S2 CHASSIS WORKSHOP MANUAL

Models: S2
S2C

STI-480, S8 (10/11P)

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.

Instructions and procedures are those recommended by Freightliner Custom Chassis Corporation (FCCC) or the component manufacturer.

Maintenance schedules and additional service information are included in the *S2 Chassis Maintenance Manual*.

IMPORTANT: Descriptions and specifications in this manual were in effect at the time of printing. Freightliner Custom Chassis Corporation (FCCC) 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.FreightlinerChassis.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.

NOTICE: 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. Each workshop/service manual section is divided into subjects that can include general information, principles of operation, removal, disassembly, assembly, installation, specifications, and troubleshooting.

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 pretrip 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

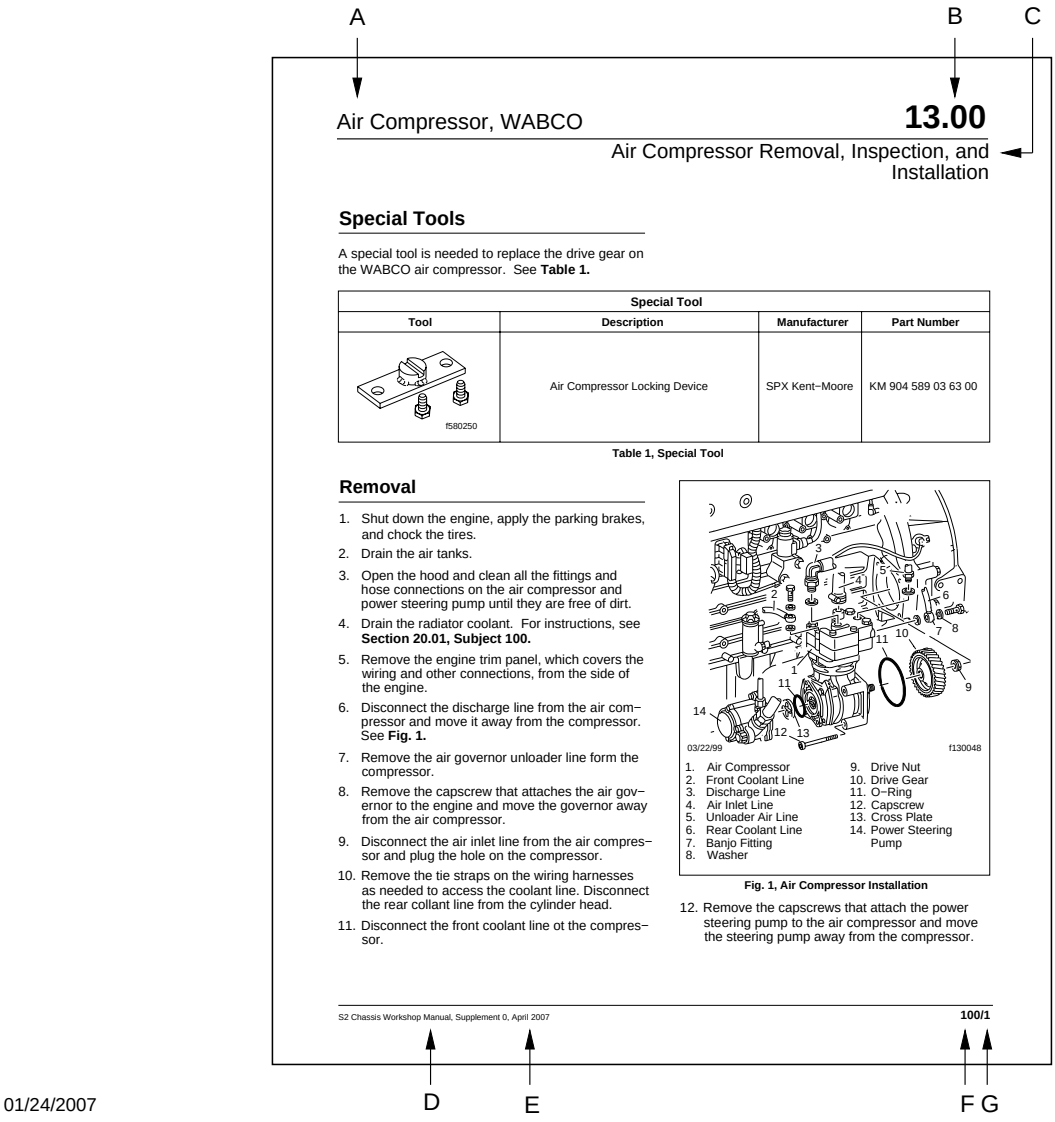
Warranty-related service information available on the AccessFreightliner.com website includes the following documentation.

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 an *S2 Chassis 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 an S2 Chassis 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
26	Transmission
30	Throttle Control
31	Frame and Frame Components
32	Suspension
33	Front Axle
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40	Wheels and Tires
41	Driveline
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46	Steering
47	Fuel
49	Exhaust
54	Electrical, Instruments, and Controls
75	Body
82	Windshield Wipers and Washer
83	Heater and Air Conditioner
88	Hood, Grille, and Cab Fenders
98	Paint

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

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 Custom Chassis Corporation (FCCC) VIN, 4UZAAAA211CA12345.

The VIN is stamped on a metal plate permanently attached to the vehicle, 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 FCCC vehicle indicates an MB45 chassis. Code AB in the same position for a Freightliner vehicle represents an FLD112 conventional truck.

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	**4 U Z**	**A**	**A A**	**A 2**	**1**	**1**	**C**	**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**
4UZ	Freightliner Custom Chassis Corporation, USA	Freightliner	Incomplete Vehicle

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

VIN Position 4 (Chassis Configuration)	
Code	**Chassis**
A	4 x 2 Truck
F	6 x 2 Truck
X	Glider

Table 3, VIN Position 4 (Chassis Configuration)

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
AA	MB45 Chassis	None	Class 4*
AB	MB45 Chassis	None	Class 5†

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
AC	MB55 Chassis	None	Class 6‡
AD	MB55 Chassis	None	Class 7§
AE	MC45 Chassis	None	Class 5
AF	MC45 Chassis	None	Class 6
AG	XC Chassis	None	Class 6
AH	XC Chassis	None	Class 7
AJ	XCS Chassis	None	Class 6
AK	VCL Chassis	None	Class 8¶
AM	MT35 Chassis	None	Class H**
AN	MT45 Chassis	None	Class 4
AP	MT45 Chassis	None	Class 5
AR	MT55 Chassis	None	Class 6
AS	MT55 Chassis	None	Class 7
AT	XB Chassis	None	Class 6
AU	XB Chassis	None	Class 7
AV	FS65 Chassis	None	Class 5
AW	FS65 Chassis	None	Class 6
AX	FS65 Chassis	None	Class 7
AY	FS65 Chassis	None	Class 8
AZ	FB65 Chassis	None	Class 6
A1	MBO Chassis	None	Class 7
A2	MBO Chassis	None	Class 8
A3	OMC Chassis	None	Class 7
A4	OMC Chassis	None	Class 8
A5	MT55 Chassis	None	Class 4
A6	XCA Chassis	None	Class 7
A7	XCA Chassis	None	Class 8
A8	FB65 Chassis	None	Class 7
A0	EF Front-Engine Bus Chassis	None	Class 6
BA	EF Front-Engine Bus Chassis	None	Class 7
BB	EF Front-Engine Bus Chassis	None	Class 8
BC	ER Rear-Engine Bus Chassis	None	Class 6
BD	ER Rear-Engine Bus Chassis	None	Class 7
BE	ER Rear-Engine Bus Chassis	None	Class 8
BF	XC Chassis	None	Class 8

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
BG	MT55 Chassis	None	Class 5
BH	MT35 Chassis	None	Class 3††
BJ	MT45 Chassis	None	Class 3
BK	FB65 Chassis	None	Class 5
BL	MB55 Chassis	None	Class 5
BM	MT45 Chassis	None	Class 6
BN	B2 Bus Chassis	None	Class 5
BP	B2 Bus Chassis	None	Class 6
BR	B2 Bus Chassis	None	Class 7
BT	B2 Bus Chassis	None	Class 8
BU	XC Straight-Rail Rear-Engine Motor Home Chassis	None	Class 6
BV	XC Straight-Rail Rear-Engine Motor Home Chassis	None	Class 7
BW	XC Formed-Rail Rear-Engine Motor Home Chassis	None	Class 6
BX	XC Formed-Rail Rear-Engine Motor Home Chassis	None	Class 7
BY	XC Modular-Rail Rear-Engine Motor Home Chassis	None	Class 6
BZ	XC Modular-Rail Rear-Engine Motor Home Chassis	None	Class 7
B1	XC Raised-Rail Rear-Engine Motor Home Chassis	None	Class 6
B2	XC Raised-Rail Rear-Engine Motor Home Chassis	None	Class 7
B3	XC Raised-Rail (Lowered-Engine) Rear-Engine Motor Home Chassis	None	Class 6
B4	XC Raised-Rail (Lowered-Engine) Rear-Engine Motor Home Chassis	None	Class 7
B5	FBX 106 Shuttle Bus Chassis	None	Class 5
B6	FBX 106 Shuttle Bus Chassis	None	Class 6
B7	FBX 106 Shuttle Bus Chassis	None	Class 7
B8	FBX 106 Shuttle Bus Chassis	None	Class 8
B9	XB Straight-Rail Rear-Engine Shuttle Bus Chassis	None	Class 6
B0	XB Straight-Rail Rear-Engine Shuttle Bus Chassis	None	Class 7
CA	XB Raised-Rail Rear-Engine Shuttle Bus Chassis	None	Class 6
CB	XB Raised-Rail Rear-Engine Shuttle Bus Chassis	None	Class 7
CC	MT45 HEV Chassis	None	Class 4
CD	MT45 HEV Chassis	None	Class 5
CE	XCS Straight-Rail Rear-Engine Motor Home Chassis	None	Class 8
CF	XCF Formed-Rail Rear-Engine Motor Home Chassis	None	Class 8
CG	XCM Modular-Rail Rear-Engine Motor Home Chassis	None	Class 8
CH	XCR Raised-Rail Rear-Engine Motor Home Chassis	None	Class 8
CJ	XCS Straight-Rail Rear-Engine Motor Home Chassis	None	Class 7

VIN Information

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
CK	XCF Formed-Rail Rear-Engine Motor Home Chassis	None	Class 7
CL	MC Front-Engine Motor Home Chassis	None	Class 6
CM	MC Front-Engine Motor Home Chassis	None	Class 7
CN	S2 106 Bus Chassis	None	Class 5
CP	S2 106 Bus Chassis	None	Class 6
CR	S2 106 Bus Chassis	None	Class 7
CS	XB Raised-Rail Rear-Engine Shuttle Bus Chassis	None	Class 8
CT	XCP Powerliner Raised-Rail Rear-Engine Motor Home Chassis	None	Class 8
CU	XCL Lowered Rail Rear-Engine Motor Home Chassis	None	Class 8
CV	XCL Lowered Rail Rear-Engine Motor Home Chassis	None	Class 7
CW	XCM Modular-Rail Rear-Engine Motor Home Chassis	None	Class 7
CX	MT55 Hybrid Electric Vehicle (HEV) Chassis	None	Class 5
CY	MT55 Hybrid Electric Vehicle (HEV) Chassis	None	Class 6
CZ	MT55 Hybrid Electric Vehicle (HEV) Chassis	None	Class 7
C1	MT45G Front-Engine Gasoline Walk-In Van Chassis	None	Class 4
C2	MT45G Front-Engine Gasoline Walk-In Van Chassis	None	Class 5
C3	MT55G Front-Engine Gasoline Walk-In Van Chassis	None	Class 6
C4	MCG Front-Engine Gasoline Motor Home Chassis	None	Class 6
C5	MCG Front-Engine Gasoline Motor Home Chassis	None	Class 7
C6	MC Front-Engine Hybrid Electric Vehicle (HEV) Motor Home Chassis	None	Class 6
C7	MC Front-Engine Hybrid Electric Vehicle (HEV) Motor Home Chassis	None	Class 7
C8	B2 106 Hybrid Electric Vehicle (HEV) Bus Chassis	None	Class 5
C9	B2 106 Hybrid Electric Vehicle (HEV) Bus Chassis	None	Class 6
DA	B2 106 Hybrid Electric Vehicle (HEV) Bus Chassis	None	Class 7
DB	B2 106 Hybrid Electric Vehicle (HEV) Bus Chassis	None	Class 8
DC	MBC Front-Engine Commercial Bus Chassis	None	Class 4
DD	MBC Front-Engine Commercial Bus Chassis	None	Class 5
DE	MBC Front-Engine Commercial Bus Chassis	None	Class 6
DF	MBC Front-Engine Commercial Bus Chassis	None	Class 7
DG	XBP Rear-Engine Commercial Bus Chassis	None	Class 8
DH	MCL Front-Engine Motor Home Chassis	None	Class 6
DJ	MCL Front-Engine Motor Home Chassis	None	Class 7
DK	MCL Front-Engine Motor Home Chassis	None	Class 5

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
DL	MT55 HHV Chassis (Hydraulic Hybrid Chassis)	None	Class 5
DM	MT55 HHV Chassis (Hydraulic Hybrid Chassis)	None	Class 6
DN	MT55 HHV Chassis (Hydraulic Hybrid Chassis)	None	Class 7
DP	S2C 106 Conventional Cab and Chassis	Conventional	Class 5
DR	S2C 106 Conventional Cab and Chassis	Conventional	Class 6
DS	S2C 106 Conventional Cab and Chassis	Conventional	Class 7
DT	S2RV 106 Conventional Cab and Chassis	Conventional	Class 5
DU	S2RV 106 Conventional Cab and Chassis	Conventional	Class 6
DV	S2RV 106 Conventional Cab and Chassis	Conventional	Class 7
DW	S2 106 Bus Chassis	None	Class 8
DX	MT45EV (Electric Vehicle)	None	Class 4
DY	MT45EV (Electric Vehicle)	None	Class 5
DZ	XC Rear Engine Motor Home Chassis Glider	None	Glider
EA	EFX Front Engine Bus Chassis	None	Class 6
EB	EFX Front Engine Bus Chassis	None	Class 7
EC	EFX Front Engine Bus Chassis	None	Class 8
EF	S2G Conventional Full Cab and Chassis	Conventional	Class 8

* Class 4 GVWR is 14,001–16,000 lb.

† Class 5 GVWR is 16,001–19,500 lb.

‡ Class 6 GVWR is 19,501–26,000 lb.

§ Class 7 GVWR is 26,001–33,000 lb.

¶ Class 8 GVWR is 33,001 lb. and over.

** Class H GVWR is 9001–10,000 lb.

†† Class 3 GVWR is 10,001–14,000 lb.

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

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
AA	Caterpillar 3176	Diesel	10.3	I–6	Air
AB	Caterpillar 3176	Diesel	10.3	I–6	Hydraulic
AC	Caterpillar 3176	Diesel	10.3	I–6	Air/Hydraulic
AK	Caterpillar 3126/CFE	Diesel	7.2	I–6	Air
AL	Caterpillar 3126/CFE	Diesel	7.2	I–6	Hydraulic
AM	Caterpillar 3126/CFE	Diesel	7.2	I–6	Air/Hydraulic

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
AN	Caterpillar C10	Diesel	10.3	I–6	Air
AP	Caterpillar C10	Diesel	10.3	I–6	Hydraulic
AR	Caterpillar C10	Diesel	10.3	I–6	Air/Hydraulic
A2	Cummins L10	Diesel	10.8	I–6	Air
A3	Cummins L10	Diesel	10.8	I–6	Hydraulic
A4	Cummins L10	Diesel	10.8	I–6	Air/Hydraulic
A5	Cummins M11	Diesel	10.8	I–6	Air
A6	Cummins M11	Diesel	10.8	I–6	Hydraulic
A7	Cummins M11	Diesel	10.8	I–6	Air/Hydraulic
A8	Cummins ISM	Diesel	10.8	I–6	Air
A9	Cummins ISM	Diesel	10.8	I–6	Hydraulic
A0	Cummins ISM	Diesel	10.8	I–6	Air/Hydraulic
BK	Cummins C8.3	Diesel	8.3	I–6	Air
BL	Cummins C8.3	Diesel	8.3	I–6	Hydraulic
BM	Cummins C8.3	Diesel	8.3	I–6	Air/Hydraulic
BN	Cummins B5.9	Diesel	5.9	I–6	Air
BP	Cummins B5.9	Diesel	5.9	I–6	Hydraulic
BR	Cummins B5.9	Diesel	5.9	I–6	Air/Hydraulic
BS	Cummins ISC	Diesel	8.3	I–6	Air
BT	Cummins ISC	Diesel	8.3	I–6	Hydraulic
BU	Cummins ISC	Diesel	8.3	I–6	Air/Hydraulic
BV	Cummins ISB	Diesel	5.9	I–6	Air
BW	Cummins ISB	Diesel	5.9	I–6	Hydraulic
BX	Cummins ISB	Diesel	5.9	I–6	Air/Hydraulic
BY	Cummins B5.9	Propane	5.9	I–6	Air
BZ	Cummins B5.9	Propane	5.9	I–6	Hydraulic
B1	Cummins B5.9	Propane	5.9	I–6	Air/Hydraulic
B2	Cummins B5.9	Natural Gas	5.9	I–6	Air
B3	Cummins B5.9	Natural Gas	5.9	I–6	Hydraulic
B4	Cummins B5.9	Natural Gas	5.9	I–6	Air/Hydraulic
B5	Cummins B8.3	Natural Gas	8.3	I–6	Air
B6	Cummins B8.3	Natural Gas	8.3	I–6	Hydraulic
B7	Cummins B8.3	Natural Gas	8.3	I–6	Air/Hydraulic

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
B8	Detroit Series 50	Diesel	8.5	I–4	Air
B9	Detroit Series 50	Diesel	8.5	I–4	Hydraulic
B0	Detroit Series 50	Diesel	8.5	I–4	Air/Hydraulic
CN	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air
CP	Mercedes-Benz MBE900	Diesel	4.3	I–4	Hydraulic
CR	Mercedes-Benz MBE900	Diesel	4.3	I–4	Air/Hydraulic
CS	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air
CT	Mercedes-Benz MBE900	Diesel	6.4	I–6	Hydraulic
CU	Mercedes-Benz MBE900	Diesel	6.4	I–6	Air/Hydraulic
CV	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air
CW	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Hydraulic
CX	Mercedes-Benz MBE4000	Diesel	12.0	I–6	Air/Hydraulic
CY	Cummins ISL	Diesel	8.9	I–6	Air
CZ	Cummins ISL	Diesel	8.9	I–6	Hydraulic
C1	Cummins ISL	Diesel	8.9	I–6	Air/Hydraulic
C2	Cummins B3.9	Diesel	3.9	I–4	Air
C3	Cummins B3.9	Diesel	3.9	I–4	Hydraulic
C4	Cummins B3.9	Diesel	3.9	I–4	Air/Hydraulic
C5	Cummins ISB 3.9	Diesel	3.9	I–4	Air
C6	Cummins ISB 3.9	Diesel	3.9	I–4	Hydraulic
C7	Cummins ISB 3.9	Diesel	3.9	I–4	Air/Hydraulic
C8	John Deere 6081H	CNG	8.1	I–6	Air
C9	John Deere 6081H	CNG	8.1	I–6	Hydraulic
DC	CAT C7	Diesel	7.2	I–6	Air
DD	CAT C7	Diesel	7.2	I–6	Hydraulic
DG	Mercedes-Benz MBE900	Diesel	4.8	I–4	Air
DH	Mercedes-Benz MBE900	Diesel	4.8	I–4	Hydraulic
DJ	Mercedes-Benz MBE900	Diesel	7.2	I–6	Air
DK	Mercedes-Benz MBE900	Diesel	7.2	I–6	Hydraulic
DL	CAT C11	Diesel	11.1	I–6	Air
DM	CAT C11	Diesel	11.1	I–6	Hydraulic
DT	Cummins ISB	Diesel	6.7	I–6	Air
DU	Cummins ISB	Diesel	6.7	I–6	Hydraulic
DV	GM 307 HP	Gasoline	6.0	V–8	Hydraulic

VIN Information

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displacement: Liter**	**Configuration**	**Brakes**
DX	Enova 120 KW	Electric	—	—	Hydraulic
E1	Fiat 4P10	Diesel	3.0	I–4	Hydraulic
E2	Powertrain Integration LPG	Propane	8.0	V–8	Hydraulic
E3	Powertrain Integration LPG	Propane	8.0	V–8	Air
00	No Engine	—	—	—	—

Table 5, VIN Positions 7 and 8 (Engine, 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
E	2014

Table 6, VIN Position 10 (Model Year)

VIN Position 11 (Build Location)	
Code	**Plant of Manufacture**
C	Gaffney, South Carolina
D	Santiago, Tianguistenco, Mexico
H	Mt. Holly, North Carolina

Table 7, VIN Position 11 (Build Location)

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.

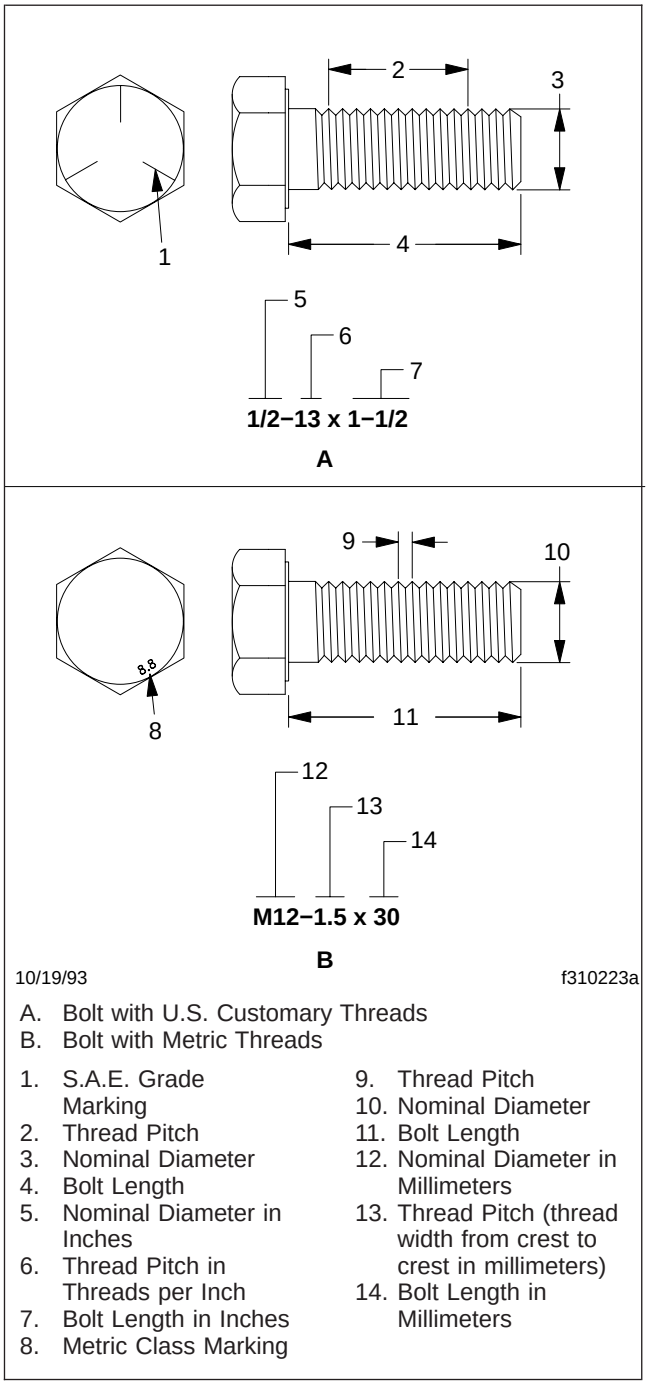
Some fasteners smaller than 1/2-inch diameter are flanged fasteners, which have integral flanges that fit against the parts being fastened. The flanges eliminate the need for washers.

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

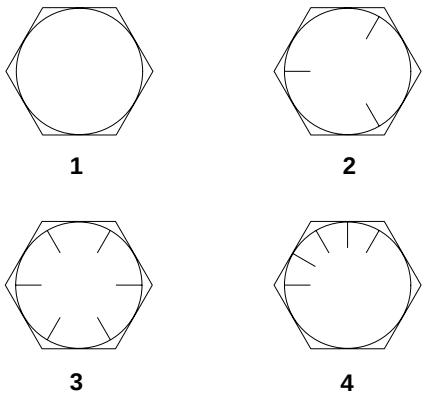


A. Bolt with U.S. Customary Threads
B. Bolt with Metric Threads

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

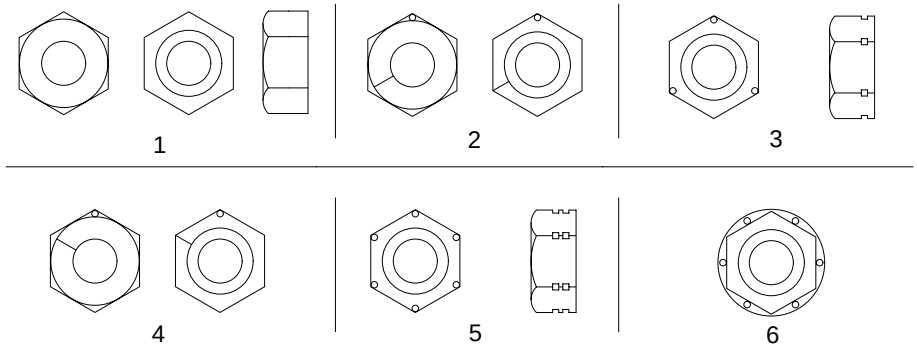
When a capscrew is tightened to its torque value in a threaded hole, or a nut is tightened to its torque value on a bolt, the shank of the capscrew or bolt is stretched slightly. This stretching (tensioning) results in a preload that reduces fatigue of the fasteners. The torque values given in the tables 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.

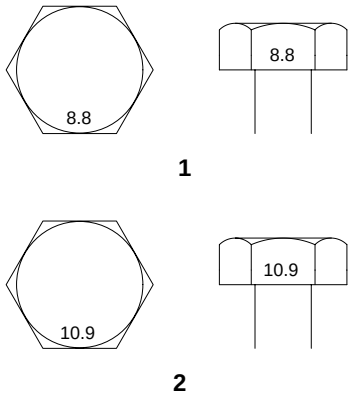


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NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification 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

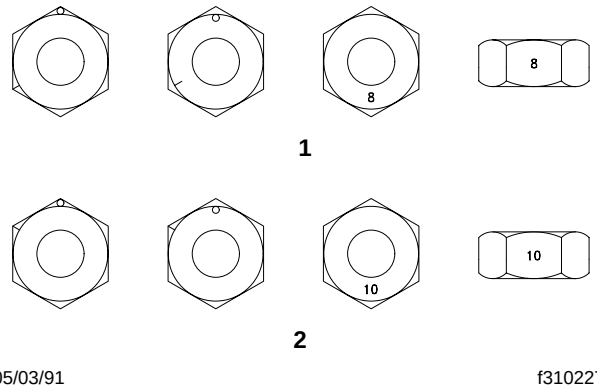


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NOTE: In addition to the class markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Class 8.8
2. Class 10.9

Fig. 4, Bolt Classes

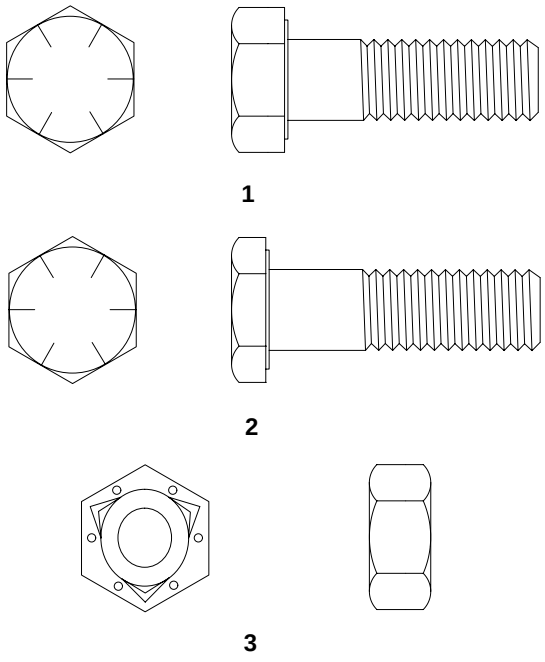


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1. Class 8 Nut
2. Class 10 Nut

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.

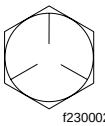
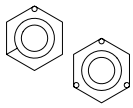
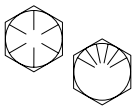
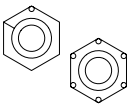
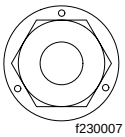
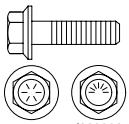
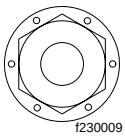
For thread diameters over 1 inch (25 mm), use Loctite 277.

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.

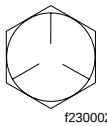
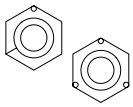
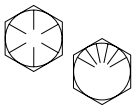
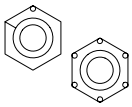
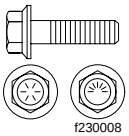
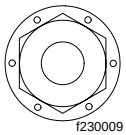
Torque Values for U.S. Customary Thread Fasteners With Lubricated* or Plated Threads†								
Thread Diameter–Pitch	Regular Hex				Flanged			
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade B Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (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, or waxed, Geomet 321XL coated, or waxed).

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

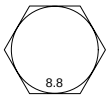
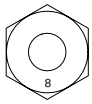
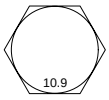
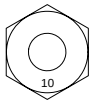
Specifications

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.

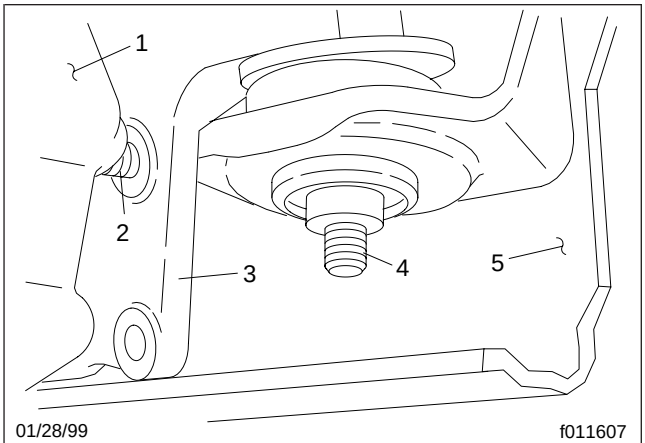
† Use these torque values if either the bolt or nut is lubricated or plated (zinc-phosphate conversion-coated, cadmium-plated, or waxed, Geomet 321XL coated, or waxed).

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

General Information

Three mounts support the engine and transmission, holding a total of almost 1800 lb (816 kg). Two of the engine mounts support the rear of the engine and transmission assembly. The third supports the front of the engine/transmission assembly.

Each of the rear engine mounts is bolted to the inside of the frame rail near the flywheel housing. See **Fig. 1**. These mounts support legs which are bolted to the flywheel housing. Engines use a rear engine leg that rests flat on the mount.



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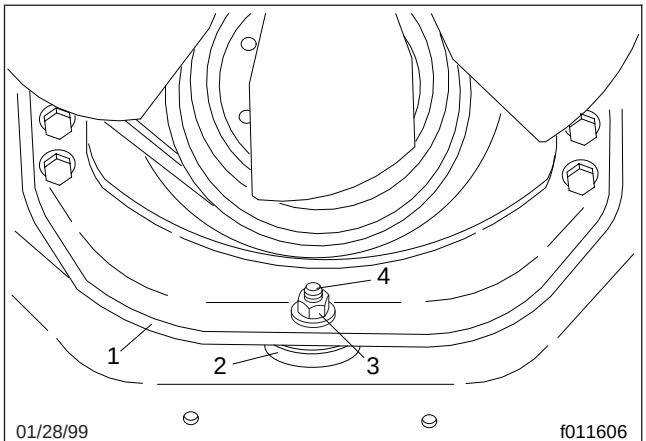
NOTE: Right mount shown

1. Flywheel Housing
2. Engine Leg Capscrew, 16 mm
3. Engine Leg
4. Isolator Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount (MBE900 engine shown)

The front engine mount is an underslung crossmember under the front of the engine. See **Fig. 2**. It supports a bracket that is bolted to the front of the engine.

To isolate the engine and transmission from road shock, and to isolate the vehicle frame from engine vibration, the engine mounts are sandwiched between rubber isolator cushions (sometimes called restriction pads). Steel snubbers protect the cushions from wearing on the engine support brackets, and a single bolt runs through the mount, cushions, and snubbers to hold the assembly together and hold the engine on the mount.



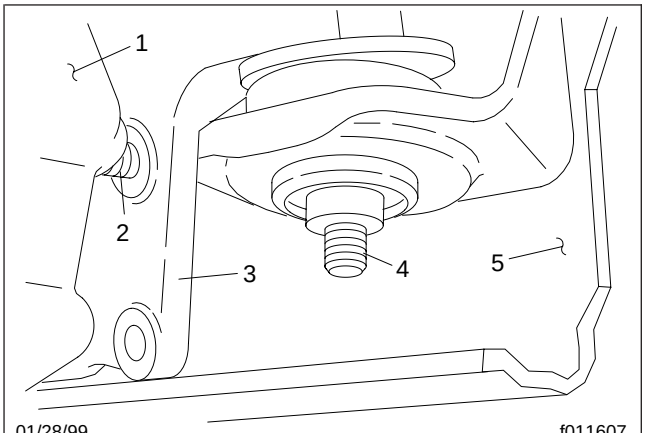
01/28/99 f011606

1. Engine Mount Bracket
2. Isolator
3. Hexnut, 5/8–11
4. Mounting Bolt, 5/8–11

Fig. 2, Front Engine Mount (MBE900 engine shown)

Replacement

See **Fig. 1** for this procedure.



1. Flywheel Housing
2. Engine Leg Capscrew
3. Engine Leg
4. Isolator Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

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.

2. Disconnect the right or left rear engine mount from the respective rear frame mount, as follows.

   2.1 Place a jack under the rear of the engine and raise the jack until it's braced against the engine.

   2.2 Remove the bolt from the right rear engine mount. Save the fasteners, rubber isolator cushions, and snubbers.

   2.3 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.

3. Remove the bolts that secure the mount to the frame rail. Remove the mount from the frame rail.

   If necessary, remove the four bolts that secure the right engine support bracket to the flywheel housing, and remove the bracket from the engine.

4. Place a new engine mount against the inside of the frame rail, and secure it with bolts, washers, and nuts. Tighten the nuts 136 lbf·ft (184 N·m).

5. If removed, install the engine support bracket on the right side of the flywheel housing. Apply thread locking compound to the bracket mounting bolts, and tighten them as follows:

   For Cummins ISB engines: tighten the bolts 60 lbf·ft (81 N·m).

   For MBE900 engines: tighten the bolts 92 lbf·ft (125 N·m).

6. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

CAUTION

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

7. Install the upper isolator in the engine mount. If applicable, place the snubber on the isolator.

WARNING

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

8. Secure the engine to the frame mount, as follows.

   8.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.

Rear Engine Mount Replacement

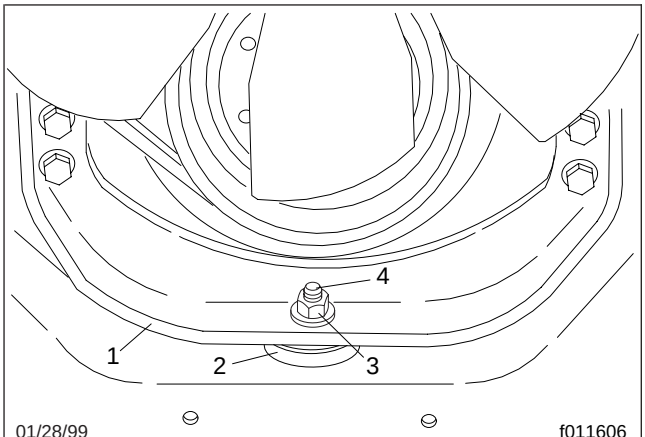
8.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.

8.3 Holding the lower isolator and snubber in place, install the bolt in the right rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).

9. Repeat this procedure for the other rear engine mount.
10. Remove the jack from under the engine, and remove the chocks from the tires.

Replacement

See **Fig. 1** and **Fig. 2** for this procedure.



01/28/99 f011606

1. Engine Mount Bracket
2. Isolator
3. Hexnut, 5/8–11
4. Mounting Bolt, 5/8–11

Fig. 1, Front Mount Assembly (MBE900 engines)

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

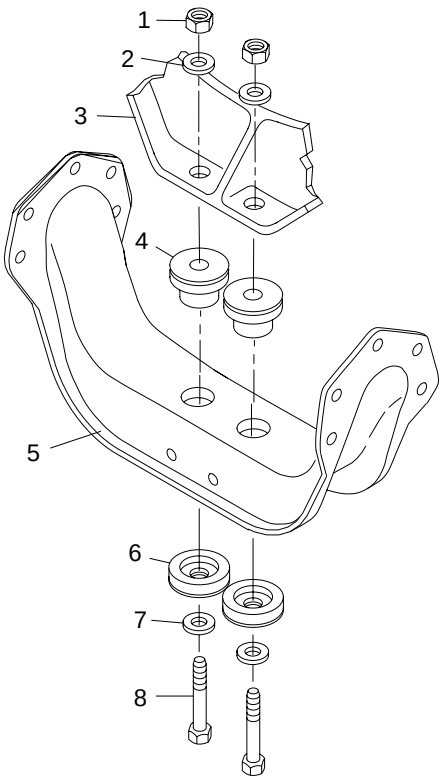
⚠ WARNING

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.

2. Disconnect the front engine mount from the frame crossmember, as follows.

   2.1 Attach a chain to the front engine lifting hook(s), and position a lifting device to lift the engine. Attach the chain to the lifting device, and raise the chain to remove any slack.

   2.2 Remove the bolt(s) from the front engine mount. Save the fasteners, rubber isolator cushions, and snubber(s).



06/16/99 f220068

1. Hexnut, 5/8–11 (2 qty.)
2. Hardened Washer (2 qty.)
3. Front Engine Support Bracket
4. Upper Isolator
5. Front Underslung Crossmember
6. Lower Isolator (2 qty.)
7. Flatwasher (2 qty.)
8. Hexbolt, 5/8–11 (2 qty.)

Fig. 2, Front Mount Assembly (Cummins ISB engines)

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

   2.3 Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.

3. If necessary, remove the bolts that secure the engine support bracket to the front of the engine. Remove the bracket from the engine.

Front Engine Mount Replacement

4. If necessary, install a new engine support bracket on the front of the engine, according to the engine manufacturer's specifications.
5. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

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

6. Install the upper isolator(s) in the engine mount. If applicable, place the snubber(s) on the isolator(s).

⚠ WARNING

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

7. Secure the front engine mount to the frame crossmember, as follows.
   - 7.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device and remove any slack.
   - 7.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 7.3 Holding the lower isolator(s) and tube(s) in place, install the bolt(s) in the front engine mount and secure it with the nut(s) and washer(s). Tighten the nuts 136 lbf·ft (184 N·m).

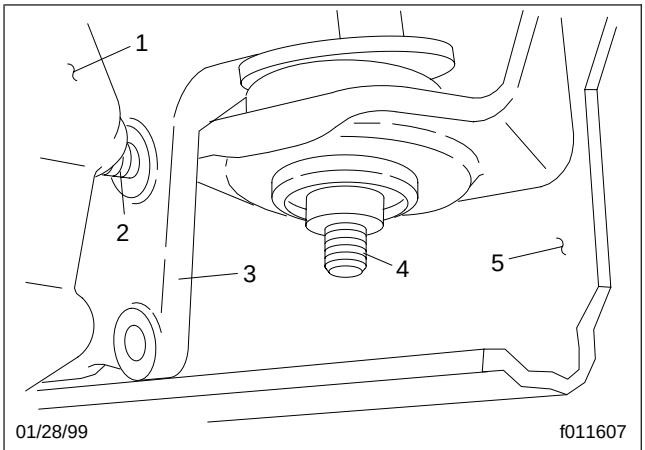
   NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m) for all engines.

   - 7.4 Remove the lifting chain from the engine lifting hooks.
8. Remove the chocks from the tires.

Rear Engine Mount Isolator Replacement

Replacement

See **Fig. 1** for this procedure.



1. Flywheel Housing
2. Engine Leg Capscrew, M16 x 2 x 55
3. Engine Leg
4. Isolator Mounting Bolt, 3/4–10
5. Frame Rail

Fig. 1, Rear Engine Mount (MBE900 engine shown)

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

⚠ 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.

2. Disconnect the right or left rear engine mount from the respective rear frame mount, as follows.
   - 2.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.
   - 2.2 Remove the bolt from the right rear engine mount. Save the fasteners and snubbers. Discard the rubber isolators.
   - 2.3 Lift the engine slightly to take its weight off the right rear engine mount. Place engine stands under the engine to keep it off the engine mount.
3. Inspect the new engine mount rubber isolators for damage and replace them if necessary.

⚠ CAUTION

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

4. Install the new upper isolator in the engine mount. If applicable, place the snubber on the isolator.

⚠ WARNING

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

5. Secure the engine to the engine mount.
   - 5.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
   - 5.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
   - 5.3 Holding the lower isolator in place, install the bolt in the left rear engine mount, and secure it with the nut and hardened washer. Tighten the nut 241 lbf·ft (327 N·m).
6. Repeat this procedure for the other rear engine mount isolator.
7. Remove the jack from under the engine, and remove the chocks from the tires.

Front Engine Mount Isolator Replacement

Replacement

See **Fig. 1** for this procedure.

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air brake system.

⚠ 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.

2. Disconnect the front engine mount from the frame crossmember, as follows.

   2.1 Attach a chain to the front engine lifting hook(s), and position a lifting device to lift the engine. Attach the chain to the lifting device and remove any slack.

   2.2 Remove the bolt(s) from the front engine mount. Save the fasteners, tube(s), and snubber(s). Discard the rubber isolator cushions.

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

   2.3 Lift the engine slightly to take its weight off the front engine mount. Place engine stands under the engine to keep it off the engine mount.

3. Inspect the new front engine mount rubber isolators for damage and replace them if necessary.

⚠ CAUTION

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

4. Install the upper isolator(s) in the engine mount.

⚠ WARNING

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

5. Secure the front engine mount to the frame crossmember, as follows.

   5.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device and remove any slack.

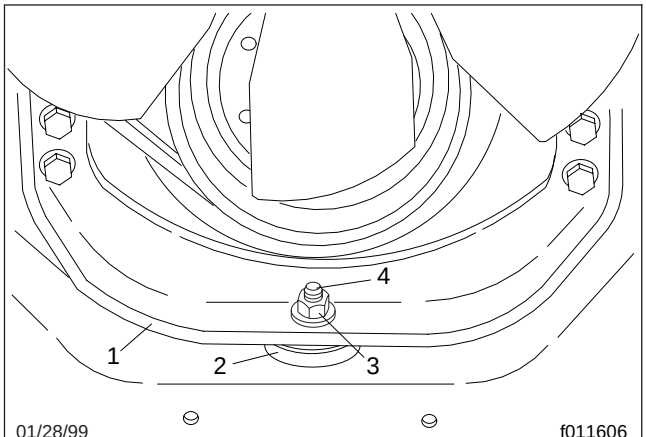
   5.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine on the engine mount.

   5.3 Holding the lower isolator(s) and tube(s) in place, install the bolt(s) in the front engine mount and secure it with the nut(s) and washer(s). Tighten the bolts 136 lbf·ft (184 N·m).

   NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m).

   5.4 Remove the lifting chain from the engine lifting hook(s).

6. Remove the chocks from the tires.



1. Engine Mount Bracket
2. Isolator
3. Front Engine Support Bracket
4. Bolt

Fig. 1, Front Mount Assembly (Mercedes-Benz engine shown)

Specifications

Mount Fastener Torque Values			
Fastener Application	**Grade/Class**	**Size**	**Torque: lbf·ft (N·m)**
Rear Engine Mount to Support-Bracket, All Engines	8	3/4–10	241 (327)
Rear Engine Mount to Frame Rail, All Engines	8	5/8–11	136 (184)
Front Engine Mount, All Engines	8	5/8–11	136 (184)
Engine Leg-to-Flywheel:			
Cummins ISB Engines	10.9	M12 x 2 x 45	60 (81)
MBE900 Engines	10.9	M16 x 2 x 55	92 (125)

Table 1, Mount Fastener Torque Values

Pulley and Drive Belt Inspection

Inspection

1. Inspect all used drive belts (including those that are being replaced) for the following conditions. See **Fig. 1**.

   NOTE: For an installed belt, gently twist the belt about 90 degrees so you can see the sidewalls and bottom.

   1.1 Inspect for glazing (shiny sidewalls). Glazing is caused by friction created when a loose belt slips in the pulleys. It can also be caused by oil or grease on the pulleys.

   1.2 Inspect for separating layers. Oil, grease, or belt dressings can cause the belt to fall apart in layers. If engine parts are leaking, repair the oil leaks. Do not use belt dressings on any belt.

   1.3 Check for jagged or streaked sidewalls. These are the result of a foreign object (such as sand or small gravel) in the pulley, or a rough pulley wall surface.

   1.4 Check for tensile breaks (breaks in the cord body). Cuts in a belt are usually caused by large foreign objects in the pulley, or by prying or forcing the belt during installation or removal.

   1.5 On poly-V belts, check for uneven ribs. Foreign objects in the pulley will erode the undercord ribs, causing the belt to lose its gripping power.

   1.6 Inspect for cracks. Small, irregular cracks are usually signs of an old belt.

   Replace the belt if any of the above conditions are found. Replace both belts of a set, at the same time. Matched belts must be from the same manufacturer.

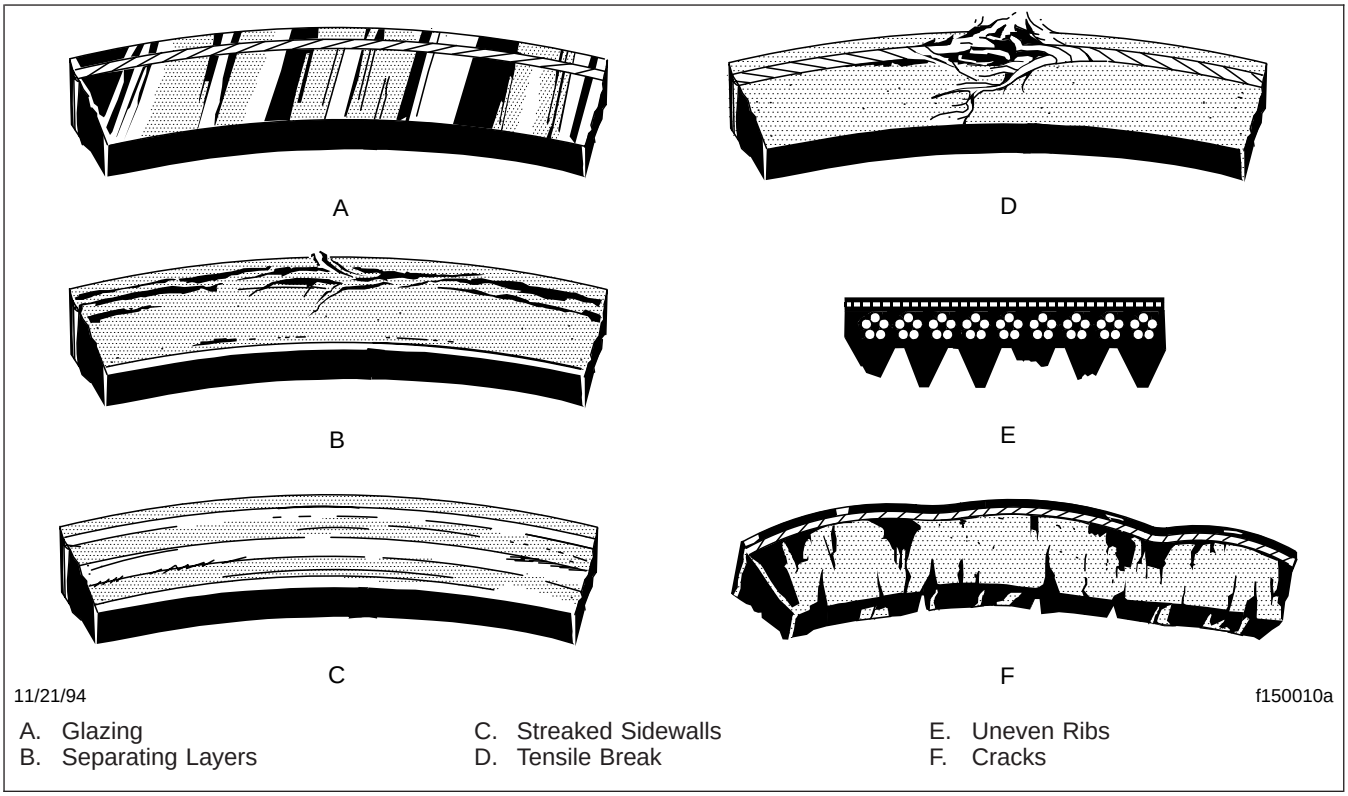
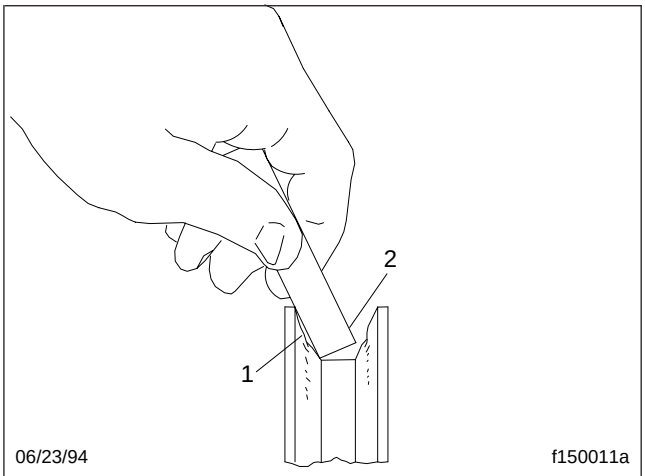


Fig. 1, Drive Belt Problems

Pulley and Drive Belt Inspection

2. Check all pulley bearings for roughness. Replace the bearings if they're rough.
3. Inspect all pulleys for foreign objects, oil, or grease in the grooves. Use a nonflammable cleaning solvent to remove oils. Use a wire brush to remove rust, and a file to remove burrs.
4. Inspect the pulleys for wear on the inner walls. Hold a small straightedge against the inside of the pulley walls, or use your little finger or fingernail to find grooves in the inner walls. See **Fig. 2**. If there are any grooves, replace the pulley.



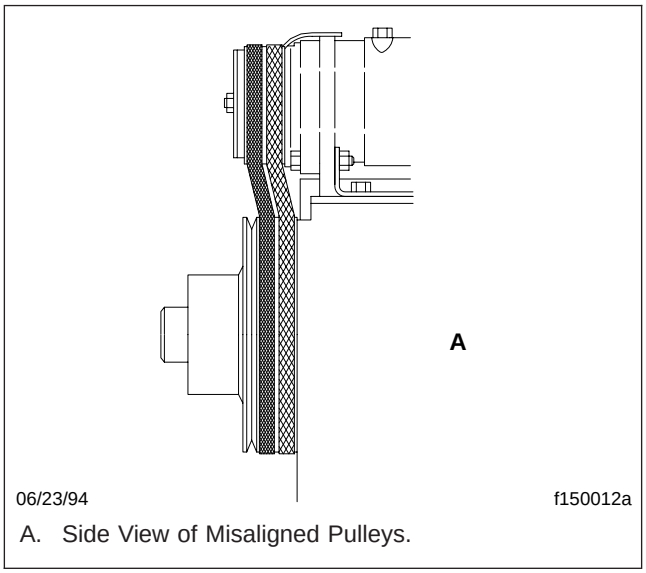
1. Groove in Pulley Wall
2. Small Straightedge

Fig. 2, Checking for Pulley Wear

5. Check alignment of pulleys. Use a thin straightedge that is longer than the longest span between the pulleys. Place the straightedge into the V-grooves of two pulleys at a time. The straightedge should be parallel to the outer edges of the pulleys; if not, the pulleys are misaligned.

   Pulley misalignment must not be more than 1/16-inch for each foot (1.5 mm for each 30.5 cm) of distance between pulley centers.

   If there is misalignment of the pulleys, adjust the pulleys or brackets if their positions are adjustable. See **Fig. 3**. Replace bent or broken pulleys, pulley brackets, or shafts.
6. Check all drive component mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners. Repair or replace cracked or damaged brackets.



