gloss, durability, and color-matching of the enamel, use only single-stage Imron 5000 or Elite EA on panels that were previously painted with Imron 5000, and use only Imron 6000 on panels painted with Elite EB.

To determine the correct paint number for color-matching any original finish on a vehicle, refer to the paint specification on the vehicle specification decal. Refer to the *108SD and 114SD Driver's Manual* for the location of this decal.

General Guidelines

This subject provides instructions for preparing large panels or the entire cab for topcoating with DuPont® products. For spot repairs or touch-ups, see **Subject 120**.

Before topcoating, the surface must be thoroughly cleaned and sanded. Any bare areas must also be conditioned and primed.

1. Preparation materials specified for one type of surface should not be used for any other type of surface.
2. Limit intermediate coatings, such as primers, to the brand and type specified by the finish-coat manufacturer.

NOTICE

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Preparation for Prime Coat

Use the cleaners and conditioners specified in each step to prepare the surface for priming. See **Specifications, 400** for a summary of the products used in this procedure.

⚠ WARNING

Do not use solvent-based cleaners on large areas of plastic or fiberglass, such as the hood or air fairing. Wiping down these large areas may cause a buildup of static electricity. The resulting spark could cause a flash fire, which could result in personal injury or property damage.

Cab and Hood Preparation

1. Wash the entire vehicle with a mild detergent, and dry.
2. Wipe all surfaces to be painted with a clean cloth soaked with solvent or cleaner. Remove all traces of wax, polish, grease, and silicones.
   - Metal—use DuPont Prep-Sol 3919 S.
   - Plastic—use DuPont Plastic Prep 2319 S.
   - Fiberglass—use DuPont Prep-N-Solv.

   2.1 Work on small areas at a time, wetting the surface liberally.

   2.2 Quickly wipe the surface with a clean cloth before the solvent or cleaner has a chance to dry. Change cloths frequently.
3. Feather the edge of all repaired areas, chipped surfaces, and scratches.

   3.1 Cut down the edges of broken spots with 220 sandpaper.

   3.2 Feather the edges by hand, using a sanding block with 400 sandpaper.
4. Sand the entire area to be painted. Using a sanding block and 400 sandpaper, remove the gloss to improve adhesion of the primer.
5. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - On metal surfaces, use DuPont First Klean 3900S, DuPont Final Klean 3901S, or DuPont 3939 S Lacquer and Enamel Cleaner. Do not use these cleaners on plastic or fiberglass substrates.
   - On plastic or fiberglass substrates, use DuPont Low VOC Final Klean 3909S.
6. Treat bare metal and rusted areas.
   - Aluminum—use DuPont 225 S aluminum cleaner.
   - Steel—use DuPont 5717 S metal conditioner.

   6.1 Mix one part of the cleaner with two parts of water in a plastic bucket.

   6.2 Apply the cleaner with a cloth or sponge. If corrosion is present, work the surface with a stiff plastic brush or 3M Scotch-Brite® pad. Do not use any pads containing iron.

   6.3 While the metal is still wet, wipe thoroughly with a clean, dry cloth. Allow the surface to dry before applying a conversion coating.
7. Apply a conversion coating to all bare metal.

Prime Coat Application

- Aluminum—use DuPont 226 S aluminum conversion coating.
- Steel—use DuPont 5718 S metal conversion coating.
- Zinc casings or galvanized surfaces (iron or steel)—use DuPont 5718 S metal conversion coating.

7.1 Pour the conversion coating into a plastic container (do not dilute). Using a 3M Scotch-Brite or similar non-iron abrasive pad, apply the conversion coating to the metal surface. Work only as much area as can be coated and rinsed before the solution dries.

7.2 Leave the coating on the surface for two to five minutes. Then, rinse off the solution with cold water, or mop with a sponge or cloth rinsed frequently in clean water.

If the metal surface dries before rinsing, reapply the conversion coating, then repeat the previous substep.

7.3 Wipe the surface dry with a clean cloth, or air dry.

8. Mask all areas that are not to be painted.

Air Fairing Kit Preparation

Before installing a new air fairing, prepare the surface for topcoating.