A. Side View of Misaligned Pulleys.

Fig. 3, Misaligned Pulleys

Poly-V Belt Removal and Installation

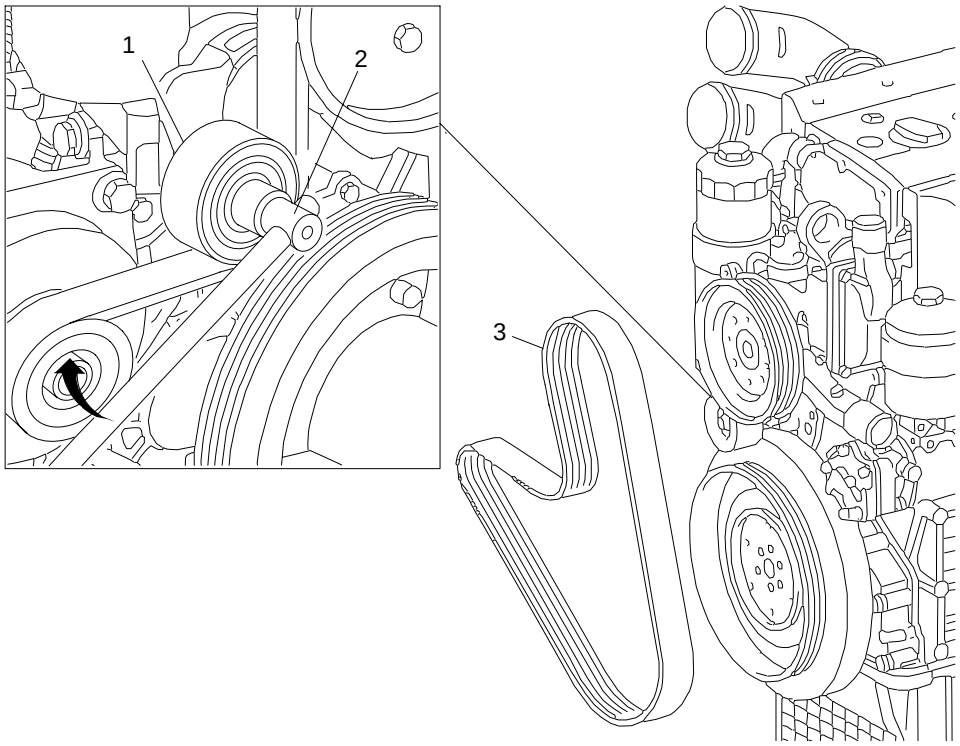
Removal

1. Place a T-handle and socket on the tensioning pulley bolt. See the insert in **Fig. 1**.

   Lift the T-handle (swivel the tensioning pulley clockwise) to remove the tension from the poly-V belt. Hold the tensioning pulley in this position for the next step.
2. Remove the poly-V belt from the alternator and coolant-pump pulleys. Be careful not to kink, stretch, or otherwise damage the belt.
3. Lower the T-handle to return the tensioning pulley to its original position. Remove the socket-wrench bit from the pulley bolt.
4. Inspect the poly-V belt for nicks, wear, or other damage. Replace the belt if necessary.
5. Inspect the following parts and replace any that are damaged or worn:
   - vibration damper
   - alternator pulley
   - coolant-pump pulley
   - belt tensioner
   - tensioning pulley

Installation

1. Fit the poly-V belt on the belt pulleys. Be careful not to kink, stretch, or otherwise damage the belt. Do not fit the belt onto the tensioning pulley yet.
2. Place the T-handle and socket-wrench bit on the tensioning pulley bolt. Swivel the tensioning pulley clockwise to overcome the spring tension.
3. With the belt in place, lower the T-handle to return the tensioning pulley to its original position,



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1. Belt Tensioner with Tensioning Pulley
2. T-Handle with Socket-Wrench Bit
3. Poly-V Belt

Fig. 1, Poly-V Belt Removal (MBE900 engine shown)

Poly-V Belt Removal and Installation

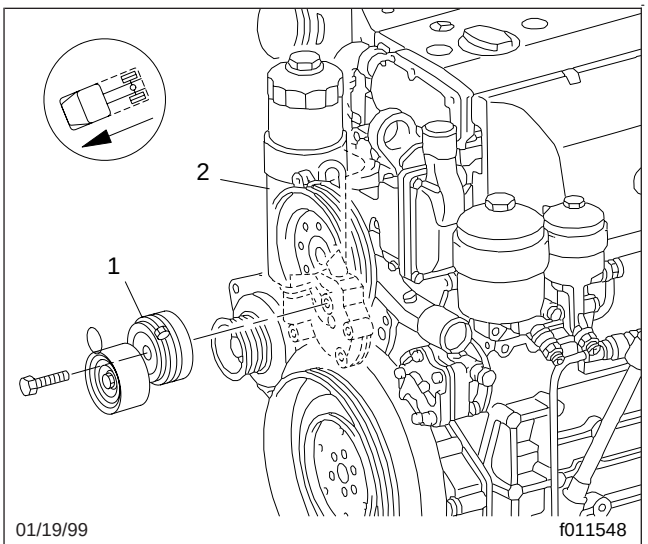
allowing the belt tensioner to automatically put the correct tension on the belt.

4. Remove the socket-wrench bit from the pulley bolt.
5. Check the poly-V belt to make sure it is in the correct position and properly aligned on the pulleys.

Belt Tensioner Removal and Installation, MBE900 Engine

Removal

1. Remove the poly-V belt from the alternator and coolant-pump pulleys. See **Subject 110** for instructions.
2. Remove the hexhead capscrew and belt tensioner from the oil filter housing. See **Fig. 1**.



1. Belt Tensioner with Tensioning Pulley
2. Oil Filter Housing

Fig. 1, Belt Tensioner Removal

Installation

1. Align the pins on the belt tensioner with the holes in the oil filter housing.
2. Install the belt tensioner on the oil filter housing and secure in place with the hexhead capscrew. Tighten the capscrew 37 lbf·ft (50 N·m).
3. Install the poly-V belt on the alternator and coolant-pump pulleys. See **Subject 110** for instructions.

Belt Tensioner

Torque Values	
Description	**lbf·ft (N·m)**
Mercedes-Benz MBE900 Engines	
Belt Tensioner Hexhead Capscrew	37 (50)
Cummins Engines	
Adjusting Link Hexnut	30 to 40 (41 to 54)
Adjusting Rod Hexnut	37 to 47 (50 to 64)
Refrigerant Compressor Mounting Hexhead Capscrew	30 to 40 (41 to 54)

Table 1, Torque Values

Air Intake Duct Replacement

General Information

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.

All air intake components and connections must be air- and water-tight. Dirt or dust entering the engine can cause internal engine damage. Much of the dirt and dust are silicates, which fuse into abrasive glass-like particles when exposed to engine combustion. These particles can grind piston rings, pistons, and cylinder liners.

To avoid chafing, air intake ducting must not contact other parts.

Replacement

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Loosen the clamps that attach the air intake ducting to the air cleaner and the turbocharger. If the vehicle is equipped with more than one piece of air intake ducting, loosen the clamps that attach the elbows to the tube. See **Fig. 1**.

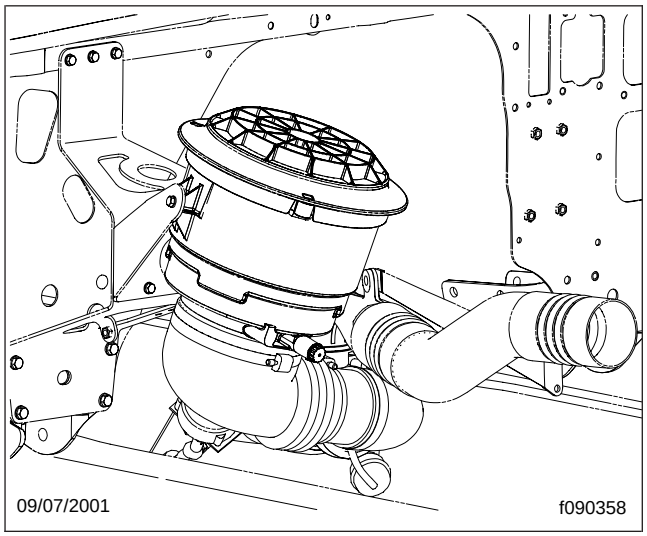


Fig. 1, Air Intake Ducting, MBE900 Engine, 160 mm Hood Height

4. Remove the air intake ducting.
5. Install new air intake ducting between the air cleaner and the turbocharger. If the vehicle is equipped with more than one piece of air intake ducting, install the elbows and tube between the air cleaner and turbocharger.
6. Tighten the clamps on the air intake ducting.
7. Lower the hood.
8. Remove the chocks from the tires.

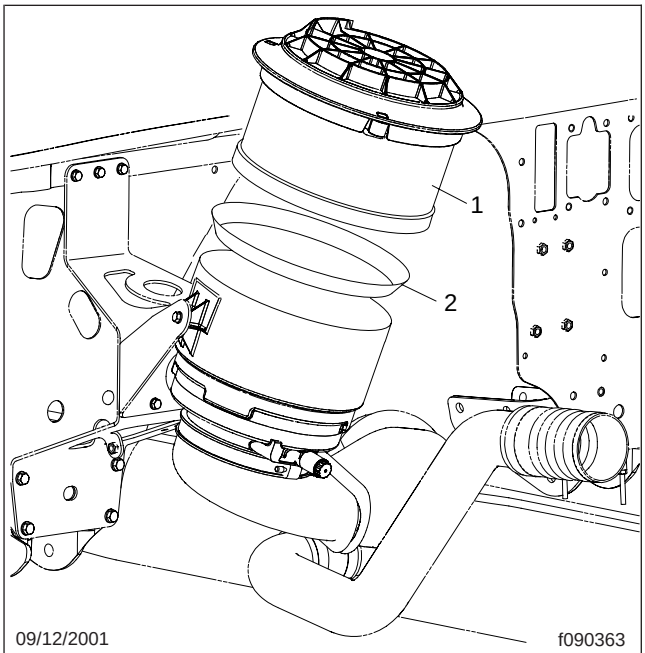
Air Cleaner Element Replacement

Replacement

NOTICE

Do not operate the engine with the air cleaner element or any air intake component removed. If the engine is started without air intake components in place, damage to the engine could occur.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the capscrews that attach the combined primary air cleaner element and air cleaner cover to the air cleaner. Remove the primary air cleaner element from the air cleaner. See **Fig. 1**.



1. Primary Air Cleaner Element
2. Secondary or Safety Air Cleaner Element

Fig. 1, Air Cleaner Elements

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

4. Remove the secondary air cleaner element or the safety air cleaner element from the air cleaner.
5. Wipe the inside of the air cleaner with a clean, damp cloth.

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.

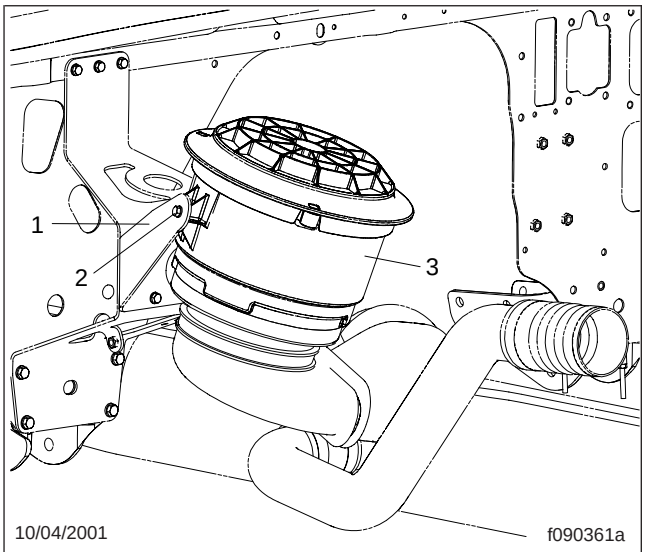
6. Inspect the new secondary air cleaner element or the new safety air cleaner element for damage or holes. Install the secondary air cleaner element or the safety air cleaner element in the air cleaner.
7. Inspect the new primary air cleaner element for damage or holes. Install the new primary air cleaner element in the air cleaner.
8. Using capscrews, secure the air cleaner element/air cleaner cover to the air cleaner. Torque the capscrews 25 to 35 lbf·in (280 to 400 N·cm).
9. Lower the hood.
10. Remove the chocks from the tires.

Replacement

NOTICE

Do not operate the engine with the air cleaner element or any air intake component removed. If the engine is started without air intake components in place, damage to the engine could occur.

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the intake-air restriction indicator.
4. Loosen the clamp that attaches the air intake ducting to the air cleaner. Remove the air intake ducting from the air cleaner.
5. Remove the three capscrews that attach the air cleaner to the air cleaner mounting bracket. See **Fig. 1**.



1. Mounting Bracket
2. Capscrew
3. Air Cleaner Installation

Fig. 1, Air Cleaner Installation

6. Using three capscrews, attach a new air cleaner to the air cleaner mounting bracket.
7. Attach the air intake ducting to the air cleaner and secure it to the air cleaner by tightening the clamp.
8. Install the intake-air restriction indicator on the air cleaner.
9. Lower the hood.
10. Remove the chocks from the tires.

Intake-Air Restriction Indicator Checking

Air flow restriction through the air cleaner element is measured at a tap in the air cleaner outlet. Check the intake-air restriction indicator at the air cleaner, or in the cab if the vehicle is equipped with a dash-mounted intake-air restriction indicator or dash-mounted intake-air restriction gauge. See **Fig. 1**.

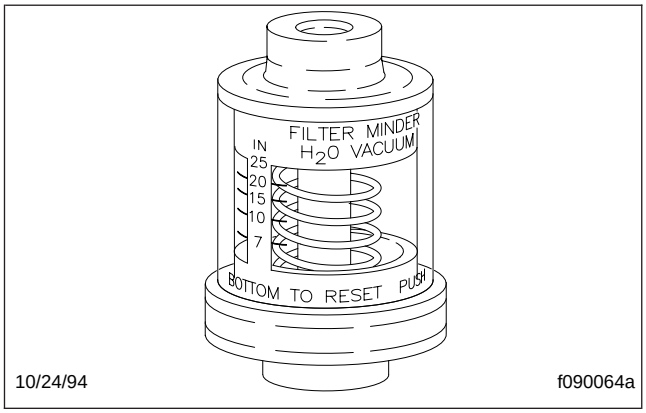


Fig. 1, Intake-Air Restriction Indicator

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.

Check the intake-air restriction indicator with the engine off to see if the reading on the indicator is equal to or exceeds the value shown in **Table 1** for service (maximum) air restriction at full load and governed rpm. If air restriction is at or above the maximum, replace the air cleaner element.

Intake-Air Restriction Vacuum Readings		
Engine Type	**Initial inH_2O (mmH_2O)**	**Service inH_2O (mmH_2O)**
Mercedes-Benz	12 (305)	20 (508)
Cummins ISB	12 (305)	25 (635)

Table 1, Intake-Air Restriction Vacuum Readings

General Information

The charge air cooler (CAC) is attached to the front of the radiator. The function of the CAC is to cool the hot, compressed air that exits the turbocharger. The CAC reduces the temperature of this air to the engine manufacturers' specified air intake temperature before the air reaches the engine intake manifold. The lower temperature reduces exhaust emissions, improves fuel economy, and increases horsepower.

Charge Air Cooler Removal and Installation

NOTE: This procedure covers only charge air coolers that are installed above a condenser.

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the four Torx® fasteners that attach the grille to the hood.
4. Open the hood.
5. Loosen the constant torque clamps that attach the flex tubes and charge air cooler (CAC) inlet and outlet air pipes to the CAC. Remove the flex tubes and CAC pipes from the CAC.
6. Standing in the grille opening of the hood, remove the nuts that attach the CAC to the mounting brackets. Remove the CAC.

Installation

1. Using nuts, attach the right side of the CAC to the mounting bracket, then attach the left side. After all four nuts are installed, torque them 25 to 31 lbf·ft (34 to 42 N·m).
2. Install the flex tubes between the CAC and the CAC inlet and outlet air pipes. Place the constant torque clamps over the flex tubes and tighten the clamps 45 lbf·in (500 N·cm).
3. Using four Torx fasteners, attach the grille to the hood.
4. Lower the hood.
5. Connect the batteries.
6. Remove the chocks from the tires.

Charge Air Cooler Inspection and Leakage Test

Inspection

1. Apply the parking brakes, chock the tires, and open the hood.
2. Check the charge air cooler (CAC) flex tubes and the inlet and outlet air piping for holes or other damage. Also check for loose or damaged constant torque clamps. Replace damaged parts. If the clamps are loose, turn them so that the screws are under the hoses or facing inboard. Tighten the clamps 45 lbf·in (500 N·cm).
3. Check the CAC core fins. If the fins are bent, use a small pair of needlenose pliers or a small screwdriver to straighten them.
4. Check the CAC core for clogged fins. Use compressed air or water to dislodge any material restricting airflow through the core.
5. Perform the "CAC Core Leakage Test."

Leakage Test

Charge air coolers are designed in such a way that they may leak an insignificant amount of air. The allowable leakage mentioned 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		
Engine	**Pressure Drop in 15 Seconds: psi (kPa)**	**Start Pressure: psi (kPa)**
Mercedes-Benz	5 (34)	30 (207)
Cummins ISB	7 (48)	30 (207)

Table 1, Leakage Rate Specifications

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

CAC Core Leakage Test

1. Apply the parking brakes, chock the tires, and open the hood.
2. Connect the test equipment to the CAC core, as follows. See **Fig. 1**.

2.1 Remove the inlet and outlet air piping from the flex tubes attached to the CAC air inlet and air outlet.

2.2 Slip a safety ring over each flex tube at the CAC air inlet and air outlet. Turn the rings so that the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.

2.3 Install an additional constant torque clamp on each flex tube.

2.4 Install the test plug without an adapter in the CAC air inlet, and turn the plug so that the safety chain is inboard. Tighten both of the rearmost constant torque clamps 72 lbf·in (815 N·cm).

2.5 Install the test plug with adapter in the CAC air outlet, and turn the plug so the safety chain is inboard. Tighten both of the rearmost constant torque clamps 72 lbf·in (815 N·cm).

⚠ WARNING

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

2.6 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adapter.

2.7 Attach a pressurized air line to the air chuck on the pressure regulator valve.

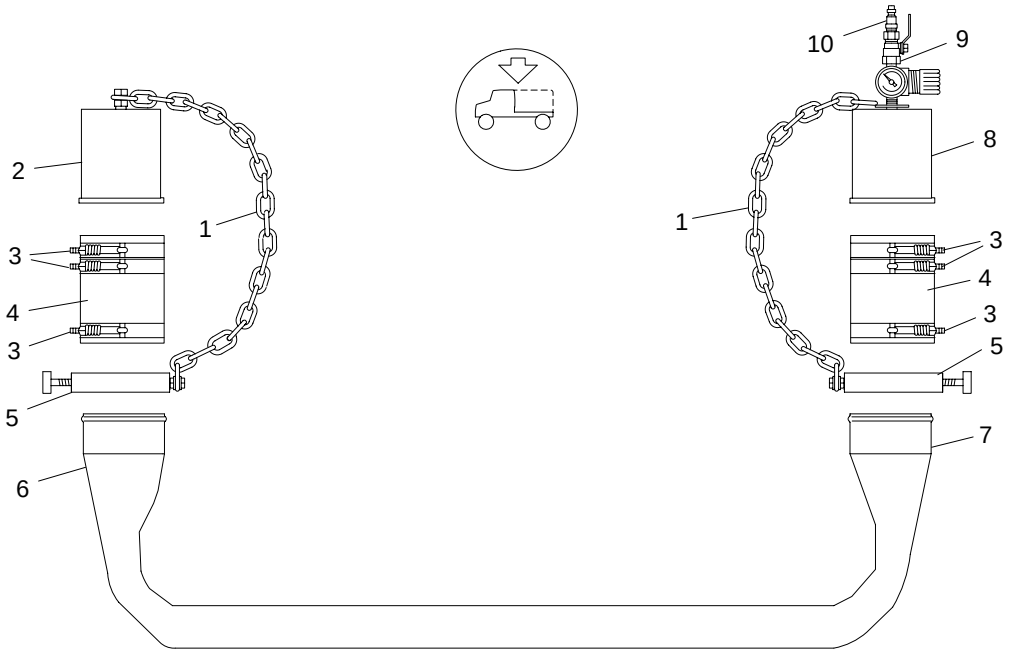
3. Test the CAC core, as follows.

⚠ WARNING

Always wear safety glasses 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.

3.1 Open the test valve, then slowly open the pressure regulator valve and allow the charge air cooler system to gradually fill with air to the start pressure specified in **Table 1**.

Charge Air Cooler Inspection and Leakage Test



1. Safety Chain
2. Test Plug
3. Constant Torque Clamp
4. Flex Tube
5. Safety Ring
6. CAC Air Inlet
7. CAC Air Outlet
8. Test Plug with Adapter
9. Test Valve/Gauge Assembly
10. Air Chuck

Fig. 1, CAC Core Testing

3.2 Close the test valve and watch the gauge for 15 seconds. If there is more than the specified drop in the charge air cooler pressure in 15 seconds, replace the charge air cooler.

IMPORTANT: Do not attempt to repair the charge air cooler.

3.3 When testing is completed, reduce the pressure on the pressure regulator valve to bleed air from the charge air cooler.

4. Remove the test equipment and the additional constant torque clamps from the flex tubes.
5. Pull the flex tubes and constant torque clamps rearward until the flex tubes cover about 1-1/2 inches (38 mm) of the CAC air inlet and air outlet piping.
6. Turn the clamps so that the screws are under the flex tubes or facing inboard. Tighten the screws 45 lbf·in (500 N·cm).
7. Lower the hood.
8. Remove the chocks from the tires.

Charge Air Cooler Flushing

If the charge air cooler is suspected of being contaminated, flush the charge air cooler.

1. Turn off the engine, apply the brakes, and chock the tires.
2. Remove the charge air cooler. For instructions, see **Subject 100**.
3. Set the charge air cooler in a horizontal position with the inlet and outlet ports facing up.

CAUTION

Use only naphtha or mineral spirits to clean the charge air cooler. 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 leaking.

4. Pour a filtered naphtha or mineral spirits solution into the charge air cooler until it is 40 percent full.
5. Cap the inlet and outlet ports on the charge air cooler.
6. Rock the charge air cooler 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 charge air cooler for more than ten minutes.

7. Remove the caps from the inlet and outlet ports.
8. Drain the charge air cooler and properly dispose of the solvent.
9. Leave the caps off and allow the residual solvent to evaporate.
10. Install the charge air cooler. For instructions, see **Subject 100**.
11. Remove the chocks from the tires.

Restriction Test

After flushing the charge air cooler because of turbocharger or engine damage, test the pressure drop across the charge air cooler and air piping as follows:

1. Remove the pipe plug from the tapped hole in the turbocharger air outlet elbow.

   Remove the pipe plug or the nylon tube and atomizer for the ether start system if so equipped, or the air line to the turbocharger air-pressure gauge if so equipped from the tapped hole in the rear-left side of the intake manifold.

   Install an air pressure gauge in each tapped hole.

2. 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 air turbulence at the turbocharger outlet, subtract 0.3 inHg (1 kPa) from the pressure measurement taken at this point to make it a true reading.

   From that reading, subtract the reading taken at the intake manifold; this is the pressure drop of the charge air cooler.

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

Air Compressor Removal, Inspection, and Installation

Special Tools

A special tool is needed to replace the drive gear on the WABCO air compressor. See **Table 1**.

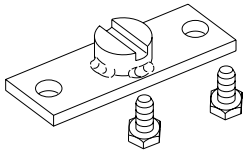
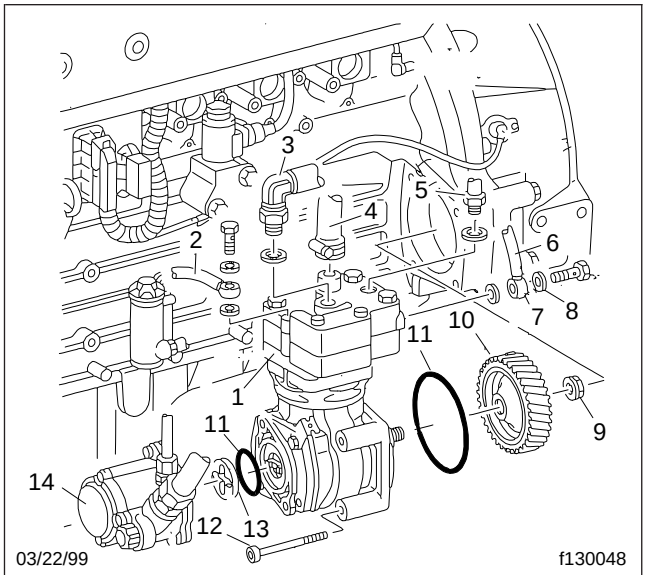
Special Tool			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580250	Air Compressor Locking Device	SPX Kent-Moore	KM 904 589 03 63 00

Table 1, Special Tool

Removal

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Drain the air tanks.
3. Open the hood and clean all the fittings and hose connections on the air compressor and power steering pump until they are free of dirt.
4. Drain the radiator coolant. For instructions, see **Section 20.01, Subject 100**.
5. Remove the engine trim panel, which covers the wiring and other connections, from the side of the engine.
6. Disconnect the discharge line from the air compressor and move it away from the compressor. See **Fig. 1**.
7. Remove the air governor unloader line from the compressor.
8. Remove the capscrew that attaches the air governor to the engine and move the governor away from the air compressor.
9. Disconnect the air inlet line from the air compressor and plug the hole on the compressor.
10. Remove the tie straps on the wiring harnesses as needed to access the coolant line. Disconnect the rear coolant line from the cylinder head.
11. Disconnect the front coolant line at the compressor.



1. Air Compressor
2. Front Coolant Line
3. Discharge Line
4. Air Inlet Line
5. Unloader Air Line
6. Rear Coolant Line
7. Banjo Fitting
8. Washer
9. Drive Nut
10. Drive Gear
11. O-Ring
12. Capscrew
13. Cross Plate
14. Power Steering Pump

Fig. 1, Air Compressor Installation

12. Remove the capscrews that attach the power steering pump to the air compressor and move the steering pump away from the compressor.

Air Compressor Removal, Inspection, and Installation

IMPORTANT: Do not remove the power steering lines. Secure the lines and the pump so they are out of the way.

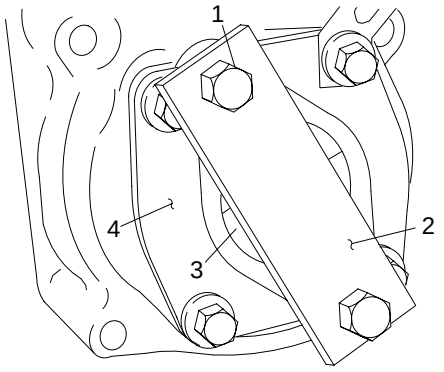
13. Remove the cross plate between the compressor and the power steering pump. See **Fig. 1**.

NOTE: On vehicles with automatic transmissions, it may be necessary to remove the brackets that attach the automatic transmission cooler lines to the engine to obtain enough room to remove the compressor.

14. Use a drain pan to catch any oil or water when the compressor is removed. Remove the capscrews that attach the air compressor to the engine and remove the compressor.

Inspection

1. Attach the fittings to the replacement compressor and replace damaged O-rings and fittings as needed. Note the position of the rear coolant line on the back of the compressor for reference during installation.
2. Install the O-ring between the power steering pump and the air compressor.
3. Inspect the drive gear for worn or broken teeth, or spalling. If necessary, replace the drive gear. If replacing the drive gear, use the instructions in the following substeps; otherwise proceed to the heading "Installation".
   - 3.1 Using two capscrews, install the SPX Kent-Moore locking device (PN KM 904 589 03 63 00) on the air compressor where the power steering pump connects to the air compressor. Tighten the capscrews until the air compressor drive is locked. See **Fig. 2**.
   - 3.2 Secure the air compressor in a vise.
   - 3.3 Using an impact wrench, remove the drive nut from the drive gear.
   - 3.4 Remove the drive gear from the air compressor. If necessary, use a gear puller to remove the drive gear.
   - 3.5 Install a new drive gear and nut on the drive shaft. Torque the nut 200 lbf·ft (270 N·m).



1. Capscrew
2. Locking Device
3. End of Drive Shaft
4. Air Compressor

Fig. 2, Locking Device Installation

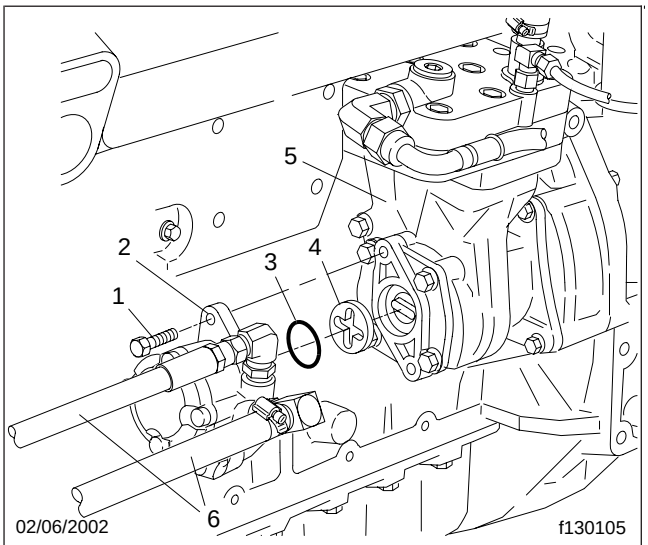
   - 3.6 Remove the locking device from the air compressor.

Installation

1. Using four capscrews, attach the air compressor to the engine. Torque the capscrews 30 lbf·ft (40 N·m).

IMPORTANT: Before installing the power steering pump, make sure the cross plate is installed on the air compressor. See **Fig. 3**.

2. Using two capscrews, attach the power steering pump to the air compressor. Torque the capscrews 30 lbf·ft (40 N·m).
3. Install the two coolant lines. Tighten the banjo fittings 30 lbf·ft (40 N·m). Use tie straps to secure the crank angle position sensor wires to the coolant line as needed.
4. If the brackets that attach the automatic transmission cooler lines to the engine were removed, use capscrews to install the brackets.
5. Install the air inlet line.
6. Using a capscrew, install the air governor on the engine.
7. Attach the unloader line to the air compressor.
8. Attach the discharge line to the air compressor.
9. Install the engine trim panel.



1. Capscrew
2. Power Steering Pump
3. O-Ring, Power Steering Pump
4. Cross Plate
5. Air Compressor
6. Hydraulic Lines

Fig. 3, Power Steering Pump Installation

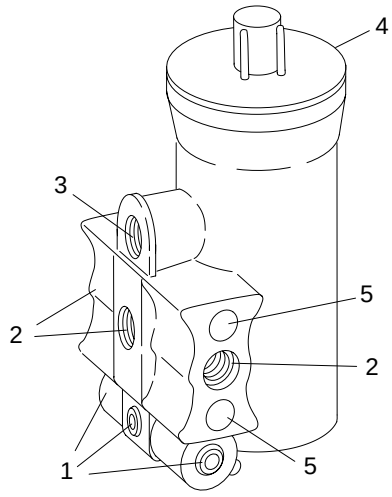
10. Fill the cooling system. For instructions, see **Section 20.01, Subject 100**.
11. Remove the chocks from the tires and close the hood.

General Information

The Bendix D-2 air governor, operating in conjunction with the air compressor unloading mechanism, automatically controls the air pressure in the air brake or air supply system between the desired, predetermined maximum and minimum pressures. Normal air pressure with the engine running is 100 to 120 psi (689 to 827 kPa). The air compressor runs continuously while the engine runs, but the actual compression of air is controlled by the air governor actuating the compressor unloading mechanism, which stops or starts the compression of air when the maximum or minimum reservoir pressures are reached.

The D-2 air governor may be mounted on the air compressor, the dryer reservoir module (DRM) if equipped with an air dryer, or on the frame rail near the air compressor.

The air governor has three reservoir ports (1/8-inch NPT), three unloader ports (1/8-inch NPT), and one exhaust port (1/8-inch NPT). See **Fig. 1**.



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

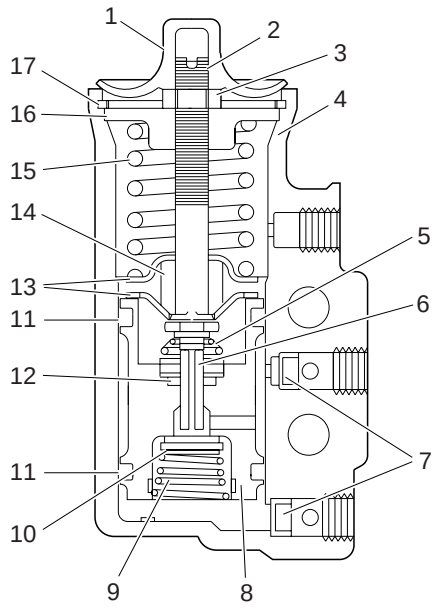
Fig. 1, Air Governor

Principles of Operation

Reservoir air pressure enters the air governor at one of its reservoir ports and acts on the piston and inlet/exhaust valve. As the air pressure builds up, the piston and valve move together against resistance of the pressure setting spring. When the reservoir air pressure reaches the cut-out setting of the governor, the exhaust stem seats on the inlet/exhaust valve, closing the exhaust passage, and then opens the inlet passage. Reservoir air pressure then flows around the inlet valve, through the passage in the piston, and out the unloader port to the compressor unloading mechanism. Air also flows around the piston which is slightly larger at the upper end. The added force resulting from this larger area assures a positive action and fully opens the inlet valve.

As the system reservoir air pressure drops to the cut-in setting of the governor, the force exerted by the air pressure on the piston will be reduced so that the pressure-setting spring will move the piston down. The inlet valve will close and the exhaust will open. With the exhaust open, the air in the unloader line will escape back through the piston, through the exhaust stem, and out the exhaust port. See **Fig. 2**.

General Information



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1. Cover
2. Adjusting Screw
3. Adjusting Screw Locknut
4. Body
5. Exhaust Stem Spring
6. Exhaust Stem
7. Filter
8. Piston
9. Inlet and Exhaust Valve Spring
10. Inlet and Exhaust Valve
11. O-Ring
12. Exhaust Stem O-Ring
13. Lower Spring Seat
14. Spring Guide
15. Pressure Setting Spring
16. Upper Spring Seat
17. Spring Assembly Retaining Ring

Fig. 2, Air Governor, Section View

Air Governor Operating and Leakage Tests

Tests

The following test should be performed when the vehicle air pressure is incorrect and the cause is unknown.

If the Bendix D-2 air governor does not function as described or if leakage is excessive, replace the air governor with a new or remanufactured air governor, or repair it using genuine Bendix parts and the instructions in this section.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. 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 or adjust the air governor.

4. 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), the cut-out pressure should be 125 to 135 psi (862 to 931 kPa).

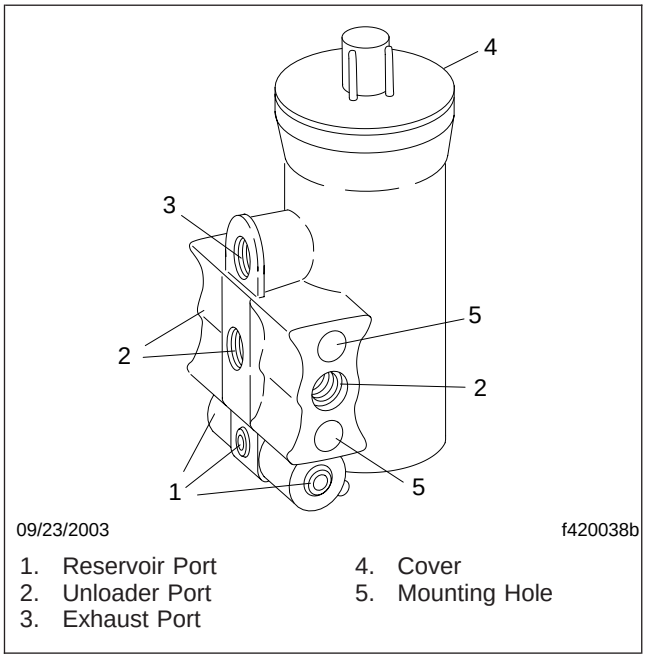
   For vehicles without a dryer reservoir module, the cut-out pressure should be 120 to 130 psi (827 to 896 kPa).

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

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

6. If either the cut-out or cut-in pressures are incorrect, proceed to **Subject 130**.
7. Test the leakage on the air governor in both the cut-in and cut-out positions.

   7.1 With the compressor in the cut-in position, apply a soap solution around the cover and on the exhaust port. See **Fig. 1**. A 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. Cover
5. Mounting Hole

Fig. 1, Air Governor

   7.2 With the compressor in the cut-out position, apply a soap solution around the cover and on the exhaust port. A 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.

8. Return the hood to the operating position.
9. Remove the chocks from the tires.

Air Governor Removal and Installation

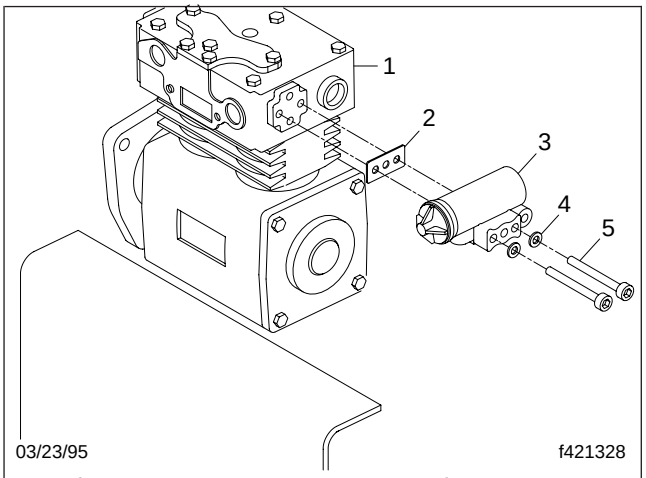
Removal

NOTE: The Bendix D-2 air governor may be mounted on the air compressor, the dryer reservoir module (DRM) if equipped with an air dryer, or on the frame rail near the air compressor.

1. Turn off the engine, apply the brakes, and chock the tires.
2. Open the hood.
3. Drain the air tanks.
4. Disconnect the reservoir port and unloader port air lines. Mark the lines for later reference. Cap the air lines tightly to keep out contaminants.
5. Remove the capscrews and washers that attach the air governor to the mating component, and remove the air governor.

Installation

1. Clean the mounting pad on both the compressor and the governor block, and be sure the compressor unloading port is clear and clean.
2. Using capscrews and washers, attach a new gasket and the air governor to the mating component. Torque the capscrews 11 to 15 lbf·ft (15 to 20 N·m). See **Fig. 1**.



1. Air Compressor
2. Gasket
3. Air Governor
4. Washer
5. Capscrew

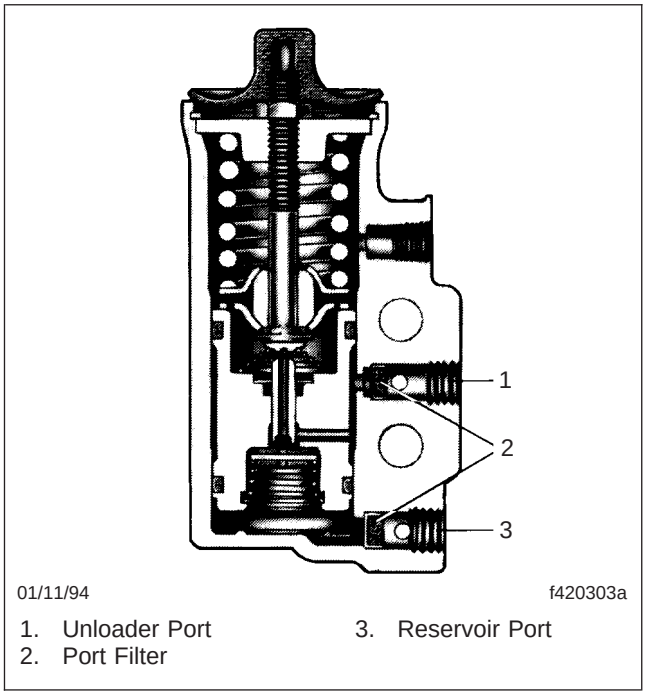
Fig. 1, Air Governor Installation on an Air Compressor

3. Remove the caps and clean the air lines. Apply Loctite® 242, or equivalent sealant, in small quantities to the reservoir and unloader fittings.

CAUTION

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

4. Connect the reservoir port and unloader port air lines. Torque the fittings 11 to 13 lbf·ft (15 to 18 N·m).
5. Perform the operating and leakage tests in **Subject 100**.
6. After the tests have been completed and the governor is operating properly, install the cover on the body and tighten it until it seals the body, preventing the entry of any foreign matter.
7. If necessary, install new filters in the reservoir and unloader ports. These cup-shaped filters can be installed with the head of a pencil. See **Fig. 2**.
8. Return the hood to the operating position.
9. Remove the chocks from the tires.



1. Unloader Port
2. Port Filter
3. Reservoir Port

Fig. 2, Air Governor, Section View

Air Governor Disassembly, Cleaning and Inspection, and Assembly

Disassembly

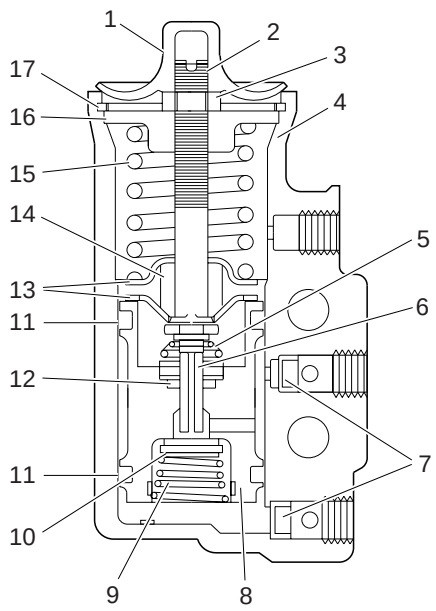
1. Using the instructions in **Subject 110**, remove the Bendix D-2 air governor.
2. Clean the air governor exterior of road dirt and grease.

NOTE: If the air governor is marked "nonadjustable" and the adjusting screw has been sheared off, this is a nonserviceable governor and must be replaced.

3. Remove the cover. See **Fig. 1**.
4. Using retaining ring pliers, remove and set aside the spring assembly retaining ring.
5. Remove the adjusting screw and spring assembly from the air governor body.
6. Remove the adjusting screw locknut, then remove the upper spring seat from the adjusting screw.
7. Remove the pressure setting spring, the lower spring seat, the spring guide, and the other lower spring seat from the adjusting screw.
8. Gently tap the open end of the valve body on a flat surface to remove the exhaust stem, the exhaust stem spring, and the piston assembly.
9. Remove and discard the two O-rings on the piston outer diameter. Using a hooked wire, remove and discard the O-rings on the piston inner diameter.
10. Disengage the inlet and exhaust valve spring from the recess in the bottom of the piston. Remove and discard the inlet and exhaust valve spring and the inlet exhaust valve.
11. Remove and discard the filters in the unloader ports and reservoir ports.

Cleaning and Inspecting

1. Clean all metal parts in mineral spirits.
2. Wipe all rubber parts dry, using a clean cloth.
3. Inspect the governor body for cracks or other damage. Be particularly careful that all air passages in the body, exhaust stem, and piston are not obstructed.
4. Check the springs for cracks, distortion, or corrosion.



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1. Cover
2. Adjusting Screw
3. Adjusting Screw Locknut
4. Body
5. Exhaust Stem Spring
6. Exhaust Stem
7. Filter
8. Piston
9. Inlet and Exhaust Valve Spring
10. Inlet and Exhaust Valve
11. O-Ring
12. Exhaust Stem O-Ring
13. Lower Spring Seat
14. Spring Guide
15. Pressure Setting Spring
16. Upper Spring Seat
17. Spring Assembly Retaining Ring

Fig. 1, Air Governor, Section View

5. Replace all worn or damaged parts.

Assembly

Prior to assembly, lubricate the two lower body bores, all O-rings, and O-ring grooves. Also lubricate the spring guide and adjusting screw if disassembled.

1. Install the exhaust stem O-ring on the piston.
2. Install the upper and lower piston O-rings.

Air Governor Disassembly, Cleaning and Inspection, and Assembly

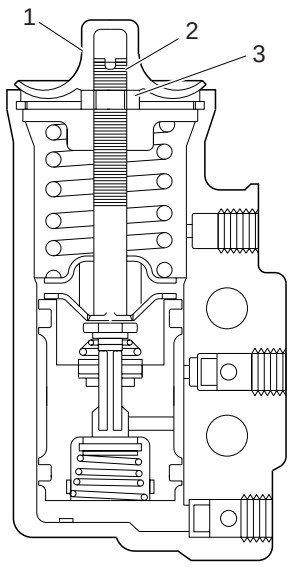
3. Drop the inlet and exhaust valve into place at the bottom of the piston.
4. Install the inlet and exhaust valve spring with the small end against the valve. Press the spring down until the larger coiled end snaps into the groove inside the piston.
5. Install the exhaust stem spring in the piston with the large coil end next to the piston.
6. Install the exhaust stem through the exhaust spring and into the piston.
7. Install the piston in the air governor body.
8. Install one lower spring seat, spring guide, the other lower spring seat, pressure-setting spring, and the hex-shaped upper spring seat on the adjusting screw, in that order. Screw the upper spring seat on the adjusting screw until the distance from the top of the seat to the bottom of the adjusting screw head is about 1-7/8 inches (48 mm).
9. Install the locknut.
10. Before placing the adjusting screw and stem assembly in the governor body, check that the exhaust stem and its spring are in place in the piston.
11. Install the adjusting screw and spring assembly, and the retaining ring.
12. Install the cover on the air governor.
13. Install filters in the air governor body.
14. Using the instructions in **Subject 110**, install the air governor.
15. Close the hood and remove the chocks from the tires.

Adjustment

NOTE: On a vehicle equipped with a Bendix D-2 air governor and a dryer reservoir module (DRM), the air governor is not adjustable.

If the pressure settings of the governor are inaccurate or if they need to be changed, use the following adjustment procedure.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the cover from the air governor and loosen the adjusting screw locknut. See **Fig. 1**.



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1. Cover
2. Adjusting Screw
3. Adjusting Screw Locknut

Fig. 1, Air Governor, Section View

4. To raise the pressure settings, turn the adjusting screw counterclockwise. To lower the pressure setting, turn the adjusting screw clockwise.

NOTE: The pressure range between cut in and cut out is not adjustable.

If these adjustments do not correct the pressure settings, repair or replace the governor.

5. Tighten the adjusting screw locknut and install the cover.
6. Return the hood to the operating position.
7. Remove the chocks from the tires.

General Information

The alternator is the electrical system's main source of power while the engine is running. It converts mechanical energy into direct current (DC) that is used to power the vehicle's electrical components and charge the batteries for starting.

The Delco Remy 22 SI QuadraMount® heavy-duty brush alternator is a pad-mounted alternator designed to provide more stability and withstand vibration better than traditional hinge-mounted alternators. It is secured directly to the engine block with four mounting capscrews.

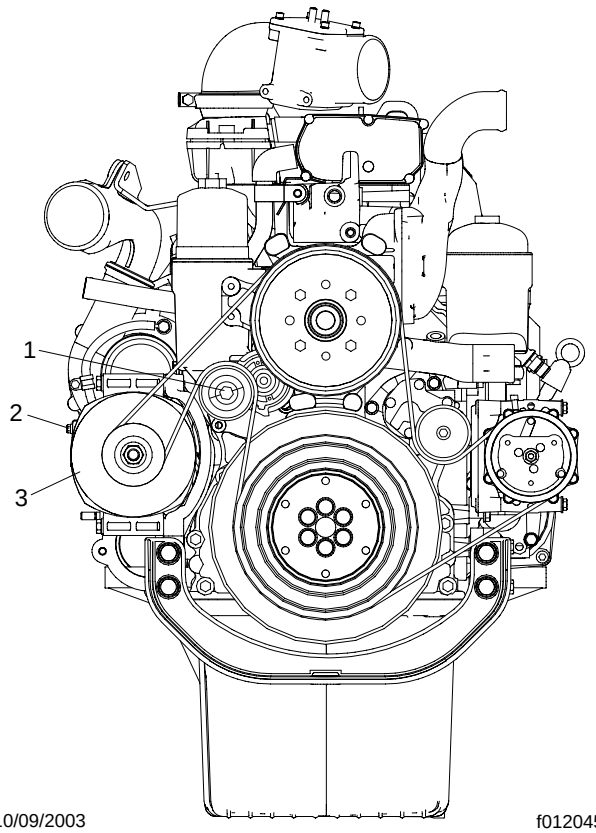
The 22 SI alternator allows charging immediately after starting. It is a high-output integral charging system with a built-in diode rectifier and voltage regulator. On 12-volt models, the diodes prevent electric spikes, clamped at 40 volts, from damaging the unit.

The 22 SI may be operated at continuous speeds of up to 10,000 alternator rpm, with intermittent speeds of up to 12,000 rpm. The ambient temperature range for proper operation is –30 to +200°F (–34 to +93°C).

Alternator Removal and Installation, MBE900 Engine

Removal

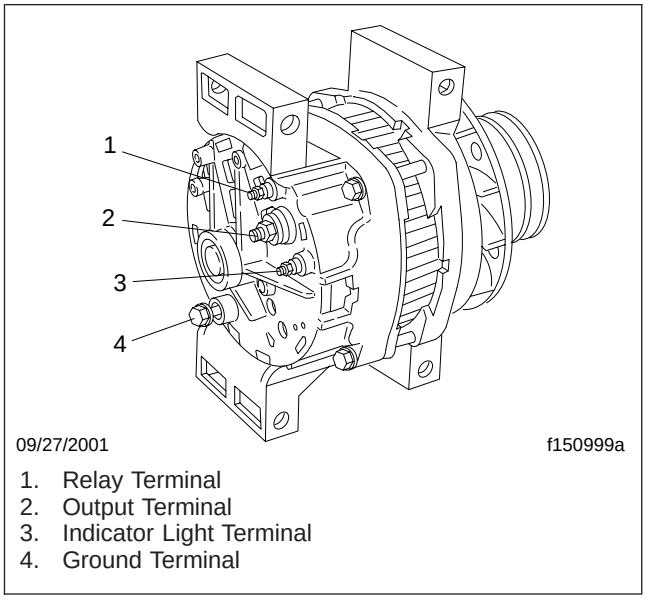
1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Open the hood.
3. Use the Delco Remy Intelli-Check™ Alternator Analyzer to check the alternator. See **Trouble-shooting 300** for instructions.
4. Rotate the battery switch to the OFF position or disconnect the negative lead from the batteries.
5. Using a 15 mm socket and handle on the bolt on the belt tensioner, rotate the tensioner to relieve tension from the belt, then slip the belt off of the alternator pulley. See **Fig. 1**.



1. Belt Tensioner
2. Capscrew and Washer
3. Alternator

Fig. 1, Delco Remy 22 SI Alternator Installation

6. Mark the electrical connections to allow for easier installation, then disconnect the leads from the alternator. See **Fig. 2**.



1. Relay Terminal
2. Output Terminal
3. Indicator Light Terminal
4. Ground Terminal

Fig. 2, Delco Remy 22 SI Electrical Connections

7. Remove the four mounting capscrews and washers and remove the alternator from the vehicle.

Installation

NOTE: Place the lower forward mounting capscrew and washer in its hole before positioning the alternator in the mount bracket.

1. Position the alternator on the mount bracket and secure it with the four mounting capscrews and washers. Torque the capscrews 35 lbf·ft (48 N·m). See **Fig. 1**.
2. Using a 15 mm socket and handle on the bolt on the belt tensioner, rotate it to apply tension to the tensioner and give slack to the belt, then slip the belt onto the alternator pulley. See **Fig. 1**.
3. Attach the electrical connections to the back of the alternator. See **Fig. 2**.
4. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Alternator Removal and Installation, MBE900 Engine

Approved Dielectric Red Enamel	
Protectant Material	**Approved Brand**
Dielectric Red Enamel Spray	MMM 1602 IVI–Spray Sealer, Red Electric Grade (Spray-On B–6–665)

Table 1, Approved Dielectric Red Enamel

5. Rotate the battery switch to the ON position or connect the batteries. Close the battery compartment door.
6. Start the vehicle and test the alternator.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Troubleshooting

Many alternators have been replaced that later investigation reveals were working properly. This may be due to incorrectly diagnosing the problem.

IMPORTANT: Before testing, make sure:

- All belts are correctly tightened;
- The wiring and terminals are clean and in good condition;
- All terminal nuts are torqued and properly protected.

Delco Remy has an alternator testing tool called the Intelli-Check Alternator Analyzer. See **Fig. 1**. This tool (DR 10457848, a single tester, or DR 10457865, a four-pack of testers) is to be used as a quick check of the alternator to see if it is working correctly.

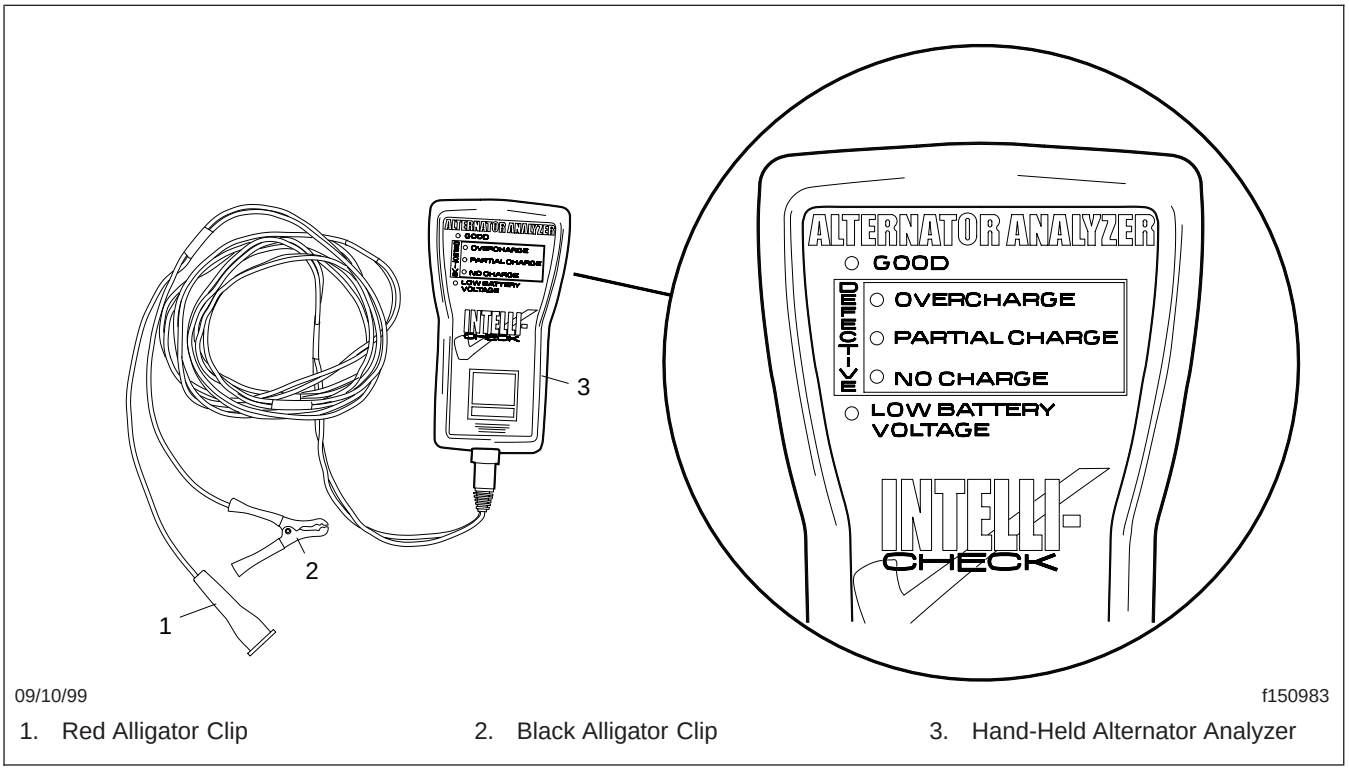
NOTE: If you do not have the Remy Intelli-Check Tester, or if the alternator rated output is above 145 amps, or if a total vehicle charging system analysis is required, see "Alternator/ Charging System Testing."