1. Wash the air fairing with a mild detergent. Dry with a clean, absorbent, lint-free cloth or paper towels.
2. Using a clean cloth soaked with DuPont Prep-N-Solv, wipe the entire surface to remove any trace of grease or oil.
3. Scuff-sand the air fairing with 320 grit sandpaper.
4. Wipe the air fairing with a clean cloth soaked in DuPont Low VOC Final Klean 3909S, or a solution of one part water and one part isopropyl alcohol. Allow 10 to 15 minutes for the air fairing to dry.
5. Mask all areas that are not to be painted.

Prime Coat

Prime all bare and feathered areas before topcoating. The specified primers can be used on any surface.

1. Clean all cracks and surfaces with dry compressed air.
2. Using a tack cloth, wipe all surfaces to be painted.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying primer, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

3. Prime all bare metal and feathered areas with DuPont Corlar® 824 S epoxy primer.

3.1 Stir Corlar 824 S primer thoroughly.

3.2 Mix two parts Corlar 824 S primer with one part DuPont 826 S activator.

3.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a no. 2 Zahn cup). Stir thoroughly.

3.4 Wait 1 to 2 hours from time of mixing before using. This provides time for complete chemical induction.

3.5 Spray one full wet coat to give a dry film thickness of 0.7 to 1.0 mil (0.018 to 0.025 mm).

3.6 Clean equipment immediately after use with DuPont 3602 S lacquer thinner.

3.7 Air dry 2 hours or force dry 20 minutes.

4. Wet sand the primer with 400 grit or finer sandpaper. Feather the edge into the surrounding area.
5. Dry the surface. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - On metal surfaces, use DuPont First Klean 3900S, DuPont Final Klean 3901S, or DuPont 3939 S Lacquer and Enamel Cleaner.

Do not use these cleaners on plastic or fiberglass substrates.

- On plastic or fiberglass substrates, use DuPont Low VOC Final Klean 3909S.

General Guidelines

This subject provides instructions for applying a topcoat of DuPont® enamel to full panels, or the entire cab. For spot repairs or touch-ups, see **Subject 120**.

NOTICE

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer. See **Specifications, 400** for a summary of the products used in this procedure.

Do not apply if the paint temperature is less than 70°F (21°C). Use warm water or paint heaters to heat the paint to an optimum temperature of 85 to 95°F (29 to 35°C). The material, substrate, or ambient temperature should be above 50°F (10°C) and below 110°F (43°C).

Before applying any topcoat:

1. Prepare the surface for topcoating. See **Subject 100** for instructions.
2. Clean all cracks and surfaces with dry compressed air.
3. Using a tack cloth, wipe all surfaces to be painted.

Imron Elite EA Topcoating

Imron Elite EA (also called Elite SS) is a single-stage, low VOC, high-solids polyurethane enamel. It provides a durable, high-gloss surface with good chemical resistance. It requires the addition of an activator.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron Elite EA enamel thoroughly.
2. Mix three parts Imron Elite EA enamel with one part of DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (414 to 448 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (354 to 473 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Using a cross-coat technique, spray one medium-wet coat in a north-to-south direction.
   - 2.3 Allow 5 to 10 minutes drying time between each application. Do not sand.
   - 2.4 Apply a second medium-wet coat in an east-to-west direction.
   - 2.5 A third medium-wet coat may be needed for good coverage of some colors.
3. To air dry, allow 2 to 4 hours with accelerator 389 S, and 6 to 8 hours without the accelerator.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
4. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

5. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, or lettering may be applied in 4 to 6 hours if DuPont 389 S accelerator is used. Wait 10 to 12 hours, if no accelerator is used.

Decals may be applied in 12 to 16 hours, if 389 S accelerator is used. Wait 24 hours if no accelerator is used.

For topcoats cured over 72 hours, scuff-sand with 400-grit sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

Imron Elite EB Topcoating

Imron Elite EB (also called Elite BC) is a two-stage, high-solids polyurethane enamel. It provides good cover with one cross-coat of the base color followed by one coat of Imron Elite EB clear coat. Both the base color and clear coat require the addition of an activator.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Mixing

1. Stir the Imron Elite EB base color thoroughly.
2. Mix three parts Imron Elite EB base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.

NOTE: The pot life of the mixture is about 2 to 4 hours at 70°F (21°C), unless an accelerator is added.

3. If faster curing time is desired, add DuPont 389 S fast-dry accelerator. Add up to 2 ounces (60 mL) to 1 gallon (3.8 L) of mixed material.
4. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (414 to 448 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (354 to 473 mL) per minute.
2. Apply the topcoating.
   - 2.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 2.2 Apply one cross-coat of the Imron Elite EB base color.
   - 2.3 Flash 10 minutes minimum. Do not sand.
   - 2.4 Purge the equipment with DuPont 3602 S lacquer thinner, or 8685 S reducer.
3. Apply clearcoat.
   - 3.1 Mix three parts DuPont 3440 S or 3480 S clear, with one part DuPont 193 S or 194 S activator.
   - 3.2 Apply one coat of the activated DuPont 3440 S or 3480 S clear. Some colors may require additional cross-coats.
4. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the clear coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
5. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
6. Clean the equipment immediately after use, with DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, and lettering may be applied in 4 to 6 hours, if DuPont 389 S accelerator is used. Wait 10 to 12 hours, if no accelerator is used.

Decals may be applied in 12 to 16 hours, if 389 S accelerator is used. Wait 24 hours, if no accelerator is used.

General Guidelines

This subject provides instructions for making spot repairs or touch-ups with DuPont® enamels. Buffing may correct minor imperfections; more serious repairs require surface preparation before a topcoating can be applied. For striping, lettering, or decal application after the repair is complete, see **Subject 110**.

1. Specific types of surfaces to be painted, require specific types of preparation materials. Do not use preparation materials specified for a given type of surface on another surface, for which it is not specified.

   See **Specifications, 400** for a summary of the materials used in this section.

2. Use only the intermediate coatings, such as primers, of the brand and type specified by the finish-coat manufacturer.
3. Do not mix additives with the finish coats unless they are specified by the finish-coat manufacturer.
4. Do not apply if the paint temperature is less than 70°F (21°C). Use warm water or paint heaters to heat the paint to an optimum temperature of 85 to 95°F (29 to 35°C). The material, substrate or ambient temperature should be above 50°F (10°C) and below 110°F (43°C).

NOTICE

Only experienced, qualified persons using proper equipment should attempt repainting or touch-up painting. Incorrect application of chemicals or paint could damage the surface or impair the finish.

Buffing Minor Imperfections

1. Clean the area carefully with a mild detergent, then rinse.
2. Remove imperfections using ultra-fine or micro-fine sandpaper (1500- or 2000-grit) and water. Rinse the area with clean water, then dry.
3. Buff the area.

   3.1 Use a clean foam pad at low speed (about 1600 rpm) with one of the following products:

   - DuPont 1500 S
   - Meguiar's No. 2 Fine-Cut Cleaner
   - 3M Finesse-it II 05928

   3.2 Using medium pressure, buff slowly in an overlapping pattern until the imperfection has been eliminated. Repeat as necessary.

   3.3 Rinse the area with clean water, then dry.

4. Polish the area.

   4.1 Apply one of the following products with a clean pad (3M Waffle Pad):

   - DuPont 3000 S
   - Meguiar's No. 9 Swirl Remover
   - 3M Perfect-it 05996

   4.2 Using medium pressure, work small areas using an even, overlapping pattern until the gloss is restored. As the polish dries and the gloss appears, ease the pressure on the polishing pad. Repeat as necessary.

Preparing for Topcoating

1. Wash the entire panel with mild detergent, containing no lanolin or additives. Before the solution dries, rinse with fresh water. Dry with a clean, lint-free cloth.
2. Cover areas around the repair area to prevent damage to surrounding objects from solvent overspray or drips.

⚠ WARNING

Solvents are flammable. Keep the container closed. Use only with adequate ventilation. Keep solvents away from heat, sparks, and open flame. Breathing the vapor can cause headache, nausea, impaired reaction time, and impaired coordination.

3. Clean the area to be repaired with DuPont 3939 S solvent and quickly wipe the surface with a clean, lint-free cloth before the solvent dries. Remove all traces of wax, polish, grease, and silicones.
4. Sand or grind all dents and scratches.