Intelli-Check Alternator Analyzer

The following information includes a pre-test procedure and operating instructions for the Remy Intelli-Check Tester, and is similar to the procedures provided by Remy with the Intelli-Check Tester.

Pre-Test Procedure (Engine Off)

1. Inspect the alternator connections to verify that all terminals are secured and tight. Verify that the sense wire is connected to the sense terminal on vehicles equipped with remote-sense alternators.
2. 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



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

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

the alternator. The tester LEDs will illuminate and then go off as it performs a self-test.

3. After 4 seconds the tester will activate. The following LEDs may illuminate depending on the condition of the batteries:
   - **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, do the following:
     A. Turn on the headlights and blower motor for 2 minutes without restarting the engine.
     B. Reset the tester by disconnecting, then reconnecting the tester alligator clips. The analyzer will again perform its self-test.
     C. Repeat the applicable steps of the Pre-Test Procedure.
   - **NO CHARGE** (red) LED indicates the battery voltage is below 12.8. This LED should illuminate for most tests. Proceed with the alternator test.
   - **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. However, after completing the Intelli-Check alternator test, perform the procedures under "Alternator/Charging System Testing" to determine the condition of the rest of the charging system.

Tester Operating Instructions (Engine Running)

1. Start the engine using onboard batteries only. If the batteries will not start the engine, they must be charged to a minimum of 12.4 volts or 75% state of charge. Start the test again after charging the batteries.
2. Verify that the engine is at idle and all electrical loads are off.
3. 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 and run the complete test again.
   - If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/Charging System Testing."
4. With the engine running, turn on all electrical loads.
5. Depress the accelerator to governed speed, hold for 10 seconds, then return to idle.
6. If the **GOOD** (green) LED illuminates, the alternator is OK and the test is complete.

NOTE: If the alternator tests OK in the above tests, and the customer's complaint is reduced battery or headlight life, see "Alternator/Charging System Testing" to completely analyze the charging system.

7. If any LEDs illuminate indicating overcharge, partial charge or no charge (the three red lights in the **DEFECTIVE** section), replace the alternator and run the complete test again.
8. If the **LOW BATTERY VOLTAGE** (blue) LED illuminates, evaluate the charging system using the instructions in "Alternator/Charging System Testing".

Alternator/Charging System Testing

Battery Open Circuit Voltage Test, Alternator Output Voltage Test, and Alternator Amperage Output Test

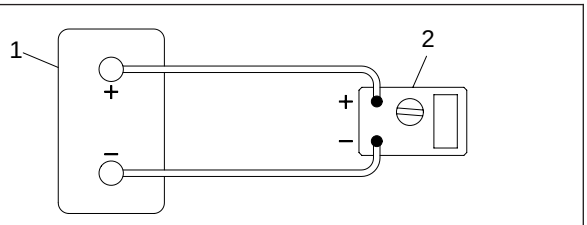
1. Use a digital volt-ohmmeter (VOM) set on the 2–20 VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in **Fig. 2**, check for voltage of 12.4 volts or more.

   If the OCV is 12.4 volts or more, turn on the vehicle headlights for approximately 3 minutes.

If the OCV is less than 12.4 volts, charge the batteries properly. For instructions, see **Group 54**.

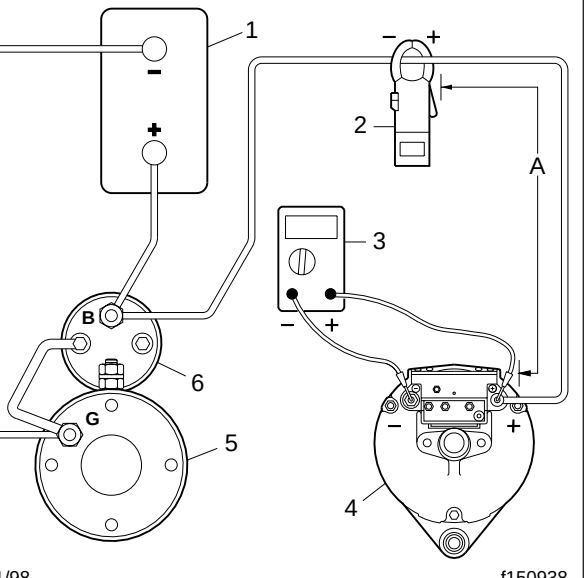
IMPORTANT: Be sure to disconnect the batteries or remove them from the vehicle before charging.

2. Check the alternator output without a load, as follows. See **Fig. 3**.



1. Battery
2. Digital Voltmeter

Fig. 2, Setup 1: Battery Open Circuit Voltage (and alternator amperage output)



A. Locate the ammeter at least 6 inches (15 cm) away from the alternator.

1. Battery
2. Ammeter
3. Digital Voltmeter
4. Alternator
5. Cranking Motor
6. Solenoid

Fig. 3, Setup 2: Alternator Output Test

2.1 Start the engine and run it at 1500 rpm for 3 to 5 minutes to stabilize the system before proceeding to the next step.

2.2 Connect the positive (+) lead of the digital voltmeter (still set on the 2–20 VDC or similar scale) to the alternator (battery) terminal. Connect the negative (–) lead of the voltmeter to the alternator negative (–) ground terminal. See **Fig. 3**.

2.3 If the voltmeter reads from 13.8 to 14.2 volts, record this reading (V1) and go to the next step. If unable to obtain acceptable output, replace the alternator.

3. Check the alternator output under load, as follows. See **Fig. 3**.

3.1 Attach a clamp-on induction ammeter around the positive (+) wire. See **Fig. 3**.

NOTE: Locate the ammeter at least 6 inches (15 cm) away from the alternator.

3.2 With the engine still running at 1500 rpm, turn on the following electrical accessories to load the alternator until the ammeter reads 60 to 75 amps.

- Both front and rear heater blowers (on HIGH)
- Headlights (high beams)
- Road lights
- Interior lights

NOTE: As an alternate method of putting load on the alternator, connect a carbon pile tester and set it to 60 to 75 amps.

3.3 Keep the voltmeter connected as in the previous step; positive (+) lead connected to the alternator positive (+) terminal; negative (–) lead connected to the alternator negative (–) terminal.

3.4 If the voltmeter reads from 13.6 to 14.2 volts, record this reading (V2) and go to the next step.

If the voltmeter reads less than 13.6 volts, replace the alternator.

4. Perform an alternator amperage output test, as follows.

Troubleshooting

4.1 Connect a carbon pile tester across the vehicle batteries as shown in **Fig. 2**.

NOTE: **Figure 2** shows a voltmeter, but the connections for the carbon pile tester are the same.

4.2 Attach a clamp-on induction ammeter around the alternator output wire. See **Fig. 3**.

NOTE: Locate the ammeter at least 6 inches (15 cm) away from the alternator.

4.3 Start the engine and make sure all vehicle electrical accessories are turned off. Run it at fast speed and adjust the tester to the alternator maximum current output. Record this output value.

NOTE: Ensure that the alternator is turning at maximum available rpm and keep adjusting the tester dial until the ammeter reads its highest value.

4.4 Turn off the tester and shut down the engine.

4.5 If the output value recorded is less than 85 percent of the rated amperage output, repeat the test. If the output value recorded is still less than 85 percent of the rated amperage output, replace the alternator.

4.6 Make sure that all test instruments are removed and that the vehicle wiring is returned to its operational state.

5. To identify other problem areas within the vehicle, check the operation of the charging system, as follows. Set up the voltmeter as shown in **Fig. 2** and **Fig. 3**.

NOTE: For any load at 1500 rpm or more, battery voltage must be within 0.5 volts of the alternator voltage.

5.1 If readings at the batteries are within 0.5 volt of the readings at the alternator, the charging system is working correctly. Check other areas of the vehicle to locate the problem.

5.2 If the reading at the batteries is more than 0.5 volt lower than the reading at the alternator, do the next step.

6. Check charging system connections, cables, and terminals.

6.1 Check all connections between the battery, starter, and alternator for tightness and signs of corrosion. Tighten and clean as necessary.

6.2 Check all cables for breaks or partial breaks. Repair or replace as necessary.

6.3 Check each ring terminal for breakage at the point where it attaches to its wire or cable.

Specifications

Mounting Fasteners			
Description	**Class**	**Size**	**Torque: lbf·ft (N·m)**
Alternator Mounting Capscrew, Hexhead	10.9	M10 x 100	35 (48)

Table 1, Mounting Fasteners

Alternator Terminal Fastener Torques, All Engines		
Description	**Size**	**Torque: lbf·in (N·cm)**
Output ("BAT") Terminal Nut	5/16–18	100 (1140)
Ground ("GND") Capscrew	1/4–20	55 (620)
Relay ("R") Terminal Nut	10–24	20 (220)
Indicator Light ("I") Terminal Nut	10–24	20 (220)

Table 2, Alternator Terminal Fastener Torques

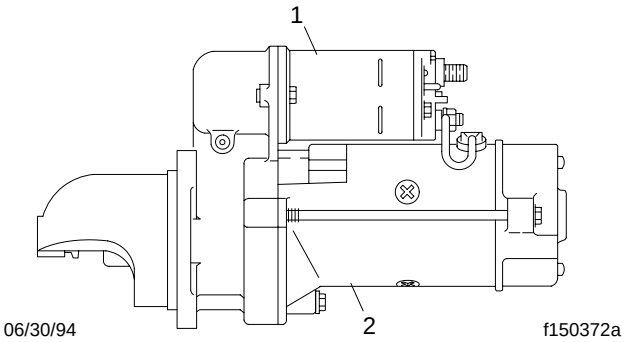
Pulley Nut Torque, All Engines		
Description	**Size**	**Torque: lbf·ft (N·m)**
Pulley Nut	1/2–20	75 (102)

Table 3, Pulley Nut Torque

General Information

The Delco Remy starter mounts at the forward face of the flywheel bell housing on the right side of the engine.

The starter assembly consists of two major parts: the solenoid and the starter motor. See **Fig. 1**. The shift lever and wiring connect the two parts, and the lever, motor, and solenoid are completely enclosed for protection from dirt, ice, and splash. See **Fig. 2**. The starter features sealed bearings with lifetime lubrication.



1. Starter Solenoid
2. Starter Motor

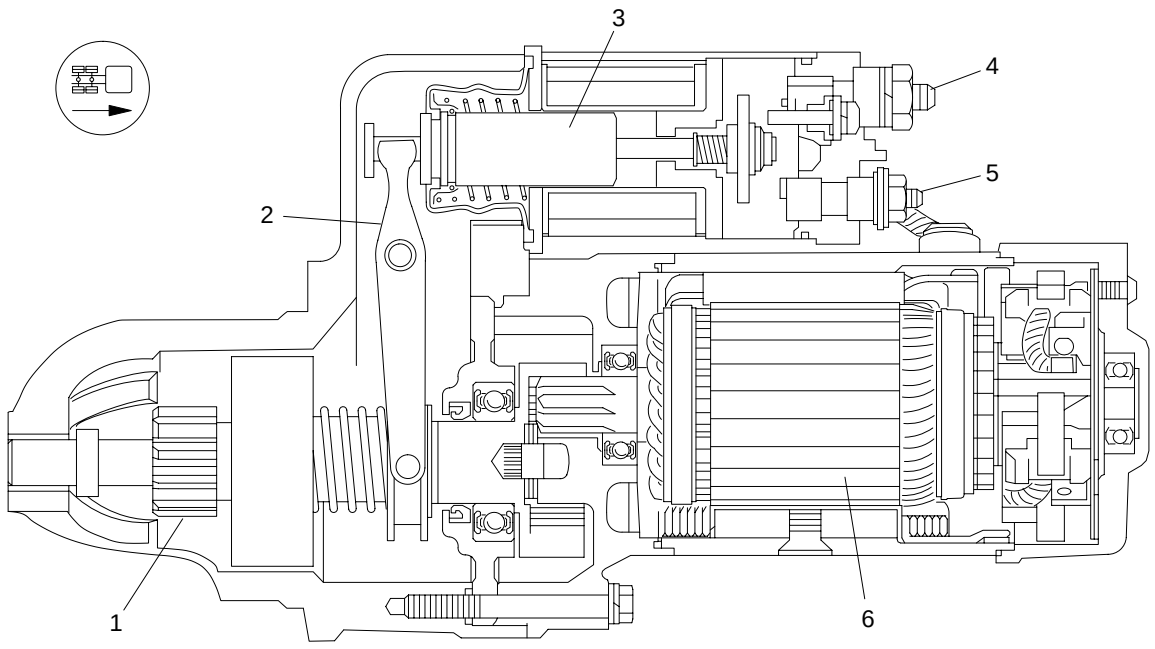
Fig. 1, Delco Remy Starter

The solenoid is wired to the starter relay, the alternator, and the batteries. Turning the key switch to start supplies power to the starter relay, and the relay activates the solenoid. Once activated, the solenoid plunger slides forward, moving the shift lever to engage the starter drive gear with the engine flywheel ring gear, and connecting the solenoid's battery terminal to the motor terminal.

The motor terminal is wired to the starter motor so power from the batteries activates the starter motor after the starter drive gear engages the engine flywheel.

Once the engine starts, and the ignition stops supplying power to the starter relay, the solenoid plunger retracts, disengaging the starter motor from the engine flywheel, and cutting battery power to the starter motor.

General Information



1. Starter Drive Gear
2. Shift Lever
3. Solenoid Plunger
4. Battery Terminal
5. Motor Terminal
6. Starter Motor

Fig. 2, Starter Components

Starter Removal and Installation, MBE900 Engine

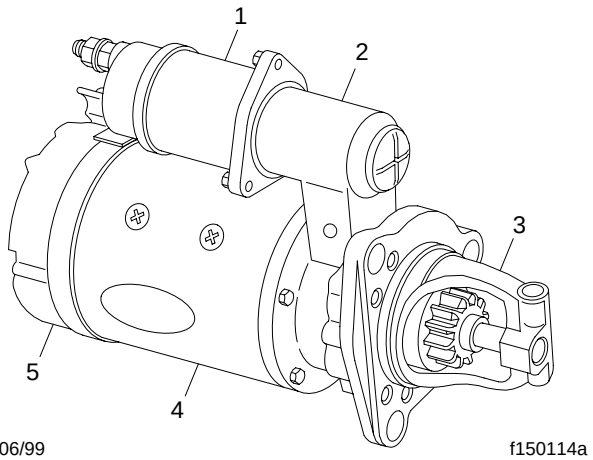
Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Rotate the battery switch to the OFF position or disconnect the negative lead from the batteries.
3. Remove or loosen any clamps or standoff brackets that block access to the starter. Move the wires away from the starter in order to gain access to it.

⚠ WARNING

The starter weighs 20 lb (9 kg). Be prepared to support it as its mounting hardware is removed. If it is not supported, the starter could fall, resulting in personal injury or property damage.

4. Remove the bolts that hold the starter to the engine.
5. Lower the starter and support it. See **Fig. 1**.
6. Remove the wires from the solenoid terminals. Mark the wires for easy installation. Remove the starter.



1. Solenoid
2. Lever Housing
3. Nose Housing
4. Field Frame
5. End Cap

Fig. 1, Starter Cranking Motor and Solenoid

Installation

1. Support the starter and connect the wires to the solenoid terminals.

NOTE: Use antiseize compound on starter mounting studs.

2. Line the starter on the threaded holes of the engine and install the bolts. Tighten the bolts to 38 lbf·ft (52 N·m).
3. Install and tighten any clamps or standoff brackets that were removed or loosened during starter removal.
4. Rotate the battery switch to the ON position, or connect the negative battery leads, then close the battery box door.
5. Start the engine to check the starter for proper operation.
6. Return the hood to the operating position.
7. Remove the chocks from the tires.

Troubleshooting Tables

Problem—Starter Cranks Slowly or Not at All

Problem—Starter Cranks Slowly or Not at All	
Possible Cause	**Remedy**
Loose drive belt.	Check the drive belt. See 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. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Damaged or missing drive belt.	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. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Undercharged batteries.	Do a load test on the batteries. See **Group 54** for instructions. Charge or replace batteries as needed. If the batteries were discharged, check the alternator voltage and output. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
Battery cables do not deliver sufficient voltage to starter.	Check the available cranking voltage. Go to "Available Cranking Voltage Test" for instructions.
Broken starter solenoid circuit.	Check the starter solenoid circuit. Go to "Starter Solenoid Circuit Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
Broken control circuit.	Check the starter wiring. Go to "Starter Wiring Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
Broken magnetic switch.	Replace the magnetic switch.
Damaged starter ring gear or pinion gear.	Visually check the ring and pinion gears. Go to "Ring and Pinion Gear Test" for instructions.
Starter does not stay engaged.	Go to "Cold Weather Starting Test" for instructions.
Damaged starter.	Replace the starter.
Mechanical problem in engine.	See **Group 01** or the engine manufacturer's manuals.

Troubleshooting Procedures

Starter Test

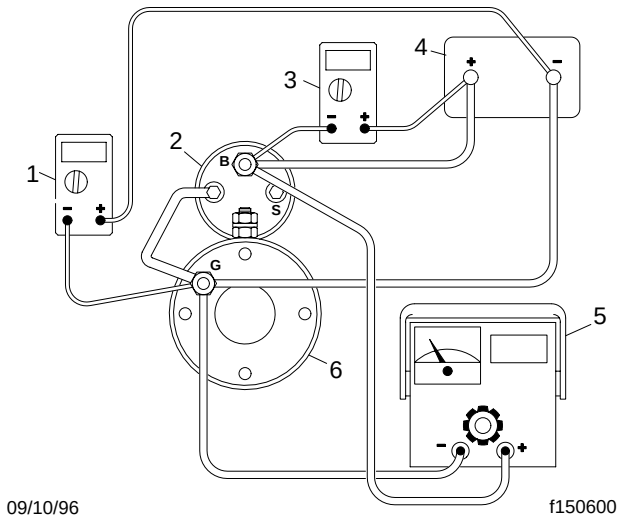
1. Connect a voltmeter from the solenoid "S" terminal to ground. Engage the start switch.

   If the voltmeter reads 6.0 volts or less, check and repair the magnetic switch circuit. If symptoms continue, proceed with the test.
2. If the voltmeter reads more than 6.0 volts or the symptoms continue after repairing the magnetic switch circuit, remove the starter and visually check the pinion.
3. If the pinion is milled, repair or replace the starter, but do not install the starter.
4. Visually check the ring gear. If the teeth are milled, replace the ring gear and check the flange to flywheel dimension.
5. Reinstall the starter and perform the "Available Cranking Voltage Test."

Available Cranking Voltage Test

Battery Cable Test

1. Connect the positive lead of a carbon pile tester to the starter solenoid "B" (battery) terminal. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal. See **Fig. 1**.



1. Voltmeter (recording V2, negative side voltage loss)
2. Starter Solenoid
3. Voltmeter (recording V1, positive side voltage loss)
4. Battery
5. Carbon Pile
6. Cranking Motor

Fig. 1, Battery Cable Test

IMPORTANT: Connect the voltmeter to the starter "B" terminal, not to the carbon pile clamp.

2. Set a digital voltmeter on the low scale (2V, 3V, or 4V, depending on type of meter) and connect the positive lead to the battery positive (+) terminal. Connect the negative lead to the starter "B" terminal.
3. Turn on the carbon pile and adjust it to a 500-amp load. Read and record the voltage (V1) on the voltmeter. Turn off the carbon pile.
4. Now connect the digital voltmeter (still set on the low scale) to the battery negative (–) terminal and the starter "G" (ground) terminal.

IMPORTANT: Connect the voltmeter to the starter "G" terminal, not to the carbon pile clamp.

5. Turn on the carbon pile again and adjust it to a 500-amp load, as before. Read and record the voltage (V2) on the voltmeter. Turn off the carbon pile.

NOTE: Ignore the minus (–) sign.

6. Add the positive (V1) and the negative (V2) voltage loss readings together. If the total voltage loss is 0.500 volts or less, the battery cables are OK.

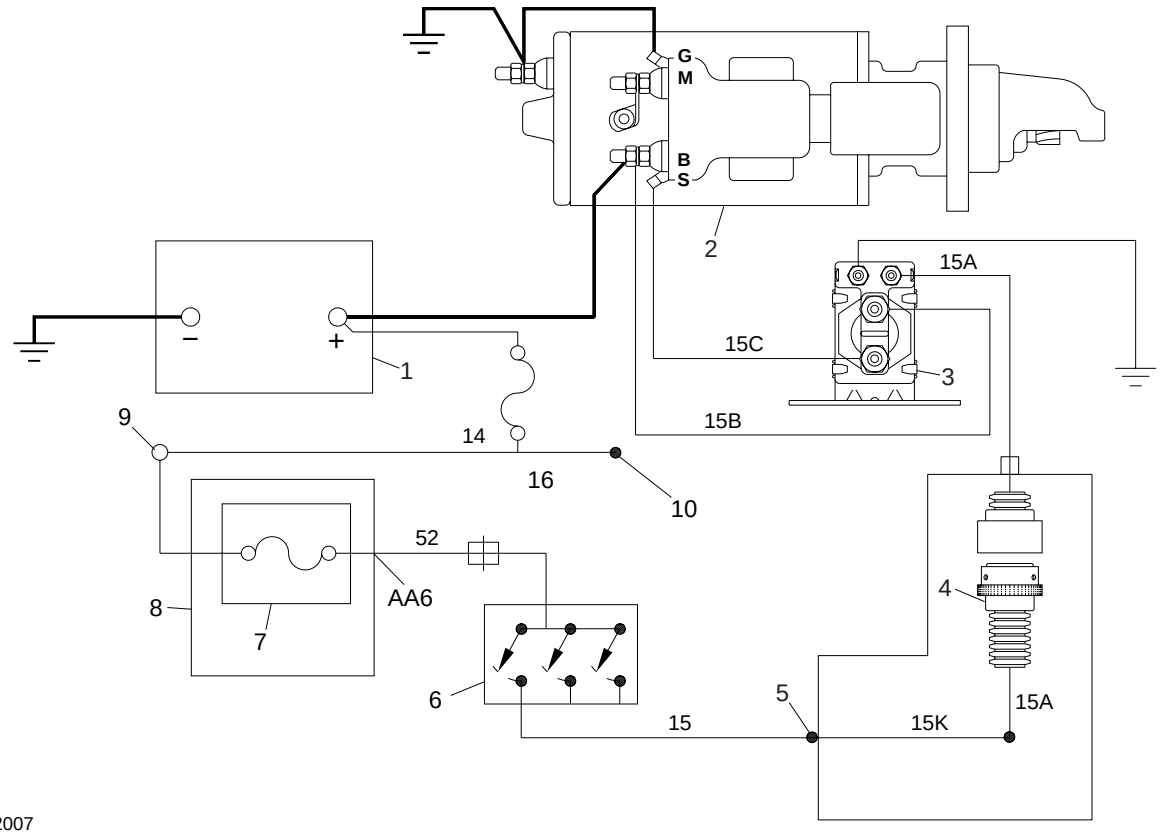
   Add the positive (V1) and the negative (V2) voltage loss readings together. If the total voltage loss is more than 0.500 volts, repair or replace as necessary.
7. Disconnect the carbon pile and the voltmeter. Reconnect the magnetic switch to the starter "S" terminal.

Interconnecting Cable Test

1. This test requires two persons. While the first person cranks the engine, the second person uses a voltmeter to measure the voltage across the starter solenoid "B" (battery) and starter "G" (ground) terminals.
2. If the voltage is 9.0 volts or less while cranking, check the battery interconnecting cables, as follows.
   - 2.1 While cranking, measure the voltage across each battery.
   - 2.2 If the difference between any two batteries in the same battery box is more than 0.5 volt, check and replace the interconnecting cables as required.
   - 2.3 If any cable or connection feels warm to the touch, check and replace the interconnecting cables as required.
3. If the starter still does not crank, go to "Ring and Pinion Gear Test."

Starter Solenoid Circuit Test

The starter solenoid circuit includes the starter solenoid, cranking motor, magnetic switch, and ignition switch. It is part of the cranking circuit. See **Fig. 2**.



NOTE: Wire 16 connects to the alternator.

1. Battery
2. Cranking Motor (top view)
3. Magnetic Switch
4. Frontwall Connector (Pin E1)
5. Bulkhead Module Input
6. Ignition Switch
7. 10-Amp Fuse
8. Power Distribution Module
9. Engine Power Stud
10. Blade Fuses on Battery Box

Fig. 2, Cranking Circuit Wiring

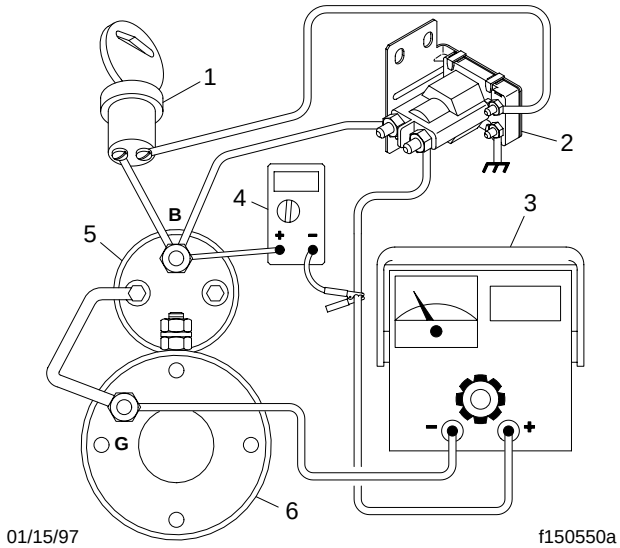
If there is excessive voltage loss in the starter solenoid circuit, the starter may not engage the flywheel at all, or it may drop out too soon when battery voltage goes down. Do the following test to check for excessive voltage loss in the starter solenoid circuit.

1. Disconnect, at the solenoid, the lead from the magnetic switch to the "S" terminal on the starter solenoid.
2. Use a small clamp or 8-gauge jumper wire to connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal. See **Fig. 3**.
3. Set a digital voltmeter on the high (20V) scale and connect the positive lead to the starter "B" (battery) terminal. Connect the negative lead to the magnetic switch lead to which the carbon pile is already connected.
4. Read and record (as V3) the battery voltage shown on the meter, about 12.6V.

NOTE: This step requires two persons.

5. Have one person turn the ignition keyswitch to the START position while the other person listens for the clicking sound of the magnetic switch closing. Read the voltage on the voltmeter. It should read very low voltage, less than 0.1V.

Troubleshooting



1. Ignition Keyswitch
2. Magnetic Switch
3. Carbon Pile
4. Digital Voltmeter
5. Starter Solenoid
6. Cranking Motor

Fig. 3, Starter Solenoid Circuit Test

IMPORTANT: If the magnetic switch does not close, do the "Magnetic Switch Circuit Test."

6. Check the starter solenoid circuit voltage loss, as follows.

   6.1 Turn the ignition key to the START position; then turn on the carbon pile and adjust it to a 100-amp load.

   6.2 Now read and record (as V4) the voltage on the voltmeter. Turn off the carbon pile.

   6.3 If the voltage drop (V4–V3) is 1.0V or less, the starter solenoid circuit is OK. Test the magnetic switch circuit.

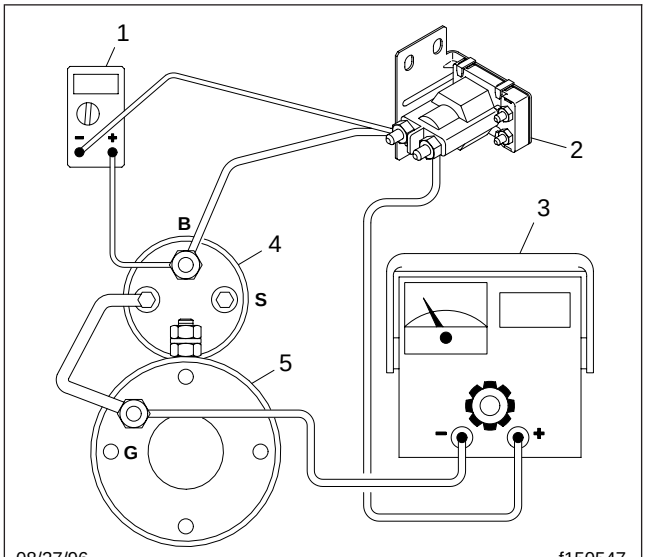
   If the voltage drop (V4–V3) is more than 1.0V, the voltage loss is excessive. Go to "Starter Wiring Test."

Starter Wiring Test

1. Disconnect the lead from the magnetic switch to the "S" terminal on the starter solenoid (leave as in "Starter Solenoid Circuit Test").

IMPORTANT: It is difficult to gain access to the starter "S" terminal. Avoid touching the starter "B" terminal at the same time as the "S" terminal, as this can cause an electric shock.

2. Connect this lead to the positive lead of a carbon pile tester. Connect the negative lead of the carbon pile to the starter "G" (ground) terminal (leave as in "Starter Solenoid Circuit Test").
3. Set a digital voltmeter on the low scale and connect the positive lead of the voltmeter to the starter solenoid "B" (battery) terminal. Connect the negative lead of the voltmeter to the large terminal of the magnetic switch that is connected to the starter "B" terminal (circuit 15B). See **Fig. 4**. If any voltage shows, reconnect to the other large terminal.



1. Digital Voltmeter
2. Magnetic Switch
3. Carbon Pile
4. Starter Solenoid
5. Cranking Motor

Fig. 4, Starter Wiring Test, First Wire Voltage Loss (V5)

NOTE: If desired, do a continuity check on the circuit to be sure that it is connected to the correct terminal. Low resistance indicates that the connections are correct.

4. Have a second person start the engine momentarily.

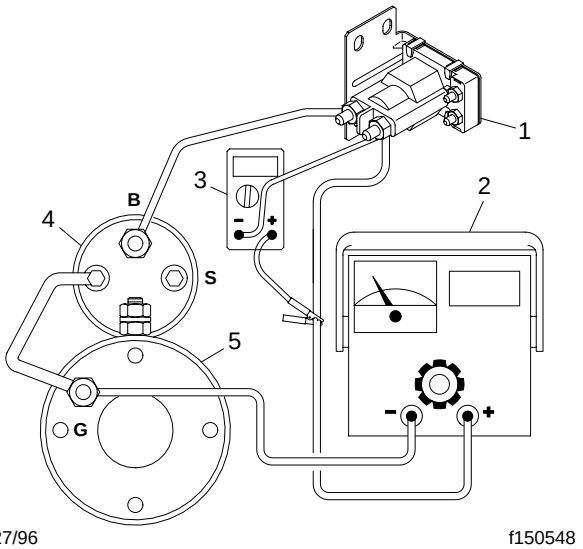
IMPORTANT: If the magnetic switch does not close, do the "Magnetic Switch Circuit Test."

5. Check the first wire voltage loss (V5), as follows.

5.1 Turn the ignition key to the START position, then turn on the carbon pile and adjust it to a 100-amp load.

5.2 Now read and record the voltage (V5) on the voltmeter. Turn off the carbon pile.

6. Now connect the positive lead of the digital voltmeter (still set on the low scale) to the magnetic switch lead which is already connected to the carbon pile (as in "Starter Solenoid Circuit Test"). Connect the negative lead of the voltmeter to the other large terminal on the magnetic switch (circuit 15C). See **Fig. 5**.



1. Magnetic Switch
2. Carbon Pile
3. Digital Voltmeter
4. Starter Solenoid
5. Cranking Motor

Fig. 5, Starter Wiring Test, Second Wire Voltage Loss (V6)

7. Have a second person start the engine momentarily.

8. Check the second wire voltage loss (V6), as follows.

NOTE: Ignore the minus (–) sign.

8.1 Turn the ignition key to the START position, then turn on the carbon pile and again adjust it to a 100-amp load.

8.2 Now read and record the voltage (V6) on the voltmeter. Turn off the carbon pile.

8.3 Add the two voltages (V5 and V6) together to get the total wire voltage loss. If the total wire voltage loss adds up to 0.8 volts or less, the wiring is OK. Replace the magnetic switch.

If the total wire voltage loss adds up to more than 0.8 volts, check the wire connections for tightness and the terminals for corrosion. Repair or replace as necessary.

9. Disconnect the carbon pile and the voltmeter. Reconnect the magnetic switch to the starter "S" terminal.

10. Check all wiring and connections and repair or replace as needed.

Magnetic Switch Circuit Test

Before replacing the magnetic switch, or repairing or replacing any of the starting and charging circuits, do this test.

1. Apply the parking brakes and chock the tires.

2. Check the wiring and the magnetic switch for wear or damage. See **Fig. 2**.

3. Check the circuit between the magnetic switch and the starter "B" terminal (circuit 15B) for correct voltage, as follows.

3.1 Disconnect the circuit running from the starter "S" terminal to the magnetic switch (circuit 15C).

3.2 Connect a voltmeter to the magnetic switch terminal where the circuit from the starter "B" terminal is connected (circuit 15B).

3.3 If the voltmeter reading is 0 volt, check for an open circuit.

If the voltmeter reading is less than 12.0 volts, check for corroded or loose connections.

If the voltmeter reading is 12.0 volts or more, go to the next step.

3.4 Repair or replace any damaged wires.

4. Check the magnetic switch ground circuit, as follows.

Troubleshooting

4.1 Connect an ohmmeter between the magnetic switch ground terminal and a known good ground.

4.2 If the ohmmeter reading is more than 0.5 ohm, check for corroded or loose connections.

4.3 Repair or replace any damaged wires.

5. Check the magnetic switch ignition wiring (circuit 15) for correct voltage, as follows.

   NOTE: This check requires two persons.

   5.1 Have one person turn on the ignition keyswitch and hold it in the "start" position.

   5.2 Have the other person connect a voltmeter between the magnetic switch terminal where the ignition circuit is connected (circuit 15A) and a known good ground.

   5.3 If the voltmeter reading is 0 volt, check for an open in circuit 15A.

   If the voltmeter reading is less than 11.0 volts, check for corroded or loose connections.

   If the voltmeter reading is 11.0 volts or more, go to the next step.

   5.4 Repair or replace any damaged wires, circuit breakers, or relays.

6. Check the circuit between the magnetic switch and the starter "S" terminal (circuit 15C) for correct voltage, as follows.

   NOTE: This check requires two persons.

   6.1 Have one person hold the ignition keyswitch in the "start" position.

   6.2 Have the other person connect a voltmeter between the magnetic switch terminal where the circuit from the starter "S" terminal is connected (circuit 15C) and a known good ground.

   6.3 If the voltmeter reading is less than 12.0 volts, replace the magnetic switch.

7. Check the voltage to the magnetic switch again. If the voltmeter reading is now 11.0 volts or more, disconnect the voltmeter, and remove the chocks from the tires. If the reading is still less than 11.0 volts, replace the magnetic switch.

Ring and Pinion Gear Test

1. This test requires two persons. While the first person bars the engine over, the second person visually checks the entire flywheel ring gear and starter pinion gear visually (check all the teeth in both gears).
2. If the pinion teeth are damaged, replace the starter. If the ring gear teeth are damaged, replace the ring gear.

NOTE: For ring gear replacement procedures, see the engine manufacturer's manuals.

3. If the engine still does not crank properly after replacing the starter, look for a mechanical problem in the engine. For instructions, see **Group 01** or the engine manufacturer's manuals.

Cold Weather Voltage Test

In cold weather, the starter may fail to engage, even though it performed well at higher temperatures. Do the following test to check for cold weather voltage loss in the cranking circuit.

1. With the ignition keyswitch on, clamp a heavy battery jumper cable between the two large studs on the magnetic switch. Remove the jumper immediately to stop the engine from cranking.
2. If the engine starts with the jumper in place, do the "Starter Wiring Test." Repair/replace the wiring connections, terminals, and/or magnetic switch as necessary.
3. If the engine now starts properly, check the starter mounting bolts for tightness and do the "Alternator Wiring Test." See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
4. If the engine still does not start properly, go to "Available Cranking Voltage Test."

General Information

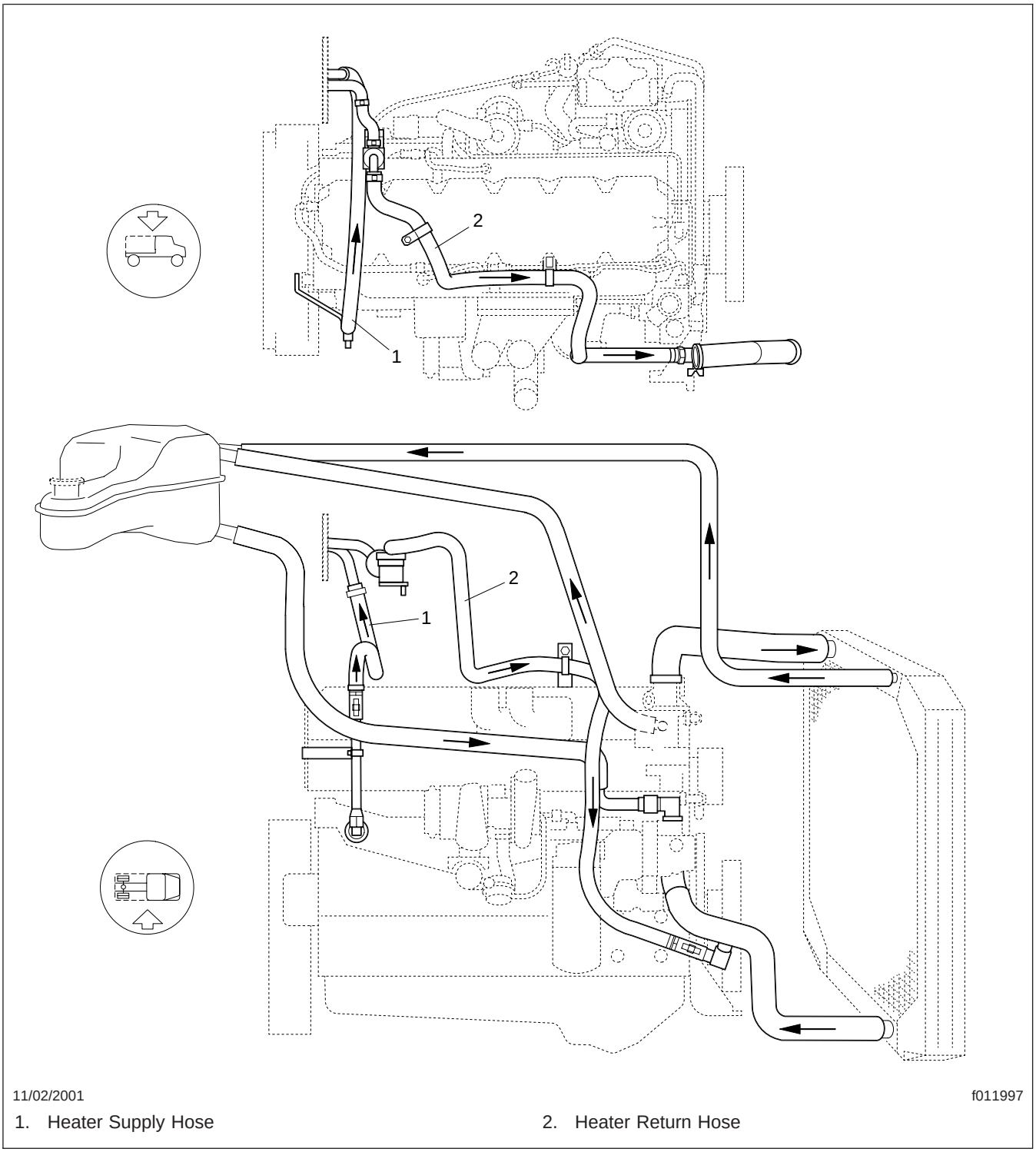
The main function of a cooling system is to keep the engine at its optimum operating temperature. This results in the most efficient use of fuel and allows the engine oil to provide a good lubricating film. For the typical coolant plumbing, see **Fig. 1**.

The cooling system is a high-flow design, where most of the coolant in a warm engine moves relatively quickly across the radiator in a single pass.

Coolant flows from the radiator to the water pump, which forces the coolant into the engine block. Inside the block, the coolant flows around and between the cylinders, and then up into the cylinder head. From the head, it flows to the temperature regulator (thermostat) housing. If the engine is cool, the thermostat directs the coolant back to the water pump, and the water pump forces the coolant back into the engine. As the engine warms, the thermostat directs the coolant to the radiator. The thermostat keeps the engine temperature in the optimum range by controlling the two flows.

To prevent air and vapor from being trapped in the radiator or engine, vent lines rise from the high points where air and vapor would collect in those components. The vent lines carry any collected air to the surge tank.

General Information



1. Heater Supply Hose
2. Heater Return Hose

Fig. 1, Coolant Plumbing (typical)

Troubleshooting Tables

Possible causes of abnormally high or low coolant temperatures are listed below. For repairs, see other sections of this manual or the engine and component manufacturer's 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, petcock and cap, block core and drain plugs, water pump, thermostat housing, surge tank, heater hoses and cores, temperature sending unit(s), cylinder head(s) mating (gasket) surfaces, coolant filter, oil cooler. Internal Leakage: cylinder head gasket, warped head or block, surfaces cracked, cylinder head or block, cylinder head capscrews loose, missing, or tightened unevenly, oil cooler aftercooler.	Do the repairs necessary to stop the leaks. Fill to the surge tank sight glass with the correct mixture of antifreeze and water. See **Group 20** of the *S2 Chassis Maintenance Manual* for coolant specifications.
Inoperative temperature gauge.	Check the gauge wiring, 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 the temperature gauge operation.
Clogged radiator, aftercooler, or condenser fins.	Clean the outside of the core and the condenser with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
Collapsed or plugged radiator hose.	Replace the hose(s).
Loose fan belt or water pump belt.	Adjust belt tension.
Damaged cooling fan shroud.	Repair or replace the shroud.
Incorrect or malfunctioning radiator cap.	Make sure the correct radiator cap is installed. If the cap does not hold the correct pressure, replace it.
Viscous fan drive not operating to specifications.	Check for unobstructed airflow through the radiator core, aftercooler, and condenser to the fan clutch sensor. Check that the radiator core is getting hot in front of the fan clutch (core is not internally clogged in that area) so that the sensor is getting a correct reading. If no radiator problems exist, refer to the viscous fan clutch section in this group for fan clutch inspection procedures and operation tests.
Incorrect engine oil level.	Fill to the high (H) mark on the dipstick.
Incorrect mixture of antifreeze in the system.	Clean and flush the cooling system. Refill the system with the correct mixture of antifreeze and water.
Incorrect or inoperative thermostat.	Make sure the correct thermostat is installed in the temperature regulator housing. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.
Malfunctioning water pump.	Repair or replace the water pump.

Troubleshooting

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
Internally plugged or damaged radiator core.	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 temperatures is normal. If blockage is suspected, clean and flush the cooling system. Repair or replace a damaged core.
Air or combustion gases entering cooling system.	Check the cylinder heads, head gaskets, cylinder liners, and aftercooler for leaks. Repair or replace parts, as necessary.
Internally plugged or damaged aftercooler.	Repair or replace the aftercooler.
Internally plugged or damaged oil cooler	Repair or replace the oil cooler.
Engine receiving too much fuel.	Refer to the engine manufacturer's fuel delivery system adjustment procedures.
Wrong replacement fan installed.	Install the correct fan.
Exhaust blockage.	Remove the blockage.
Frozen coolant in radiator due to subfreezing temperatures.	Use the proper antifreeze-to-water ratio needed for winter temperatures.

Problem—Coolant Temperature Below Normal

Problem—Coolant Temperature Below Normal	
Possible Cause	**Remedy**
Inoperative temperature gauge	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 the temperature gauge operation.
Viscous fan drive operates continuously	See **Section 20.03** for fan clutch inspection procedures and operation tests. Replace the fan drive if necessary.
Incorrect or inoperative thermostat	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.
Low coolant	Fill to the mark on the surge tank with the correct mixture of antifreeze and water. See **Group 20** of the *S2 Chassis Maintenance Manual* for coolant specifications.

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.

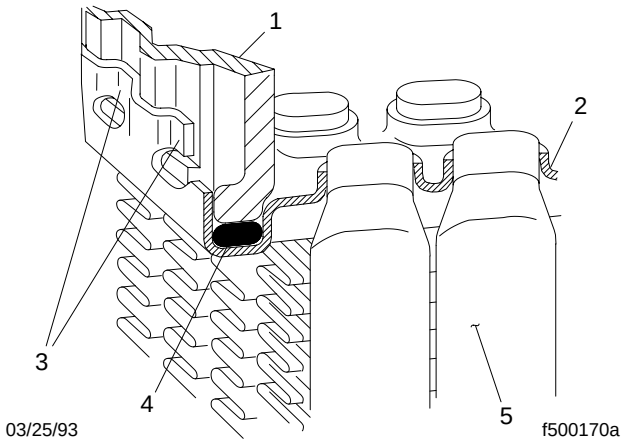
The low coolant level sensor in the surge tank warns the driver when coolant is running low. The surge tank is translucent polypropylene so you can see the coolant level and compare it to the maximum and minimum levels marked on the tank.

The S2 chassis uses a full-flow (or high-flow) radiator. 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.

There are two sizes of two-row radiators in use:

- 805-square-inch area
- 870-square-inch area

The radiators use glass-filled-nylon side tanks. The edges of the radiator core header are compressed in a "dimple wave lock" crimp that holds the tanks on the radiator core, and the tanks and core are held in steel channels that mount on the front closing crossmember. See **Fig. 1**. The radiator is also secured by struts that run between the top of the radiator and the firewall. The fins of the radiator core are reinforced along their forward edge to resist damage from road debris and pressure washing.



1. Nylon Tank
2. Radiator Header
3. Dimple Wave Lock Crimp
4. Sealing Gasket
5. Radiator Core

Fig. 1, Radiator Core and Header (cutaway view)

Because crimping holds the nylon side tanks in place, the radiators can be disassembled and assembled.

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.

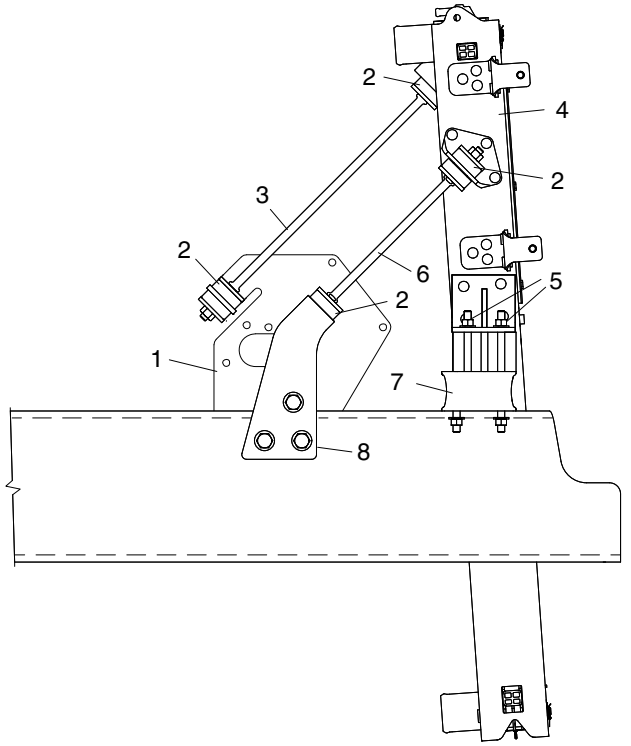
Standard transmissions: The presence of water and/or ethylene glycol coolant mixtures in the lubricant in standard transmissions decreases the effectiveness of the lubricant and causes rust and wear to internal parts. If contamination is detected, refer to the transmission manufacturer's service literature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

Removal

The 805-square-inch radiator mounts with brackets attached to the sides of the radiator that attach to isolators mounted on the frame rails. Two strut rods attach to the sides of the radiator and to brackets on the frame rail. See **Fig. 1** for the installation drawing.

The 870-square-inch radiator is held in place by a support bracket that is attached to the front of the radiator and the closing crossmember. An isolator assembly is installed between the L-shaped radiator support bracket and the front closing crossmember. Four strut rods, attached to the sides of the radiator and the frontwall, stabilize the radiator. See **Fig. 2** for the installation drawing.

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 hood damper from the bracket on the bumper by pulling the end of the cylinder out of the nylon clip.



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1. Left Strut Rod Bracket
2. Strut Rod Bushing
3. Left Strut Rod
4. Radiator
5. Hexnuts
6. Right Strut Rod
7. Isolator
8. Right Strut Rod Bracket

Fig. 1, 805-Square-Inch Radiator Installation

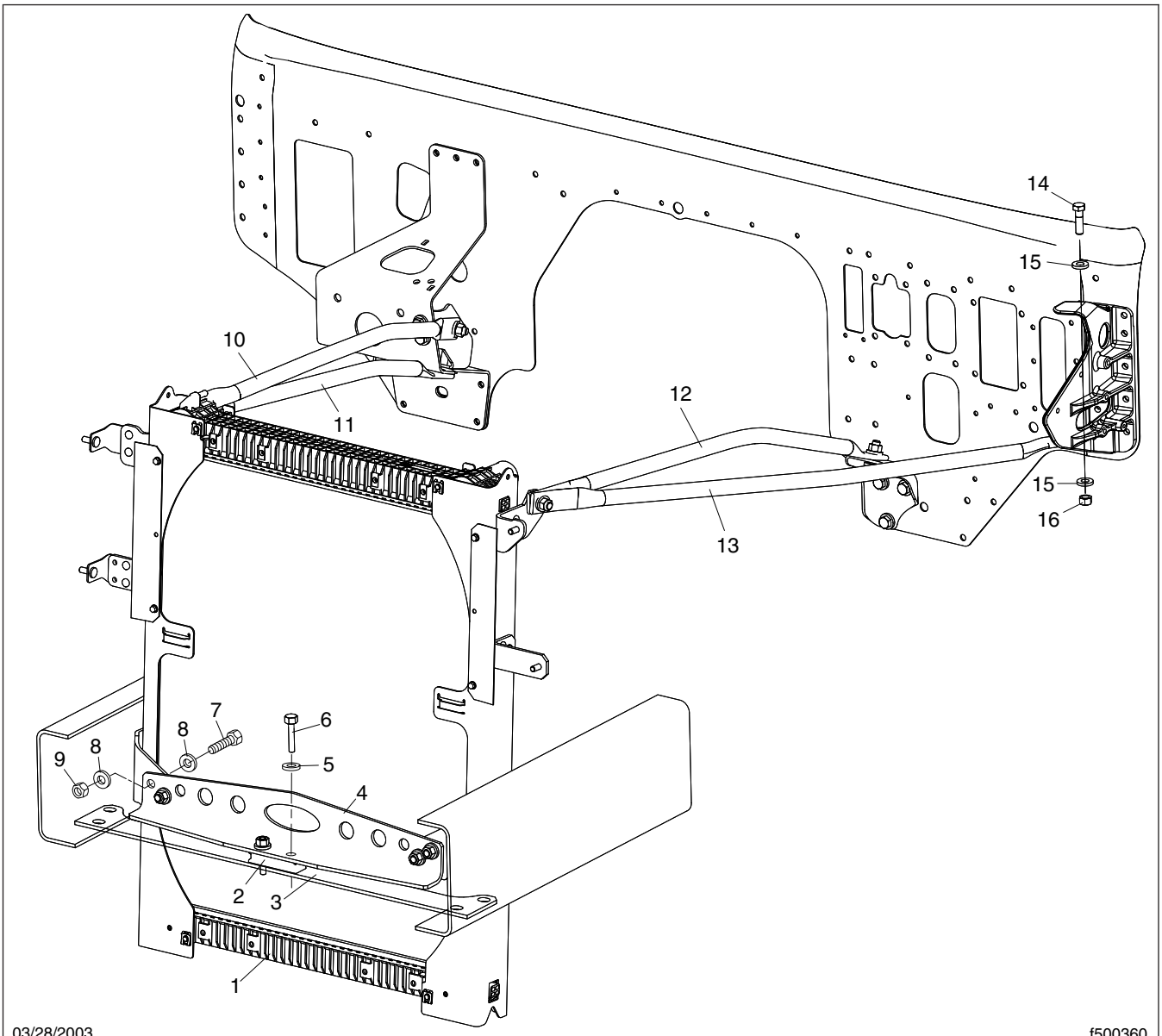
WARNING

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

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

4. Drain the coolant, as follows.
   - 4.1 Remove the cap from the surge tank.
   - 4.2 Place a clean container under the radiator.
   - 4.3 Open the draincock at the bottom of the radiator.

Radiator Removal and Installation



1. Radiator
2. Isolator
3. Front Crossmember
4. Support Bracket
5. Lockwasher
6. Hexbolt
7. Hexbolt
8. Flatwasher
9. Hexnut
10. Right Upper Strut Rod
11. Right Lower Strut Rod
12. Left Inner Strut Rod
13. Left Outer Strut Rod
14. Hexbolt
15. Washer
16. Hexnut

Fig. 2, 870-Square-Inch Radiator Installation

5. If so equipped, disconnect the transmission oil cooler hoses, as follows.

5.1 Place a clean container under the hose connections.

5.2 As applicable, disconnect the transmission oil cooler hoses from the radiator or the transmission oil cooler mounted below the radiator.

After the hoses have drained, cover them to keep out dirt. Secure the hoses to the side, above the level of the automatic transmission.

6. Disconnect the upper and lower radiator hoses.
7. Disconnect the upper left surge tank hose from the radiator.
8. Disconnect the charge air cooler hoses from the charge air cooler.
9. With an assistant supporting the hood, disconnect the hood-stop cables from the top of the radiator and support the hood on a padded table.
10. Disconnect the radiator struts from the radiator. Swing them out of the way.
11. If equipped with a viscous fan clutch, remove the fan and clutch from the fan hub. See **Section 20.03, Subject 110** for the procedure.
12. Remove the fasteners that hold the fan shroud to the radiator, then remove the fan shroud.

NOTE: Do not disconnect the refrigerant lines.

13. Move the A/C condenser aside, as follows.

13.1 Free up the refrigerant lines from any stand-off brackets near the radiator.

13.2 Swing the condenser out of the way and wrap it with cardboard. Secure it with tie-straps.

14. Position a hoist over the radiator.
15. Connect straps or chains to the radiator.
16. Remove the nuts from the studs on the lower radiator brackets that hold the radiator to the radiator support bracket.
17. Carefully move the radiator back toward the frontwall. If needed, pry the lower bracket studs from the holes in the radiator support bracket.
18. Lift the radiator assembly from the vehicle.
19. If needed, remove the charge air cooler from the radiator. For instructions, see **Group 09**.
20. If applicable, remove the transmission oil cooler from the radiator. For instructions, see **Group 26**.

Installation

1. If applicable, install the transmission oil cooler onto the radiator.
2. If it was removed, install the charge air cooler onto the radiator. For instructions, see **Group 09**.
3. Using a suitable hoist, lower the radiator into place, aligning the studs of the radiator lower brackets with the holes in the radiator support bracket.
4. For 870-square-inch radiators, install the 1/2–13 hexnuts and washers onto the studs on the radiator lower brackets. Tighten 68 lbf·ft (92 N·m).

   For 805-square-inch radiators, install the nuts and washers onto the studs on the isolators at the sides of the radiator.
5. Remove the chains or straps from the radiator.
6. Attach the radiator strut rods to the radiator. Tighten the 1/2–13 hexnuts 68 lbf·ft (92 N·m).
7. Install the air conditioner condenser onto the front of the radiator. Tighten the fasteners firmly.
8. Install any standoff brackets that were removed from the refrigerant lines.
9. Install the fan shroud onto the radiator.
10. Install the fan and the viscous fan clutch on the fan hub. See **Section 20.03, Subject 110**, for the procedure.
11. Connect the upper surge tank hose to the radiator.
12. Connect the upper and lower radiator hoses.
13. Connect the charge air cooler hoses.
14. If applicable, connect the transmission oil cooler hoses.
15. Attach the hood-stop cables to the top of the radiator.
16. Connect the hood damper to the bracket on the bumper.
17. Fill the radiator with coolant, as follows. See **Subject 400** for approved coolants and system capacities.

    17.1 Add approved coolant to the radiator.

    IMPORTANT: If the heater circuit valves were closed earlier, open the valves now.

Radiator Removal and Installation

17.2 Idle the engine with the heater circulation valve open for 15 to 20 minutes.

17.3 Add coolant as needed to fill the system to capacity.

18. While the engine is idling, check for leaks. Tighten any fittings/connections as needed.
19. Return the hood to the operating position.

Pressure Testing

1. Remove the radiator from the vehicle. For instructions, refer to **Subject 100**.
2. Plug the inlet, outlet, and all other ports on the radiator assembly.

CAUTION

Do not apply a higher amount of air pressure than specified below; too much pressure will damage the radiator core.

3. Remove the radiator cap, and install a pressure regulator and gauge. Using a hand pump, apply 20 psi (138 kPa) air pressure through the filler neck.
4. Submerge the radiator in a tank of water and check it for leaks. Remove the radiator from the water.
5. Remove the plugs and the testing gauge, and install the radiator cap. Repair the radiator, if necessary.
6. Install the radiator in the vehicle. For instructions, refer to **Subject 100**.

Radiator Disassembly and Assembly

IMPORTANT: Disassembling and assembling radiators with nylon tanks requires the special tools listed in **Table 1**.

Radiator Dissassembly/Assembly Tools	
Description	**Quantity**
Plastech II® Tanking Machine With Five 2-Inch Cylinders	1
T-Bar	1
Hooked-End Bar	1
Wave Form Bar	1

Table 1, Radiator Dissassembly/Assembly Tools

Order these tools from:

RAD PAL
2364 17 St.
Detroit, MI 48216
313-963-3194

Disassembly

Before disassembling the radiator, pressure flush it and check the surge tank, following the instructions in **Group 20** of the *S2 Chassis Maintenance Manual*. Clean and check the exterior of the radiator, following the instructions in the *S2 Chassis Driver's Manual*.

1. Remove the radiator from the vehicle; for instructions, refer to **Subject 100**. See **Fig. 1**.

CAUTION

Use care when handling or supporting the nylon tanks. Failure to do so could damage the tanks.

2. Remove the side channels from the radiator assembly, as follows.
   - 2.1 Remove the four spring clips that hold the side channel mounting pins in position. See **Fig. 2**. Insert a screwdriver blade in the open end of each clip, and pry the clip open until it clears the edge of the mounting pin. Then, slip the clip off the pin.
   - 2.2 Use a rubber mallet and a punch to tap out the four mounting pins. See **Fig. 3**.
   - 2.3 Slip the side channels off the radiator core and tank assembly. See **Fig. 4**.
3. Leak test the radiator core and tank assembly, as follows.
   - 3.1 Securely plug all tank ports.

CAUTION

Do not apply a higher amount of pressure than specified below; too much pressure will damage the radiator core.

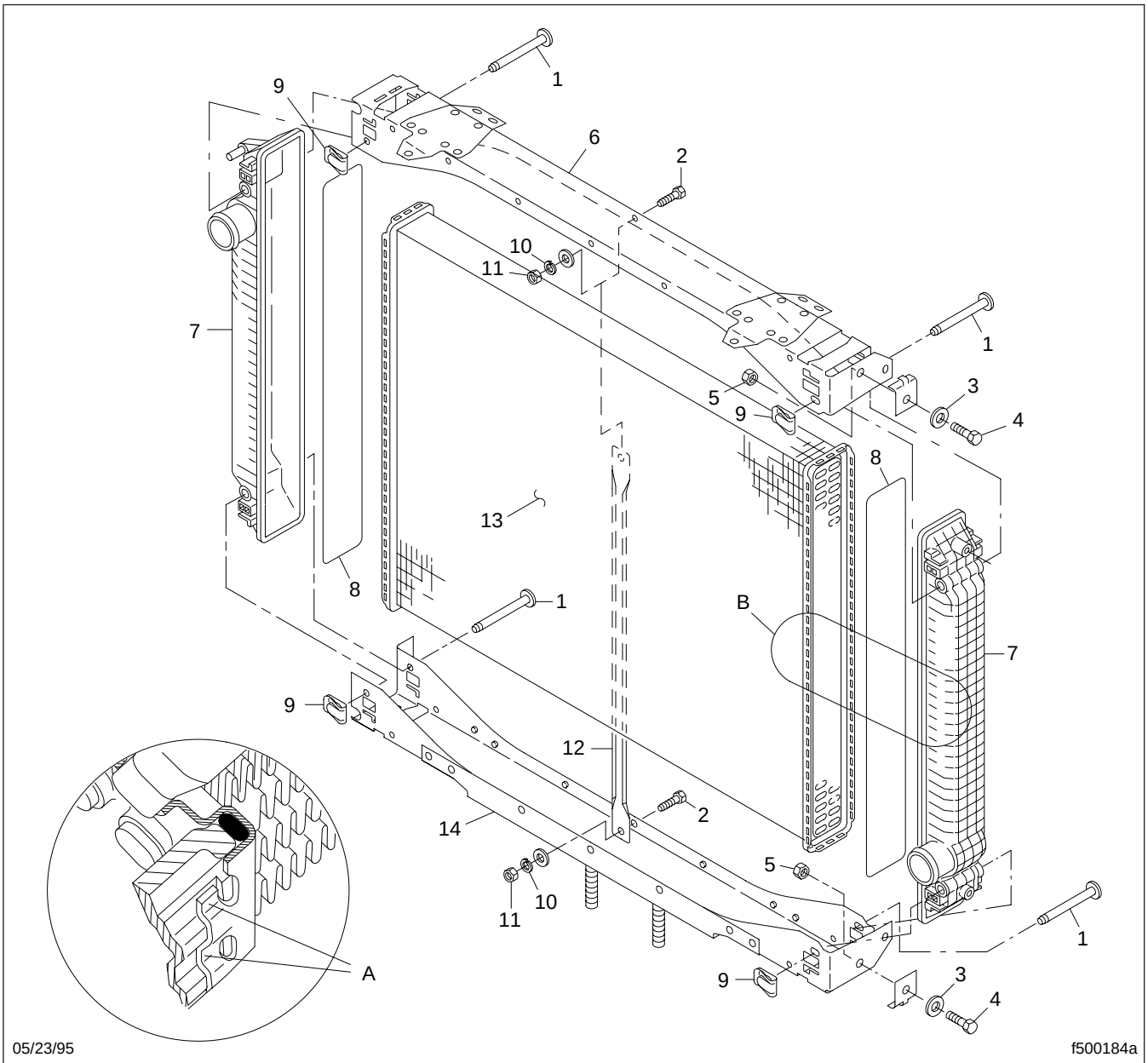
   - 3.2 At one tank port, install a pressure regulator and gauge. Using a hand pump, apply 20 psi (138 kPa) air pressure through the port.
   - 3.3 Submerge the radiator in a tank of water and check it for leaks. Mark any leaks for repair. If a leak is between the radiator core header and a tank, remove the tank and inspect the tank flange, the header sealing surface, and the sealing gasket. If the leak is in the core, but within 3 inches (7.5 cm) of the tank, remove the tank before repairing the leak. If the leak is in the tank, replace the tank.
4. Remove the tanks, as follows.
   - 4.1 Place the radiator core and tank assembly in the disassembly/assembly fixture, and clamp the assembly securely in place. See **Fig. 5**.
   - 4.2 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will not press against breakable fittings, such as vent tube ports.

CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

   - 4.3 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

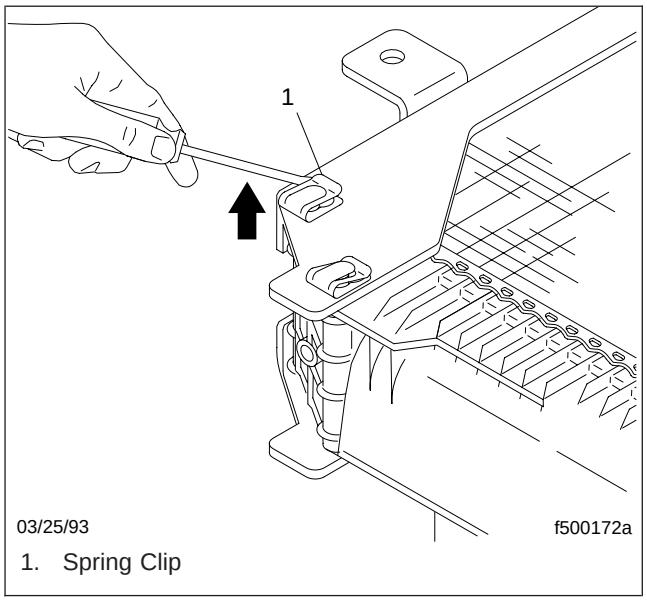
Radiator Disassembly and Assembly



A. Dimple Wave Lock Crimp
B. See Detail

1. Channel Mounting Pin
2. Bolt
3. 3/8-Inch Flatwasher
4. 3/8–16 Bolt
5. 3/8–16 Nut
6. Side Channel (top)
7. End Tank
8. End Tank Gasket
9. Spring Clip
10. Lockwasher
11. Nut
12. Radiator Brace Rod
13. Radiator Core
14. Side Channel (bottom)

Fig. 1, Radiator With Plastic End Tanks



1. Spring Clip

Fig. 2, Removing the Spring Clip

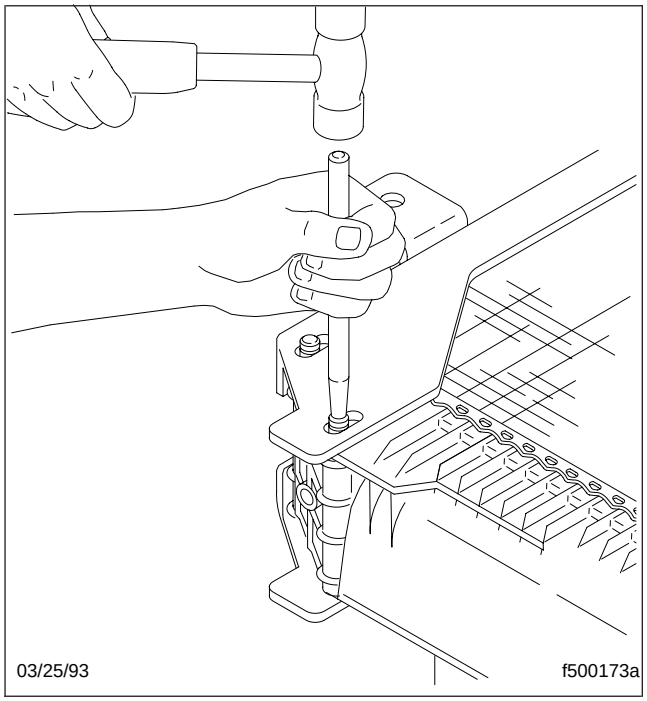
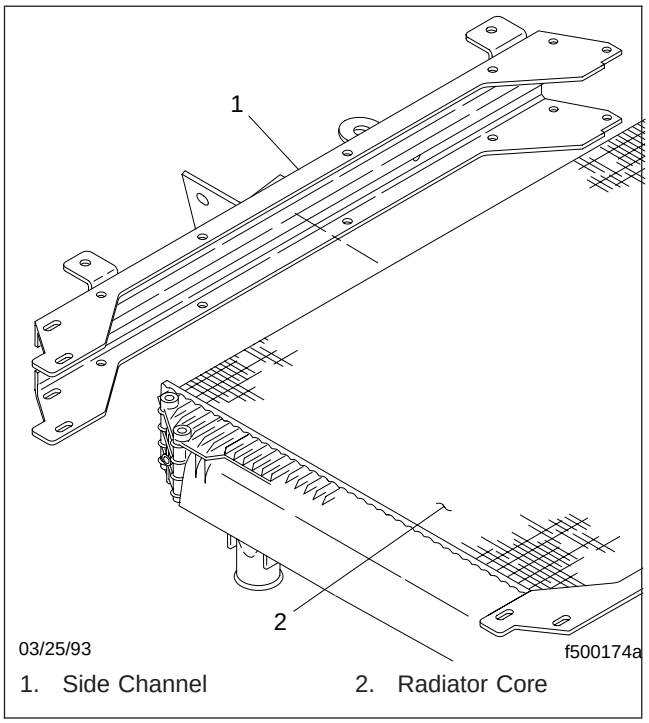


Fig. 3, Tapping Out the Mounting Pins

CAUTION

In some places, especially around the tank ports, the wave lock crimps may have to be unlocked with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.



1. Side Channel
2. Radiator Core

Fig. 4, Removing the Side Channels

4.4 Place the T-bar into the T-bar groove in the disassembly/assembly fixture. See **Fig. 6**.

4.5 Slide the hooked-end bar over the T-bar. Place the hook over the top of the wave crimp and pull the T-bar back to unlock the crimp. See **Fig. 6**.

4.6 Slide the hooked-end bar and the T-bar down the T-bar groove to the next wave crimp, and repeat the previous substep until all the wave crimps are unlocked.

4.7 Release the pressure from the tank, and move the clamping cylinders off the radiator core and tank assembly.

CAUTION

If needed, use a rubber mallet or the heel of your hand to tap the side of the tank to loosen it. Do not use a screwdriver against the tank sealing

Radiator Disassembly and Assembly

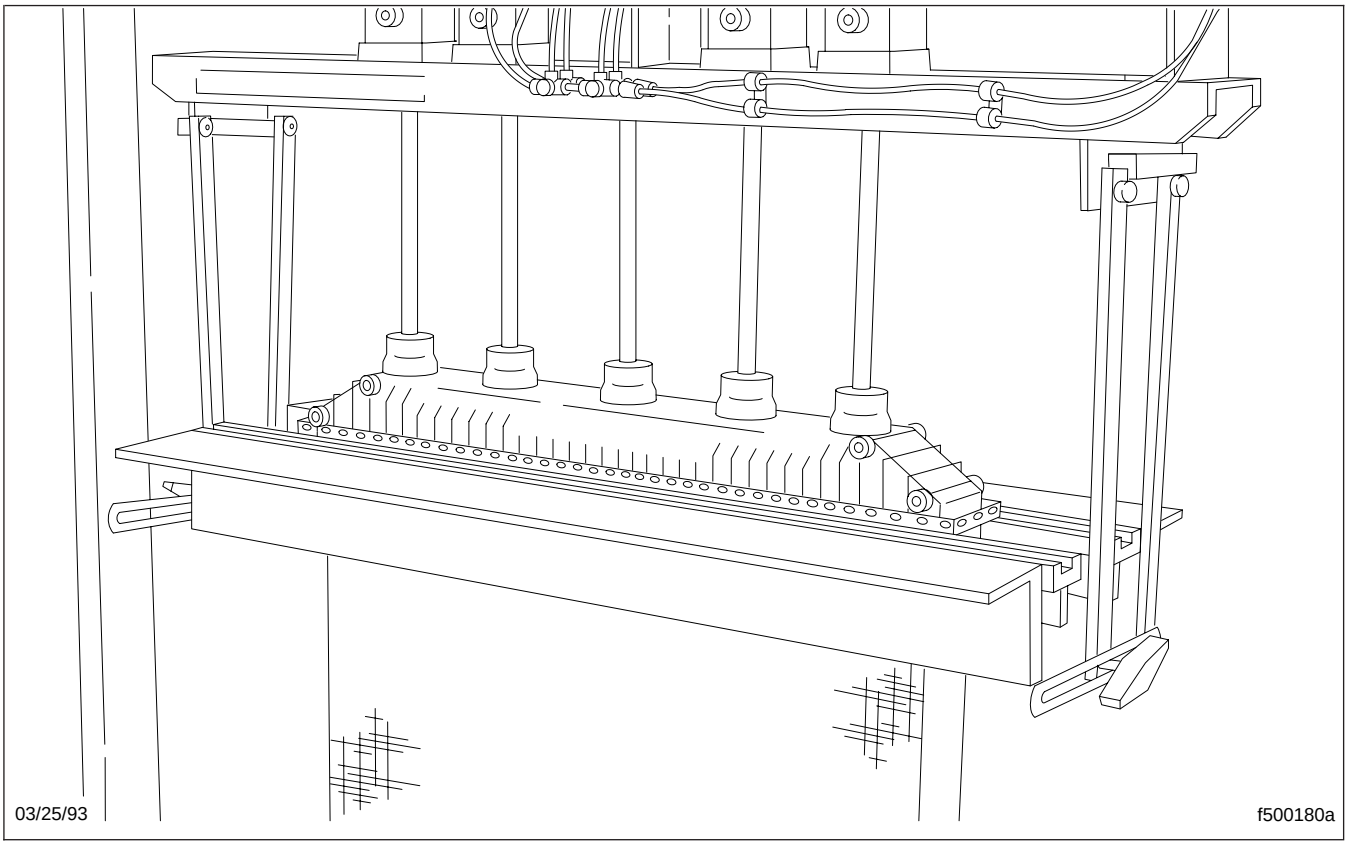


Fig. 5, Clamping the Radiator in the Disassembly/Assembly Fixture

flange. A screwdriver blade may damage the flange and prevent a good seal after the tank is installed.

4.8 Lift the tank from the forward side, the side opposite the tank ports. Remove the nylon tank from the radiator core. See **Fig. 7**.

4.9 Remove the sealing gasket from the sealing surface of the radiator core header. See **Fig. 8**.

4.10 Clean the sealing surface of the radiator core header.

4.11 Repair any leaks marked during leak testing.

4.12 Repeat the preceding steps to remove the opposite tank.

IMPORTANT: Check the tubes of the radiator core for scale deposits. If the radiator has been pressure-flushed, and the tubes are still clogged, the radiator should be rodded or boiled out with acid by an experienced radiator shop. Otherwise, replace the core.

Assembly

1. Install the nylon tanks on the radiator core, as follows.

1.1 With the radiator securely clamped in the disassembly/assembly fixture, header sealing surface up, make sure the bottom of the radiator core and tank assembly is completely supported, and that the header sealing surface is free of any dents, tool marks, or foreign particles.

1.2 Lubricate a new sealing gasket with a soap and water solution, and position the

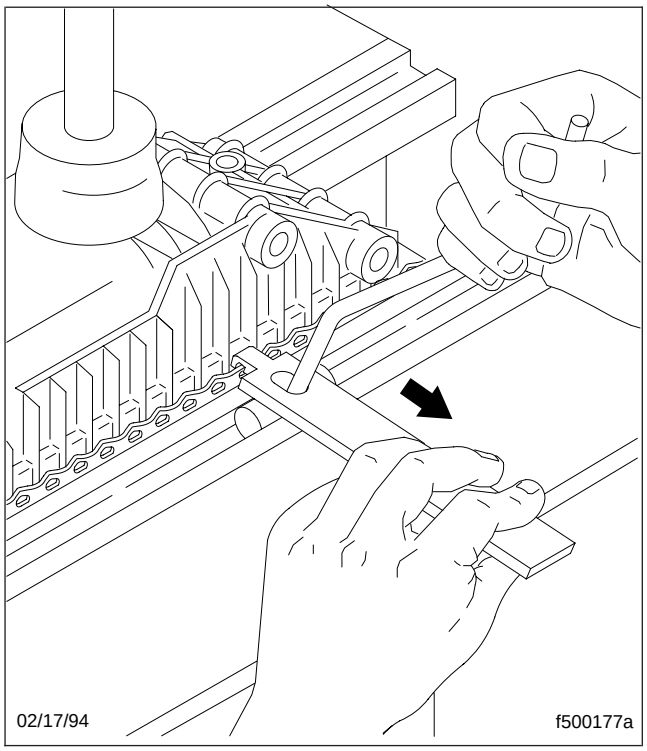


Fig. 6, Placing the T-Bar

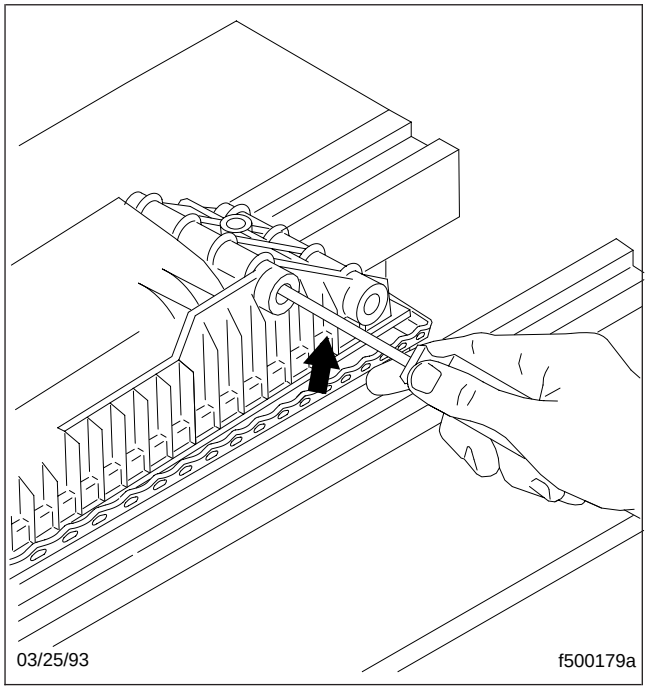


Fig. 7, Lifting the Tank

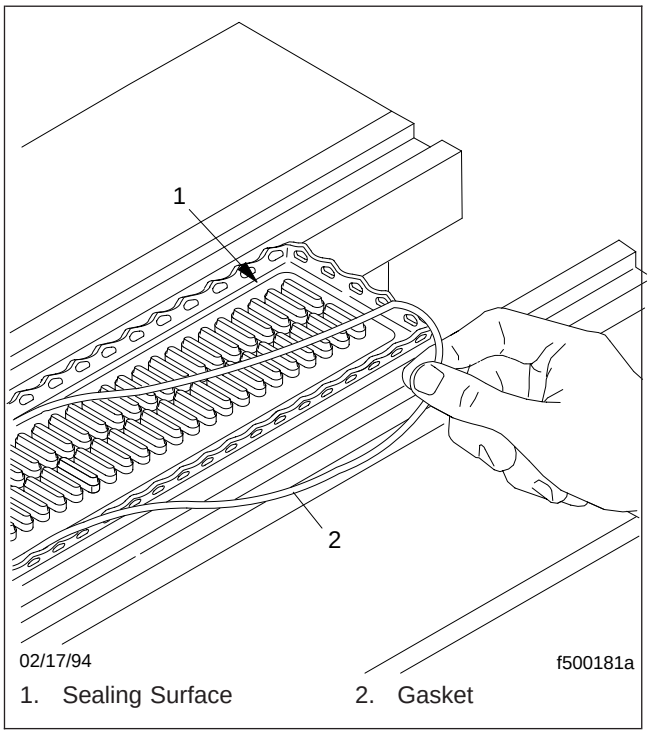


Fig. 8, Removing/Installing the Gasket

gasket on the header sealing surface. See **Fig. 8**. To make sure the gasket is not twisted, run a finger along the gasket as it lies on the sealing surface. The mold lines of the gasket should be on the outside and inside diameters of the gasket; if you can feel a mold line cross over the top of the gasket, the gasket is twisted.

1.3 Inspect the tank sealing flange. The flange must be clean and free of defects. If the sealing flange is damaged, replace the tank.

1.4 Place the tank on the gasket, and tap the tank with a rubber mallet or the heel of your hand to seat the tank. Make sure the tank ports are facing the correct direction.

1.5 Position the tank clamping cylinders evenly across the top of the tank. Make sure the cylinders' rubber plungers will not press against breakable fittings, such as vent tube ports. See **Fig. 5**.

Radiator Disassembly and Assembly

CAUTION

Apply only enough pressure to compress the sealing gasket. Too much pressure will crack the nylon tank.

1.6 Apply pressure evenly across the top of the tank until the tank-to-core sealing gasket is compressed enough to show a small gap between the bottom of the dimple wave lock crimp and the tank sealing flange.

1.7 Place the T-bar into the T-bar groove in the disassembly/assembly fixture.

1.8 Slide the wave form bar over the T-bar, and center the bar in front of the wave crimp slot.

CAUTION

Do not push the wave crimp until it touches the side of the nylon tank, or the tank may crack.

1.9 Push the T-bar forward to crimp the header's edge until it almost touches the tank's side. See **Fig. 9**.

1.10 Slide the tools down the T-bar groove to the next wave crimp slot, and repeat the previous steps until all the wave crimps are crimped.

CAUTION

In some places, especially around the tank ports, the wave crimps may have to be crimped with a screwdriver. When using a screwdriver, use care not to crack or gouge the nylon tank.

1.11 Release the pressure from the tank, and move the clamping cylinders off the radiator core and tank assembly.

1.12 Repeat all of the substeps in this step to install the opposite tank.

2. Leak test the radiator core and tank assembly. For instructions, refer to "Disassembly."

3. Install the radiator side channels, as follows.

3.1 Slide the side channels onto the radiator core and tank assembly.

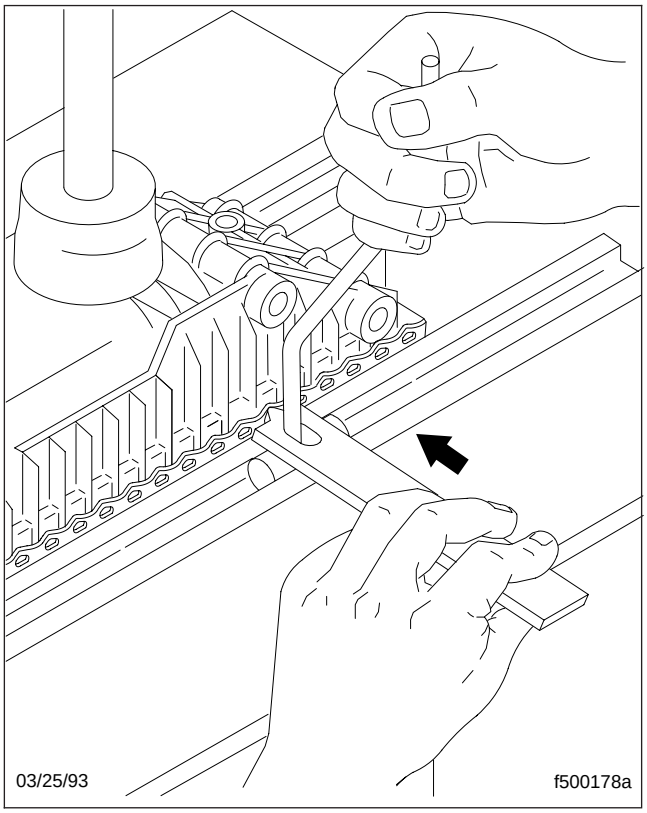


Fig. 9, Crimping the Header

3.2 Using a rubber mallet and a punch, install the four mounting pins through the side channel holes and tank bosses. See **Fig. 10**.

3.3 Install the four spring clips to secure the mounting pins in position. See **Fig. 11**. To install each clip, place the clip over the end of the mounting pin, and slide the clip until it engages the groove in the pin and the open end of the clip snaps over the edge of the pin. If necessary, use a clamp to compress the side channel while installing the clips.

4. Install the radiator in the vehicle. For instructions, refer to **Subject 100**.

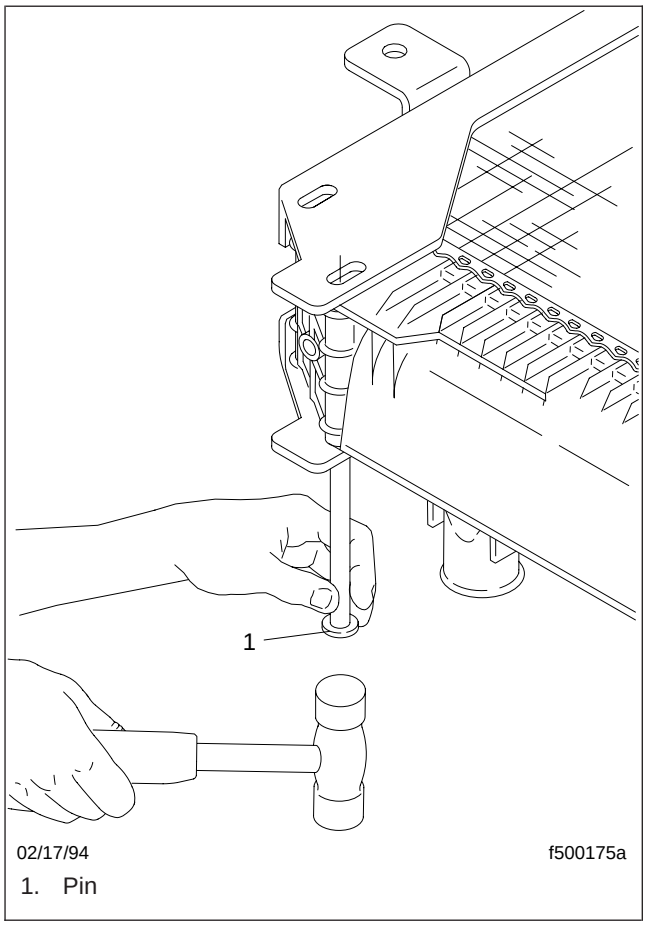


Fig. 10, Installing the Mounting Pins

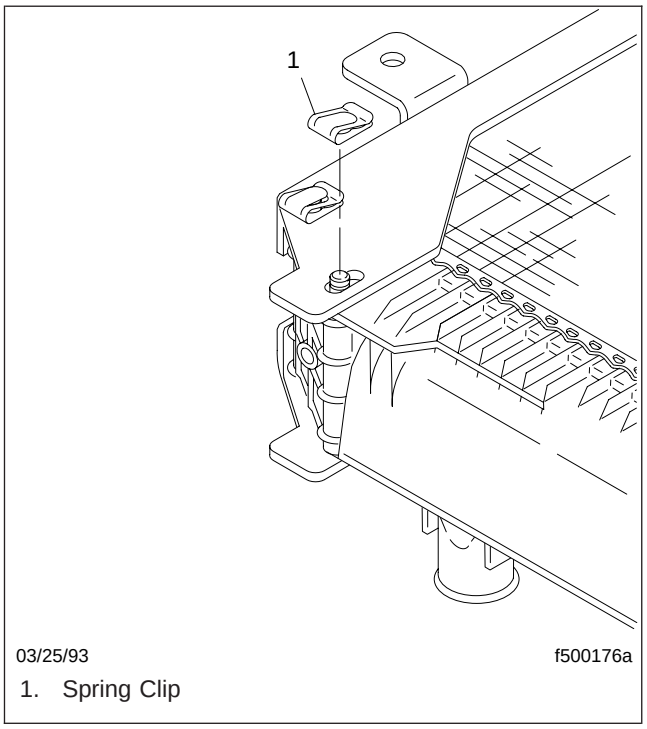


Fig. 11, Installing the Spring Clips

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 hot could cause severe personal injury due to scalding.

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

3. Drain the radiator, as follows.
   - 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, as follows.
   - 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**.

   NOTE: Cap all the disconnected hoses to prevent the remaining coolant from spilling.
   - 4.2 Remove the fasteners that hold the right side of the surge tank to the air cleaner bracket. See **Fig. 1**.
   - 4.3 Remove the fasteners that hold the left side of the surge tank to the frontwall and the HVAC air plenum.
   - 4.4 Remove the surge tank from the vehicle.
5. If replacing the surge tank, remove the overflow hose from the bottom.

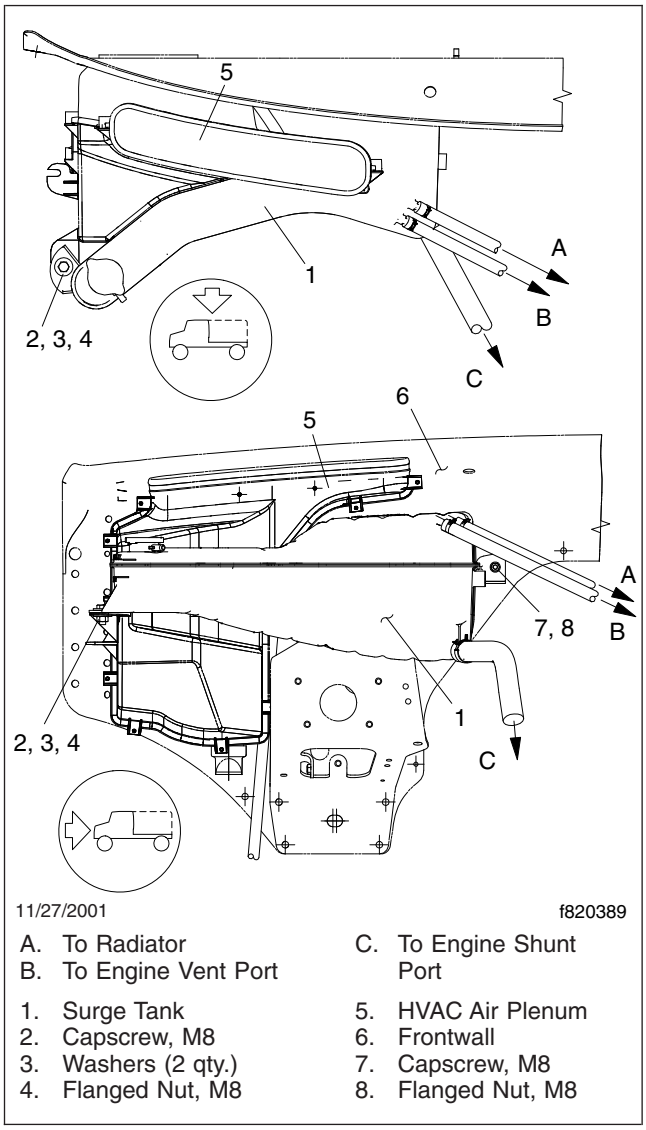
Installation

1. If it was removed, install the overflow hose on the bottom of the surge tank.
2. Position the surge tank onto the air cleaner bracket, then install the M8 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. Fill the cooling system through the surge tank.
7. Install the surge tank cap.

IMPORTANT: If the heater circuit valves were closed earlier, open the valves now.

8. Start the engine and check for coolant leaks. Repair any leaks.
9. Lower the hood.

Surge Tank Removal and Installation



A. To Radiator
B. To Engine Vent Port
C. To Engine Shunt Port

1. Surge Tank
2. Capscrew, M8
3. Washers (2 qty.)
4. Flanged Nut, M8
5. HVAC Air Plenum
6. Frontwall
7. Capscrew, M8
8. Flanged Nut, M8

Fig. 1, Surge Tank Installation (top and front views)

Specifications

Fastener Torques				
Description	Grade	Size	Torque	
			lbf·ft (N·m)	lbf·in (N·cm)
Radiator Lower-Bracket Stud Hexnuts	8	1/2–13	68 (92)	—
Fan Shroud Mounting Screws	—	1/4–20 x 3/4	—	108 (1220)
Radiator Strut Nuts	8	1/2–13	68 (92)	—

Table 1, Fastener Torques

Coolant Capacities*	
Engine Make and Model	Coolant Volume: quarts (liters)
Cummins ISB	30.5 (28.9)
MBE900 (6.4L)	37 (35)

* The total coolant volume is dependent on the number and location of optional passenger heaters.

Table 2, Coolant Capacities

Approved Coolants		
Engine Type	Coolant Manufacturer	Coolant Designation*
Diesel	Old World Industries	Fleet Charge®
	Shell	Shell HD/N Antifreeze
	Texaco	JC04 Antifreeze
	Van Waters and Rogers Ltd. (Canada)	Diesel Antifreeze No. 6038
Propane	Chevron	Chevron Delo Antifreeze No. 275110†

* Freightliner-approved antifreeze must meet one of the following conditions: A. Ethylene glycol solution that meets GM 6038–M Engineering Standards. B. Ethylene glycol solution that has less than 0.1% anhydrous sodium metasilicate and meets either GM 1825–M or GM 1899–M Engineering Standards.

† Chevron Delo coolant is approved for use in LPG engines only.

Table 3, Approved Coolants

General Information

An engine block heater keeps the engine coolant about 80°F (27°C) warmer than the ambient air temperature. In cold weather, the heater helps engine starting and reduces wear on the piston walls.

When starting the engine, the diesel fuel normally ignites on the compression stroke of each piston, when the compressed air within the cylinder reaches about 725°F (385°C). However, during cold-weather starts, the heat of the compressed air dissipates into the surrounding engine block so the diesel fuel may never reach the temperature it needs to ignite. Using the engine block heater, the engine block is already warm so heat is held in the cylinder to ignite the diesel fuel. To reduce engine wear, the block heater warms the oil film on the piston walls and reduces piston drag caused by cold oil film.

The Phillips 1000W heater consists of an element that screws into the side of the engine water jacket. See **Fig. 1**. A cord plugs into the outside end of the element, and the cord runs to a plug below the front bumper.

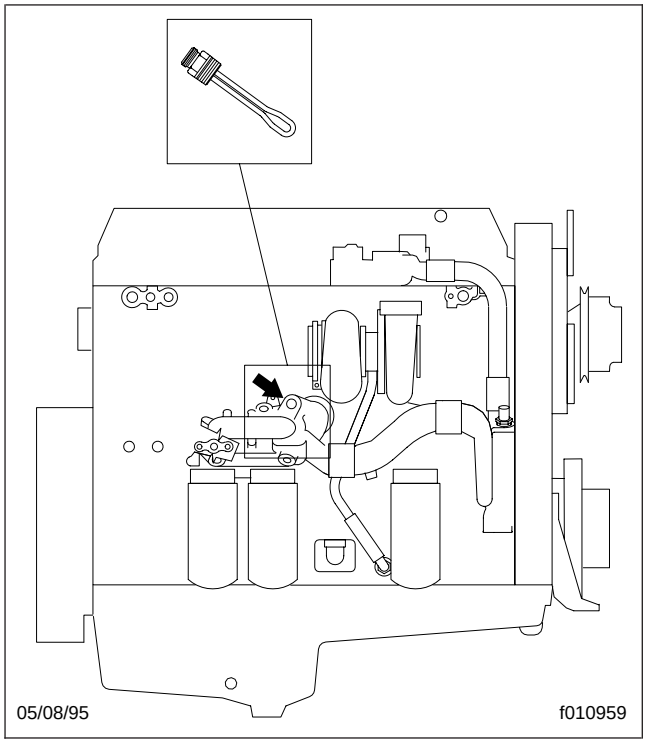


Fig. 1, Block Heater Element Installation (typical)

To turn on the heater, connect the heater cord to a power source. The element has no thermostat. Heat dissipating from the engine block prevents coolant overheating.

Block Heater Element Replacement

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

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

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

3. Drain the radiator. For instructions, refer to **Section 20.01**.
4. If applicable, unscrew the threaded cover that secures the cord to the element. See **Fig. 1**.

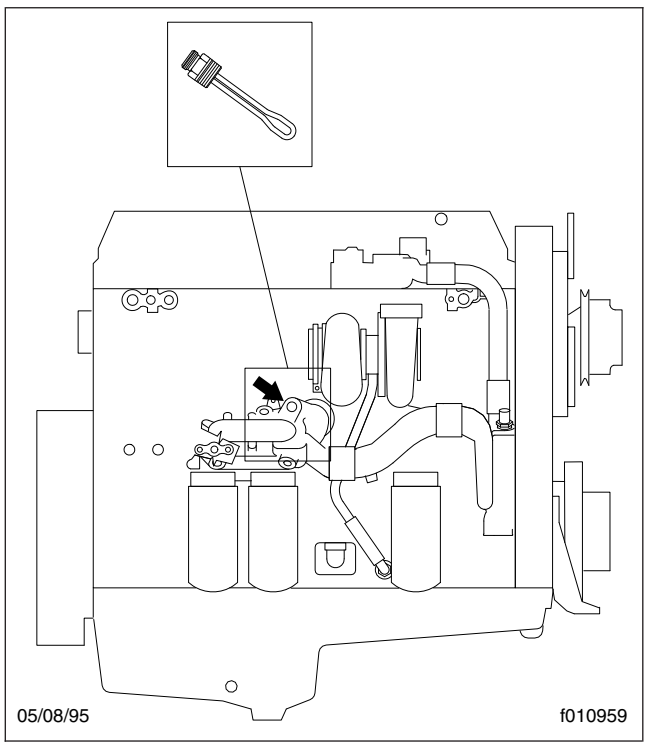


Fig. 1, Block Heater Element Installation (typical)

5. Pull the cord from the element.
6. Remove the element from the engine block by loosening the jam nut (if applicable) and unscrewing the element from the engine block.
7. Position the heater element in the engine block.

   Coat the threads of the new element with a small amount of sealant. For the approved sealants, refer to **Specifications, 400**.
8. Secure the heater element in the engine block by screwing the element into the engine block hand-tight, then use a wrench to turn the element 1-1/2 turns more.
9. Plug the cord into the element and (if applicable) secure it by screwing the threaded cord cover in place.
10. Fill the cooling system. For instructions, refer to **Section 20.01**.

IMPORTANT: If the heater circuit valves were closed earlier, open the valves now.

11. Start the engine and check for leaks. Repair any leaks as necessary. Run the engine for half an hour to purge any air from the cooling system.
12. To test the heater, plug a wattmeter into a power source, and connect the heater cord to the meter. A reading on the meter will indicate the heater is working.
13. Return the hood to the operating position.

Troubleshooting

Use the following procedures to check for the most common engine block heater problems.

Wiring Problems

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. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element.
4. Using an ohmmeter, check the continuity between the two poles of the element. The resistance should be very low, typically between 9 and 10 ohms. If there is no reading, the element has burned out. If the reading is very high, the element is about to burn out.
5. If the element is good, check the cord. Plug the cord into the element and secure it by screwing the threaded cover in place.
6. Using an ohmmeter at the receptacle, check the continuity between the two power terminals. The resistance should be low, typically between 9 and 10 ohms. If there is no reading or a very high reading, the cord is damaged; replace the cord.
7. Check the continuity between each power terminal and the ground terminal. There should be no ohmmeter reading. If there is a reading, replace the cord.
8. Check the ohmmeter reading between the ground terminal and a good vehicle ground. The reading should be zero. If not, replace the cord.

Fouled Element

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 hot could cause severe personal injury due to scalding.

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

3. Drain the radiator. For instructions, refer to **Section 20.01**.
4. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element.
5. Remove the element from the engine block. For element installation instructions, refer to **Subject 100**.
6. Inspect the element for residue deposits, discoloration, or damage.

   Coolant dye residue indicates the coolant solution contains too much antifreeze. Install a new element, and refer to **Group 20** of the *S2 Chassis Maintenance Manual* for the recommended antifreeze/water ratio.

   Gray or black residue indicates anti-leak coolant additives have been added to the system. Install a new element, and refer to **Group 20** of the *S2 Chassis Maintenance Manual* for the recommended coolant additives.

   Blue or black discoloration on the element indicates the cooling system needs more coolant. Install a new element, and fill the cooling system until coolant is visible in the surge tank sight glass.

   Holes in the element indicate the coolant solution contains too little antifreeze. The weak solution is boiling inside the engine block and causing pitting of the element and block. Install a new element, and refer to **Group 20** of the *S2 Chassis Maintenance Manual* for the recommended antifreeze-to-water concentrations.

   For element installation instructions, refer to **Subject 100**.

Specifications

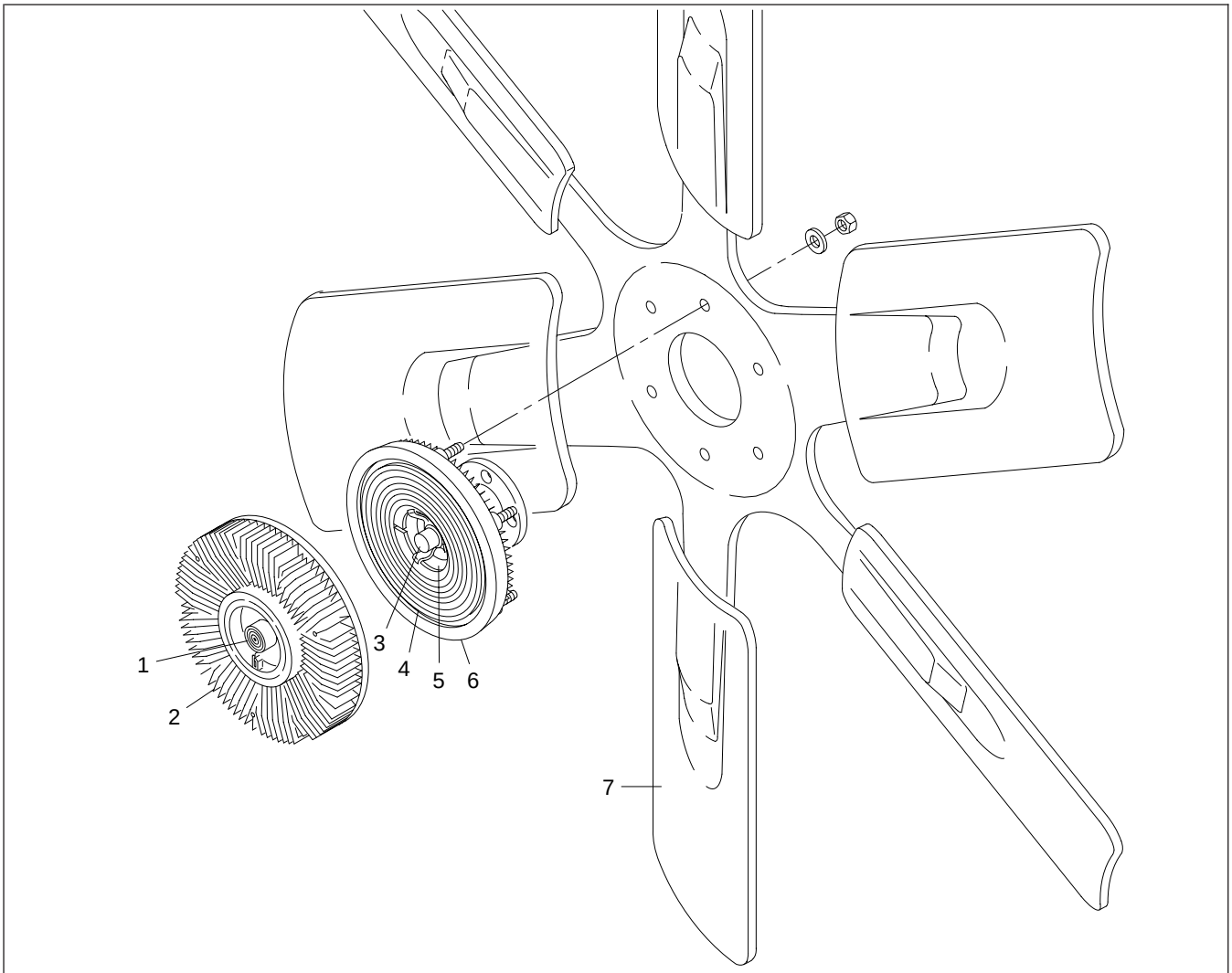
Approved Sealants

- Loctite 567
- Henkel 790 Pipegrip
- Perma-Loc LH-150

General Information

The fan clutch senses the air temperature behind the radiator core, and engages or disengages the fan depending on that temperature. It spins the fan when more cooling airflow is needed, and disengages it when the radiator is sufficiently cooled.

The BorgWarner 805 viscous fan clutch drive consists of two basic parts: the input plate and shaft, and the output plate. See **Fig. 1**. The input shaft is mounted to the fan hub, so they turn together as the engine runs. The output plate is attached to the fan, but engages with the input plate only when extra engine cooling is needed.



1. Heat Sensor
2. Input Plate
3. Input Shaft
4. Concentric Grooves
5. Drive Chamber
6. Output Plate
7. Fan

Fig. 1, Viscous Fan Clutch

General Information

To spin the fan, the heat sensor on the front of the clutch opens a valve in the clutch drive chamber. The centrifugal force of the turning input plate forces the thick silicone fluid, stored in the drive chamber, to flow out through tightly meshing grooves between the input and output plates. this creates friction between them. As that friction increases, it causes the output plate and fan to turn with the input plate. The fluid continues to spread out between more grooves, increasing the friction between the plates until they spin at about the same speed.

When air passing through the radiator is cool enough, the heat sensor disengages the fan clutch. It does this by closing the valve in the drive chamber. That stops the flow of silicone fluid to the input and output plates. For the fluid already between the plates, centrifugal force continues to push it outward until it has moved beyond the grooves. There, at the outer edge of the clutch, it returns through a passage in the input plate to the drive chamber.

With only a small amount of fluid to create friction between the two plates, the fan turns much slower than the input plate and the input shaft.

When the fan is disengaged, a single bearing allows the output plate and fan to free-wheel in relation to the input shaft and plate.

Inspection

⚠ CAUTION

If the fan drive assembly is damaged, replace the unit as soon as possible. Operating a vehicle with a seized or otherwise damaged clutch reduces fuel economy, and could cause serious engine damage.

The fan clutch is only one part of the cooling system and will function well only if all other parts of the system are working correctly. All parts of the system should be checked if there is a cooling problem. Do each of the checks in the cooling system troubleshooting section in this group, and pay special attention to the fuel flow rate and exhaust temperature. Over-fueling can cause engine overheating and high exhaust temperatures.

1. Park the vehicle on a level surface, set the parking brake, shut down the engine, and chock the rear tires.
2. With the engine off, rotate the fan at least one full turn by hand. It should have a smooth, steady drag. If it does not, replace the fan clutch.
3. Check for physical damage to the fan or fan shroud.
4. Inspect the fan clutch mounting, as follows.
   - 4.1 Check the torque of the bolts that hold the fan hub to the engine. They should be tightened 15 lbf·ft (20 N·m).
   - 4.2 Check for wear of the fan clutch bearings. There should be no side-to-side or in-and-out movement of the fan clutch.
5. Remove the chocks from the tires.

Operation Check

Use the following procedure to check for correct engagement and disengagement of the fan clutch:

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Coolant temperature in the radiator should be below 140°F (60°C) before the start of the test; the outside temperature should be above 50°F (10°C). Ideally, a temperature probe placed about 1/2 inch (13 mm) from the fan clutch sensor is needed to see if the fan clutch engages at the right temperature.
3. Disconnect any hydraulic pumps (such as the power steering pump) to prevent oil overheating.
4. Use a piece of cardboard large enough to block the entire front of the radiator. Cut a round 7-inch (18-centimeter) hole in the cardboard; locate the hole so that it lines up with the fan clutch. Do not put the cardboard in front of the radiator yet.

⚠ WARNING

Before starting the engine, make sure your hands and all other objects are away from the fan blades. Do not try to restrict the fan blade rotation when the engine is on. It is extremely dangerous to get too close to the fan blades when the engine is on, because the fan could start operating without warning. This could result in serious personal injury.

5. Turn off the air conditioner, if so equipped. Start the engine and let it idle until the oil pressure is normal.
6. As soon as there is normal oil pressure, bring the engine up to high idle (about 80 percent of governed engine speed) and lock the throttle at this speed.

   If the engine has been idle for more than 8 hours, the fan clutch may engage as soon as the engine is started. If this happens, the usual noise from the fan will be heard; the noise will stop after 5 minutes or less, when the fan clutch disengages.
7. After the fan clutch disengages, put the cardboard in front of the radiator.
8. Look at the temperature gauge and note at what point the engine thermostat opens. As the engine warms up, the coolant temperature will rise steadily and then seem to level off after the thermostat opens. It will then start rising again, before the fan clutch engages.
9. Keep watching the coolant temperature and, if possible, the temperature of the air in front of the fan clutch, until the clutch engages. Note the temperature(s) at which the clutch engages. The

Inspection and Operation Check

fan should be fully engaged when the air at the fan clutch sensor rises to about 155 to 165°F (68 to 74°C).

With the clutch engaged, the coolant temperature will keep rising, at a slower rate, as long as the radiator is blocked with cardboard.