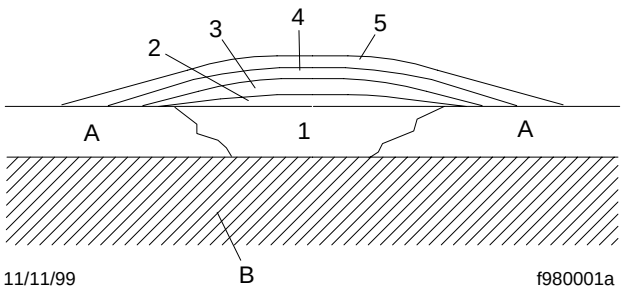
Spot Repair

5. Wet sand the area being repaired with 320-grit or finer sandpaper, or a 3M Scotch-Brite® or similar non-iron abrasive pad. Feather the edge.
6. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
7. Mask all areas that will not be painted.
8. Clean all cracks and surfaces with dry compressed air.
9. Using a tack cloth, wipe all surfaces to be painted.

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

10. Prime all bare metal and feathered areas with DuPont primer. See **Fig. 1**.
    - Steel and aluminum—use Corlar 824 S epoxy primer.
    - Fiberglass—use Corlar 825 S epoxy primer.



NOTE: Scale exaggerated for clarity. The number of layers depends on the specific application.

A. Existing Paint
B. Panel Material (substrate)

1. Primer
2. First Color Topcoat
3. Second Color Topcoat
4. Third Color Topcoat
5. Clear Coat

Fig. 1, Spot Repair Cross-Section

10.1 Stir primer thoroughly.

10.2 Mix two parts Corlar epoxy primer with one part DuPont 826 S activator.

10.3 Reduce three parts of this mixture with one part DuPont 3602 S lacquer thinner (viscosity reading is 18 to 22 seconds in a no. 2 Zahn cup). Stir thoroughly.

10.4 Wait 1 to 2 hours from time of mixing before using. This provides time for complete chemical induction.

10.5 Set the air pressure at the spray gun to 45 psi (310 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (354 to 473 mL) per minute.

10.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

10.7 Spray one wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

10.8 Clean the equipment immediately after use with DuPont 3602 S lacquer thinner.

10.9 Air dry 2 to 4 hours or force dry 20 minutes.

11. Wet sand the primer with 400-grit or finer sandpaper. Feather the edge into the surrounding area.
12. If the original paint was Imron Elite EB (also called Elite BC) hand-rub the area around the spot repair with a medium grade compound to ensure a seamless finish.
13. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
14. Wipe the repair area with a tack cloth.
15. If the finish is old, apply one coat of DuPont 222 S adhesion promoter over the entire repair area.

15.1 Set the air pressure to 35 psi (241 kPa) at the spray gun.

15.2 Flash for 5 to 10 minutes at 70°F (21°C) before topcoating.

Topcoating a Spot Repair

⚠ WARNING

Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC-19C) when mixing or spraying paint products, and until the work area has been exhausted of all vapor and spray mist. Breathing paint fumes can cause serious personal injury.

Imron Elite EB Topcoating

1. Mix the Elite EB polyurethane enamel.
   - 1.1 Stir the Elite EB base color thoroughly.
   - 1.2 Mix three parts Elite EB base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.
   - 1.3 Mix thoroughly and strain.

Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.

2. Set the air pressure at the spray gun at 60 to 65 psi (414 to 448 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (354 to 473 mL) per minute.
3. Apply the topcoating.
   - 3.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.
   - 3.2 Apply one cross-coat of the Elite EB base color over the primed area. No flash time is required before applying a clear coat.
   - 3.3 Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.
   - 3.4 Mix three parts DuPont 3440 S or 3480 S clear with one part DuPont 193 S or 194 S activator.

   NOTE: For best results, apply the clear coat over the entire panel. If a blend of the repair area is attempted, apply the clear coat only over the repair area, overspraying the edge slightly.
   - 3.5 Apply one coat of the activated DuPont 3440 S or 3480 S clear.
4. Purge the equipment with DuPont 3602 S lacquer thinner or 8685 S reducer.
5. Blend the 3440 S or 3480 S clear into the surrounding topcoat.
   - 5.1 Set the air pressure to 25 psi (172 kPa) at the spray gun.
   - 5.2 Apply one coat of 3401 S blending clear over the repair area, only to the overspray edge.
   - 5.3 Flash 2 minutes. Repeat if necessary.
6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).
7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.
8. Clean the equipment immediately after use, with DuPont 3602 S lacquer thinner or 8685 S reducer.

Imron Elite EA Topcoating

1. Mix the Elite EA polyurethane enamel.
   - 1.1 Stir the Elite EA enamel thoroughly.
   - 1.2 Mix three parts Elite EA base color with one part DuPont 193 S or 194 S activator. No further reduction is necessary for application.
   - 1.3 Mix thoroughly and strain.