10. Remove the cardboard. Keep watching the coolant temperature while the clutch is engaged; you should notice a decrease after the cardboard is removed.
11. The fan should disengage when the air temperature at the fan clutch sensor drops to about 120 to 130°F (49 to 54°C).

    If the coolant temperature keeps rising, even though the fan is engaged and the cardboard has been removed, the fan clutch may be working properly; the problem is probably in another part of the cooling system.

IMPORTANT: If the air temperature in front of the clutch is being tested, and it does not rise as the coolant temperature rises, the problem could be a clogged radiator or a stuck engine thermostat.

If the engine still overheats during operation, even though everything described above checks out properly, use a stroboscope to check peak fan speed. The fan speed should be at least 93 percent of the fan pulley speed when the clutch is fully engaged.

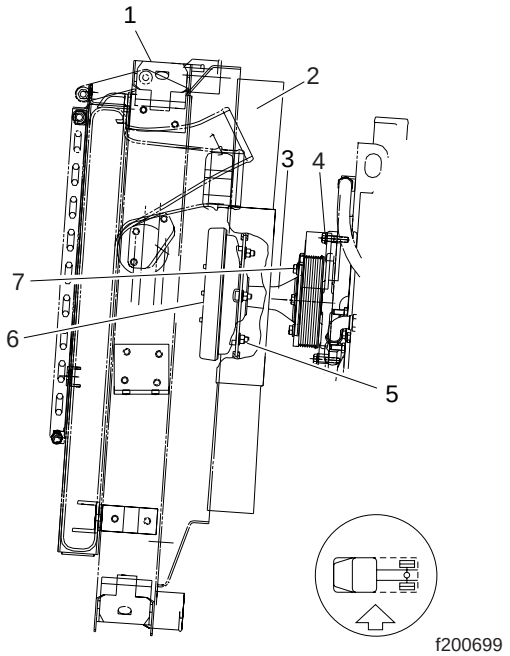
Example: 2160 = fan pulley speed x .93 = 2009 = 93 percent of fan pulley speed. Fan speed must be at least 2009 rpm when the fan clutch is fully engaged.

12. Remove the chocks from the tires.

Removal

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries or, if the vehicle is equipped with a battery shutoff switch, turn off the switch.

   Then disconnect the battery ground cable at the vehicle frame.
3. Tilt the hood.
4. Disconnect the radiator struts from the radiator side-channels.
5. If so equipped, disconnect the left-side charge air cooler hose from the charge air cooler.
6. Disconnect the fan clutch from the fan hub, as follows. See **Fig. 1**.



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1. Radiator
2. Fan
3. Fan Hub
4. Hexbolt, M8
5. Locknut, 5/16–18
6. Fan Clutch Assembly
7. Hexbolt, M8

Fig. 1, Viscous Fan Clutch Mounting, MBE900 Engine

   6.1 Holding the fan to keep it from turning, remove the four locknuts or four capscrews that hold the fan clutch to the fan hub.

   6.2 Remove the fan (with the fan clutch attached to it) from the fan hub, and push them forward into the fan shroud.
7. Using a 1/2-inch breaker bar, move the belt tensioner clockwise. Remove the serpentine drive belt from the various engine and component pulleys.
8. Remove the top two bolts that hold the fan hub to the engine block. Then loosen the bottom two bolts. It is not necessary to remove them. Remove the fan hub from the engine block.
9. Remove the fan and the attached fan clutch from the vehicle.
10. Remove the locknuts and washers that hold the fan clutch to the fan. Remove the clutch.

Installation

1. Install the fan clutch on the fan. Tighten the 5/16–18 locknuts 15 lbf·ft (20 N·m).

NOTE: Use only approved fans. Never go over the maximum input speeds, and do not make changes to the engine that will raise the operating speed of the fan.

2. Install the fan hub onto the engine, as follows. See **Fig. 1**. **Figure 2** is an example of the fan clutch mounting for a Cummins engine.

   2.1 Put the hub in place on the engine so the lower mounting holes fit over the holes on the engine block.

   2.2 Install the four hexbolts and washers. Tighten all the hexbolts 15 lbf·ft (20 N·m).
3. Install the serpentine drive belt.
4. Connect the left-side charge air cooler hose to the charge air cooler.
5. Connect the radiator struts to the radiator side-channels. Tighten the fasteners firmly.
6. Lower the hood and connect the batteries.
7. Remove the chocks from the tires.

Removal and Installation

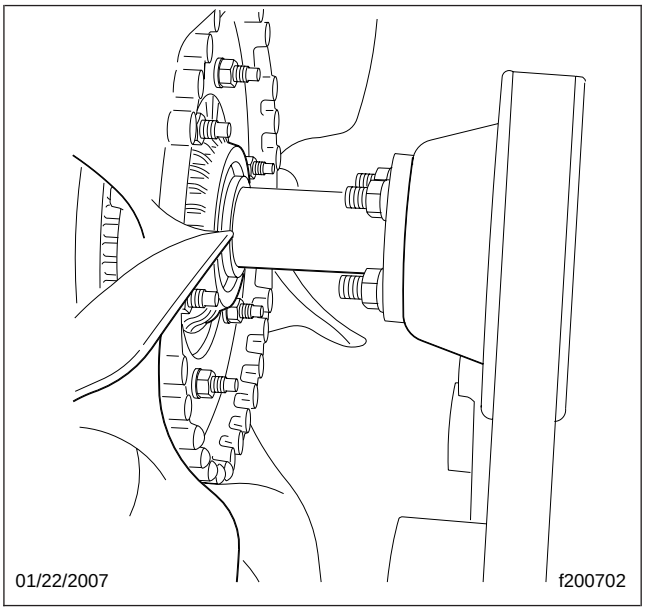


Fig. 2, Viscous Fan Clutch Mounting, Cummins Engine

Specifications

Mercedes-Benz Fastener Torques			
Description	**Class/ Grade**	**Size**	**Torque: lbf·ft (N·m)**
Fan Hub-to-Engine Hexbolts	10.9	M8	15 (20)
Fan Clutch-to-Fan Locknuts	G	5/16–18	21 (28)

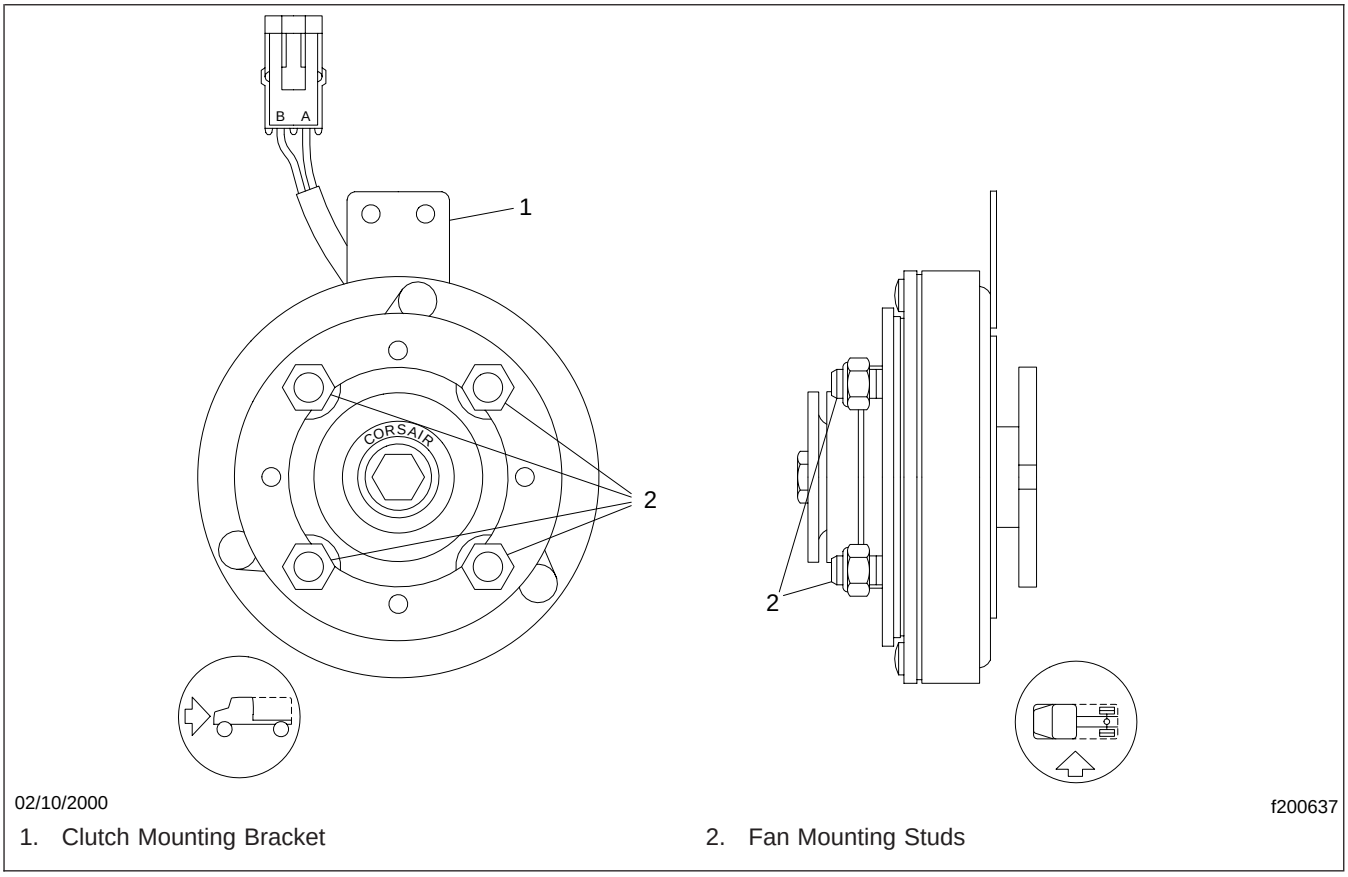
Table 1, Mercedes-Benz Fastener Torques

Cummins Fastener Torques			
Description	**Class/ Grade**	**Size**	**Torque: lbf·ft (N·m)**
Fan Hub-to-Engine Hexbolts	10	M10	33 to 42 (45 to 57)
Fan Clutch-to-Fan Locknuts	C	5/16–18	13 to 16 (18 to 22)

Table 2, Cummins Fastener Torques

General Information

The Horton EC450 fan clutch is an electromagnetic on/off-style engine cooling fan clutch. See **Fig. 1**. The fan clutch is electrically operated, and is not connected to the vehicle's air system.



1. Clutch Mounting Bracket
2. Fan Mounting Studs

Fig. 1, Horton EC450 Electromagnetic Fan Clutch

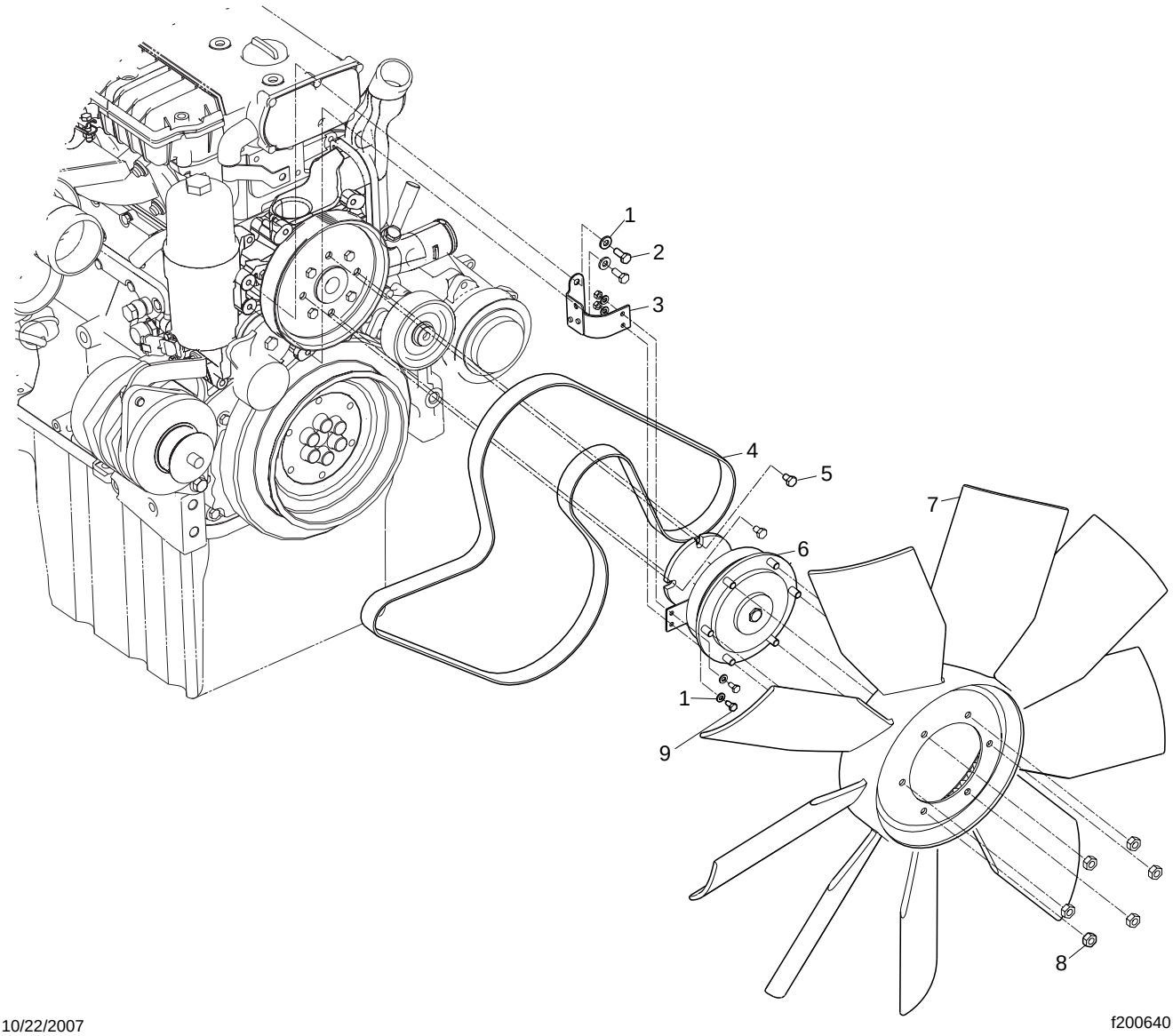
When vehicle motion (ram air effect) provides enough airflow through the radiator to keep engine coolant temperature within operating limits, the fan is disengaged by de-energizing the fan clutch. Disengaging the fan saves fuel, lowers power consumption and engine noise, and, for cold starts, allows the engine and the cab to warm up faster.

When the vehicle is stationary, or whenever extra air flow through the radiator is necessary, the fan clutch is engaged to connect the fan with the fan drive pulley and provide extra engine cooling. On most vehicles, this extra cooling is seldom needed; the clutch is deactivated and the fan is not turning 90 to 95 percent of the time.

Replacement

1. Shut down the engine, set the parking brake, and chock the rear tires.
2. Disconnect the battery ground cable at the vehicle frame, or if the vehicle is equipped with a battery shutoff switch, turn off the switch.
3. Open the hood.
4. Remove the fan clutch. See **Fig. 1**.
   - 4.1 Disconnect the fan clutch field coil connector.
   - 4.2 Remove the locknuts from the fan clutch studs.
   - 4.3 Remove the fan from the fan clutch.
   - 4.4 Remove the two capscrews, lockwashers, and hexnuts that hold the clutch-side clutch mounting bracket to the fan clutch.
   - 4.5 Remove the four capscrews that hold the fan clutch to the fan clutch adaptor or the fan hub.
   - 4.6 Remove the fan clutch from the vehicle.
5. Install the new fan clutch.
   - 5.1 Position the fan clutch on the fan clutch adaptor or the fan hub.
   - 5.2 Secure the fan clutch with four capscrews. Tighten the capscrews 19 lbf·ft (26 N·m).
   - 5.3 Secure the clutch-side clutch mounting bracket to the fan clutch with two capscrews. Use new split lockwashers, and tighten the capscrews 85 lbf·in (960 N·cm).
   - 5.4 Position the fan on the fan clutch, and secure it with new locknuts. Tighten the locknuts 16 lbf·ft (22 N·m).
   - 5.5 Connect the fan clutch field coil wiring to the engine wiring harness.
6. Test the fan clutch operation by running the engine until the coolant temperature is above 200°F (93°C). The fan clutch should engage.
7. Close and latch the hood.
8. Remove the chocks from the rear tires.

Fan Clutch Replacement

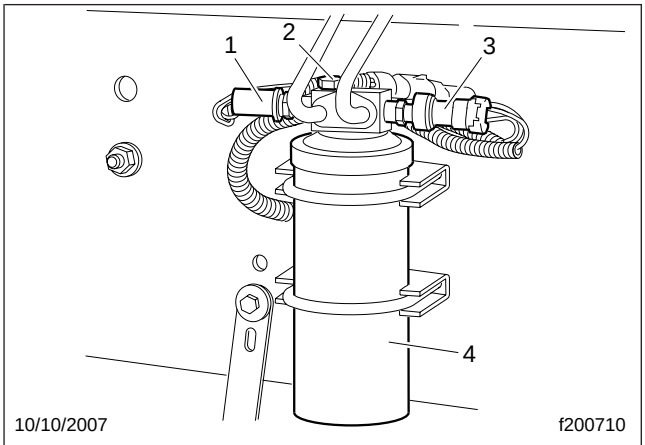


1. Washer
2. Bolt
3. Bracket
4. Belt
5. Capscrew
6. Fan Clutch
7. Fan
8. Locknut
9. Capscrew

Fig. 1, Fan Clutch Mounting, Mercedes-Benz MBE900 Engine

Replacement

1. Shut down 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. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

4. Remove the fan cycling switch.
5. Install a new fan cycling switch on the receiver-drier.
6. Connect the wiring harness to the fan cycling switch.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Removal

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the heater power supply by removing the 20-amp flat fuse (blue) from the Webasto fuse holder.
3. Disconnect the electrical connections from the heater. Disconnect the antenna cable to the Telestart receiver at the screw-type locking connector.

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

⚠ WARNING

Do not remove or loosen the radiator cap until the engine and cooling system have completely cooled. Use extreme care when removing the cap. A sudden release of pressure from removing the cap prior to the system cooling can result in a surge of scalding coolant that could cause serious personal injury.

4. Open the radiator cap to release any pressure, then close the cap.

NOTE: Collect the escaping coolant in a drain pan.

5. Loosen the hose clamps and disconnect the coolant hoses from the heater. Disconnect and plug the fuel line.
6. Loosen the heater from its mount and remove it.

Installation

1. Connect the fuel line to the heater and secure it with a clamp.
2. Connect the coolant hoses and secure them with spring band steel clamps.
3. Restore all electrical connections at the connector terminal.
4. Connect the antenna cable to the Telestart receiver.
5. Install the 20-amp flat fuse in the fuse holder.
6. Fill the engine cooling system with the heater valves closed.
7. If the heater circuit was drained, open only the supply valve and the heater circuit vent, near the return valve, to bleed air from the heaters without sending it through the engine. If the heater circuit was not drained, open both valves.
8. Turn the ignition ON and set the heater control to hot; do not start the engine. If so equipped, turn the heater circuit booster pump on.
9. Start the engine and maintain the coolant level in the surge tank, filling to the full mark as needed.
10. If bleeding air from the heaters, close the vent when coolant is present and open the return valve.
11. Continue running the engine until the thermostat opens, then shut down the engine.
12. Once the engine has cooled, top off the coolant to the full mark and reinstall the radiator cap.
13. Bleed the coolant circuit.
14. Bleed the fuel system as needed.

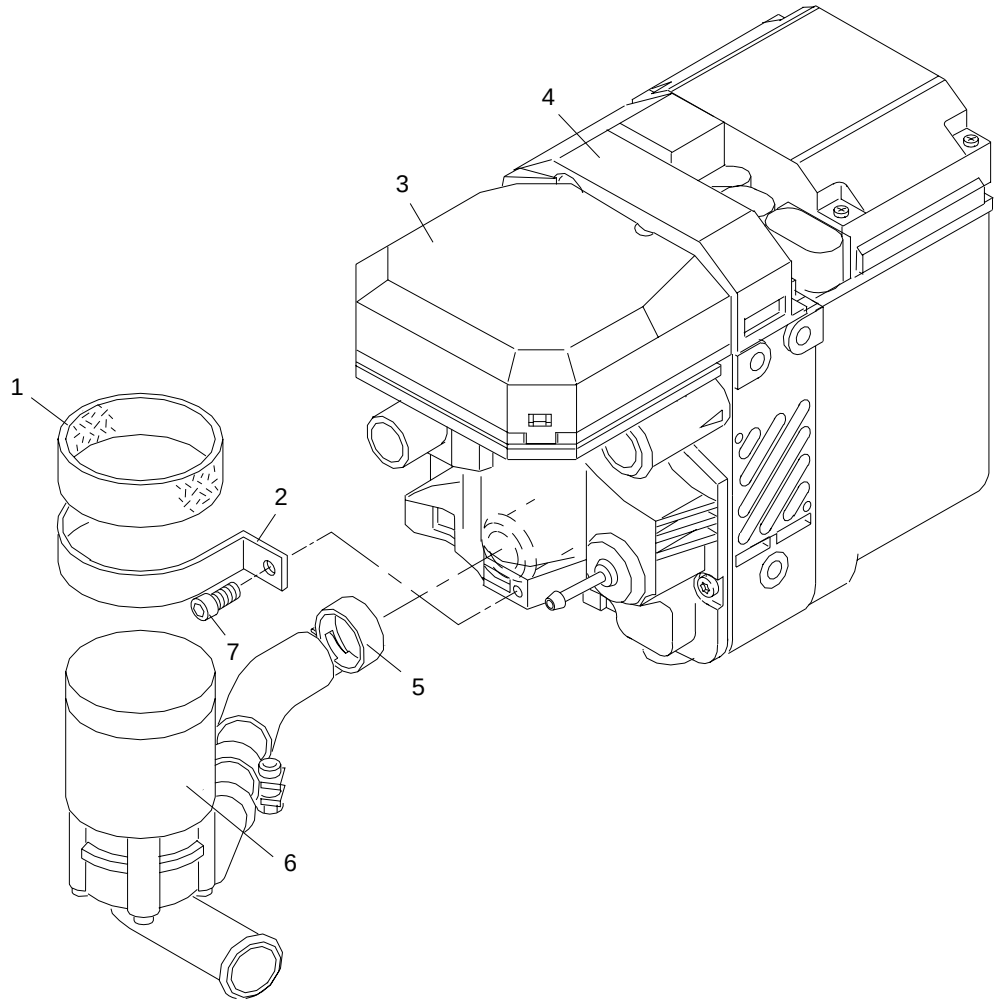
Circulation Pump (Thermo Top C) Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the cover and disconnect the electrical connector from the circulation pump. See **Fig. 1**.
3. Loosen the spring-band steel clamp.
4. Remove the screw and the clamp.
5. Take out the circulation pump and remove the spring-band steel clamp.
6. Remove the collar.

Installation

1. Slide the spring-band steel clamp onto the hose end. See **Fig. 1**.
2. Position the collar on the circulation pump.



1. Collar
2. Clamp
3. Combustion Air Fan
4. Cover
5. Spring-Band Steel Clamp
6. Circulation Pump
7. Screw

Fig. 1, Circulation Pump (Thermo Top C) Removal and Installation

Circulation Pump (Thermo Top C) Removal and Installation

3. Using the clamp and screw, install the circulation pump on the combustion air fan.
4. Position the spring-band steel clamp.
5. Tighten the screw 36 lbf·in (407 N·cm).
6. Connect the circulation pump electrical connection and install the cover.
7. Remove the chocks from the tires.

Combustion Air Fan Removal and Installation

Removal

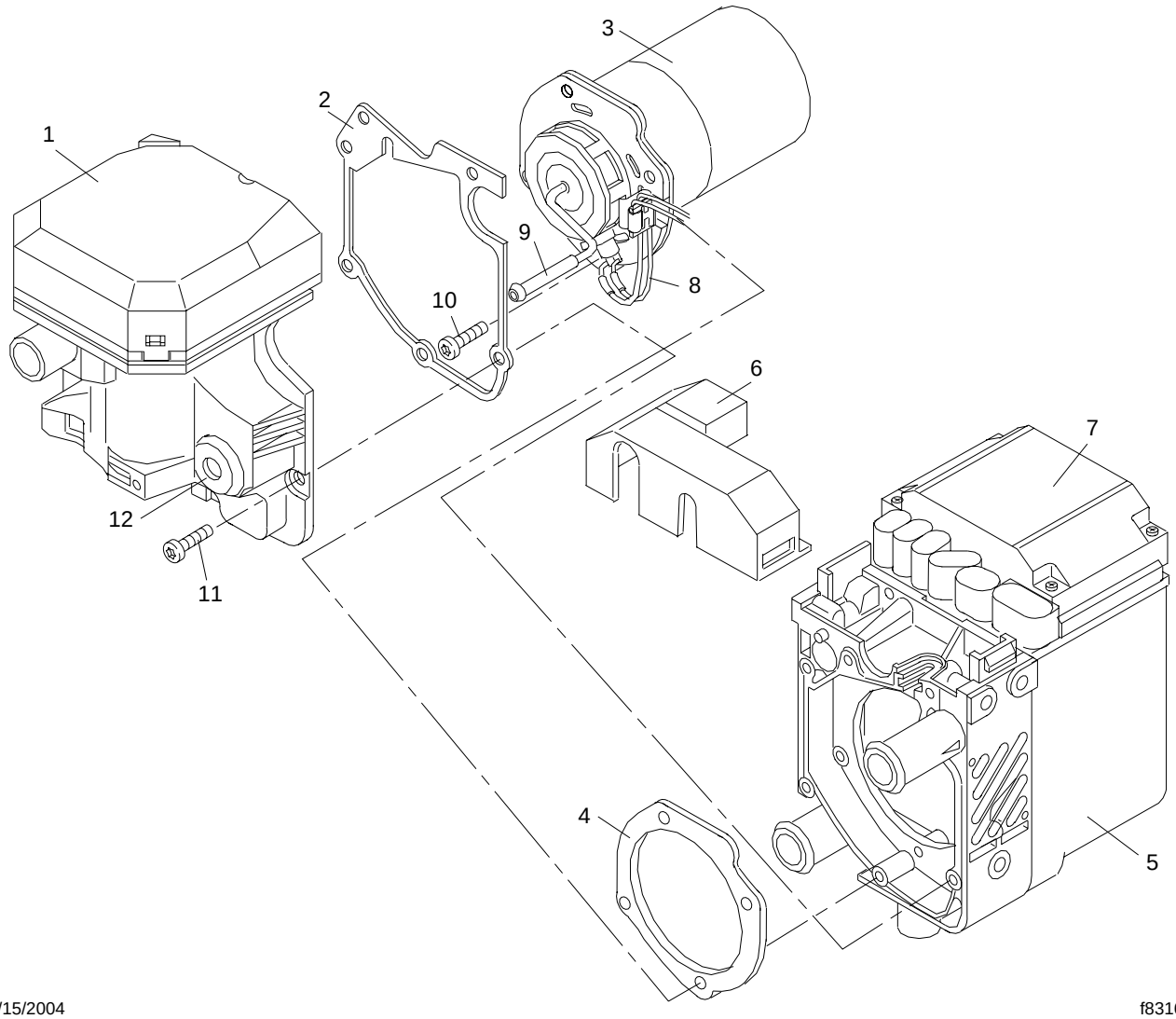
IMPORTANT: In the case of the Thermo Top C, the circulation pump must be removed first. See **Subject 110**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Carefully remove the cover. See **Fig. 1**.
3. Disconnect the electrical connector from the combustion air fan.
4. Remove the combustion air fan screws.
5. Remove the combustion air fan from the burner housing and the fuel pipe.
6. Discard the combustion air fan gasket.

Installation

1. Install a new gasket on the combustion air fan and position it on the burner housing. See **Fig. 1**.
2. Slide the combustion air fan onto the fuel pipe to bring the fan into installation position.
3. Secure the combustion air fan with the screws. Tighten the screws 36 lbf·in (407 N·cm).
4. Restore all electrical connections on the combustion air fan.
5. Install the circulation pump. See **Subject 110**.
6. Install the cover.
7. Remove the chocks from the tires.

Combustion Air Fan Removal and Installation



1. Combustion Air Fan
2. Gasket, Combustion Air Fan
3. Burner Insert
4. Gasket, Control-Unit/Heat-Exchanger
5. Burner Housing
6. Cover
7. Control-Unit/Heat-Exchanger
8. Glow-Plug/Flame-Sensor
9. Fuel Pipe
10. Screw, Combustion Air Fan
11. Screw, Combustion Air Fan
12. Gasket

Fig. 1, Heater Unit Assembly

Burner Insert with Glow-Plug/Flame-Sensor Removal and Installation

Removal

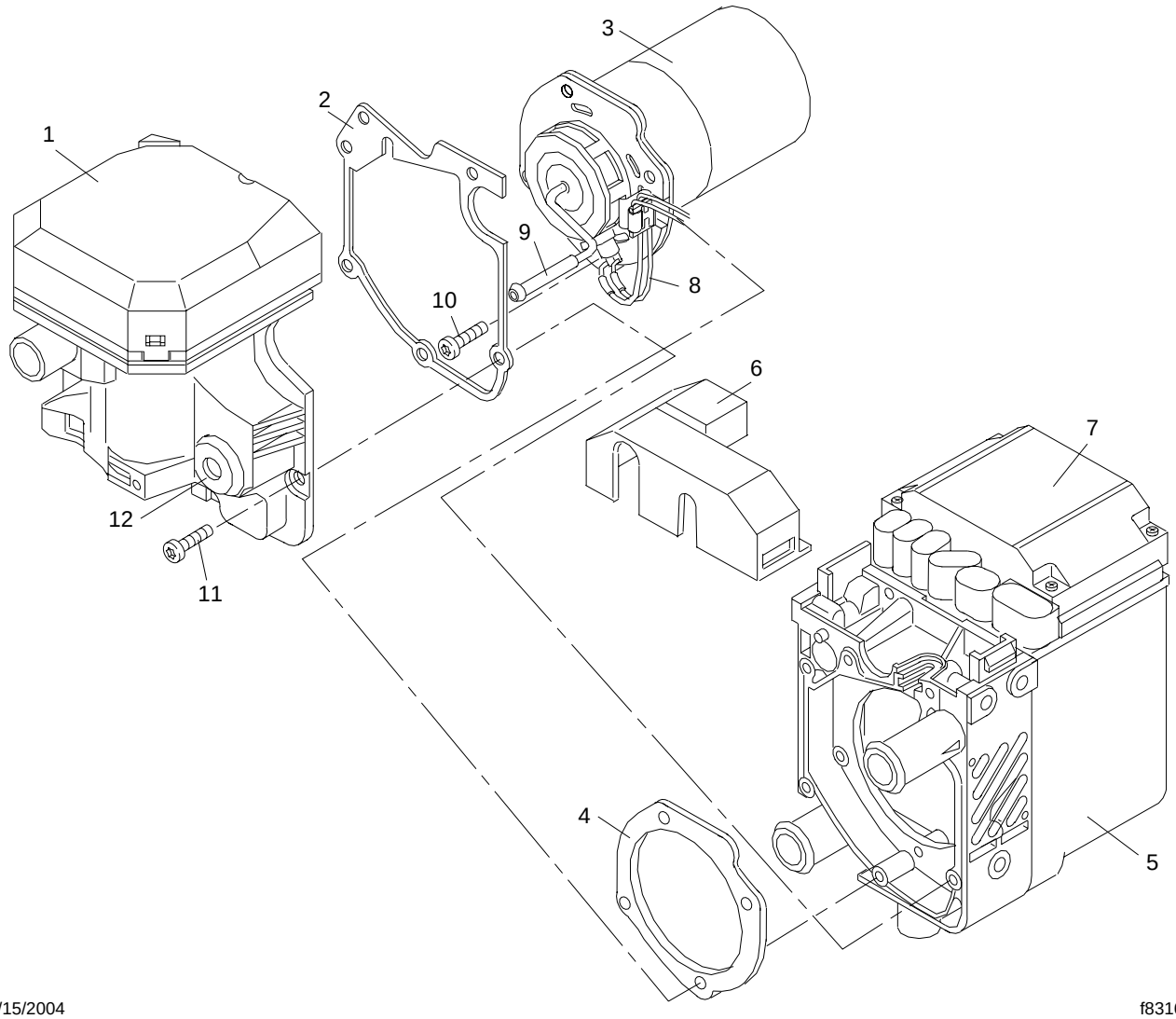
IMPORTANT: In the case of the Thermo Top C, the circulation pump must be removed first. See **Subject 110**.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the combustion air fan. See **Subject 120**.
3. Push the grommet of the glow-plug/flame-sensor cable out of the burner housing. See **Fig. 1**.
4. Remove the combustion air fan screws.
5. Remove the burner insert with the glow-plug/flame-sensor from the burner housing.
6. Discard the combustion air fan gasket.

Installation

1. Install a new gasket on the burner housing.
2. Install the burner insert, and tighten the screws 36 lbf·in (407 N·cm).
3. Press the grommet of the glow-plug/flame-sensor cable into the burner housing.
4. Install the combustion air fan. See **Subject 120**.
5. Install the circulation pump. See **Subject 110**.
6. Remove the chocks from the tires.

Burner Insert with Glow-Plug/Flame-Sensor Removal and Installation



1. Combustion Air Fan
2. Gasket, Combustion Air Fan
3. Burner Insert
4. Gasket, Control-Unit/Heat-Exchanger
5. Burner Housing
6. Cover
7. Control-Unit/Heat-Exchanger
8. Glow-Plug/Flame-Sensor
9. Fuel Pipe
10. Screw, Combustion Air Fan
11. Screw, Combustion Air Fan
12. Gasket

Fig. 1, Heater Unit Assembly

Control-Unit/Heat-Exchanger with Burner Housing Removal and Installation

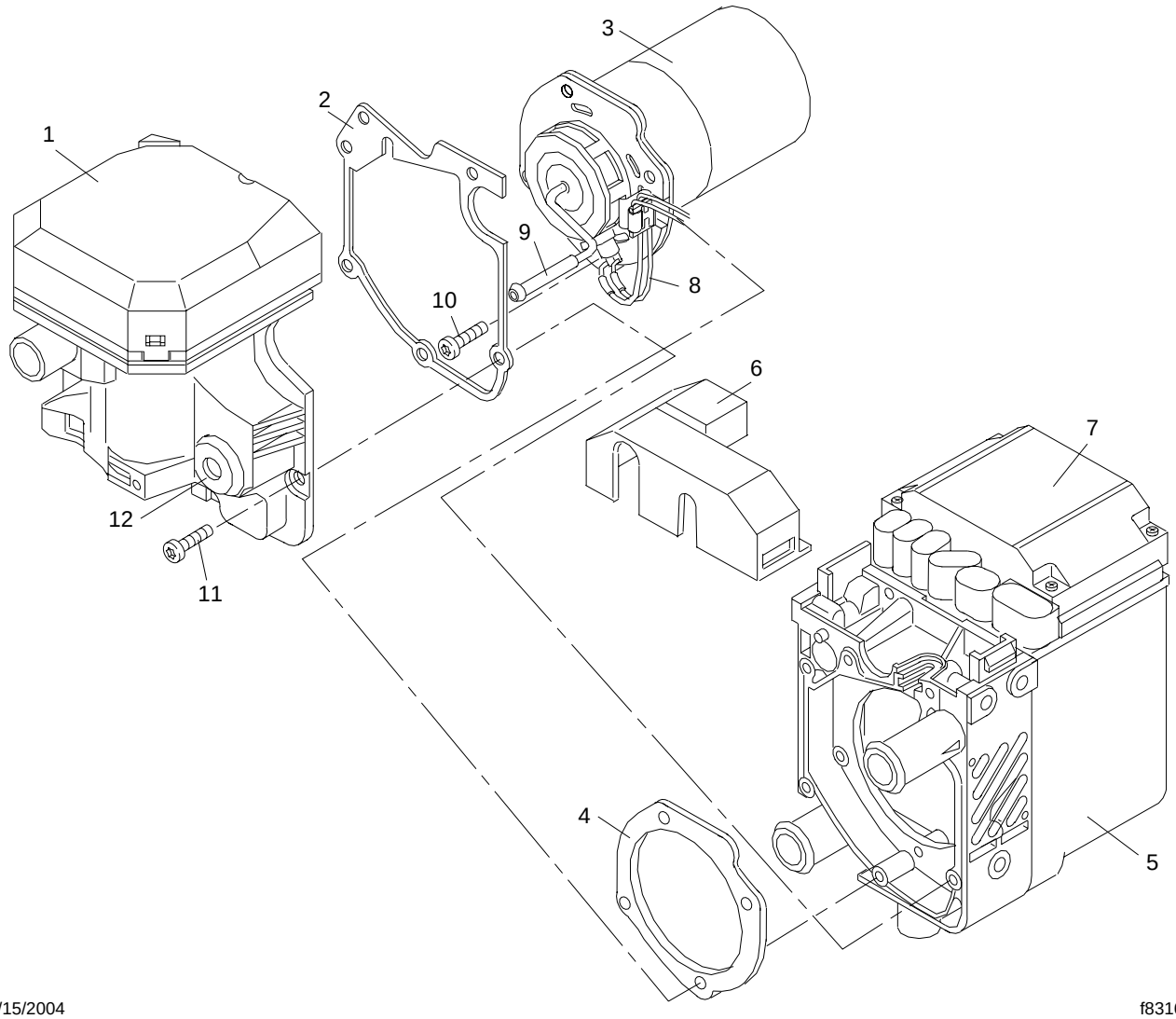
Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Push the grommet of the glow-plug/flame-sensor cable out of the burner housing. See **Fig. 1**.
3. Remove the combustion air fan screws.
4. Remove the control-unit/heat-exchanger.
5. Discard the control-unit/heat-exchanger gasket.

Installation

1. Install a new gasket on the burner housing.
2. Install the control-unit/heat-exchanger, and tighten the screws 36 lbf·in (407 N·cm).
3. Press the grommet of the glow-plug/flame-sensor cable into the burner housing.
4. Remove the chocks from the tires.

Control-Unit/Heat-Exchanger with Burner Housing Removal and Installation



1. Combustion Air Fan
2. Gasket, Combustion Air Fan
3. Burner Insert
4. Gasket, Control-Unit/Heat-Exchanger
5. Burner Housing
6. Cover
7. Control-Unit/Heat-Exchanger
8. Glow-Plug/Flame-Sensor
9. Fuel Pipe
10. Screw, Combustion Air Fan
11. Screw, Combustion Air Fan
12. Gasket

Fig. 1, Heater Unit Assembly

Problem—The Coolant Heater Switches Off Automatically

Problem—The Coolant Heater Switches Off Automatically	
Possible Cause	**Remedy**
There is no combustion after start or automatic repeat start.	Turn off the coolant heater momentarily and turn it on again. If three unsuccessful attempts to start the coolant heater are made, it will enter lockout mode. See "Heater-Lockout Reset Procedure" in this subject to correct this problem.
The flame extinguishes during operation.	Turn off the coolant heater momentarily and turn it on again.
The coolant heater over-heats.	Check the coolant heater lines for obstructions, closed valves, and kinks. Check the coolant level. Allow the coolant heater to cool down, reset the over heat limiter, turn the coolant heater off momentarily, then turn it on again. An over-heat condition may put the coolant heater in lockout. See "Heater-Lockout Reset Procedure" in this subject to correct the problem.
The vehicle electrical system voltage is too low.	Charge the battery. Turn off the coolant heater momentarily and turn it on again.

Problem—The Heater Expels Black Fumes from the Exhaust

Problem—The Heater Expels Black Fumes from the Exhaust	
Possible Cause	**Remedy**
The combustion air and/or the exhaust ducting are blocked.	Check the combustion and exhaust ducting for obstructions.

Heater-Lockout Reset Procedure

The Webasto coolant heater is designed with a lock-out safety feature built into the control unit. After three consecutive unsuccessful startup attempts, the heater will lock itself out from any further start attempts. The heater may also enter the lockout mode after experiencing an over-heat condition. If a lockout is suspected as a problem, use the steps below to clear the lockout mode and reset the heater for normal operation.

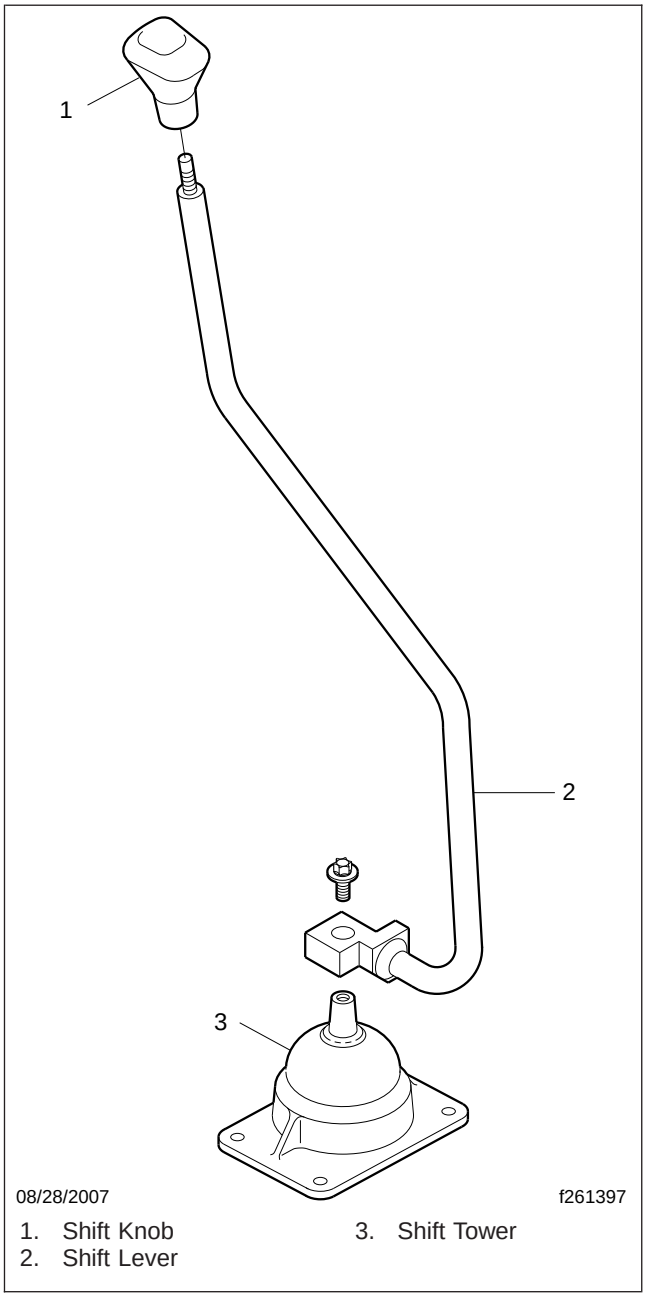
1. Remove main fuse F1, and wait 10 seconds before reinserting the fuse.
2. Insert fuse F1, and wait another 10 seconds before turning the heater on, using the On/Off switch or the "instant on" button of the optional timer, if so equipped.
3. Wait 10 seconds after turning the heater on, then remove fuse F1 again.
4. Wait 30 seconds, then turn the heater off using the On/Off switch or the optional timer, if so equipped.
5. After waiting 3 to 10 seconds after shutting off the heater, reinsert fuse F1.
6. Wait 10 seconds, then turn the heater on again.

   The lockout mode should be cancelled, and the heater should operate normally.

Eaton® Fuller® Transmission Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the rear tires.
2. From inside the cab, remove the shift lever and shift tower from the transmission top cover, as follows. See **Fig. 1**.
   - 2.1 Before removing the shift lever, place the transmission in high gear.
   - 2.2 If installed, disconnect any electrical connector(s) on the shift lever.
   - 2.3 Remove the four 3/8–16 shift tower mounting capscrews from the shift tower. Remove the shift tower and shift lever from the transmission top cover. See **Fig. 2**.
3. If necessary to replace the shift lever or components of the shift linkage, disassemble the shift linkage, as follows. Remove the M10 shift linkage flange screw that attaches the shift lever to the shift tower.
4. From underneath the vehicle, disconnect the driveshaft from the transmission, as follows.
   - 4.1 Support the midship bearing.
   - 4.2 Remove the midship bearing bracket. See **Fig. 3**.
   - 4.3 Remove the bolts from the U-joint end caps and slide the front of the driveshaft out of the transmission output yoke. See **Fig. 4**.
   - 4.4 Support the disconnected driveshaft and chain it out of the way. See **Fig. 5**.
5. Drain the transmission fluid. See **Fig. 6** for the location of the drain plug.
6. Remove the transmission temperature sensor and fitting from the transmission top cover.
7. Remove the fuel lines and the fuel line standoff bracket from the transmission. See **Fig. 7**.
8. Unplug the electrical connector on the speedometer sensor. Disconnect any other sensors (neutral start switch, back-up switch, etc.), if installed.



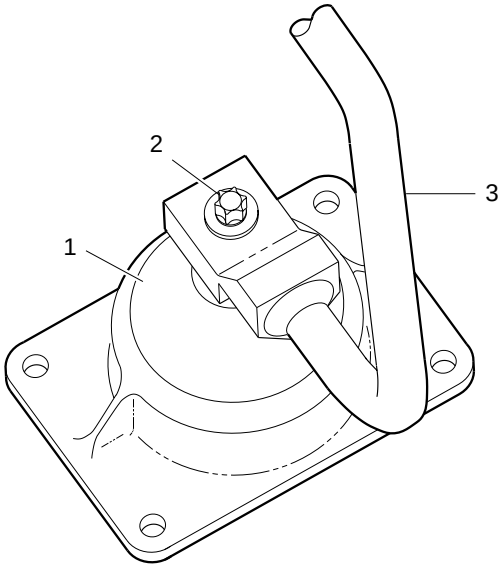
1. Shift Knob
2. Shift Lever
3. Shift Tower

Fig. 1, Shift Lever Connection

⚠ WARNING

Do not press down on the clutch pedal after removing the slave cylinder. Clutch hydraulic fluid (DOT 4 brake fluid) may squirt out, causing personal injury and damage to the vehicle.

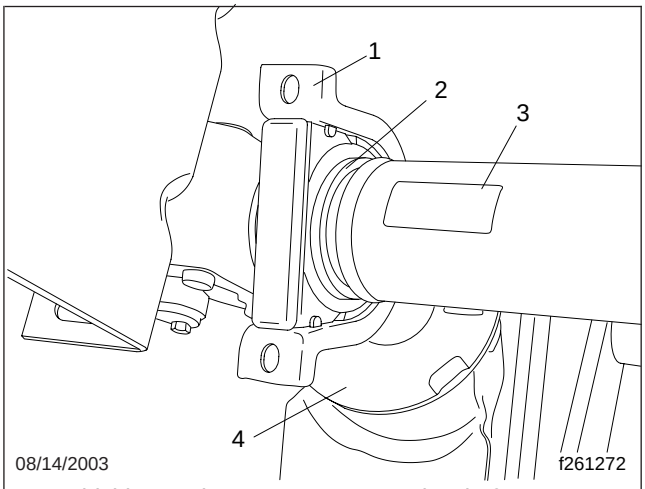
Eaton® Fuller® Transmission Removal and Installation



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1. Shift Tower
2. Shift Linkage Flange Screw, M10
3. Shift Lever

Fig. 2, Shift Linkage Connection

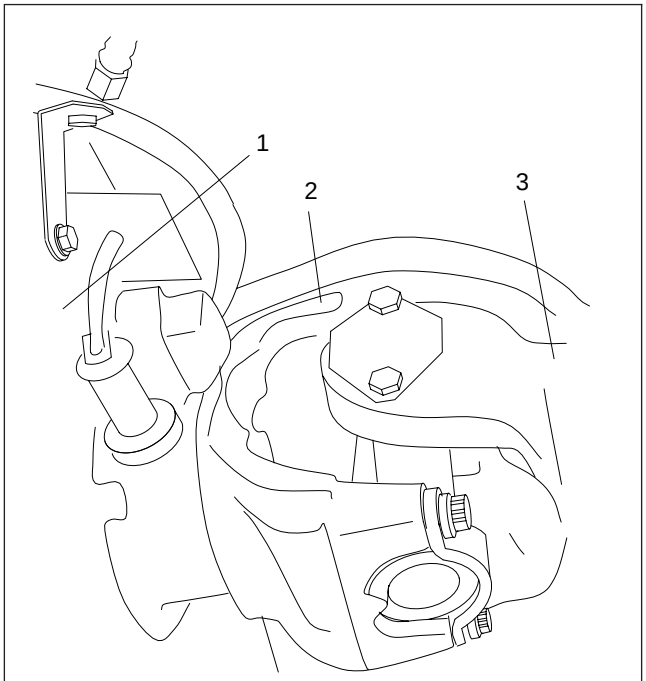


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1. Midship Bracket
2. Midship Bearing
3. Driveshaft
4. Jack

Fig. 3, Midship Bearing Bracket

9. Remove the bolts that attach the clutch slave cylinder to the mounting flange on the bell housing. Move the slave cylinder out of the way. See **Fig. 8**.



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1. Transmission
2. Output Yoke
3. Driveline

Fig. 4, Output Yoke

10. Remove the battery cable bracket(s) around the transmission and move the battery cables out of the way. See **Fig. 9**.
11. Remove the exhaust pipe hanger bracket from the gear case. See **Fig. 10**.
12. Support the transmission with a jack, as follows. See **Fig. 11**.
    - 12.1 Except for the top two, remove all the bolts that attach the transmission bell housing to the engine flywheel housing.
    - 12.2 Position a transmission jack under the transmission and raise its support plates against the base of the transmission.
    - 12.3 Adjust the support plates to cradle the transmission.
    - 12.4 Using a chain, secure the transmission to the jack.
    - 12.5 Remove the last two bolts that attach the bell housing to the flywheel housing.

Eaton® Fuller® Transmission Removal and Installation

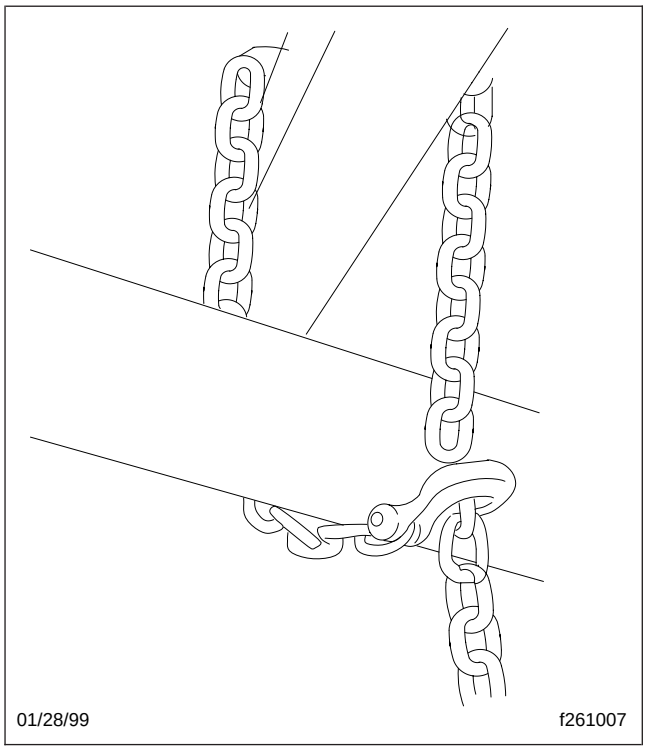


Fig. 5, Driveline Supported with a Chain

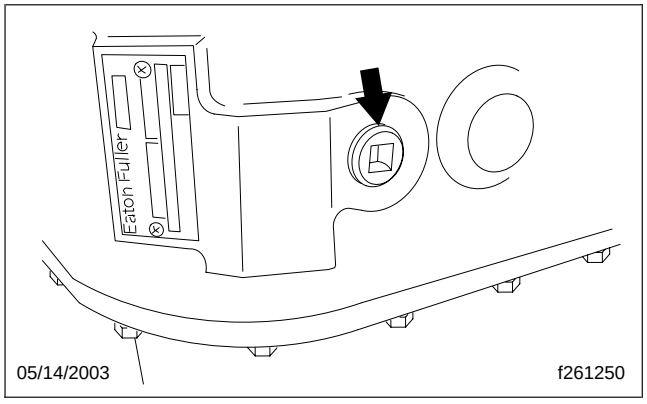
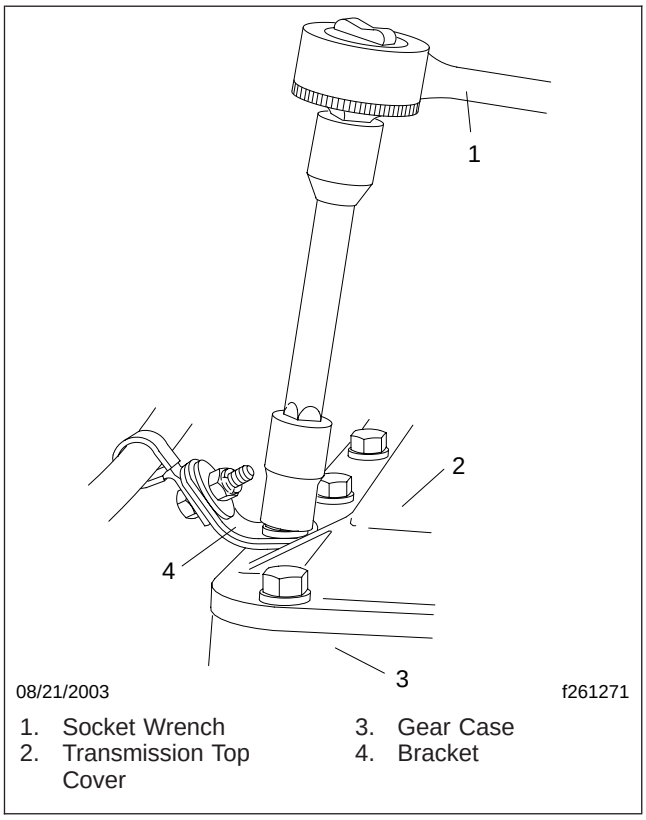


Fig. 6, Transmission Drain Plug

NOTICE

Do not allow the rear of the transmission to drop, and do not allow the transmission to hang unsupported. Keep the flange of the bell housing parallel (all the way around) to the flange of the flywheel housing until the input shaft is clear of the flywheel. Taking these precautions will prevent damage to the input shaft, flywheel, and clutch.



1. Socket Wrench
2. Transmission Top Cover
3. Gear Case
4. Bracket

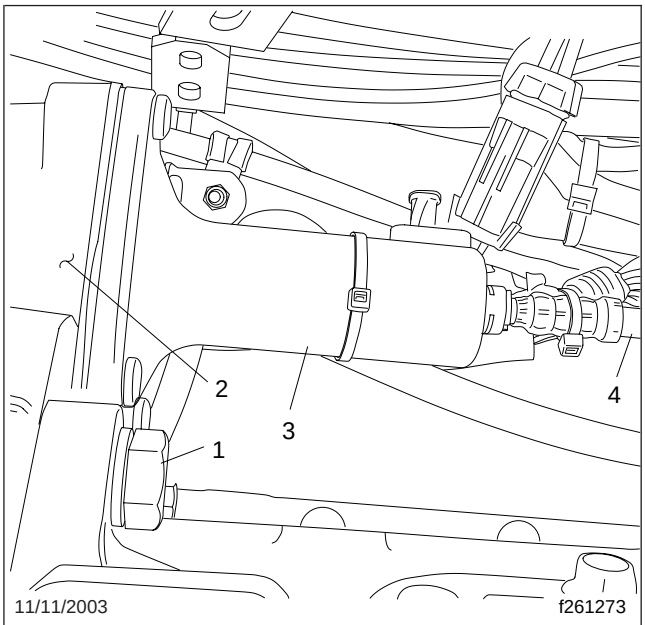
Fig. 7, Fuel Line Standoff Bracket

13. Remove the transmission, as follows. See **Fig. 12**.
    - 13.1 Pull the transmission and jack straight back until the transmission input shaft is clear of the clutch.
    - 13.2 Pull the transmission away from the vehicle. If there is not enough clearance to allow it to go straight out the back, use the space behind the front wheel on the driver's side.

Installation

IMPORTANT: Before installing the transmission, make sure that the rear tires are chocked and that the transmission is securely chained to the support plates on the transmission jack.

Eaton® Fuller® Transmission Removal and Installation

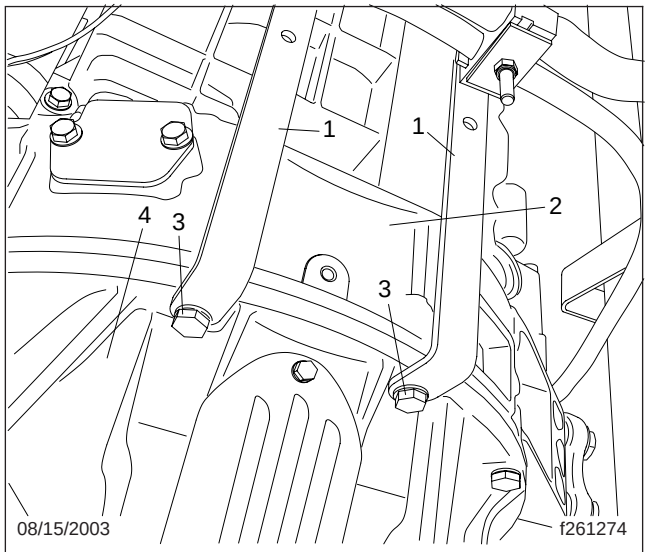


1. Capscrew
2. Bell Housing
3. Slave Cylinder
4. Hydraulic Line

Fig. 8, Hydraulic Clutch Slave Cylinder

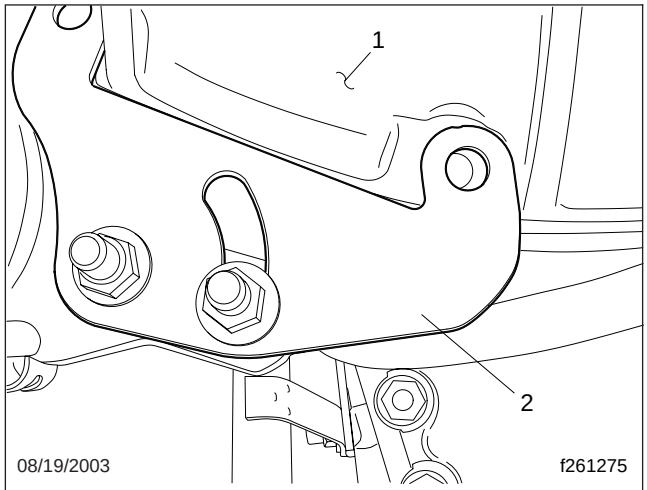
1. Install the transmission, as follows. See **Fig. 13**.
   - 1.1 Align the jack and the transmission behind the engine. Make sure the fingers of the release yoke are rotated to clear the release bearing housing.
   - 1.2 Coat the splines of the input shaft with antiseize compound.
   - 1.3 Raise the transmission and adjust the angle of the jack until the bell housing and the flange of the flywheel housing are parallel.
   - 1.4 Push the transmission and jack straight forward.
   - 1.5 Through the inspection opening in the bell housing, make sure the fingers of the release yoke are inserted into the ear (curved protrusion) on the release bearing housing. See **Fig. 14**.

   NOTE: Before installing the bolts, coat the threads of each bolt with Loctite 262 (or equivalent thread-locking compound).



1. Battery Cable Bracket
2. Engine Flywheel Housing
3. Bell Housing-to-Flywheel Housing Bolt
4. Bell Housing

Fig. 9, Battery Cable Brackets

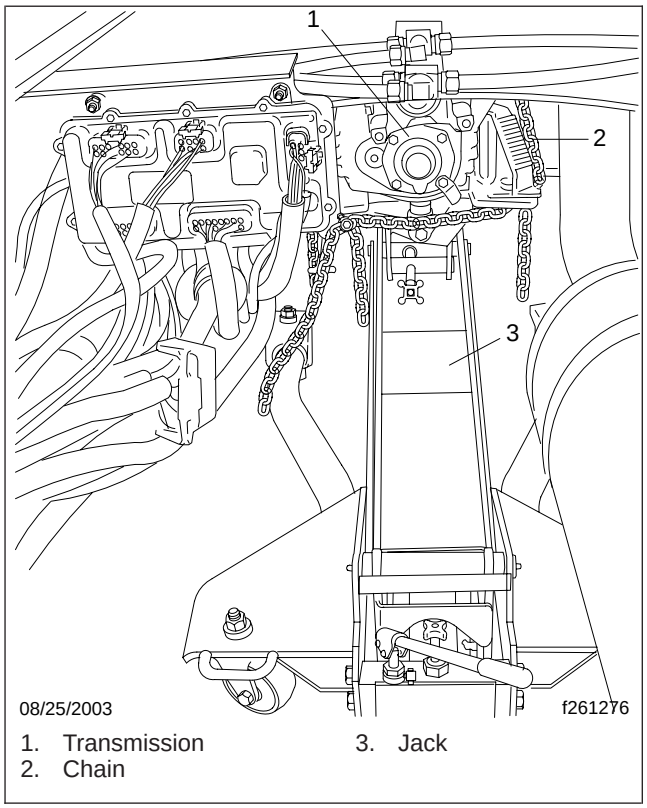


1. Gear Case
2. Hanger Bracket

Fig. 10, Exhaust Pipe Hanger Bracket

   - 1.6 Install the bolts that hold the bell housing to the flywheel housing. Use a crossover pattern. Do a final tightening of the bolts to 33 lbf·ft (45 N·m).

Eaton® Fuller® Transmission Removal and Installation



1. Transmission
2. Chain
3. Jack

Fig. 11, Supporting the Transmission

1.7 While installing the bell housing-to-flywheel housing bolts, also install the battery cable brackets, as removed.

1.8 Remove the chain that's securing the transmission to the jack; then remove the jack.

2. Install the fuel line standoff bracket and connect the fuel lines to the bracket.
3. Connect the electrical connectors. Connect the electrical cable to the speedometer sensor.
4. If necessary, assemble the shift linkage, as follows. Attach the shift lever to the shift tower. Tighten the M10 shift linkage flange screw 25 lbf·ft (34 N·m). See **Fig. 1**.
5. From inside the cab, install the shift tower and shift lever, as removed, on the transmission top cover, as follows. See **Fig. 2**.

5.1 If removed, connect any electrical connectors to the shift lever.

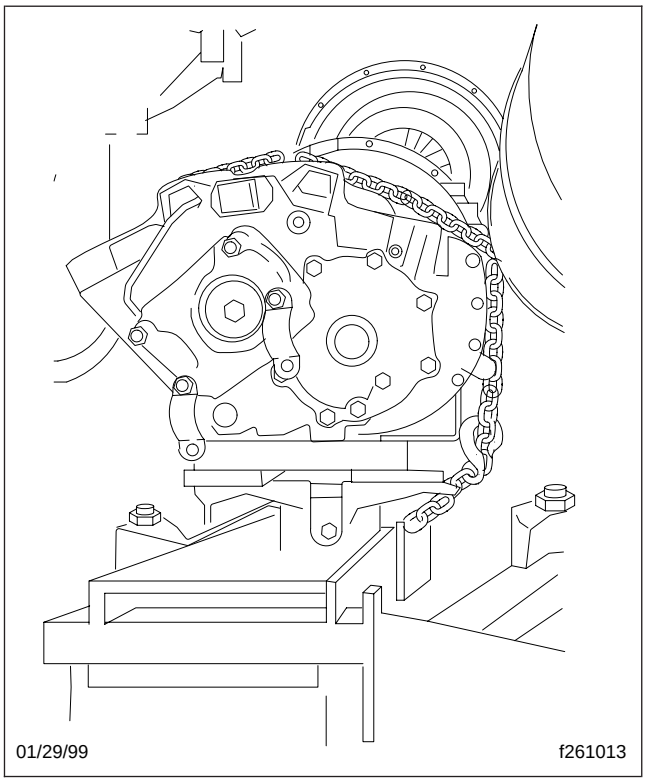


Fig. 12, Transmission Removal

5.2 Check the position of the shift lever to be sure it is still positioned in high gear, as removed, and that the gears shift normally.

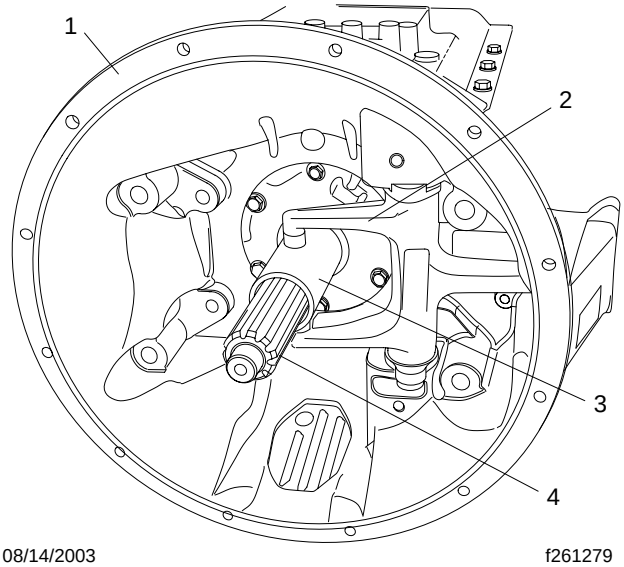
5.3 Tighten the four 3/8–16 shift tower mounting capscrews 30 to 35 lbf·ft (40 to 47 N·m).

6. From underneath the vehicle, fasten the clutch slave cylinder, with the plunger fully extended to contact the release yoke, to the mounting flange on the bell housing. Make sure the tab on the spacer points inboard as shown in **Fig. 15**. Tighten the four mounting bolts 15 lbf·ft (20 N·m).
7. If necessary, bleed the hydraulic clutch system.
8. Connect the driveshaft, as follows.

8.1 Slide the front of the driveshaft into the transmission output yoke.

8.2 Install the U-joint end caps on the output yoke. Tighten the bolts 50 lbf·ft (68 N·m) for 3/8-inch end cap bolts and 110 lbf·ft (149 N·m) for 1/2-inch end cap bolts.

Eaton® Fuller® Transmission Removal and Installation



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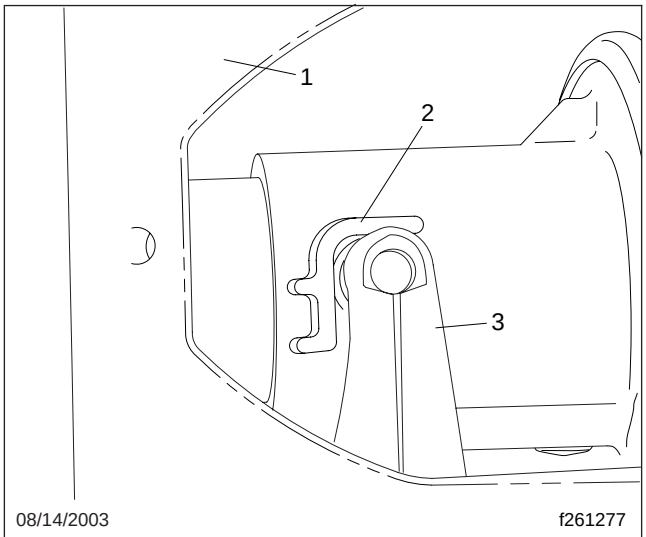
Make sure the fingers of the release yoke are rotated to clear the release bearing.

1. Bell Housing
2. Release Yoke
3. Input Shaft
4. Input Shaft Splines

Fig. 13, Transmission Input Shaft and Release Yoke

8.3 Install the bolts and nuts on the midship bearing bracket. Tighten the nuts 95 lbf·ft (129 N·m).

9. Clean the transmission drain plug and install it on the transmission, along with a new aluminum gasket. Tighten the drain plug 50 lbf·ft (68 N·m).
10. Add transmission fluid until it is level with the lower edge of the fill opening. See **Fig. 16** for the correct level. See **Group 26** of the *S2 Chassis Maintenance Manual* for approved transmission lubricants and lubricant capacities.
11. Clean the transmission fill plug and install it on the transmission, along with a new aluminum gasket. Tighten the plug as follows:
    - 25 to 35 lbf·ft (34 to 48 N·m) for Eaton Fuller transmissions with 3/4-inch pipe threads.
    - 60 to 75 lbf·ft (81 to 102 N·m) for Eaton Fuller transmissions with 1-1/4-inch pipe threads.
12. Remove the chocks from the rear tires.

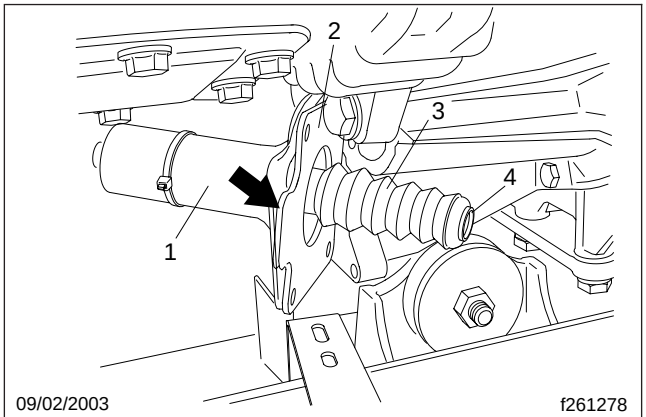


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The finger of the release yoke must fit as shown into the ear of the release bearing housing.

1. Bell Housing
2. Ear of Release Bearing Housing
3. Finger of Release Yoke

Fig. 14, Release Yoke Alignment



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The tab on the spacer must face inboard.

1. Slave Cylinder
2. Spacer
3. Boot
4. Plunger (inside boot)

Fig. 15, Slave Cylinder Installation

Eaton® Fuller® Transmission Removal and Installation

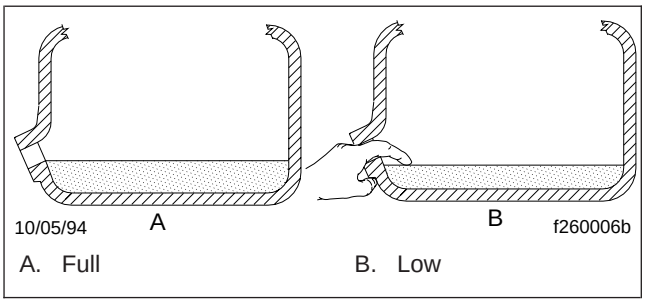


Fig. 16, Transmission Fluid Level Checking

Specifications

Torque Values, Eaton® Fuller® Transmissions			
Description	**Size**	**Class**	**Torque: lbf·ft (N·m)**
Bell Housing-to-Timing Case Capscrews	M10 x 1.5	8.8	33 (45)
Clutch Slave Cylinder Bracket Mounting Bolts	M8	8.8	15 (20)
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)
Shift Linkage Flange Screws	M10 x 1.5	8.8	25 (34)
Shift Tower Mounting Capscrews	3/8–16	—	30–35 (40–47)
Transmission Fluid Drain Plug	—	—	50 (68)
Transmission Fluid Fill Plug (with 3/4-inch pipe fittings)	—	—	25–35 (34–47)
Transmission Fluid Fill Plug (with 1-1/4-inch pipe fittings)	—	—	60–75 (81–102)
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 1, Torque Values, Eaton® Fuller® Transmissions

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the rear tires.
2. Disconnect the batteries and place the transmission in neutral.
3. Remove the transmission drain plug from the bottom of the transmission and drain the automatic transmission fluid (ATF) into a suitable clean container. See **Fig. 1**. Install the drain plug and tighten to the following specifications based on the model:

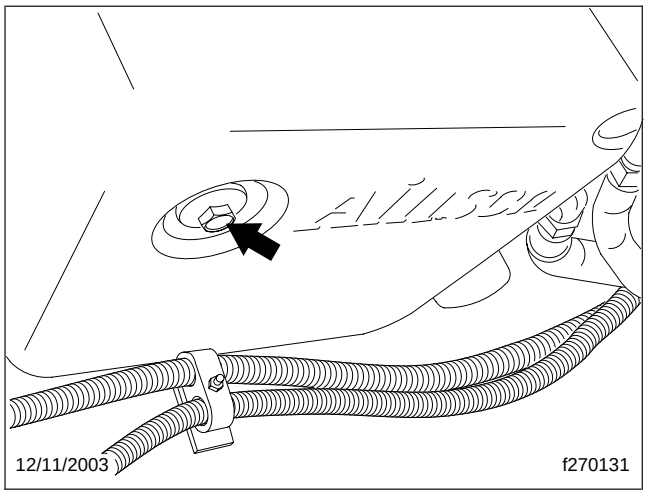


Fig. 1, Drain Plug

- Models 2100/2200/2500: 22 to 30 lbf·ft (30 to 40 N·m)
- Model 3000: 18 to 24 lbf·ft (25 to 32 N·m)

NOTE: The ATF drained from the transmission can be used again if it is clean and if the container into which it was drained contained no ethylene glycol.

4. Support the driveline with a jack stand between the aft midship bearing and the rear axle.
5. Disconnect the driveline from the transmission, as follows.
   - 5.1 Remove the bolts that hold the aft midship bearing bracket. See **Fig. 2**.
   - 5.2 Remove the front driveline guard. See **Fig. 3**.

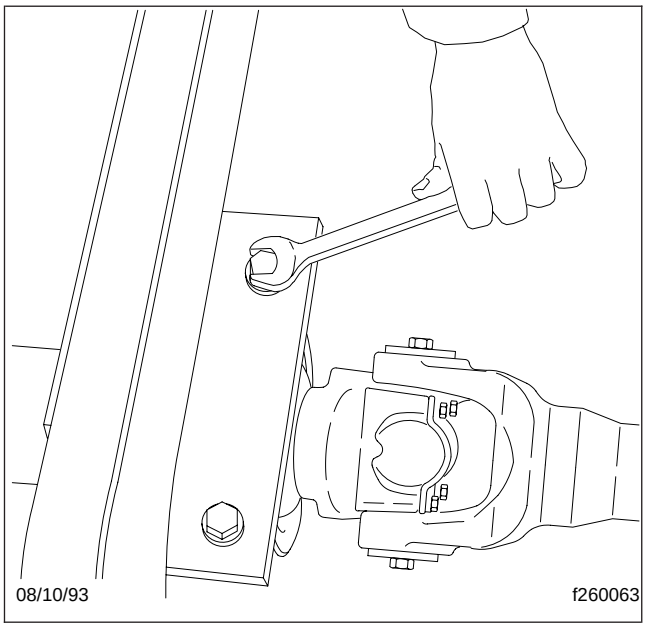
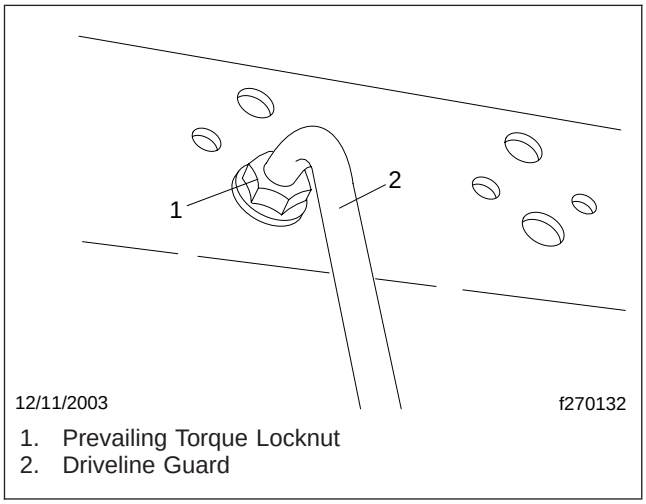


Fig. 2, Midship Bearing Fastener

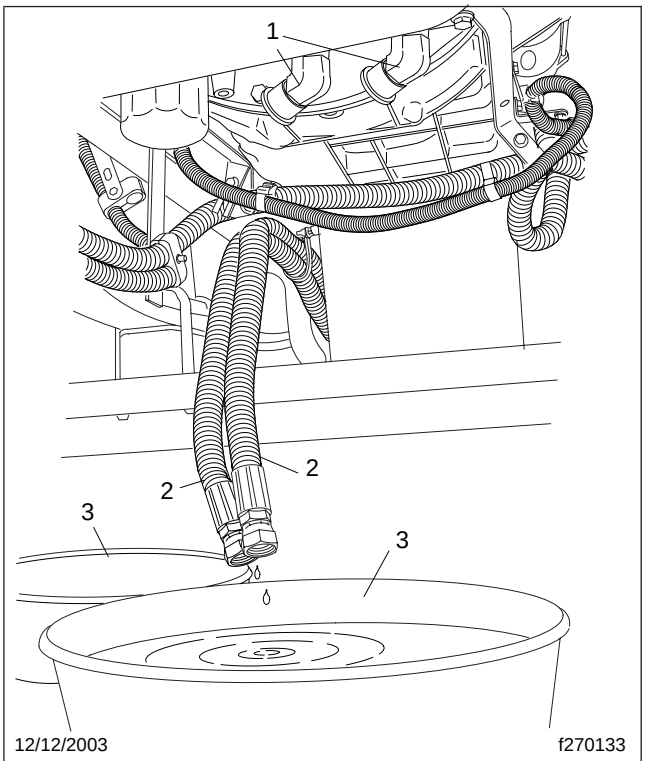


1. Prevailing Torque Locknut
2. Driveline Guard

Fig. 3, Driveline Guard

   - 5.3 Remove the forward midship bracket.
   - 5.4 Remove the transmission yoke U-joint from the transmission.
   - 5.5 Support the disconnected driveshaft.
6. Disconnect the transmission fluid cooler lines from the transmission and drain the remaining ATF into a suitable container. See **Fig. 4**. Cap the fittings to prevent entry of foreign matter.

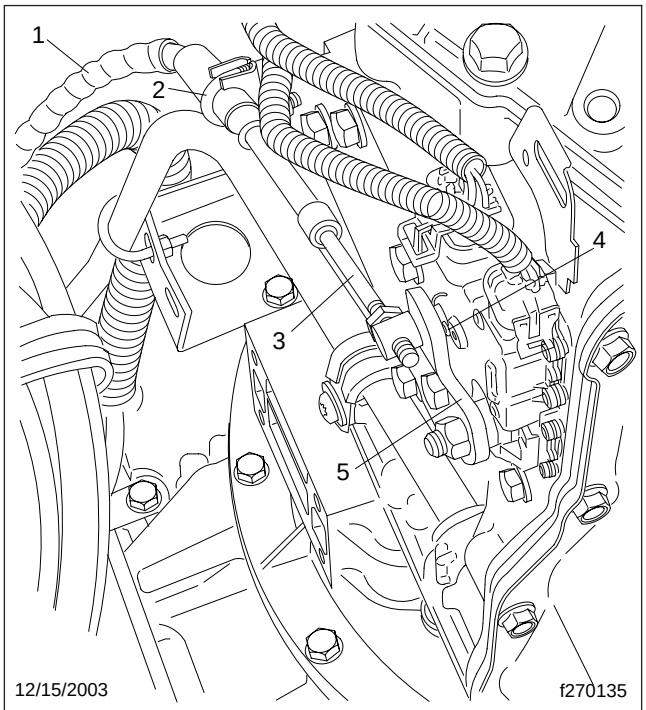
Removal and Installation



1. ATF Fluid Fitting
2. ATF Fluid Line
3. Container

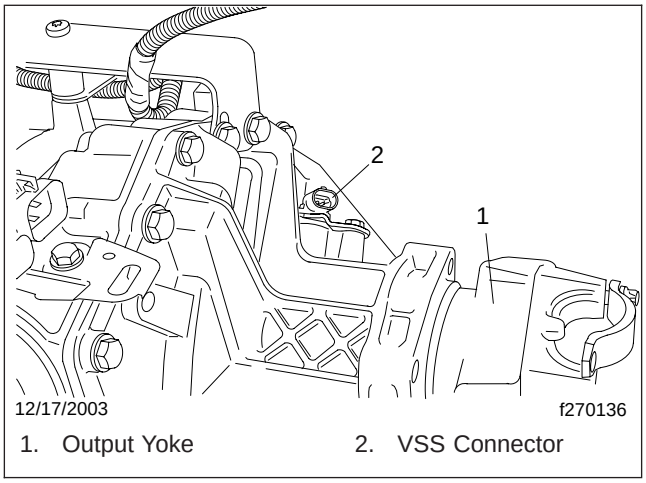
Fig. 4, Fluid Cooler Lines

7. Disconnect the shift cable from the transmission. See **Fig. 5**. For detailed instructions, see **Subject 110**.
8. Disconnect the electrical harnesses from the transmission, as follows.
   - 8.1 Disconnect the speedometer sensor cable from the small vehicle speed sensor (VSS) connector near the output yoke. See **Fig. 6**.
   - 8.2 Disconnect the cannon plug on the right-hand side of the gear box just above the oil pan. See **Fig. 7**.
   - 8.3 Disconnect the double shift/back-up connector on the left-hand side of the gear box next to the shift link. See **Fig. 8**.
   - 8.4 On 2100/2200/2500 models, disconnect the transmission harness from the transmission control unit (TCU) mounted on the frame rail. See **Fig. 9**.



1. Shift Cable
2. U-Bolt
3. Shift Rod
4. Cotter Pin
5. Shift Link

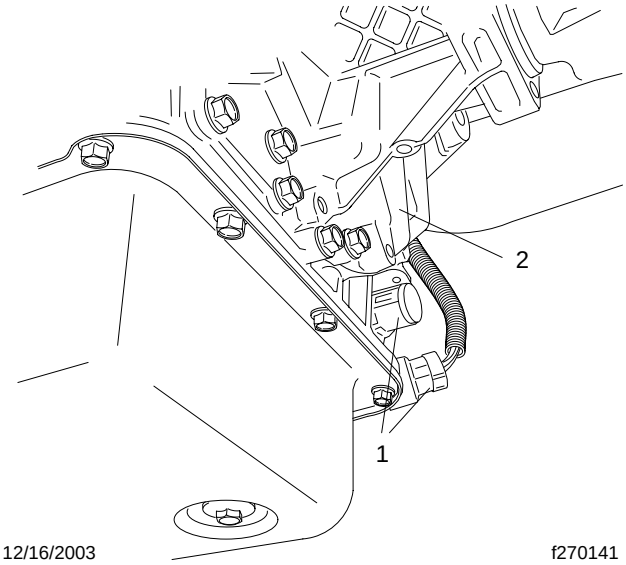
Fig. 5, Shift Cable Connection



1. Output Yoke
2. VSS Connector

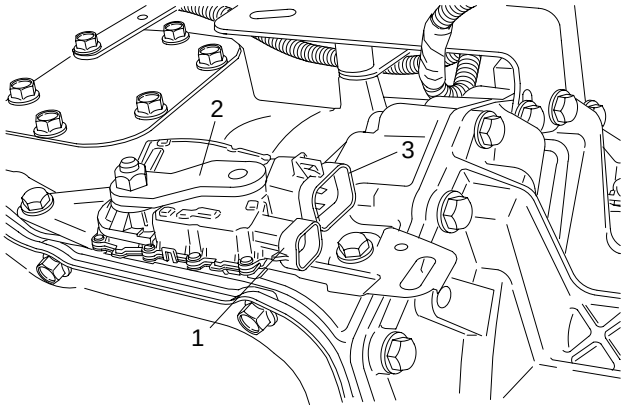
Fig. 6, VSS Connector

On the 3000 model, disconnect the three-piece TCU connector from the transmission control unit (TCU) on top of the gear box.



1. Cannon Plug and Connector
2. Rear of Gear Box

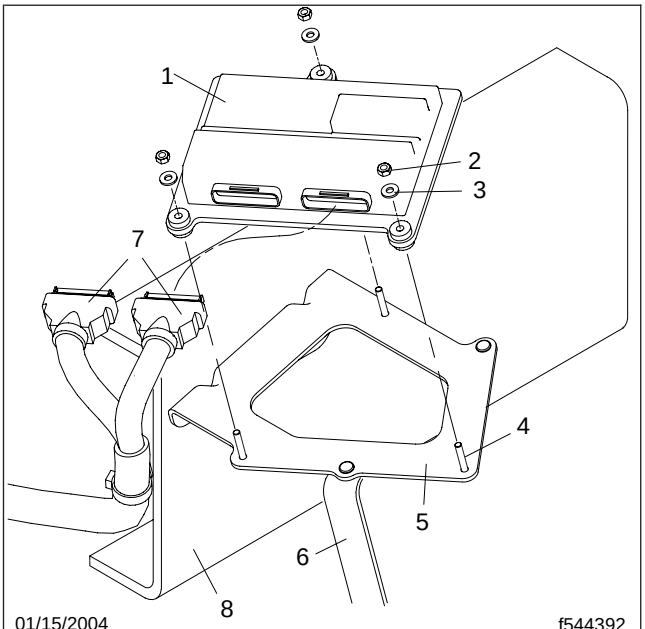
Fig. 7, Cannon Plug



1. Small Connector
2. Shift Link
3. Large Connector

Fig. 8, Shift/Backup Connectors

9. Remove the ATF fill/dipstick tube, as follows. See **Fig. 10**.
   - 9.1 Remove the mounting screw and cushioned clamp that holds the fill/dipstick tube.



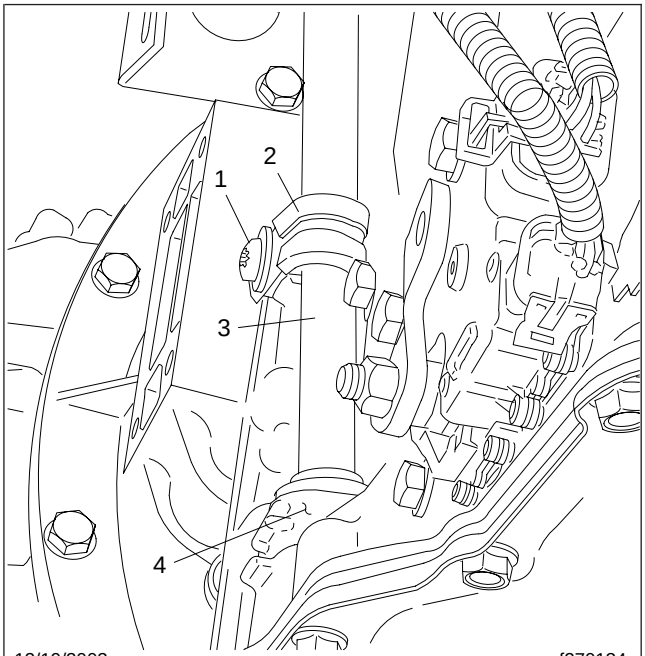
1. Transmission Control Unit
2. Nut, 1/4–20
3. Washer, 1/4-inch
4. Stud
5. Bracket
6. Brace
7. Harness Connectors
8. Frame Rail

Fig. 9, Transmission Control Unit

   - 9.2 Remove the U-bolt that secures the fill/dipstick tube to the clamp bolted onto the bell housing.
   - 9.3 Pull the fill/dipstick tube out of the transmission case.
   - 9.4 To prevent entry of foreign material, use a clean shop towel to plug the hole where the dipstick mounts.

10. Remove the capscrews that attach the flexplate to the flywheel ring gear, as follows. See **Fig. 11**.
    - 10.1 Remove the capscrews that attach the ring gear inspection cover. Then remove the cover from the timing case (flywheel housing).
    - 10.2 Using a screwdriver, turn the ring gear until one of the capscrews that attach the flexplate adaptor to the torque converter can be removed through the flexplate access hole.

Removal and Installation



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1. Clamp Mounting Screw
2. Cushioned Clamp
3. Fill/Dipstick Tube
4. Dipstick Mount

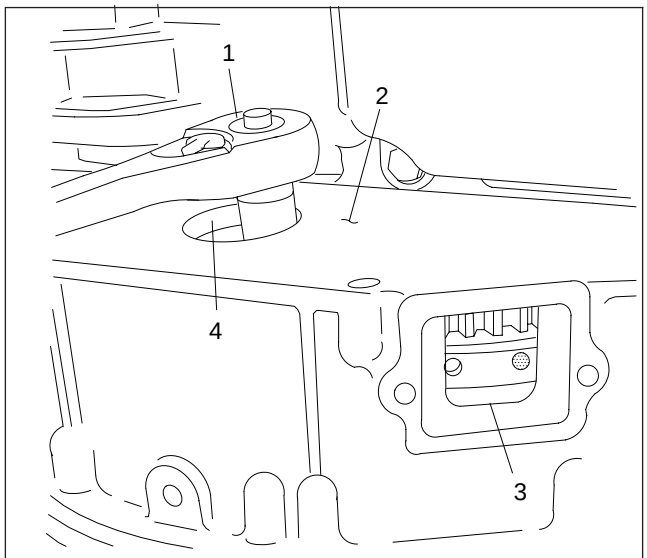
Fig. 10, Fill/Dipstick Tube

10.3 For ease of installation, mark the ring gear with a paint pen at each point where a capscrew is removed.

10.4 Continue turning the ring gear and removing the capscrews through the access hole until all are removed.

NOTE: There are 6 capscrews on 2100/2200/2500 models, and 12 on the 3000 model.

11. Slide the jack into place under the transmission. Protect the oil pan with the jack support brackets. See **Fig. 12**. Secure the transmission with a chain. Anchor the chain with bolts at the front lifting bosses on the top of the transmission.
12. Remove the 12 transmission mounting bolts. See **Fig. 13**.
13. Remove the battery cable bracket and the fill/dipstick tube clamp, which are both supported by one of the transmission mounting bolts.



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Mark the ring gear with a paint pen at each point where a capscrew is removed.

1. Wrench
2. Timing Case
3. Inspection Hole
4. Access Hole

Fig. 11, Ring Gear Access

14. Remove the muffler support bracket, which is supported by two of the transmission mounting bolts. See **Fig. 14**.

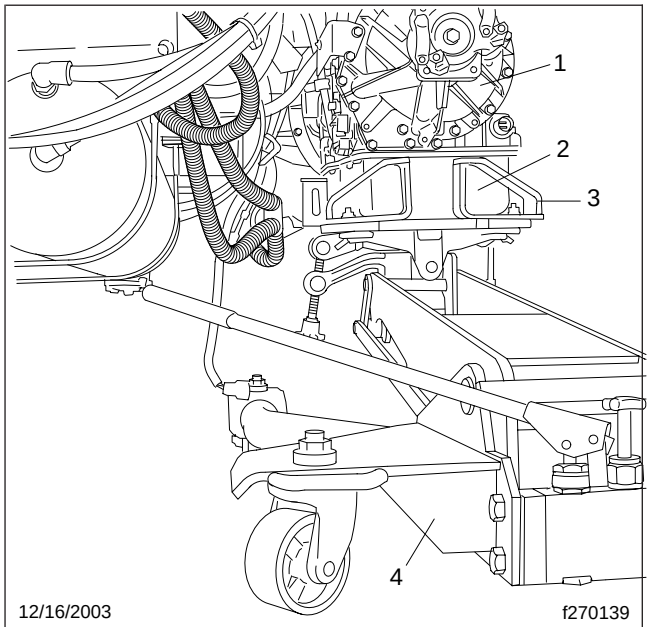
⚠ WARNING

Do not allow the torque converter to become disengaged from the oil pump. This could allow the torque converter to fall, possibly causing component damage and/or personal injury.

15. Move the transmission jack to the rear. Lower the jack and lift the vehicle, as needed, to allow the transmission to clear the frame rail and any other attached components.
16. If necessary to remove the transmission, place jack stands under the vehicle.
17. Roll the transmission jack back and remove the transmission.

Installation

IMPORTANT: Before installing the transmission, make sure the rear tires are chocked and the



12/16/2003 f270139

1. Transmission
2. Oil Pan
3. Jack Support Bracket
4. Jack

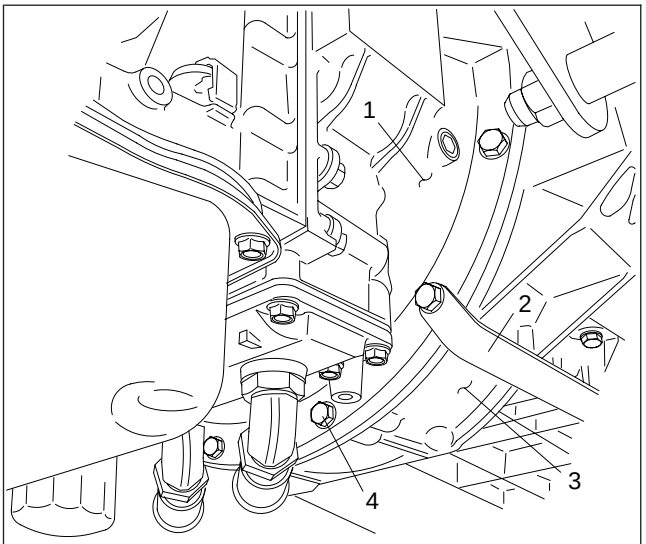
Fig. 12, Supporting the Transmission

transmission is securely chained to the transmission jack.

1. If necessary, raise the vehicle frame with a hydraulic jack to obtain adequate clearance for installing the transmission. Place jack stands under the front of the vehicle.
2. With the transmission on a jack, roll the transmission into place behind the flexplate. Remove the jack stands, and lower the vehicle frame.
3. Raise the jack until the transmission lines up with the flexplate.
4. Push the transmission toward the engine until it seats squarely against the engine timing case with the bolt holes in the transmission housing aligned with those in the timing case.

NOTE: No force is required. If interference is encountered, move the transmission away from the engine and correct the problem.

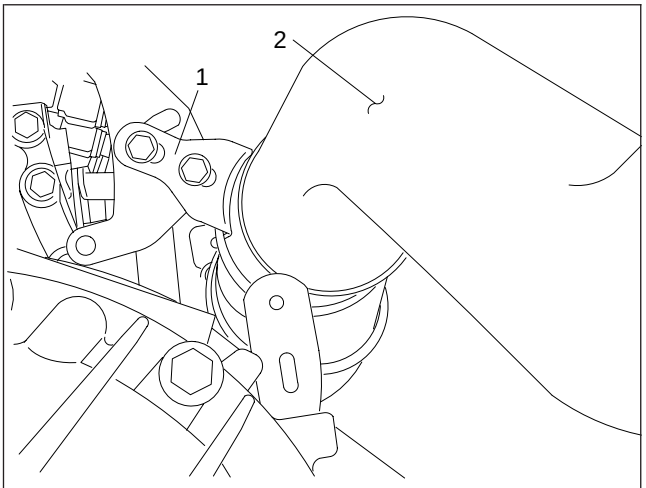
5. Install the transmission mounting bolts until firm. While installing the transmission mounting bolts, attach the muffler bracket, battery support bracket, and fill/dipstick tube clamp to the appropriate bolts, as removed.



12/19/2003 f270140

1. Bell Housing
2. Battery Cable Bracket
3. Timing Case
4. Transmission Mounting Bolt

Fig. 13, Transmission Mounting Bolts



12/15/2003 f270137

1. Muffler Support Bracket
2. Exhaust Pipe

Fig. 14, Muffler Support Bracket

Removal and Installation

6. Install the flexplate adaptor capscrews, as follows.
   6.1 Turning the ring gear for access, install all the capscrews through the access hole. Don't tighten them now.

   Be careful not to drop the capscrews inside the torque converter cover. The transmission must be removed to get them out.

   IMPORTANT: To prevent cocking of the flexplate adaptor, install all the capscrews before tightening any of them.

   6.2 Tighten the capscrews, in a star pattern, to the following specifications based on the model:
   - Models 2100/2200/2500: 48 lbf·ft (65 N·m)
   - Model 3000: 18 to 21 lbf·ft (24 to 29 N·m)

   6.3 Install the access cover and its capscrews.
7. Tighten the M10 transmission mounting bolts 38 to 45 lbf·ft (51 to 61 N·m) in a star pattern. See **Fig. 13**.
8. Remove the chain that's holding the transmission to the transmission jack.
9. Lower the transmission jack and remove it.
10. Connect the transmission fluid cooler hoses to the transmission. Tighten the fittings 40 to 50 lbf·ft (54 to 68 N·m). See **Fig. 4**.
11. Install the ATF fill/dipstick tube, as follows.
    11.1 Inspect the fill/dipstick tube seal. Replace it if damaged.

    11.2 Install the fill/dipstick tube and cushioned clamp. Tighten the clamp capscrew 12 lbf·ft (16 N·m).
12. Connect the shift cable to the transmission. See **Fig. 5**. For detailed instructions, see **Subject 110**.
13. Connect all electrical lines to the transmission, as removed. Install new tie straps as needed.
14. Connect the driveshaft, as follows.
    14.1 Slide the front of the driveshaft into the transmission output yoke.

    14.2 Install the transmission yoke U-joint end caps and lock straps.

    14.3 If the midship bearing bracket bolts and nuts were removed, install them. Tighten the nuts 95 lbf·ft (129 N·m).

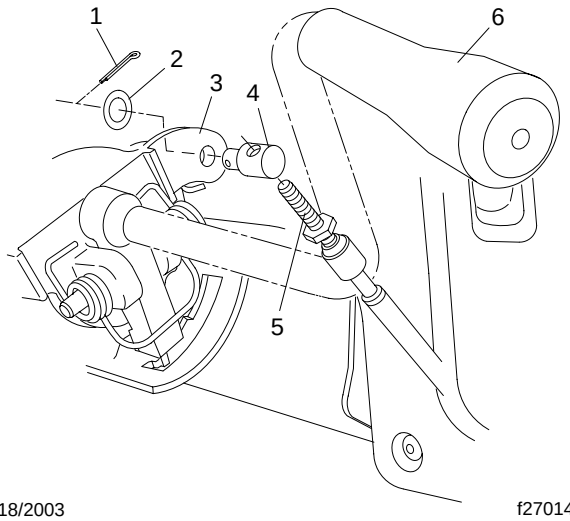
    14.4 Install the driveline guard. Tighten the prevailing torque locknuts 68 lbf·ft (92 N·m).
15. Fill the transmission with ATF. See **Specifications 400** for approved fluids and fill quantities.
16. Connect the batteries.
17. Make sure the transmission is still in neutral. With the service brakes applied, start the engine, and check around the transmission for leaks. Repair leaks as necessary.
18. Check the ATF level. Add fluid as needed.
19. Remove the chocks from the rear tires.
20. Road test the vehicle, and check the transmission for correct operation.

Removal

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

IMPORTANT: Make sure the shift lever is in neutral when the shift cable is disconnected.

2. From inside the driver's compartment, disconnect the top end of the shift cable from the shifter bracket, as follows. See **Fig. 1**.



1. Cotter Pin
2. Washer
3. Shifter Bracket
4. Cable Head
5. Shift Rod (threaded end)
6. Shift Lever

Fig. 1, Connection to Shift Lever

2.1 Remove the clamshell covers on the steering column. For instructions, see **Section 46.02, Subject 110**.

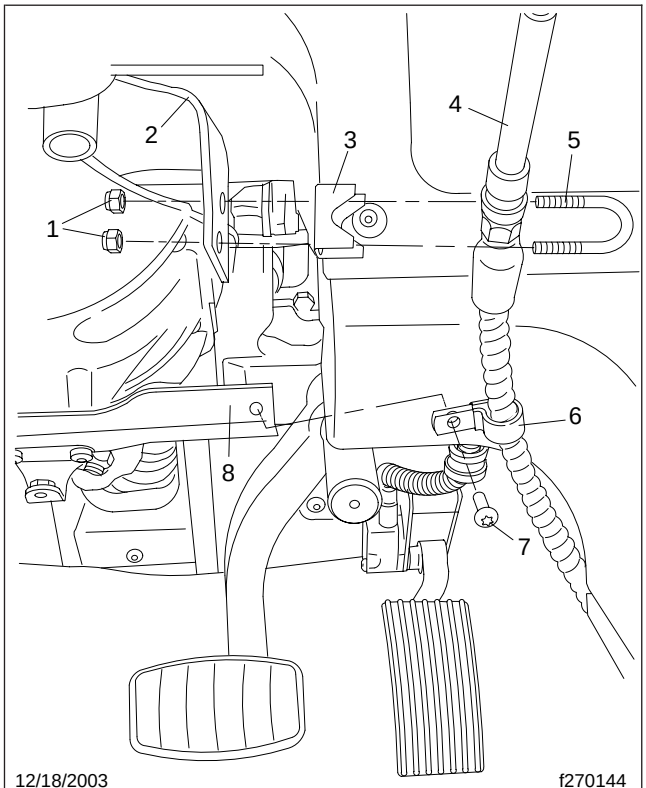
2.2 Pull the cotter pin out of the small hole in the cable head. Remove the cotter pin and washer from the cable head.

NOTE: It may be necessary to loosen the U-bolt and/or cushioned clamp to allow the cable head to come out.

2.3 Pull the cable head out of the hole in the shifter bracket.

2.4 Unscrew the cable head from the threaded end of the shift rod.

3. Remove the U-bolt that holds the shift cable tight against the dash-mounted bracket. See **Fig. 2**.



1. Plastic-Insert (Ny-Lok) Locknuts
2. Dash-Mounted Bracket
3. Clamping Piece
4. Shift Cable
5. U-Bolt
6. Cushioned Clamp
7. Torx Screw
8. Steering Column Standoff Bracket

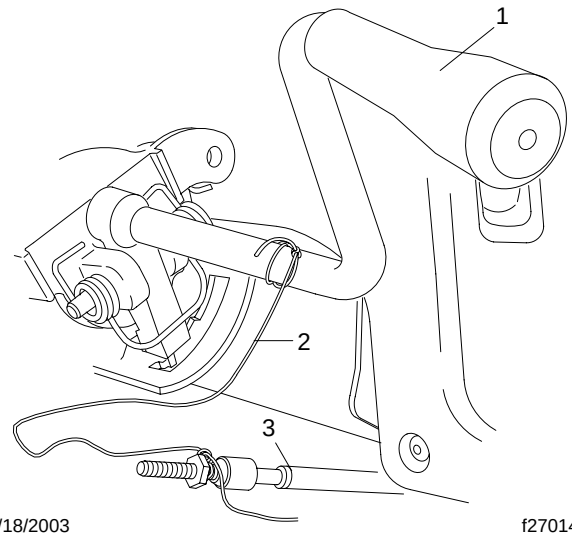
Fig. 2, Bracketry in Driver's Compartment

4. Remove the cushioned clamp that fastens the shift cable to the steering column standoff bracket.

5. Attach a length of wire to the exposed end of the shift cable. Loop the other end of the wire around the shift lever. See **Fig. 3**.

NOTE: During installation, this wire will be used to pull the new cable up through the driver's compartment floor.

Shift Cable Removal and Installation



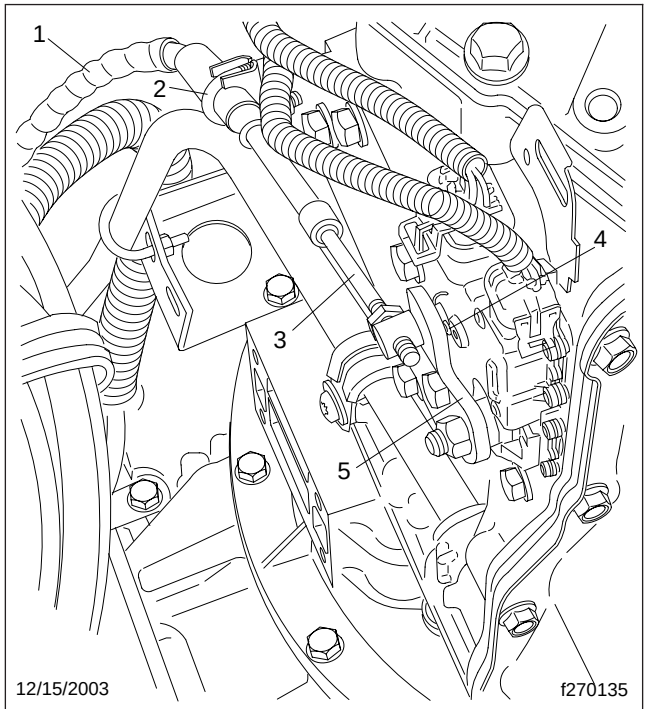
1. Shift Lever
2. Wire
3. Shift Cable

Fig. 3, Wire Looped Around the Shift Lever and Cable

6. From underneath the chassis, disconnect the bottom end of the shift cable from the shift selector lever, as follows. See **Fig. 4**.
   - 6.1 Pull the cotter pin out of the small hole in the cable head. Remove the washer from the cable head.
   - 6.2 Pull the cable head out of the hole in the shifter bracket.
   - 6.3 Unscrew the cable head from the threaded end of the shift rod.
7. Remove the U-bolt that holds the shift cable tight against the gear box.
8. Remove the cushioned clamp that fastens the shift cable to the upper chassis bracket. See **Fig. 5**.
9. Pull the shift cable down through the metal sleeve in the driver's compartment and out through the hole in the floor. Detach the cable from the wire.

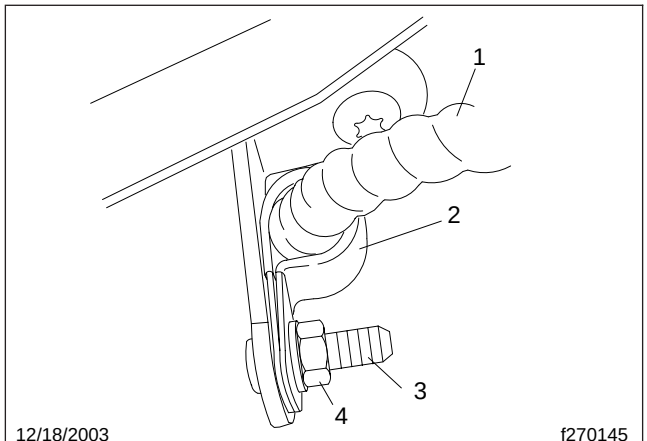
Installation

1. From underneath the chassis, attach the cable to the wire, as removed.



1. Shift Cable
2. U-Bolt
3. Shift Rod
4. Cotter Pin
5. Shift Selector Lever

Fig. 4, Connection to Shift Selector Lever



1. Shift Cable
2. Cushioned Clamp
3. Torx Screw
4. Locknut

Fig. 5, Upper Chassis Clamp

2. From inside the driver's compartment, pull up on the wire looped around the shift lever until the

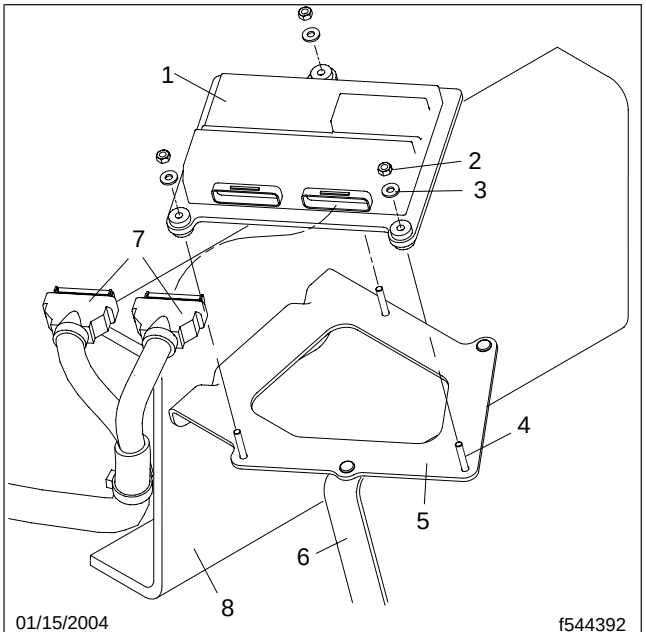
shift cable has sufficient length inside the driver's compartment to attach to the shifter bracket.

IMPORTANT: Make sure the shift lever is in neutral before connecting the shift cable.