   Note: The viscosity of the mixture is about 10 to 19 seconds in a no. 3 Zahn cup, depending on the color. Adding reducer could affect the color match on some metallics.
2. Set the air pressure at the spray gun at 60 to 65 psi (414 to 448 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (354 to 473 mL) per minute.
3. For metallic topcoats only, apply one coat of DuPont 500 S urethane clear.

Spot Repair

3.1 Mix eight parts of 500 S urethane with one part 193 S activator.

3.2 Reduce the activated 500 S urethane mixture 50 percent with 8685 S reducer.

3.3 Apply a medium-wet coat of the reduced 500 S urethane over the entire repair area, and well beyond where the color will be applied.

3.4 Flash 3 minutes before applying the Elite EA topcoat.

4. Apply the solid color or metallic topcoating.

4.1 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

4.2 Spray one medium-wet coat over the primed area.

4.3 Flash 5 to 10 minutes.

4.4 Apply a second medium-wet coat. Extend the spray area slightly to taper the edge and avoid a visible ring.

4.5 A third medium-wet coat may be needed for good coverage of some colors. Allow each coat to flash before applying the next coat.

NOTE: A mist coat of five parts of color to three parts of 8022 S is recommended when applying metallics. Hold the gun about 18 inches (45 cm) from the surface.

5. Blend the repair area into the OEM finish.

5.1 Lower the air pressure to 15 to 20 psi (103 to 138 kPa) at the spray gun.

5.2 Empty the spray cup and refill it with DuPont 8022 S reducer or a blend of 8022 S and 8093 S.

5.3 Carefully blend the edge of the repair with even coats to melt in the overspray.

5.4 Spray one or two medium coats of the reducer over the entire area.

5.5 If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500 S one-step polish.

6. To air dry, allow 2 to 4 hours if DuPont 389 S accelerator is used, and 6 to 8 hours if no accelerator is used.

To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140 to 180°F (60 to 82°C).

7. To prevent tape marking, remove all masking tape and paper immediately after the final coat is applied. Avoid contacting the freshly painted surface with masking paper.

8. Clean the equipment immediately after use with DuPont 3602 S lacquer thinner or 8685 S reducer.

DuPont Surface Preparation Materials				
Step	**Aluminum**	**Steel**	**Plastic**	**Fiberglass**
Wash and dry	Mild detergent, such as dish washing detergent			
Wipe with cleaner	Prep-Sol 3919 S		Plastic Prep 2319 S	Prep-N-Solv
Sand and feather	220 grit, then 400 grit			320 grit
Remove sanding dust	3939 S lacquer and enamel cleaner			Mix: - 1 part water - 1 part isopropyl alcohol
Treat bare metal	225 S aluminum cleaner	5717 S metal conditioner	—	—
Apply conversion coating to bare metal	226 S aluminum conversion coating	5718 S metal conversion coating	—	—
Apply sealer primer	Mix: - 2 parts Corlar 824 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner			

Table 1, DuPont Surface Preparation Materials

DuPont Topcoating Materials	
Step	**Topcoating Materials**
Mix enamel	Mix: - 3 parts Imron 5000 with 1 part 193 S or 194 S activator
Add accelerator (optional)	389 S accelerator (up to 2 oz/gal of activated enamel)
Pressure at gun	60 psi (414 kPa)
Equipment cleanup	3939 S lacquer and enamel cleaner or 8685 S reducer

Table 2, DuPont Topcoating Materials

DuPont Spot Repair Materials	
Step	**Spot Repair Materials**
Cleaning	3939 S lacquer and enamel cleaner
Sanding	320 grit or finer
Sealer primer	Mix: - 2 parts Corlar 824 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner
Adhesion promoter	222 S adhesion promoter
Topcoat	Mix: - 3 parts Imron 5000 with 1 part 193 S or 194 S activator
Topcoat viscosity	9–20 sec (#3 Zahn cup)
Accelerator (optional)	389 S accelerator

Specifications

DuPont Spot Repair Materials	
Step	**Spot Repair Materials**
Blending clear	1 coat 3401 S blending clear
Equipment cleanup	3939 S lacquer and enamel cleaner or 8685 S reducer

Table 3, DuPont Spot Repair Materials