3. Connect the top end of the shift cable to the shifter bracket, as follows. See **Fig. 1**.
   - 3.1 Thread the cable head onto the exposed end of the shift cable.
   - 3.2 Insert the cable head through the hole in the shifter bracket.
   - 3.3 Install the washer on the cable head.
   - 3.4 Insert a new cotter pin into the small hole in the cable head and bend the ends back. Make sure the shift cable is firmly attached to the shifter bracket.
4. Install the U-bolt that holds the shift cable tight against the dash-mounted bracket. See **Fig. 2**.
5. Install the cushioned clamp that fastens the shift cable to the steering column standoff bracket.
6. From underneath the chassis, connect the bottom end of the shift cable to the shift selector lever, as follows. See **Fig. 4**. If necessary to adjust the shift selector lever, see the instructions in the *Allison Mechanic's Tips*.
   - 6.1 Thread the cable head onto the exposed end of the shift cable.
   - 6.2 Insert the cable head through the hole in the shift selector lever.
   - 6.3 Install the washer on the cable head.
   - 6.4 Insert a new cotter pin into the small hole in the cable head and bend the ends back. Make sure the shift cable is firmly attached to the shift selector lever.
7. Install the U-bolt that holds the shift cable tight against the gear box.
8. Install the cushioned clamp that fastens the shift cable to the upper chassis bracket. See **Fig. 5**.
9. Remove the chocks from the rear tires.
10. Start the engine and check the shift lever and transmission for proper operation in both forward and reverse gears. Adjust the pointer on the shift lever as needed.

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the transmission harness connectors from the transmission control unit (TCU) mounting plate on the left-hand frame rail just behind the front wheel well and just forward of the battery compartment. See **Fig. 1**.



The TCU for the 2100/2200/2500 models is shown. The 3000 model has a different mounting hole pattern and three harness connectors.

1. TCU
2. Nut, 1/4–20
3. Washer, 1/4-inch
4. Stud
5. Bracket
6. Brace
7. Harness Connectors
8. Frame Rail

Fig. 1, Transmission Control Unit

4. Remove the three nuts and washers from the studs on the mounting plate.
5. Lift the old TCU away from the mounting plate and remove it from the vehicle.
6. Position the new TCU on the studs of the mounting plate. Install the nuts and washers and tighten the nuts 72 lbf·in (800 N·cm). See **Fig. 1**.
7. Connect the two harness connectors to the new TCU.
8. Remove the chocks from the tires.

For a schematic diagram of the transmission wiring routed through the J1 connector, see **Fig. 1**. For a schematic diagram of the transmission wiring routed through the J2 connector, see **Fig. 2**.

Torque Values, 2100/2200/2500 Models				
Description	**Size**	**Grade/Class**	**Torque**	
			lbf·ft (N·m)	**lbf·in (N·cm)**
Transmission Mounting Bolts	M10 x 1.5	8.8	38–45 (51–61)	—
Dipstick Clamp Screw	—	—	12 (16)	—
Driveline Guard Prevailing Torque Locknuts	1/2–13	C	68 (92)	—
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)	—
Flexplate Adaptor Capscrews	M10 x 1.5	—	48 (65)	—
Transmission Control Unit Mounting Nuts	1/4–20	—	—	72 (800)
Transmission Fluid Cooler Hose Fittings	#16	—	40 (54)	—
Transmission Fluid Drain Plug	—	—	22–30 (32–40)	—
U-Joint End Cap Bolts	3/8–24	—	50 (68)	—
	1/2–20	—	110 (149)	—

Table 1, Torque Values, 2100/2200/2500 Models

Torque Values, 3000 Model			
Description	**Size**	**Grade/Class**	**Torque: lbf·ft (N·m)**
Transmission Mounting Bolts	M10 x 1.5	8.8	38–45 (51–61)
Dipstick Clamp Screw	—	—	12 (16)
Driveline Guard Prevailing Torque Locknuts	1/2–13	C	68 (92)
Midship Bearing Bracket Capscrews	3/4–11	—	95 (129)
Flexplate Adaptor Capscrews	M8 x 1.25	—	18–21 (24–29)
Transmission Fluid Cooler Hose Fittings	#16	—	40–50 (54–68)
Transmission Fluid Drain Plug	—	—	18–24 (25–32)
U-Joint End Cap Bolts	3/8–24	—	50 (68)
	1/2–20	—	110 (149)

Table 2, Torque Values, 3000 Model

Specifications

Approved Allison Transmission Lubricants*		
TES-295 Approval Number	**Company**	**Product Brand Name**
AN-051005	ExxonMobil Lubricants and Petroleum Specialties Company	Mobil Delvac Synthetic ATF
AN-011001	Castrol Heavy Duty Lubricants	TranSynd
AN-031002	BP	Autran Syn 295
AN-031003	Cognis Corporation	Emgard 2805
AN-031004	International Truck & Engine Company	Fleetrite Synthetic ATF
AN-071006	John Deere & Company	HD SynTran

* To check the latest Allison approved fluids, go to www.allisontransmission.com. Lubricants listed in order of preference. Do not mix types of oil.

Table 3, Approved Allison Transmission Lubricants

Allison Transmission Lubricant Capacities	
Transmission Model	**Fill Capacity:* qt (L)**
2100/2200/2500 Series (standard sump)	15 (14)
2100/2200/2500 Series (shallow sump)	13 (12)
3000 Series (4-inch sump)	29 (27)
3000 Series (2-inch sump)	26 (25)

* Quantities listed are approximate. Do not overfill.

Table 4, Allison Transmission Lubricant Capacities

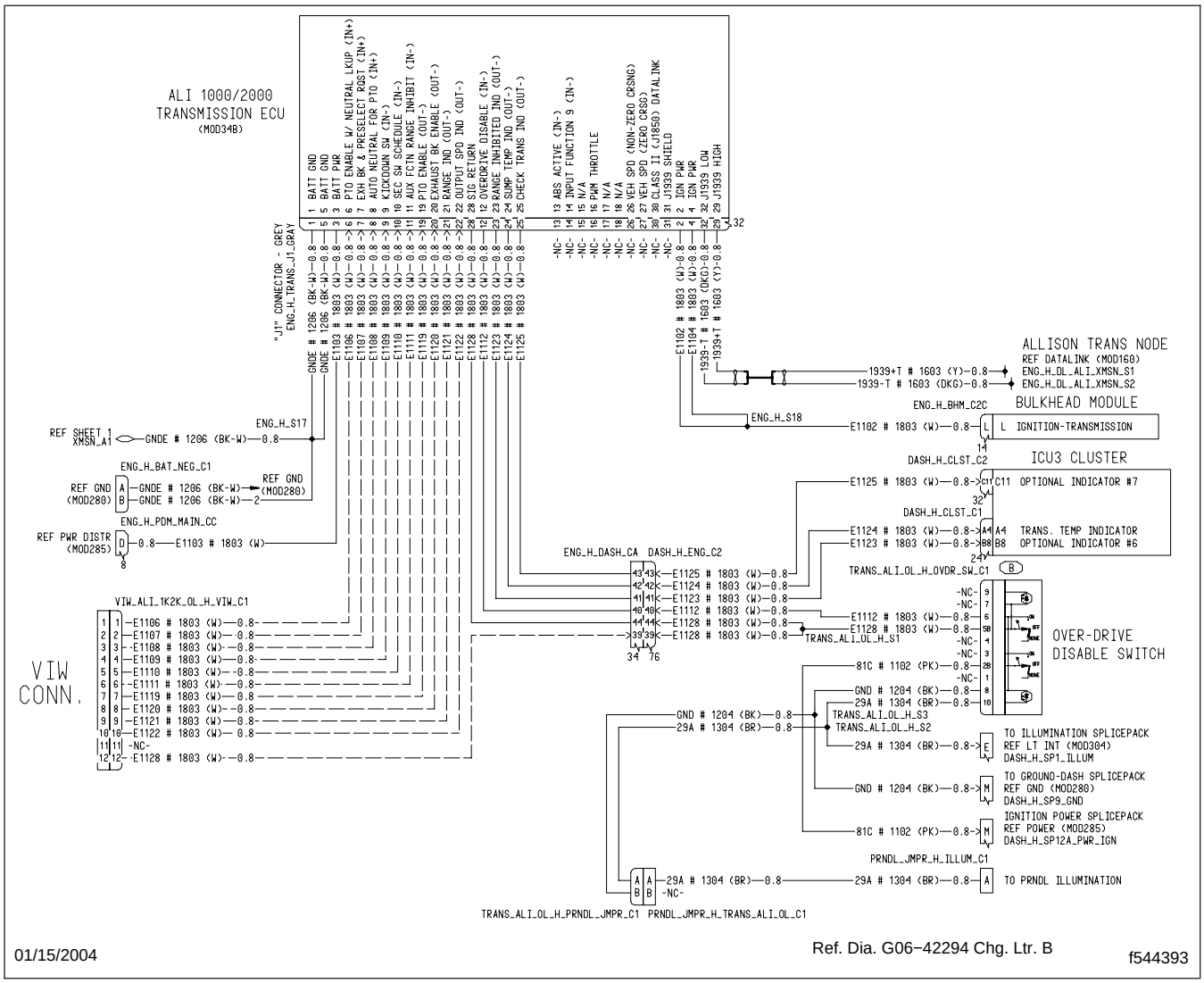


Fig. 1, Transmission Wiring, J1 Connector

Specifications

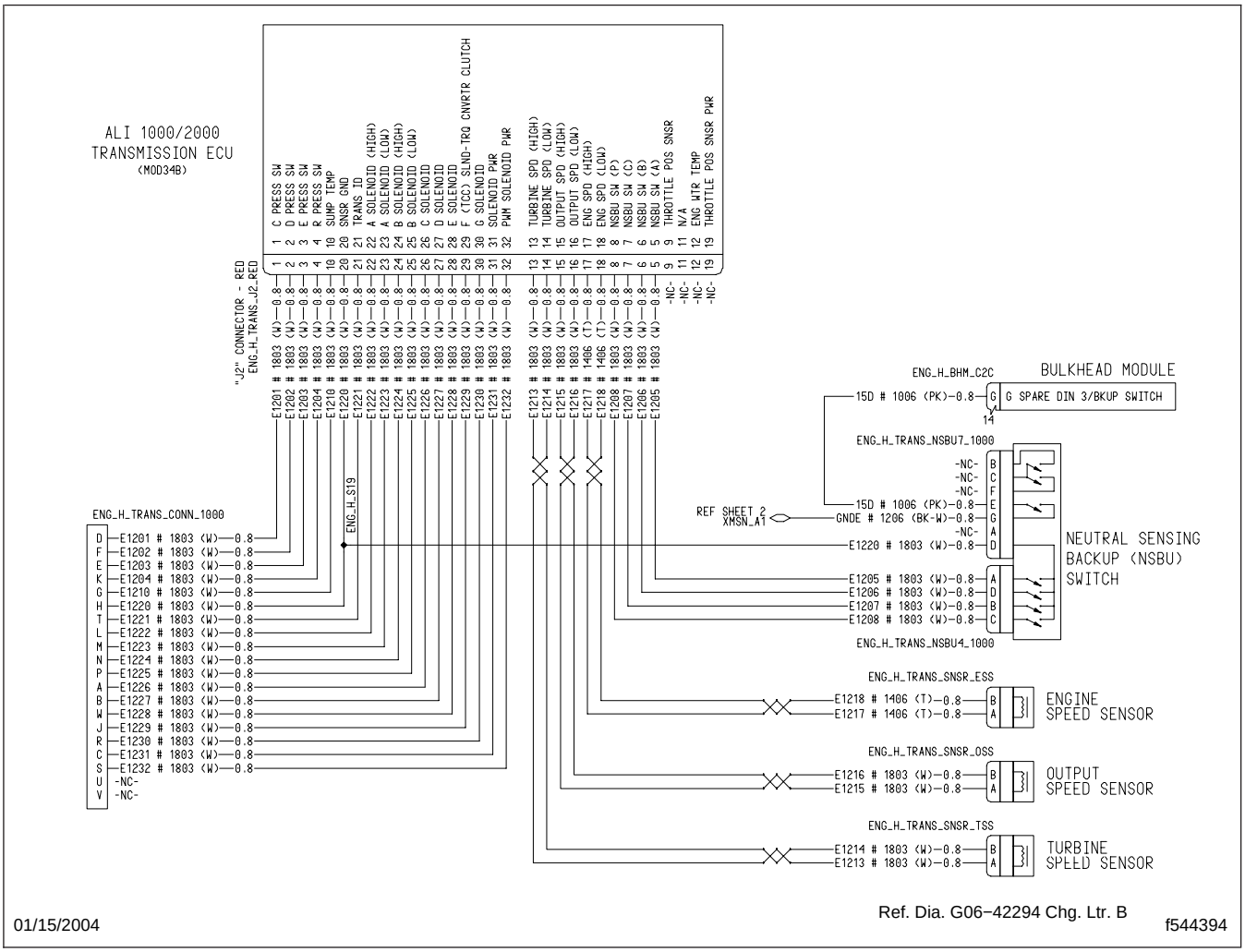


Fig. 2, Transmission Wiring, J2 Connector

General Information

The suspended electronic throttle pedal is designed to provide an electrical signal to an engine control module in response to the driver's demand for engine power. The throttle pedal complies with FMVSS-124 requirements when installed according to specifications set by Williams Controls Industries.

The optional adjustable throttle pedal assembly is manufactured by TeleFlex and uses electronic parts provided by Williams Controls Industries. It functions identically to the standard assembly. It has a motorized mechanical adjustment, controlled by a switch on the dash, that allows the driver to move the throttle and brake pedal assemblies forward or back for ease of operation.

Williams Control Throttle Pedal Removal and Installation

Removal

1. Shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the tie strap that attaches the throttle pedal wiring harness to the air line. Disconnect the wiring harness from the throttle pedal. See **Fig. 1**.
4. Remove the four Torx® fasteners that attach the throttle pedal to the frontwall. Remove the throttle pedal.
5. Remove the two Torx fasteners that attach the throttle pedal sensor to the throttle pedal. Remove the sensor.

Installation

1. Using two Torx fasteners, attach the throttle pedal sensor to the throttle pedal.
2. Using four Torx fasteners, attach the throttle pedal to the frontwall. Torque the fasteners 84 to 120 lbf·in (940 to 1350 N·cm).
3. Connect the wiring harness to the throttle pedal. Using a tie strap, secure the wiring harness to the air line.
4. Connect the batteries.
5. Remove the chocks from the tires.

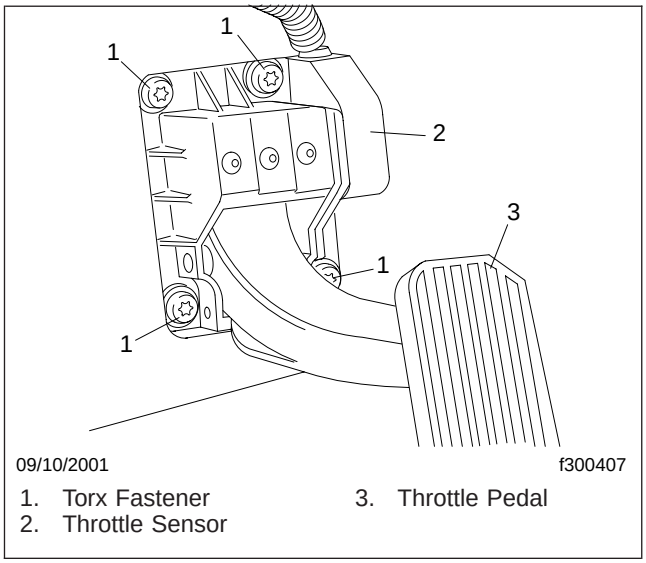


Fig. 1, Throttle Pedal

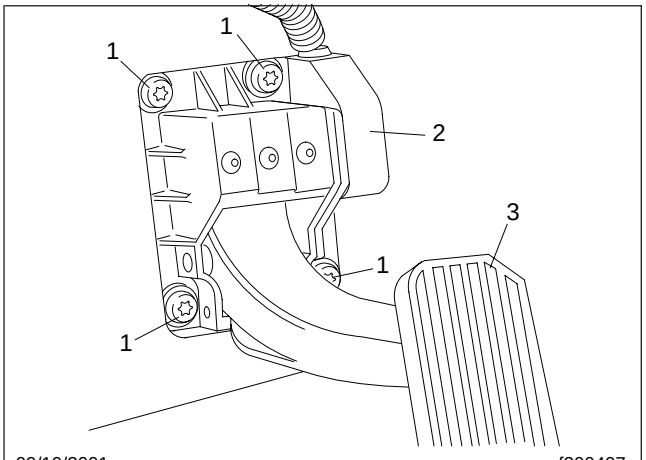
Throttle Pedal Sensor Removal and Installation, Williams Controls

Removal

1. Shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the tie strap that attaches the throttle pedal wiring harness to the air line. Disconnect the wiring harness from the throttle pedal. See **Fig. 1**.
4. Remove the throttle pedal. See **Subject 100** or **120**.
5. Remove the two Torx® fasteners that attach the throttle pedal sensor to the throttle pedal. Remove the sensor.

Installation

1. Using two Torx fasteners, attach a new throttle pedal sensor to the throttle pedal.
2. Attach the throttle pedal to the frontwall. See **Subject 100** or **120**. Torque the fasteners 84 to 120 lbf·in (940 to 1350 N·cm).
3. Connect the wiring harness to the throttle pedal. Using a tie strap, secure the wiring harness to the air line.
4. Connect the batteries.
5. Remove the chocks from the tires.



1. Torx Fastener
2. Throttle Sensor
3. Throttle Pedal

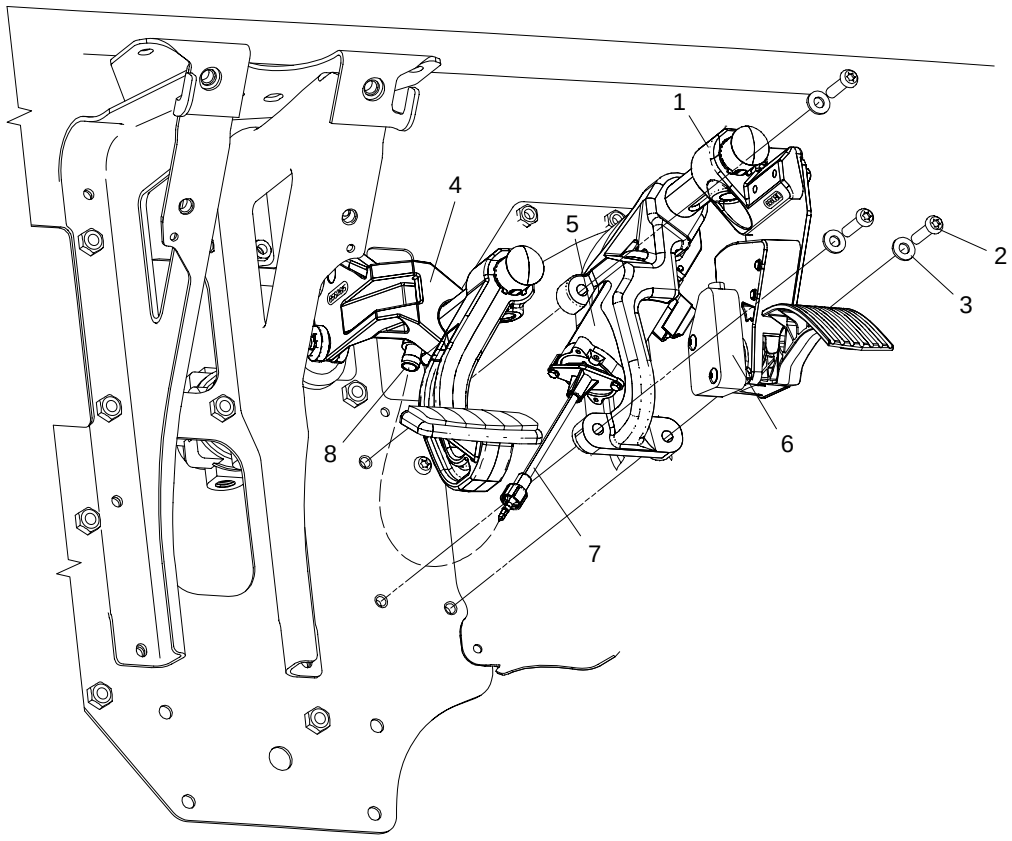
Fig. 1, Throttle Pedal

TeleFlex Adjustable Throttle Pedal Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Disconnect the wiring harness from the throttle pedal sensor. See **Fig. 1**.
4. Disconnect the drive cable from the brake pedal adjustment transmission.
5. Remove the three Torx® fasteners that attach the throttle pedal assembly to the frontwall. Remove the throttle pedal assembly.
6. Disconnect the wiring harness from the throttle pedal adjusting motor, and remove any tie straps that hold the harness in place on the pedal assembly.

NOTE: If the pedal assembly is to be replaced, remove the sensor from the old assembly and install it on the new one. See **Subject 130** for the procedure.



12/08/2003 f300415

1. Throttle Pedal Assembly
2. Torx Fastener
3. Flatwasher
4. Brake Pedal Assembly
5. Adjustment Motor
6. Throttle Sensor
7. Drive Cable (to brake pedal adjustment transmission)
8. Brake Pedal Adjustment Transmission

Fig. 1, Throttle Pedal Installation

TeleFlex Adjustable Throttle Pedal Removal and Installation

Installation

1. Connect the wiring harnesses to the throttle pedal adjusting motor, and secure the harnesses with a tie strap as needed.
2. Using three Torx fasteners, attach the throttle pedal to the frontwall. Torque the fasteners 84 to 120 lbf·in (940 to 1350 N·cm).
3. Connect the wiring harnesses to the throttle pedal sensor.
4. Connect the batteries.
5. Using the adjustment motor, move the throttle pedal to a position as close as possible to the same position that the old pedal was in.
6. Connect the drive cable to the brake pedal adjustment transmission.
7. Adjust the pedals to the full-in position.

NOTE: When one pedal reaches the end of its travel, both will stop.

8. Check to see that both pedals are fully in to the stop. If the brake pedal is not fully in to the stop, disconnect the drive cable from the brake pedal adjustment transmission and adjust the throttle pedal back, then reconnect. When the brake pedal is fully in to the stop, disconnect the drive cable from the brake pedal adjustment transmission and cycle the throttle pedal to the stop.
9. Connect the drive cable to the brake pedal adjustment transmission.
10. Cycle the pedal adjustment through the full range of motion several times to ensure proper operation of both the throttle and brake pedals and to ensure that there is not contact with any adjacent components.
11. Remove the chocks from the tires.

Throttle Pedal Sensor Removal and Installation, TeleFlex Adjustable Throttle Pedal

Removal

1. Shut down the engine, set the parking brake, and chock the tires.
2. For ease of access, adjust the pedal assembly out to clear the frontwall.
3. Disconnect the batteries.
4. Disconnect the wiring harness from the throttle pedal sensor.
5. Remove the two Torx® fasteners that attach the throttle pedal sensor to the throttle pedal. Remove the sensor.

Installation

1. Using two Torx fasteners, attach a new throttle pedal sensor to the throttle pedal.
2. Connect the wiring harness to the throttle pedal sensor.
3. Connect the batteries.
4. Remove the chocks from the tires.

Troubleshooting Procedures

CAUTION

The throttle pedal assembly is designed so that the throttle position sensor (TPS) will not reach the internal stop points when it is mounted to the pedal assembly. Very little sensor rotational adjustment is available once the TPS is installed. Attempting to modify the TPS, in an effort to gain adjustment range, or forcing the TPS shaft beyond the internal stop points will result in severe damage to the TPS.

Common Problems and Indications

A number of symptoms may be reported which can indicate a problem with the throttle pedal, throttle position sensor, or wiring to the electronic engine, including:

- low power or poor acceleration
- the vehicle programmed top speed is not being met
- the engine is stuck at idle
- the engine brake or engine retarder does not function
- slow deceleration
- the check engine light comes on
- an engine fault code indicating a TPS problem appears

These symptoms do not always indicate a throttle pedal, TPS, or wiring problem. Symptoms can disappear when the TPS is replaced; however, the TPS may not be faulty. A thorough diagnosis of the entire TPS system must be performed to ensure that a TPS is faulty.

Preliminary Checks

1. Using the particular engine manufacturer's diagnostic software and tools, verify that the TPS is operating properly.

IMPORTANT: **Table 1** is a guide for common engine installations. It is necessary to verify the correct information for the specific engine installed in the vehicle.

2. If the engine manufacturer's diagnostic software and tools produce the readings shown in **Table 1**, the TPS is not at fault. If you are unable to produce the readings shown in **Table 1**, go to the next step.
3. Verify that the TPS is wired properly. See **Table 2**.

IMPORTANT: Reversing the TPS signal line and the ground line can result in a percentage TPS reading that does not change and may also produce a fault code at the engine ECU. Reversing the TPS signal line and the +v supply line can prevent the TPS signal from reaching 100 percent. Reversing the +v supply line and the common line will result in the TPS providing "inverted" pedal information or not working at all. Verify circuit positions and circuit designations in the engine ECU connector using the engine manufacturer's troubleshooting documentation.

4. Check the voltage to the TPS. See **Table 3** for TPS connector pin locations.

IMPORTANT: The ignition key must be in the ON position. For Mercedes-Benz engines, use or fabricate a breakout harness. After diagnosis, clear any historical TPS fault codes to prevent misdiagnosis in the future.

NOTE: It is normal for the engine to report fault codes when the TPS connector is disconnected.

5. Inspect and ensure that all connector pins at the TPS sensor, frontwall, and engine ECU are free of corrosion and are not bent or damaged. Inspect and ensure that the connections between the pins and the wires are secure and also free of corrosion.

NOTE: If the TPS does not return to idle, one of two conditions exists. Either the idle validation switch (IVS) on an Mercedes-Benz engine is faulty or the TPS signal voltage or PWM (pulse width modulation) duty cycle, recorded by the engine ECU, is dropping significantly after the engine has calibrated the idle position.

6. If you do not read the voltages shown in **Table 3**, test resistance on the +v supply and common circuits between the TPS and the engine connectors. Disconnect the OEM harness connector at the engine ECU.

Troubleshooting

IMPORTANT: Disconnect the TPS connector from the TPS. Ensure that the ignition key is in the OFF position before making any tests.

7. If a resistance greater than 10 ohms is read, there is a potential wiring problem. Correct any wiring problem before attempting further tests. If a wiring problem is discovered and repaired, go back and repeat step 1 to determine if this was the only problem.

NOTE: If circuit resistance is 10 ohms or less but the voltage is below that listed in **Table 3**, the Mercedes-Benz engine VCU is probably faulty. If both voltage and circuit resistance are within specifications, go to the next step.

8. Remove the pedal assembly from the floor. Loosen, but do not remove, the TPS mounting screws. By hand, rotate the TPS sensor assembly toward the pedal as far as possible. Then securely tighten the mounting screws. Check the operation of the TPS again.

Diagnostic Software/Tool Readings		
Engine	**Pedal Position**	**Reading**
Cummins ISB*	Idle	0% TPS
	Full Throttle	100% TPS
	Between Idle/Full Throttle	Varies Smoothly Between 0% and 100% IVS Transitions Between On-Idle and Off-Idle At, or Before, 15% TPS
Mercedes- Benz	Idle	0% TPS
	Full Throttle	100% TPS
	Between Idle/Full Throttle	Varies Smoothly Between Idle and Full Throttle Values

* The ECM converts raw TPS data to % TPS.

Table 1, Diagnostic Software/Tool Readings

Throttle Position Sensor (TPS) Wiring			
Engine	**Engine Manufacturer Circuit**	**TPS Connector Pin**	**Engine ECU (2 pin) or CPC (1 pin) Connector**
Mercedes-Benz	440T (Throttle Position Sensor)	A	7
	440P- (Sensor Ground)	B	4
	440P+ (Sensor Supply)	C	8
	440V2 (Idle Validation Switch 2)	D	3
	440V1 (Idle Validation Switch 1)	E	6
	GNDE (Ground)	F	—
Cummins ISB	440T (Pedal Position 1)	A	35
	440P- (Sensor Return)	B	28
	440P+ (5V Sensor Supply 1)	C	27
	440P2+ (5V Sensor Supply 2)	D	26
	440P2- (Sensor Return)	E	22
	440T2 (Pedal Position 1)	F	25

Table 2, Throttle Position Sensor (TPS) Wiring

TPS Connector Pin Locations			
Engine	**TPS +V Supply**	**TPS Common (Ground)**	**Voltage**
Cummins ISB	Pin C/D	Pin B/E	+5v ±0.5v
Mercedes-Benz	Pin C	Pin B	+5v ±0.5v

Table 3, TPS Connector Pin Locations

NOTE: In some cases, it may be necessary to exchange the existing TPS with another because the TPS and pedal assembly tolerances result in an idle position too close to the edge of acceptable operation. In this situation, the TPS is probably not faulty and may perform acceptably in another pedal.

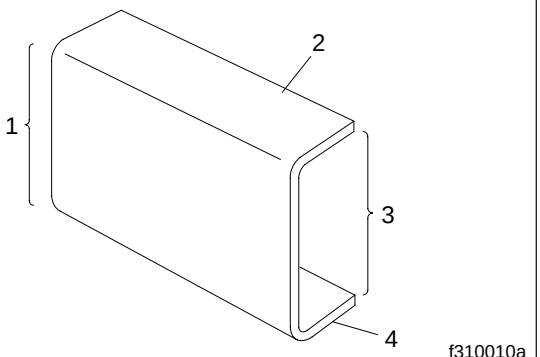
9. If the engine will not reach rated speed or recognize full throttle, the cause is something other than the TPS. Check the engine ECU parameters and reset them if necessary. Check and ensure that the TPS is wired correctly. Remove the TPS from the pedal assembly and move the pedal through the full range of operation. Watch the operation of the TPS actuator tab. Ensure that no parts are binding or broken.
10. If the TPS does not leave idle, check IVS operation on Mercedes-Benz engines and ensure that the switch transitions from the idle to the off idle state. Check for a signal on the appropriate wires at the engine ECU for both idle and off idle states. On vehicles not equipped with an IVS, check and ensure that the TPS is connected correctly to the engine.
11. If the problem has still not been resolved, the problem is not with the TPS. See CasePoint in ServicePro for further guidance.

General Information

IMPORTANT: This manual *does not cover* the procedures and calculations necessary to do frame modifications. Before doing any modification to the frame rails, consult with your regional service representative for approval.

The main body of the frame consists of two frame rails connected by a series of crossmembers. 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 a lower flange, upper flange, and web (the surface area between the flanges). The inside area of the frame rail is called the channel. See **Fig. 1**.



1. Web
2. Upper Flange
3. Channel
4. Lower Flange

Fig. 1, Frame Terminology

A frame station is a reference point on the frame rail from which the location of each component (mounted on the frame rail) is measured. There is no identifying mark for station zero (usually written as 0.00"). It is located at a given reference point to the rear of the most forward edge of the frame rail. The vehicle's frame drilling chart lists the location of each frame rail component. For example: if a component is given a location of 2500, then that component is installed on the frame rail 98-7/16 inches (2500 mm) aft of station zero.

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.

Whenever the frame rails are lifted or moved, take care to avoid anything that may scratch, cut, or damage the exposed frame assembly. Use pencil lines or soapstone marking for any work that requires marking of the frame rail. High visibility can be obtained by first chalking the surface of the frame rail, then making the pencil marks. 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.

Never heat the frame rails for straightening purposes. Such work should be done cold, as the frame rails have been heat-treated.

⚠ CAUTION

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.

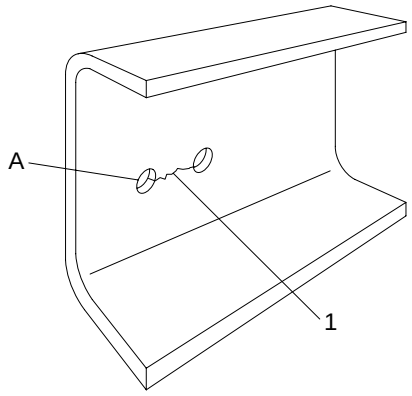
Repairing Cracks

IMPORTANT: In most cases, cracked or damaged frame rails should be replaced. 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 110.

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**.



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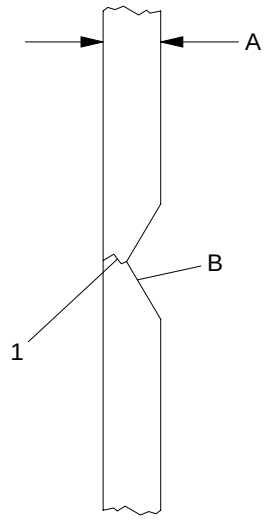
A. Drill 1/8-inch (3-mm) Diameter Holes at Each End
1. Crack

Fig. 1, Preventing Cracks from Spreading

2. Grind a V-groove to a depth of two-thirds of the stock thickness. See **Fig. 2**.

NOTE: If it will not be possible to grind both sides of the frame rail, then grind the V-groove on one side to the full depth of the stock thickness. See **Fig. 3**.

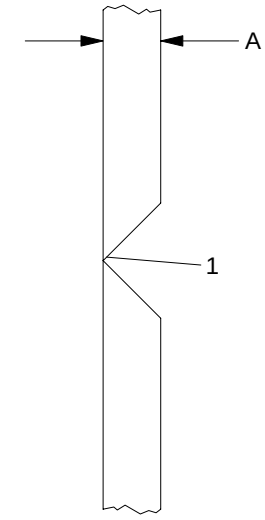
3. Clamp a copper or aluminum bar on the opposite side of the groove. The bar will act as a "chill strip," keeping the heat from spreading to the surrounding area of the frame rail. See **Fig. 4**. Deposit the weld material using the applicable welding method described in this section.



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A. Frame Rail Thickness
B. Grind V-groove to 2/3 depth of stock thickness.
1. Crack

Fig. 2, Cross-Section View



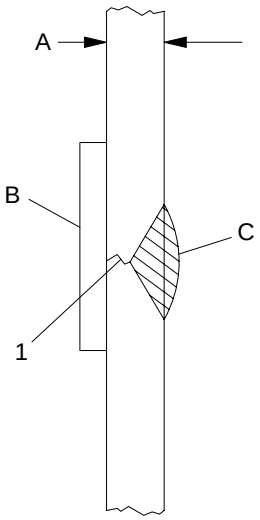
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A. Frame Rail Thickness
1. V-Groove (full depth)

Fig. 3, Full Depth Groove

4. Grind the weld flush with the frame rail. See **Fig. 5**.

Frame Rail Repair

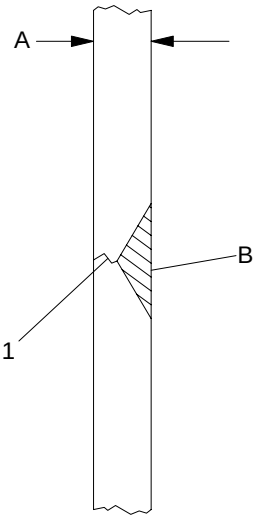


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A. Frame Rail Thickness
B. Clamp the chill strip on the opposite side of the groove.
C. Deposit weld material.

1. Crack

Fig. 4, Using a Chill Strip



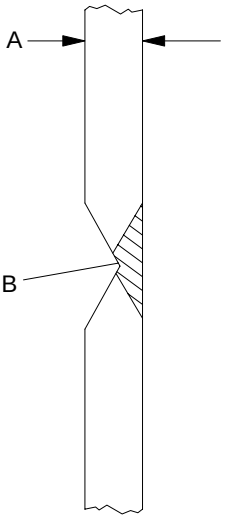
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A. Frame Rail Thickness
B. Grind the weld flush with the frame rail.

1. Crack

Fig. 5, Weld Ground Flush

5. 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 the V-groove deep enough to reach the weld.

Fig. 6, Cross-Section View

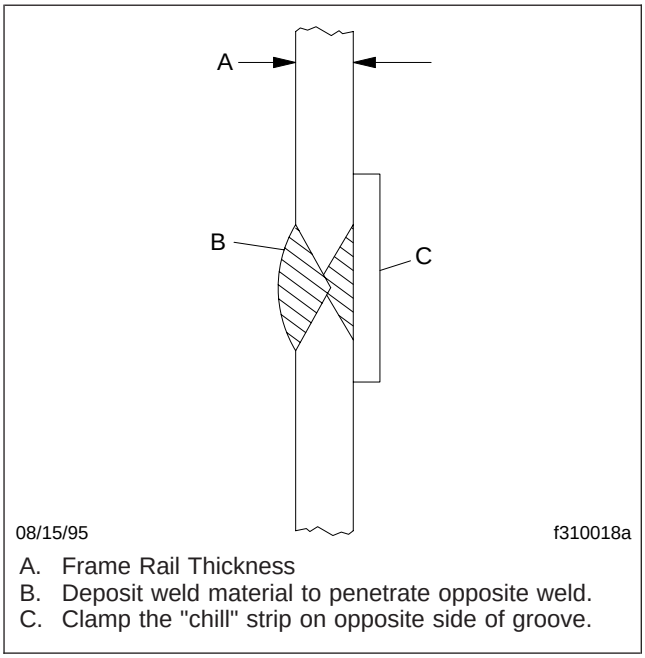
6. Clamp the chill strip on the opposite side of the groove. See **Fig. 7**. Weld the V-groove, as instructed above. Make full penetration of the weld.
7. Grind the weld flush with the frame rail. See **Fig. 8**.

Filling Unused Holes

1. Fill all unused holes in the frame assembly with the 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 the applicable nut, washer, and bolt combination.
3. Tighten the fasteners to the applicable torque value. For proper frame fastening instructions, refer elsewhere in this group.

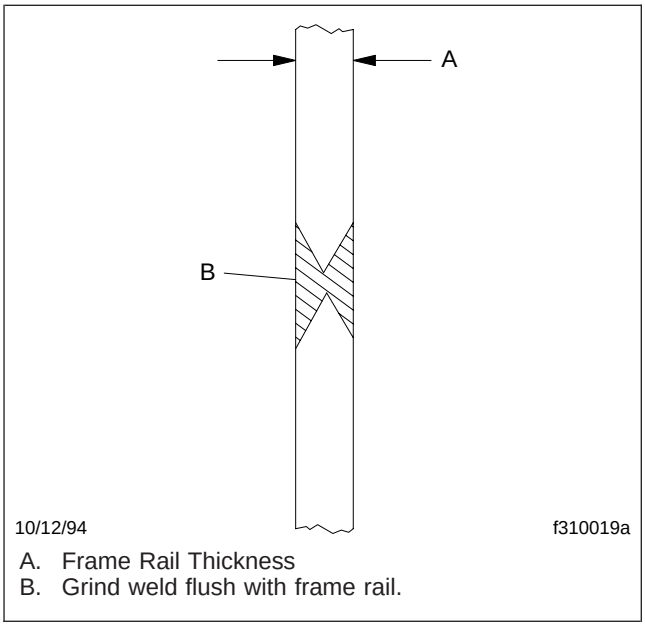
Drilling Holes

During vehicle manufacture, holes are drilled or punched in the frame rail only as specified on the



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



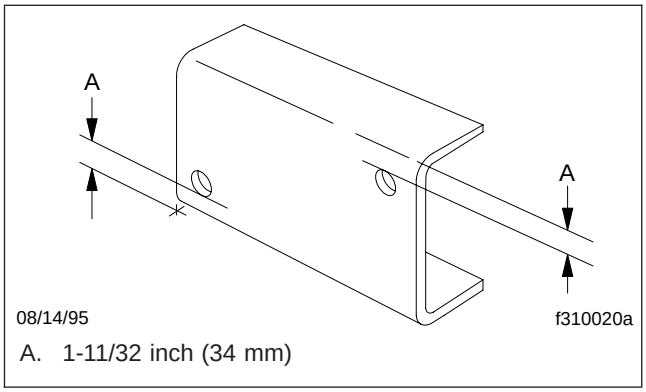
A. Frame Rail Thickness
B. Grind weld flush with frame rail.

Fig. 8, Second Weld Ground Flush

vehicle frame drilling chart. If any additional holes need to be drilled, contact your regional service representative for approval.

Holes to mount brackets, out riggers, and supports may be drilled in the vertical frame rail web 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.



A. 1-11/32 inch (34 mm)

Fig. 9, Minimum Distance for Drilling Holes

- 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 axle centerline and the rear axle centerline cannot exceed 3/4 inches (19 mm).

Welding 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.

CAUTION

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.

IMPORTANT: Before any welding is done, 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, disconnect the battery power and ground cable, and any electronic control units (ECUs) or similar devices installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Vehicle components that typically use ECUs include the electronic engine, electronic automatic transmissions, and the antilock braking system (ABS).

1. For any ECU with a battery power harness, disconnect the ground terminal from the chassis ground. Disconnect the power terminal from the positive post of the battery.

NOTE: It is also acceptable practice to disconnect the main connection at the ECU.

2. Disconnect the batteries, including any isolated battery. Attach the welding ground strap as close to the work being done as safely possible.
    - Do not weld attachments to the frame rail. For guidelines on the attachment of equipment on the frame rails, refer elsewhere in this section.
    - 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 to 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.

    See **Subject 400** for welding specifications.

Extending Frame Rails

CAUTION

Before performing any electric welding on a vehicle, read and understand the welding precautions in Subject 110.

Steel frame rails can be lengthened by welding a frame rail extension onto the rear of the frame rail. The frame rail end 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.

1. Cut the frame rail end and extension to the specified applicable dimensions in **Specifications 400**.

NOTE: If the length of the extension is to be 6 inches (152 mm) or less, then straight-cut the frame rail end and extension.

2. Grind the cut ends of the frame rail and extension to the dimensions in **Fig. 1**.
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 (1.6 to 3.2-mm) gap between them. See **Fig. 2**. Using a torch, heat the cut ends to 70°F (21°C), if necessary, before welding.

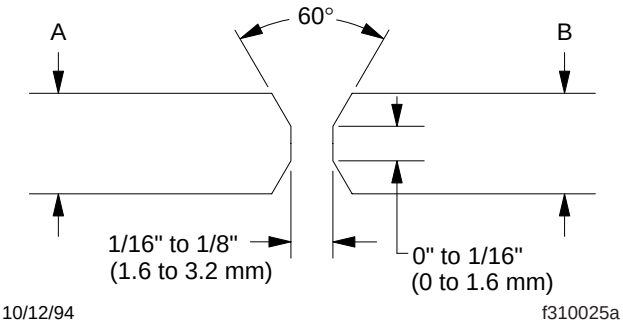
NOTE: A 1/16-inch (1.6-mm) gap is recommended. The ends must not contact each other. Maintain the joint spacing by placing a short piece of clean, 1/16-inch (1.6-mm) diameter bare steel wire between the extension and frame rail. The wire sections must be short enough to be completely fused by the welding process.

4. Using one of the methods in **Specifications 400**, weld the extension to the frame rail, making full penetration. See **Fig. 2**. Remove any slag between passes, and back-gouge the root of the first vee before welding the other side.

CAUTION

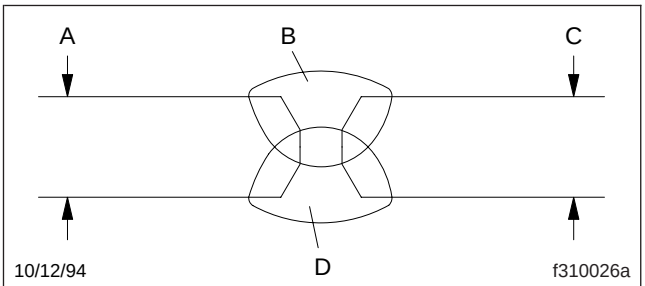
Residual stresses will occur in the weld if the web area is not welded first, or if the flanges contact each other when welding the web.

IMPORTANT: Weld the web area first, then the flange, working from the inside of the channel.



A. Frame Rail Thickness
B. Extension Thickness

Fig. 1, Grinding Dimensions



A. Frame Rail Thickness
B. First Weld
C. Extension Thickness
D. Second weld penetrates the first weld.

Fig. 2, Correct Weld Penetration

When welding the web, make sure that the flanges do not contact each other.

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.

CAUTION

Do not "hollow grind" the weld. Small depressions from improper grinding of the weld will reduce the strength of the frame rail.

Crossmember Removal and Installation

Removal

The placement of crossmembers affects the overall stability of the frame. If a crossmember is being eliminated, added, or relocated, Freightliner dealers must contact their Regional Service Office for instructions and approval. All others must contact a Freightliner dealership, which will contact the Regional Service Office for approval.

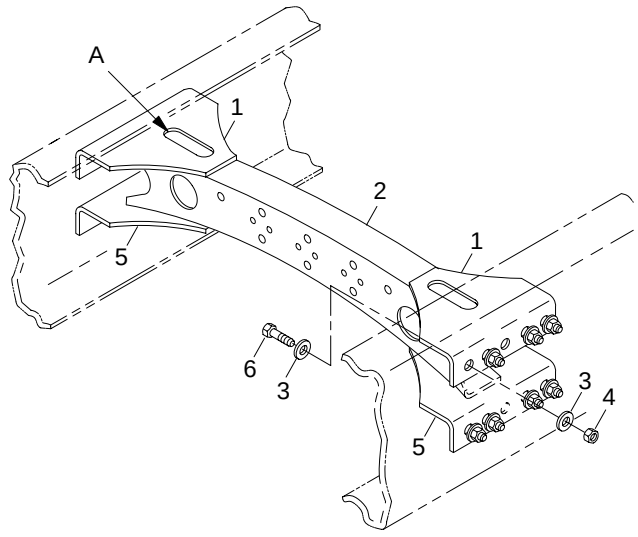
IMPORTANT: Before removing any crossmember, note the direction, size, and type, of all fasteners that attach the crossmember to the frame rail, and that attach other parts to the crossmember. Also note which direction the open channel of the crossmember is facing, for installation reference.

NOTE: If a 5-piece (welded) crossmember must be removed, it must be cut in two, removed, then replaced with a 5-piece crossmember having upper and lower gussets that bolt in place. See **Fig. 1** and **Fig. 2**.

5-Piece (Welded) Crossmember (Removal for replacement with a 5-piece bolted crossmember)

1. Apply the parking brakes, then chock the tires on both the front and rear axles.
2. If any air brake valve is attached to the crossmember, drain the air reservoirs, then remove the valve(s) from the crossmember.

   Remove any clamps that attach air lines or wiring to the crossmember. Secure the lines or wires away from the crossmember.
3. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the crossmember, support the rear of the frame at its normal ride height, using safety stands.
4. Using a cutting torch, cut the crossmember channel in two. A 3-inch (76-mm) cut will make removal easier.
5. Remove the fasteners that attach the crossmember halves to the frame rails, and remove the crossmember. See **Fig. 1**.



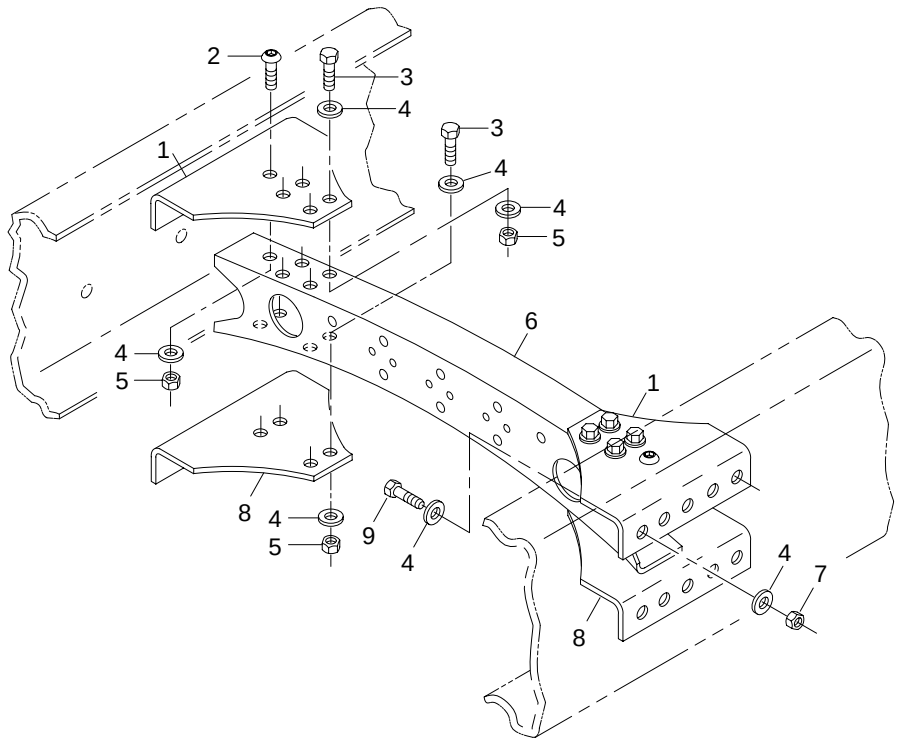
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A. Welded (typical at all 4 gussets)

1. Upper Gusset
2. Channel
3. Hardened Steel Flatwasher
4. 5/8–11 Locknut
5. Lower Gusset
6. 5/8–11 Grade 8 Bolt

Fig. 1, Welded 5-Piece Crossmember Assembly

Crossmember Removal and Installation



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1. Upper Gusset
2. 1/2–13 Button-Head Capscrew
3. 1/2–13 Grade 8 Hexbolt
4. Hardened Steel Flatwasher
5. 1/2–13 Locknut
6. Crossmember Channel
7. 5/8–11 Locknut
8. Lower Gusset
9. 5/8–11 Grade 8 Hexbolt

Fig. 2, Bolted 5-Piece Crossmember Assembly

Splayed Crossmember

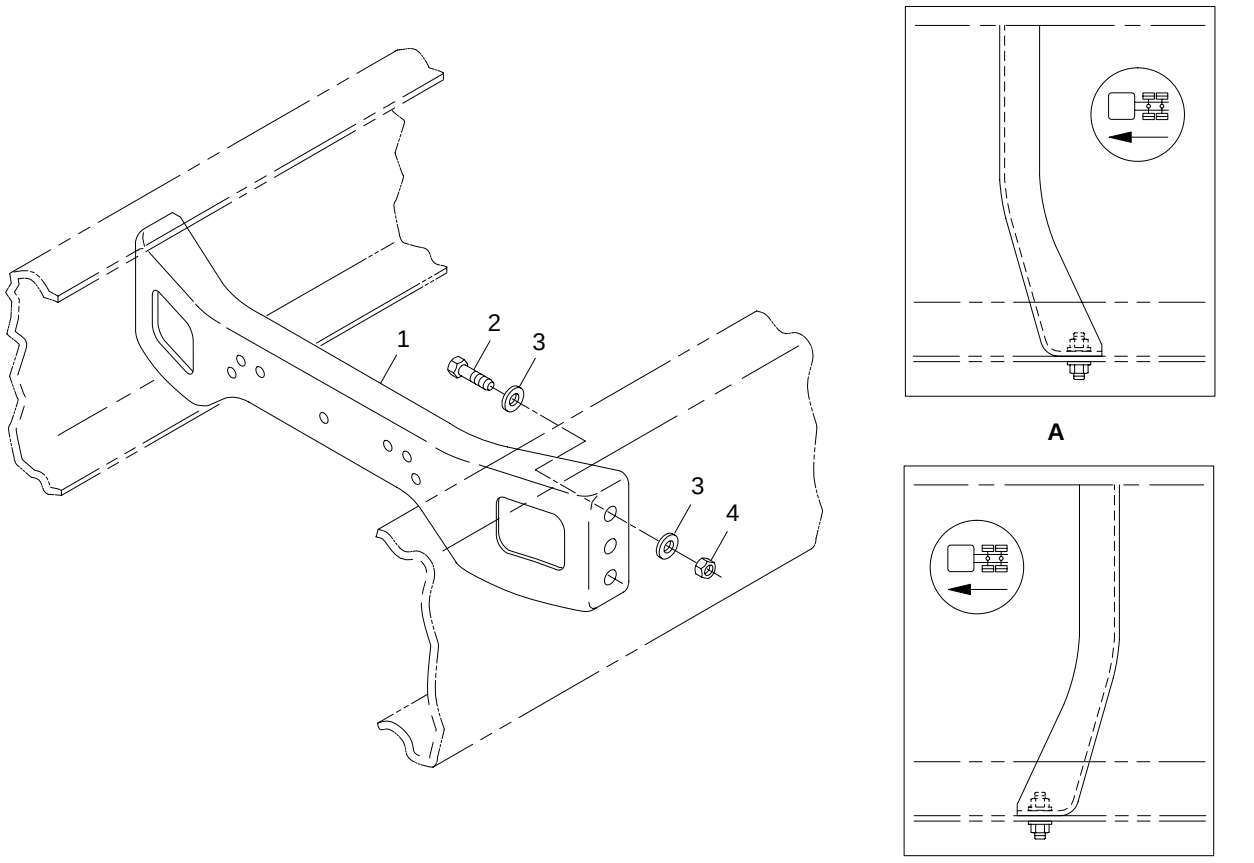
1. Apply the parking brakes, then chock the tires.
2. If removing a midship bearing crossmember, support the driveline on a safety stand, then remove the fasteners that attach the midship bearing bracket to the crossmember.
3. Unbolt the crossmember from both frame rails. See **Fig. 3**.
4. At one end of the crossmember, use a deadblow hammer to tap against its curved side (the closed side of the channel), until the crossmember is no longer wedged in the frame. Remove the crossmember.

Installation

5-Piece (Bolted) Crossmember (Installation for replacement of a 5-piece welded crossmember)

1. Attach one upper gusset to the crossmember channel; tighten the fasteners snug, but not to their final torque value. See **Fig. 2**.
2. Install the crossmember channel and gusset in the frame rails with its open channel facing the same direction that was noted during removal. Position the crossmember so its channel is supported on the lower flanges of both frame rails.
3. Attach the other upper gusset to the crossmember channel; tighten the fasteners snug, but not to their final torque value.

Crossmember Removal and Installation



08/05/94 f310246a

A. Top Views

1. Splayed Midship Crossmember
2. 1/2–13 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 1/2–13 Locknut

Fig. 3, Splayed Crossmember

4. Tighten the locknuts on the button-head capscrews at the outboard end of both upper gussets 68 lbf·ft (92 N·m).
5. Using a deadblow hammer, tap the crossmember up into place. Align the mounting holes of the upper gussets with the holes in the frame rails. Install the fasteners, but don't tighten them.
6. Install the lower gussets on the crossmember channel, but don't tighten the fasteners at this time. Install the fasteners that attach the lower gussets to the frame rails.
7. Tighten the fasteners that attach the gussets to the frame rails 136 lbf·ft (184 N·m). Then, tighten the fasteners that attach the gussets to the crossmember channel 68 lbf·ft (92 N·m).
8. If any air brake valve was attached to the crossmember, install the valve(s) on the crossmember.

   Install any clamps that attach air lines or wiring to the crossmember.
9. Remove the chocks.

Splayed Crossmember

1. Install the crossmember in the frame rails with its open channel facing the same direction that was noted during removal. Align the mounting holes

Crossmember Removal and Installation

at one end of the crossmember with the holes in the frame rail. See **Fig. 3**.

NOTE: With the crossmember not straight across in the frame rails, and the holes not aligned on the opposite end, the holes at that end will be in approximate alignment.

2. Install the fasteners in that end of the crossmember and frame rail, but tighten the locknuts finger-tight only.
3. At the other end of the crossmember, use a deadblow hammer to tap against its straight side, until the crossmember is straight across in the frame rails, and the mounting holes at both ends are in alignment with the holes in the frame rails.
4. If a midship bearing crossmember is being installed, install the fasteners that attach the midship bearing bracket to the crossmember. Remove the safety stands that supported the driveline.
5. Tighten all of the fasteners to their applicable torque values; refer to **Group 00** of this manual.
6. Remove the chocks.

Frame Rail Alignment

Frame rail alignment is checked by measuring the distances from two sets of points on the lower flanges of the frame rails. The aft set of points must be as far back as possible from the forward set of points. There must be no obstruction along or between the frame rails that would prevent measuring from any one of the four points to the other three points.

There are no marks or bolt holes in the bottom 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.

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 lower flanges, and to measure inboard from the outside face of the frame rails.

1. Locate a forward set of points. The forward points must be at identical locations on both frame rails.
   - 1.1 Mark the most forward point at which the lower flanges of both frame rails are clear and unobstructed.
   - 1.2 On each frame rail, find a bolt hole on the frame rail web, that is aligned with, or just rearward of, this forward point. The bolt holes must be at 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 bottom flange of its respective frame rail.
   - 1.4 Find the exact center of the width of each lower flange, and mark the point on each projected line. This will be the forward set of points.

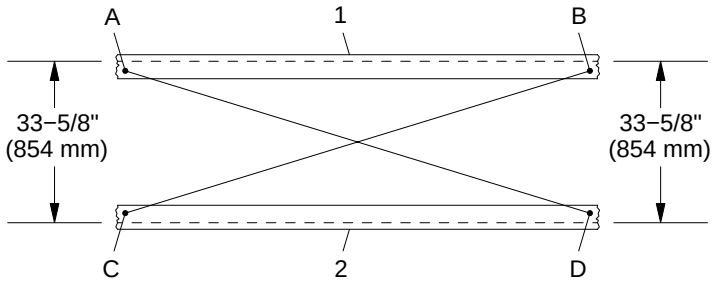
IMPORTANT: Use a pencil or soapstone to make all lines, points, or other marks. Do not use any marker or tool that will scratch the surface of the frame rail. Use a machinist's square to project all points from the webs to the lower flanges, and to measure inboard from the outside face of the frame rails.

2. Locate an aft set of points. The aft points also must be at identical locations on both frame rails.
   - 2.1 Measuring back along each frame rail, find a set of bolt holes *at least* six feet (1.8 m) aft of the forward set of points. The bolt holes must be at exactly the same location in each frame rail.

   IMPORTANT: If, because of obstructions, the distance must be less than six feet (1.8 m), the distance must be the maximum that is possible.
   - 2.2 Project the exact vertical centerline of each bolt hole, and mark a line across the top flange of its respective frame rail.
   - 2.3 Along each line, measure and mark a point two inches (5 cm) inboard from the outside face of its respective frame rail. This will be the aft set of points.
3. Measure the width of the frame, from the outside face of each frame rail. At both locations, this distance must be 33-5/8 inches (854 mm). See **Fig. 1**.
   - 3.1 At the forward set of points, measure the width of the frame. Measure from the outside face of one frame rail to the outside face of the other. Record this measurement.
   - 3.2 At the aft set of points, measure the width of the frame again, from the outside face of one frame rail to the outside face of the other. Compare this measurement to the one taken at the forward set of points.
4. Check the alignment of the frame rails. See **Fig. 1**.
   - 4.1 Measure the distance from the forward point on one frame rail to the aft point on the opposite frame rail. Record this measurement.
   - 4.2 Then measure the distance from the other forward point to the aft point on its opposite frame rail. Record this measurement.
   - 4.3 Compare the two measurements.

     If the values differ by more than 1/8 inch (3 mm), proceed to the next step.

Frame Rail Alignment



A. Right Forward Point or Bolt Hole
B. Right Rear Point or Hole
C. Left Forward Point or Bolt Hole
D. Left Rear Point or Hole
1. Right Frame Rail
2. Left Frame Rail

Fig. 1, Frame Rail Squaring

If the measurements are within 1/8 inch (3 mm) of each other, the frame rails do not need to be aligned. If any frame fasteners are loose, tighten as described below.

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.

5. Align the frame rails, if needed.
   - 5.1 Loosen all of the frame fasteners just enough to allow movement of the parts when force is applied.
   - 5.2 Place a large wooden block against the rear end of the longer frame rail (defined as the one with its aft point the greater distance from its opposite rail's front point). Tap the block until the measurements are within 1/8 inch (3 mm) of each other.
   - 5.3 Using a large hammer, tap the block until the measurements are within 1/8 inch (3 mm) of each other.
   - 5.4 Tighten the fasteners for the front closing crossmember and the rear crossmember to their applicable torque values, as given in **Specifications, 400**.
6. Check the frame rail alignment again to be sure it is correct.
7. Tighten all of the frame fasteners, starting at the middle of the frame and working alternately toward both ends. Tighten each fastener to the torque value appropriate to its size, as given in **Specifications, 400**.
   - 7.1 First, tighten each fastener that attaches a crossmember to the frame.
   - 7.2 Tighten each fastener that attaches an upper strut, lower strut, or gusset to the frame.
   - 7.3 Finally, tighten each fastener that attaches a lower strut or gusset to a crossmember.
8. If the frame rails did need aligning, check the rear axle alignment. See **Group 35** for instructions.

Frame Shaping

IMPORTANT: Obtain approval from your regional service representative before doing any cutting or frame shaping.

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 edge 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.

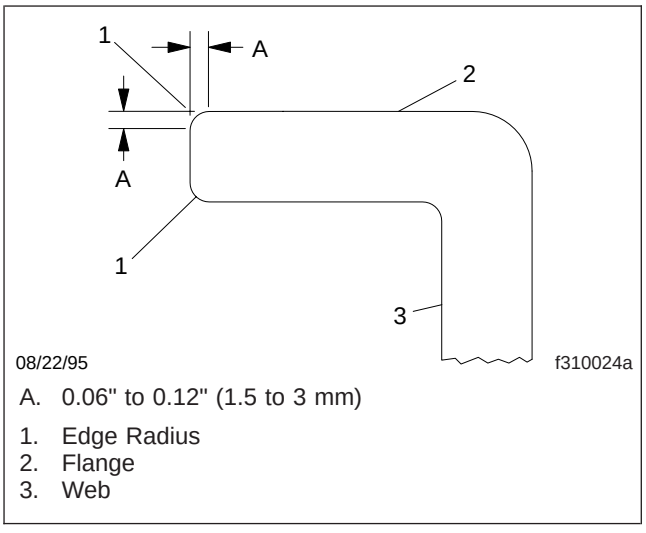
⚠ WARNING

Wear protective eye and face gear when grinding. Failure to wear this gear can result in personal injury due to flying metal debris from the grinding process.

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. Do not grind across the edges. See **Fig. 2**.

⚠ CAUTION

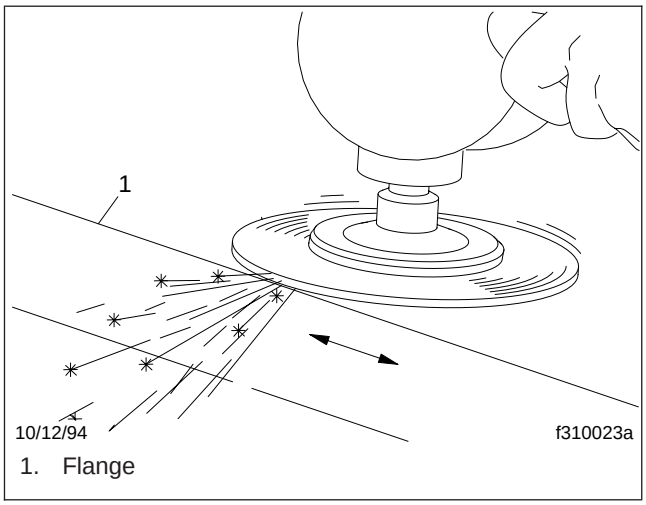
Apply light pressure only. Heavy pressure can result in harmful overheating and a loss of surface temper. Grind only in the direction of the cut. See Fig. 2. Grinding across the direction of the cut can reduce the structural strength of the frame rail.



A. 0.06" to 0.12" (1.5 to 3 mm)

1. Edge Radius
2. Flange
3. Web

Fig. 1, Radius Dimensions

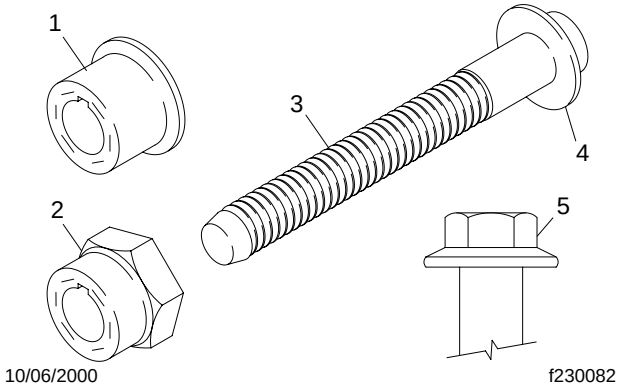


1. Flange

Fig. 2, Direction of Grind

Replacement

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**. 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.



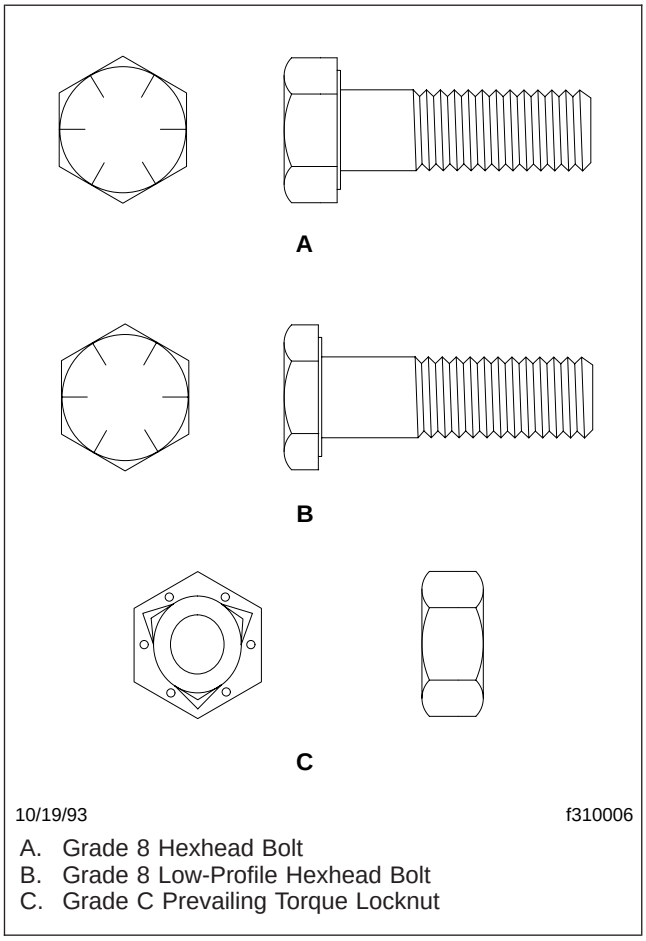
1. Spin Collar with Round Head
2. Spin Collar with Hexhead
3. Lock Pin
4. Round Head
5. Hexhead

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. These special hardened washers are used on the frame rails and for engine rear supports, and rear suspension brackets. They are cadmium- or zinc-plated, and have a hardness rating of 38 to 45 HRC.

Hexhead Bolt Replacement

1. Replace hexhead bolts with identical fasteners. See the Freightliner LLC Parts Book for fastener specifications.



A. Grade 8 Hexhead Bolt
B. Grade 8 Low-Profile Hexhead Bolt
C. Grade C Prevailing Torque Locknut

Fig. 2, Hexhead Fasteners

CAUTION

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.

2. Apply Alumilastic® compound, or an equivalent, to all surfaces where steel and aluminum parts contact each other.
3. 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.
    - For bolts 4 inches (102 mm) or less in length, make sure that at least 1-1/2

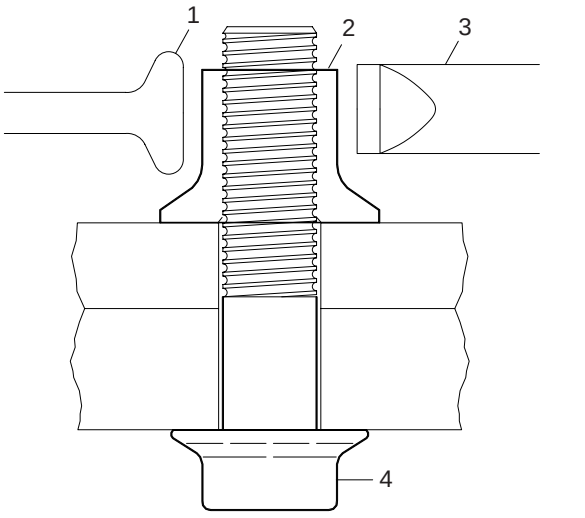
threads and no more than 5/8-inch (16-mm) bolt length extend through the self-locking nut after it has been tightened.

- For bolts longer than 4 inches (102 mm), allow a minimum of 3 threads and a maximum of 3/4-inch (19-mm) bolt length.

Huck Fastener Removal

1. The collar for Huck fasteners is spun on when they are installed. If a hexhead collar is used, it can be removed with an impact wrench.

   In the event a collar without the hexhead is used, it cannot be unscrewed. 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**.



1. Anvil
2. Spin Collar
3. Chisel
4. Lock Pin

Fig. 3, Huck Fastener Removal

2. Drive out the lock pin with a punch.
3. Discard the fastener after removing it.

⚠ CAUTION

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.

4. Replace Huck fasteners with standard Grade 8 threaded fasteners if the repair location does not have the equipment to properly install replacement Huck fasteners.

Frame Fastener Tightening

⚠ CAUTION

Tighten standard frame fasteners periodically. Continued vehicle operation with loose fasteners could result in component, bracket, and frame damage.

1. Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating).
2. 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**.

NOTE: Huck fasteners do not require periodic tightening.

Specifications

Gas-metal arc welding is the recommended welding method for use on frame rails. Gas-metal arc welding uses DC current only (MIG welding). Use either a short arc beading technique or a narrow weave technique. If gas-metal arc welding is not available, coated-electrode arc welding can be used.

For the gas-metal arc welding method, use the following materials:

- Weld wire that meets American Welding Society (AWS) specification A 5.28, Class E110S.
- Linde M-5 gas or an equivalent argon-oxygen mixture of 5 percent oxygen.

See **Table 1** for machine settings for gas-metal arc welding.

For the coated-electrode arc welding method, use the following materials:

- Weld rod type AWS-E-11018, on 1/8-inch. On 1/4-inch thick frame rails only, weld rod type AWS-E-9018 can be used.

See **Table 2** for amperage and voltage settings for coated-electrode arc welding.

See **Table 3** for frame fastener torque specifications.

Machine Settings for Gas-Metal Arc Welding				
Wire Diameter	Current (amperes)		Wire Extension	
			Optimum	Maximum
Inches (mm)	Minimum	Maximum	Inches (mm)	Inches (mm)
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, Machine Settings for Gas-Metal Arc Welding

Amperage and Voltage Settings for Coated-Electrode Arc Welding		
Weld Position	Amperes	Volts
Downhand	130/140	21/23
Overhead	130/140	21/23
Vertical Up	110/120	22/24

Table 2, Amperage and Voltage Settings for Coated-Electrode Arc Welding

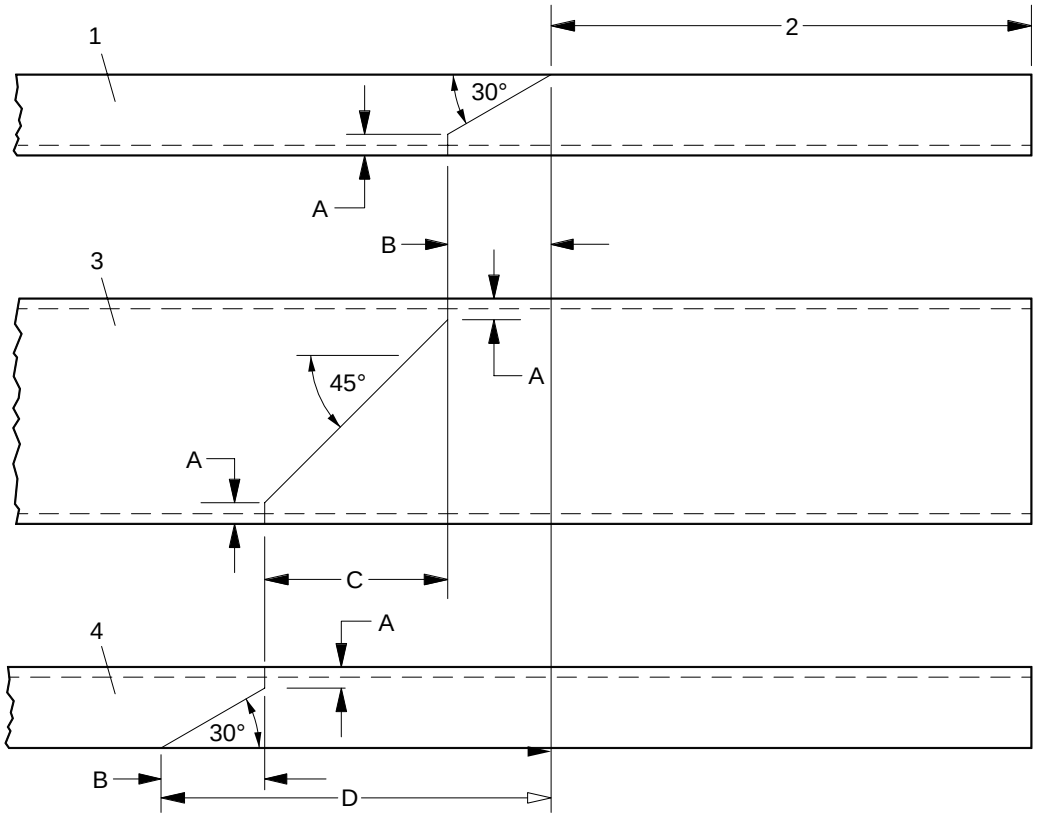
Torque Values for Frame Fasteners*	
Size	Torque: lbf·ft (N·m)
1/2–13	68 (92)
9/16–12	98 (133)
5/8–11	136 (184)
3/4–10	241 (327)
3/4–16	269 (365)
7/8–9	388 (526)
7/8–14	427 (579)

* Lubricated or plated threads.

Table 3, Torque Values for Frame Fasteners

Specifications

See **Fig. 1** for frame rail and extension cutting dimensions.



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)

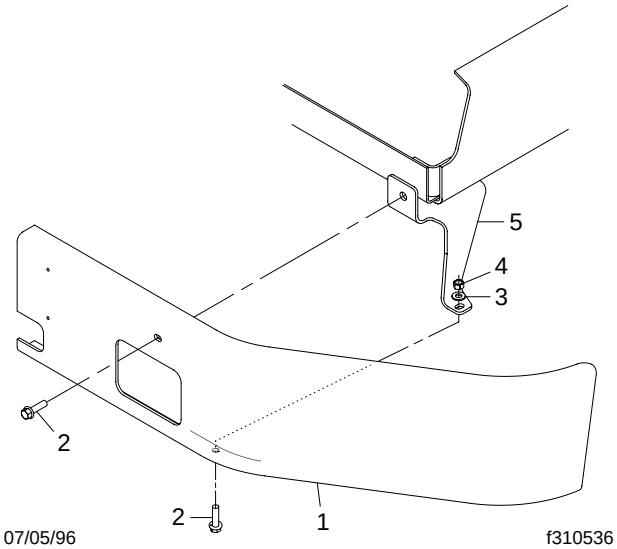
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1. Upper Flange
2. Extension Length
3. Web
4. Lower Flange

Fig. 1, Frame Rail and Extension Cutting Dimensions

Removal

1. Park the vehicle on a level surface; then apply the parking brakes. Chock the tires.
2. Support the bumper. On one side of the vehicle, first remove the lower, then the upper 1/2–13 fasteners that attach the bumper to the frame rail bracket. See **Fig. 1**.



1. Bumper
2. 1/2–13 Capscrew
3. 1/2-Inch Washer
4. 1/2–13 Hexnut
5. Frame Rail Bracket

Fig. 1, Bumper Installation

3. Repeat the procedure on the other side of the vehicle, and remove the bumper assembly from the vehicle.

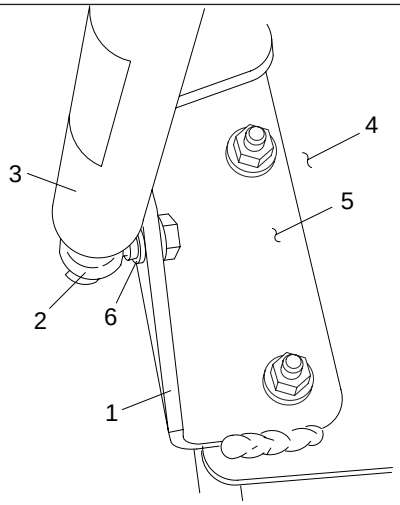
Installation

1. Support the bumper on the frame rail brackets.
2. Install the 1/2–13 fasteners and tighten the nuts 68 lbf·ft (92 N·m).
3. Remove the chocks from the tires.

Non-Aerodynamic Bumper Removal and Installation

Removal

1. Chock the front tires.
2. Raise the hood.
3. On the right-hand side of the vehicle, remove the lower end of the hood damper from the ball stud. See **Fig. 1**. Lift the steel spring clip with a small screwdriver and pop the end of the damper off. Pivot the hood damper on the upper ball stud and move it out of the way.



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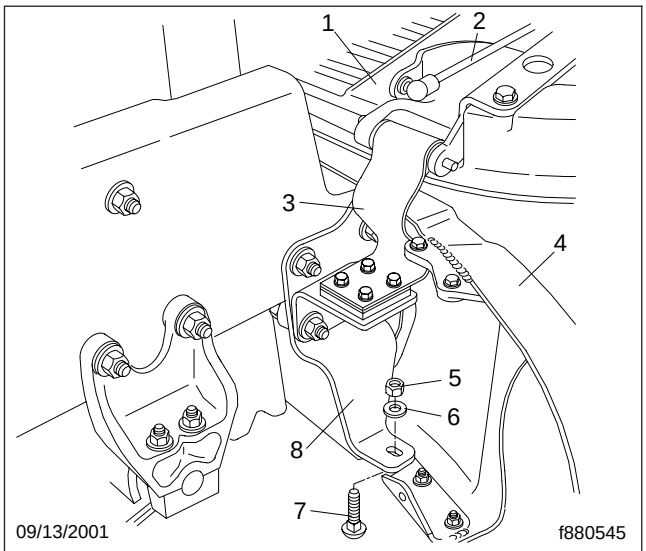
1. Flange of Reinforcement
2. Ball Stud
3. Hood Damper
4. Bumper
5. Bumper Reinforcement
6. M8 Ball Stud Fastener

Fig. 1, Hood Damper

NOTE: It is not necessary to remove the upper ball stud on the hood damper.

4. On each side of the vehicle, remove the lower bumper mounting bolt, washer, and locknut that attaches the bumper to the bumper mounting bracket. See **Fig. 2**.
5. On each side of the vehicle, loosen the upper bumper mounting bolt, and remove the nut and washer. Push up slightly on the hood to gain clearance, and remove both upper mounting bolts through the top of the bumper. See **Fig. 3**.

NOTE: Two persons are required for this step.



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Right-hand side is shown; left-hand side is similar.

1. Hood
2. Hood Damper
3. Hood Pivot
4. Bumper
5. Bumper Locknut, 1/2–13
6. Washer
7. Lower Bumper Mounting Bolt, 1/2–13
8. Bumper Mounting Bracket

Fig. 2, Lower Bumper Mounting Bolt

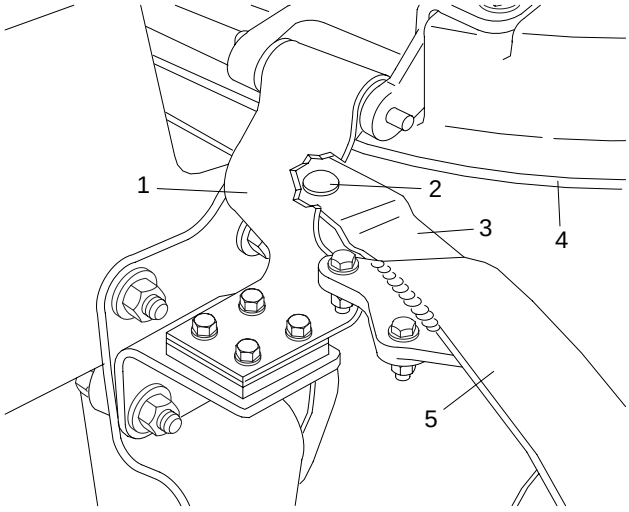
6. With a helper, remove the bumper from the vehicle.

Installation

NOTE: Two persons are required for this step.

1. With a helper, position the bumper on the support brackets so that the holes for the mounting bolts line up. Install the upper and lower mounting bolts, nuts, and washers.
2. On each side of the vehicle, tighten the 1/2–13 grade 8 locknuts 68 lbf·ft (92 N·m).
3. Fasten the bottom end of the hood damper to the bumper, as follows.
   - 3.1 Pivot the hood damper down, and line up the ball stud with the fastener hole in the flange of the bumper reinforcement.
   - 3.2 Attach the M8 ball stud fastener to the ball stud.

Non-Aerodynamic Bumper Removal and Installation



Right-hand side is shown; left-hand side is similar.

1. Hood Pivot
2. Upper Bumper Mounting Bolt, 1/2–13
3. Bumper
4. Hood
5. Bumper End Cap

Fig. 3, Upper Bumper Mounting Bolt

3.3 Tighten the fastener 13 lbf·ft (18 N·m).

4. Lower the hood.
5. Remove the chocks from the tires.

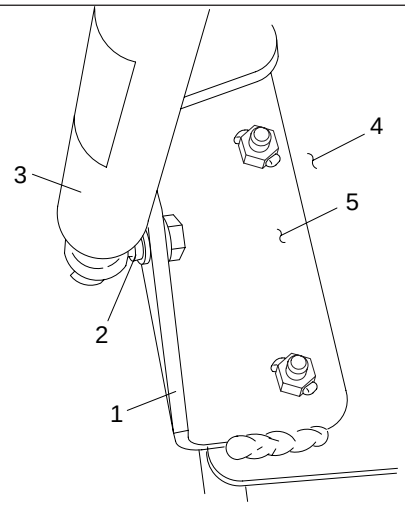
Non-Aerodynamic Bumper End Cap Removal and Installation

Removal

1. Chock the front tires.
2. Raise the hood.

NOTE: It is not necessary to remove the lower end of the hood damper for this procedure. The lower end of the hood damper is attached to the center bumper, and the end caps can be removed with it installed. However, it is easier and quicker to do the following steps with the damper out of the way.

3. On the right-hand side of the vehicle, remove the lower end of the hood damper from the ball stud. See **Fig. 1**. Lift the steel spring clip with a small screwdriver and pop the end of the damper off. Pivot the hood damper on the upper ball stud and move it out of the way.



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1. Flange of Reinforcement
2. Ball Stud
3. Hood Damper
4. Bumper
5. Bumper Reinforcement

Fig. 1, Hood Damper

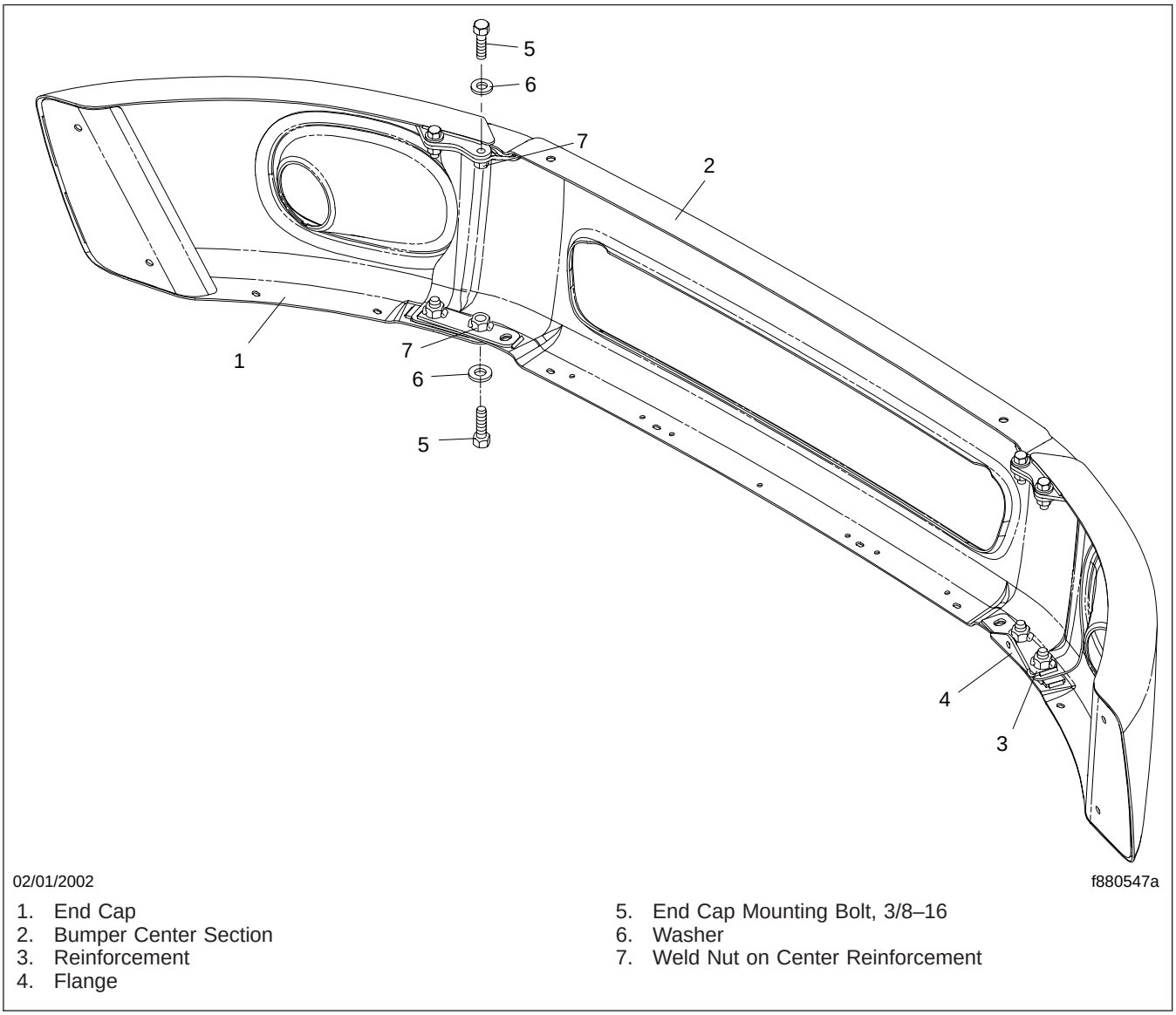
NOTE: It is not necessary to remove the upper ball stud on the hood damper.

4. On one side of the vehicle, remove the end cap from the bumper, as follows. See **Fig. 2**.
   - 4.1 Remove the lower end cap mounting bolt and washer that attaches the end cap to the bumper center section.
   - 4.2 Remove the upper end cap mounting bolt and washer that attaches the end cap to the bumper center section.
   - 4.3 Remove the end cap from the bumper center section.
5. On the other side of the vehicle, remove the other end cap by following the same procedure.

Installation

1. Install one end cap on either end of the bumper center, as follows.
   - 1.1 Position one end cap on either end of the bumper center so that the holes for the mounting bolts line up.
   - 1.2 Install the upper and lower mounting bolts and washers.
2. Install the other end cap by following the same procedure.
3. On each side of the vehicle, tighten the 3/8–16 grade 5 mounting bolts 26 lbf·ft (36 N·m).
4. Fasten the bottom end of the hood damper to the bumper, as follows.
   - 4.1 Pivot the hood damper down, and line up the ball stud with the fastener hole in the flange of the bumper reinforcement.
   - 4.2 Attach the M8 ball stud fastener to the ball stud.
   - 4.3 Tighten the fastener 13 lbf·ft (18 N·m).
5. Lower the hood.
6. Remove the chocks from the tires.

Non-Aerodynamic Bumper End Cap Removal and Installation



1. End Cap
2. Bumper Center Section
3. Reinforcement
4. Flange
5. End Cap Mounting Bolt, 3/8–16
6. Washer
7. Weld Nut on Center Reinforcement

Fig. 2, Bumper End Caps

Specifications

Bumper Torque Values			
Description	**Size**	**Grade/Class**	**Torque: in lbf·ft (N·m)**
Ball Stud Fastener, Hood Damper	M8	8.8	13 (18)
Bumper Mounting Bolts	1/2–13	5	68 (92)
Bumper End Cap Mounting Bolts	3/8–16	—	26 (36)

Table 1, Bumper Torque Values

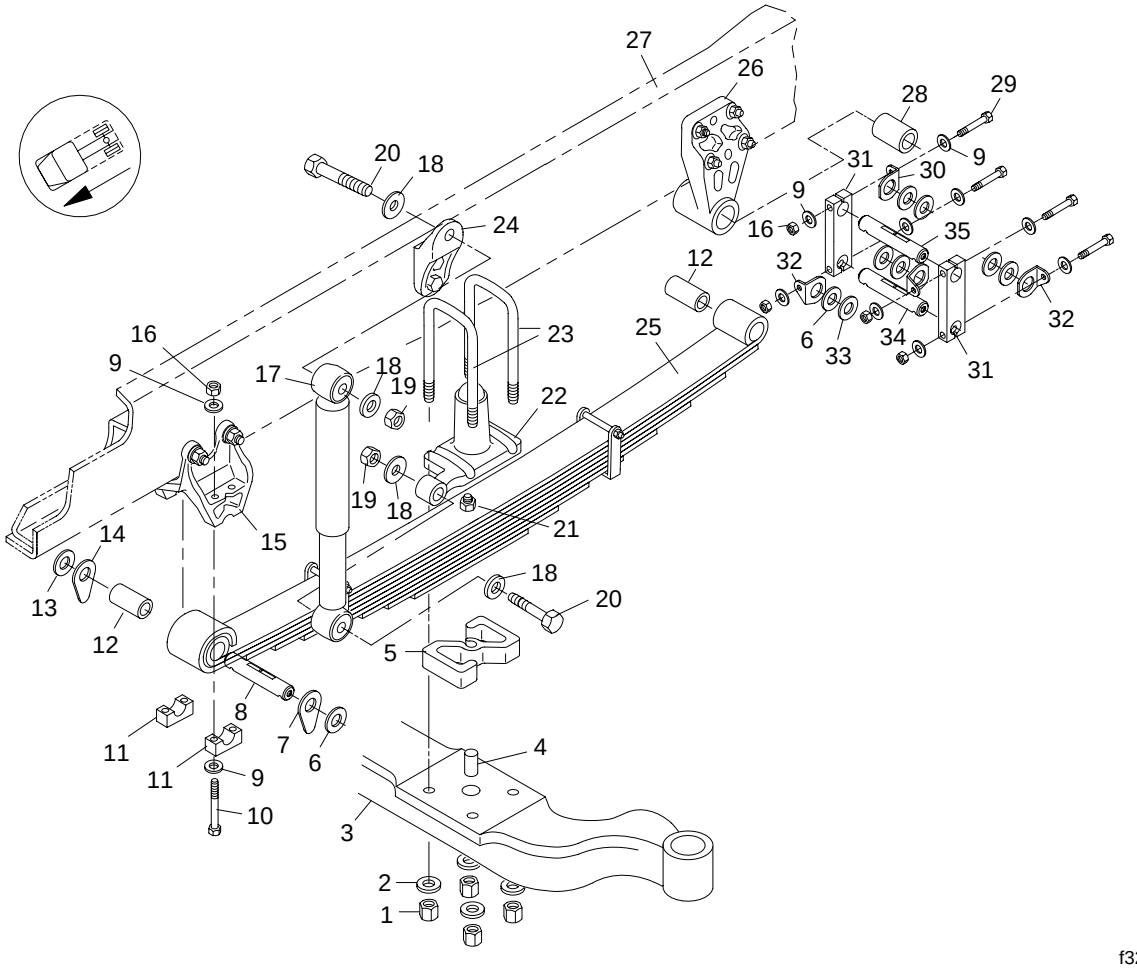
General Information

S2 Chassis front suspensions use a tapered leaf assembly. The tapered leaf suspensions are available in varying capacities from 7000-pound (2722 kg) to 12,000-pound (5443 kg). Shock absorbers are standard.

The spring assemblies are attached to the axle with U-bolts, hardened washers, and high nuts. See **Fig. 1**. The forward end of each spring mounts to a stationary front spring bracket. The rear of each spring mounts to either a spring shackle suspended from a frame-mounted bracket, or fits straight into the frame-mounted bracket, and is locked in place by a carriage bolt. The shackle or deflection pad allows for variations in spring length as the spring flexes.

The leaf spring assembly absorbs and stores energy over bumps, releasing it at a controlled rate to smooth the ride. Individual spring leaves are held together by a center bolt. Alignment clips limit the sideways spread and vertical separation of the individual leaves.

General Information



12/19/2001 f320938

1. U-Bolt High Nut
2. Bearing Washer
3. Axle
4. Dowel
5. Spacer
6. Outboard Spacing Washer(s)
7. Outboard Spring Spacer
8. Spring Pin, Forward Spring Eye
9. Hardened Washer, 1/2–13
10. Hexbolt, 1/2–13 x 5"
11. Spring Pin Retainer
12. Spring-Eye Bushing
13. Hardened Washer
14. Inboard Spring Spacer
15. Front Suspension Bracket
16. Locknut, 3/4–10
17. Shock Absorber
18. Hardened Washer
19. Locknut, 3/4–10
20. Hexbolt, 3/4–10
21. Spring Center-Bolt and Nut
22. Axle Stop and Shock Absorber Lower Mounting Bracket
23. U-Bolt
24. Shock Absorber Upper Mounting Bracket
25. Leaf Spring
26. Shackle Bracket
27. Frame Rail
28. Shackle Bracket Bushing
29. Pinch Bolt, 1/2–13 x 4"
30. Inboard Wear Plate
31. Shackle
32. Outboard Wear Plate
33. Hardened Washer, 2-1/4" o.d.
34. Spring Pin, Rear Spring Eye
35. Shackle Bracket Pin

Fig. 1, Front Suspension, Standard Application

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine, set the parking brakes, and chock the rear tires.
2. Tilt the hood.
3. Remove the front bumper end cap. For instructions, see **Group 31**.
4. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.

IMPORTANT: Make sure the frame rails are level and an equal distance off the ground.

5. Raise the front of the vehicle until both wheels are off the ground and the frame is supported with safety stands. The axle and leaf springs can then be manipulated with the floor jack.
6. Support the frame and axle with safety stands.

⚠ WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

7. Remove the leaf spring assembly, as follows.

   7.1 Remove the U-bolt high nuts and washers, then remove the U-bolts.

   7.2 Remove the shock absorber lower mounting bolt. Swing the shock absorber out of the way.

   7.3 If so equipped, remove the spring shackle lower bolt. See **Fig. 1**.

   If equipped with spring pins, remove the lower pinch bolts from the spring shackle.

   7.4 Remove the fasteners from the forward spring eye.

   If equipped with spring bolts: Remove the bolt, nut, and washers from the forward spring eye. See **Fig. 2**.

   If equipped with spring pins: Remove the front spring pin by removing the fasteners that hold the spring pin retainers in place. Remove the spring pin.

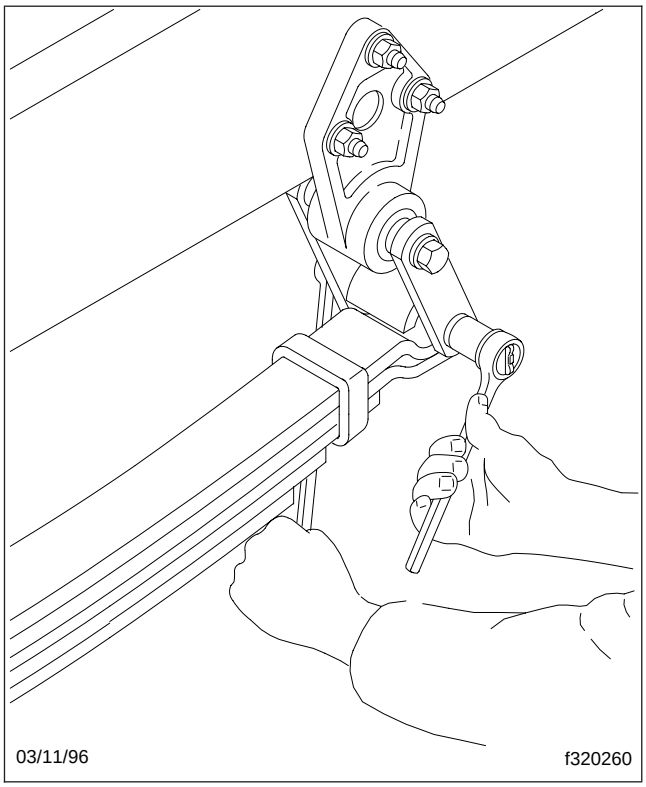


Fig. 1, Spring Shackle Lower Bolt Removal/Installation (typical)

NOTE: If removing the driver's side spring, the steering must be at right full-lock so the bolt can clear the drag link.

7.5 Support the front axle with a jack. Remove the safety stand, then lower the front axle enough to allow removal of the spring. Note the location of the spring spacer and any caster adjustment shims.

⚠ WARNING

The spring assembly is heavy. To prevent bodily injury, always use two people to remove it.

7.6 Remove the spring by sliding it toward the front of the vehicle. See **Fig. 3**.

8. If so equipped, remove the shackle upper bolt and nut. Press out the bushing. Remove the fasteners that hold the shackle bracket to the frame and remove the bracket.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

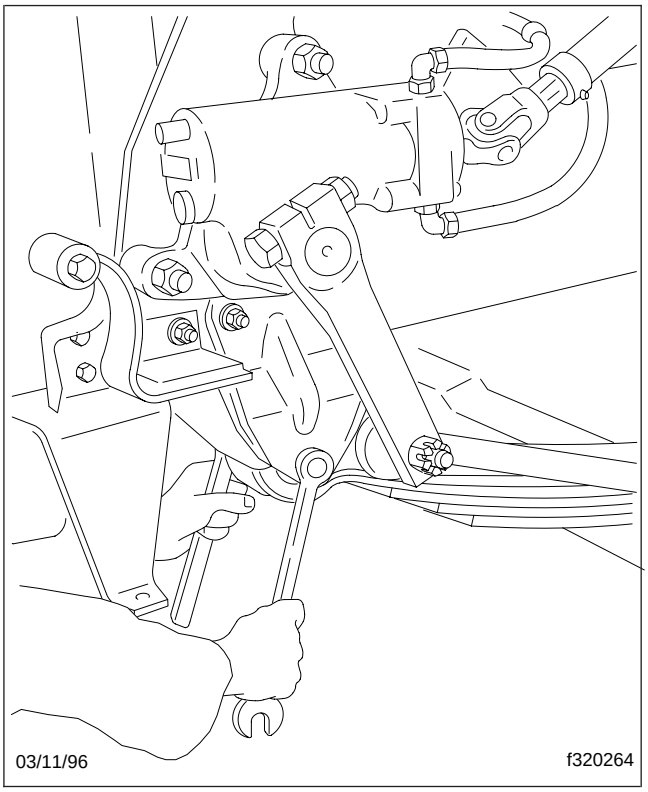


Fig. 2, Forward Spring Eye Bolt Removal/Installation (typical)

Cleaning and Inspection

1. Using a wire brush and solvent or steam cleaning equipment, wash all parts to remove dirt, grease, and scale.

IMPORTANT: When using a solvent, follow all of the solvent manufacturer's warnings, cautions, and instructions.

2. Inspect all components for damage, as follows.
   - 2.1 If so equipped, inspect the spring shackles and the shackle bracket for cracks, wear, and other damage. Replace any damaged parts.
   - 2.2 Inspect the leaf spring assembly for cracks or corrosion. If any leaves are cracked or broken, replace the *entire spring assembly.*

⚠ WARNING

Do not replace individual leaves of a 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.

   - 2.3 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 spring assembly.

Installation

IMPORTANT: For normal highway operation do not install springs of two different designs or load capacities on the front axle. In order to maintain a balanced front suspension system, install identical spring assemblies.

1. If the shackle bracket was removed, install it. Tighten the mounting bolts 135 lbf·ft (183 N·m).

NOTE: All suspension bracket (frame) fasteners require periodic retightening. Refer to **Group 00** of the *S2 Chassis Maintenance Manual* for the recommended intervals.

2. If the spring shackle was removed, install it. Don't tighten the upper bolt in the shackle at this time.

⚠ WARNING

The spring assembly is heavy. To prevent injury, always use two people to install it.

3. Install the spring assembly, as follows.
   - 3.1 Lift the spring into position. See **Fig. 3**.
   - 3.2 Install the fasteners in the forward spring eye.

     If equipped with spring bolts: Install the mounting bolt and washer in the forward

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

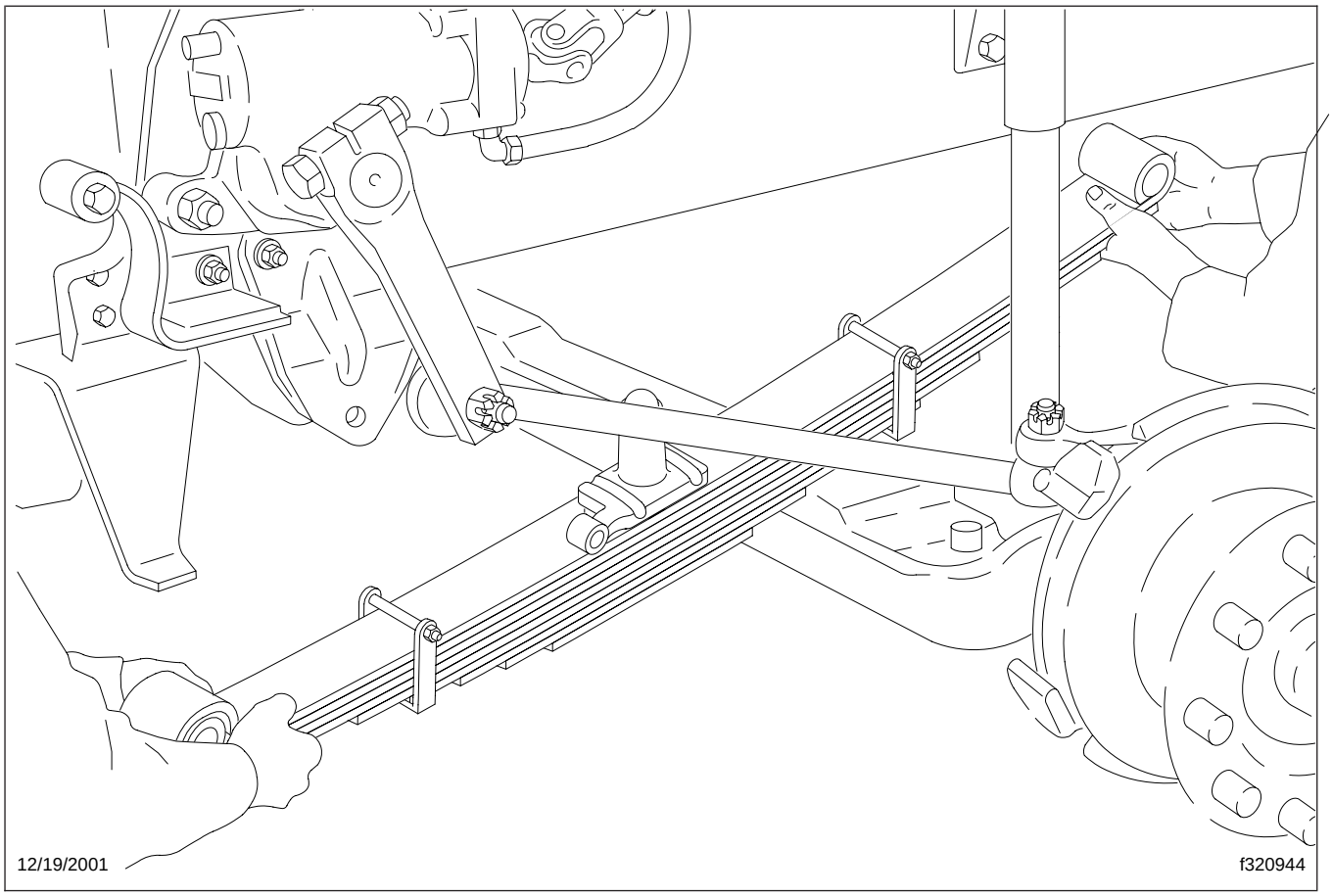


Fig. 3, Spring Removal/Installation (typical)

spring eye. Install the other washer and nut. Tighten 240 lbf·ft (325 N·m).

If equipped with spring pins: Install the spring pin in the forward spring eye. Install the spring pin retainers. Tighten the fasteners 250 lbf·ft (339 N·m).

3.3 Install the fasteners in the rear spring eye.

If equipped with spring bolts: Install the lower shackle bolt, nut, and washers. Tighten the upper and lower bolts 240 lbf·ft (325 N·m).

If equipped with spring pins: Install the lower spring pin assembly through the spring eye and the lower shackle. Install the pinchbolts in the bottom of the shackle. Tighten the upper and lower shackle pinch bolts 45 lbf·ft (61 N·m), for aluminum shackles, or 70 lbf·ft (95 N·m) for steel shackles.

3.4 Apply Alumilastic® or a similar compound to the top and bottom of the spring spacer and any caster adjustment shims.

⚠ CAUTION

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 suspension parts.

3.5 Place the dowel, caster adjustment shim, and the spring spacer on the axle.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

3.6 Place the axle stop/shock absorber lower mounting bracket in position on the leaf spring.

3.7 Using a jack, lift the axle into position.

3.8 Install the U-bolts over the shock absorber lower mounting bracket, the spring leaves, spring spacer, caster adjustment shims, and through the front axle.

3.9 Install the high nuts on the U-bolts and tighten them as described in **Specifications 400**.

4. Attach the shock absorber to its lower mounting bracket. Tighten the nut 140 lbf·ft (190 N·m).
5. Remove the floor jack and safety stands.
6. Install the wheel and tire. See **Group 40** for instructions.
7. Install the front bumper end cap. See **Group 31** for instructions.
8. Lower the hood, and remove the tire chocks.

Shackle Bracket Bushing Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the rear tires.
2. Tilt the hood.
3. Remove the front bumper end cap. For instructions, see **Group 31**. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
4. Remove the shackle bracket from the vehicle, as follows.
   - 4.1 Jack up the frame until the shackle lower bolt can be removed. Remove the bolt.
   - 4.2 Remove the shackle upper bolt and the spring shackle.
   - 4.3 Remove the shackle bracket from the frame.
5. Using a press, remove the bushing from the shackle bracket.
6. Inspect the shackle bracket and new bushing, as follows.
   - 6.1 With an inside micrometer or bore gauge, check whether the bracket bore is out-of-round. Replace the bracket if the bushing bore is out-of-round.
   - 6.2 Before installing the new bushing, check the shackle bracket bolt for ease of fit in the bushing. There should be an easy slip fit without wobble between the bolt and the bushing.
7. Using a press, insert the new bushing into the bracket until the bushing is centered in the bracket.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

8. Check the shackle bracket bolt again for ease of fit in the bushing. It should still fit easily without wobble between the bolt and the bushing. If it binds, the bushing may have been distorted during installation. Replace the bushing and check again for proper fit.
9. Install the shackle bracket. Install the fasteners and tighten them 135 lbf·ft (183 N·m).
10. Connect the leaf spring, as follows.
    - 10.1 Install the spring shackle and the shackle upper bolt.
    - 10.2 Adjust the height of the jack supporting the frame until the bushing at the rear of the leaf spring lines up with the hole for the shackle lower bolt.
    - 10.3 Install the shackle lower bolt. Tighten it 240 lbf·ft (325 N·m).
11. Install the wheel and tire. For instructions, see **Group 40**.
12. Install the front bumper end cap. For instructions, see **Group 31**.
13. Lower the hood and remove the tire chocks.

Spring Bushing Replacement

1. Remove the leaf spring from the vehicle. See **Subject 100** for instructions.
2. Using a press, remove the worn or damaged bushing.
3. Using a press, insert the new bushing into the spring eye until the bushing is flush with the edges of the spring eye.

IMPORTANT: Do not press in the bushing by the center sleeve. This could damage the bushing.

4. Install the leaf spring. See **Subject 100** for instructions.

Replacement

1. Apply the parking brake, chock the rear tires, and tilt the hood.
2. Remove the locknut from the shock absorber upper mount, then remove the 3/4–10 hexbolt and washers.
3. Remove the locknut from the shock absorber lower mount, then remove the 3/4–10 hexbolt and washers.
4. Remove the shock absorber.
5. Install the new shock absorber. Tighten the locknuts 140 lbf·ft (190 N·m).
6. Lower the hood, and remove the tire chocks.

Troubleshooting Tables

Problem—Vehicle Leans to One Side

Problem—Vehicle Leans to One Side	
Possible Cause	**Remedy**
One or more spring leaves are broken.	Replace the spring assembly.
The spring assembly is weak or fatigued.	Replace the spring assembly.
Unmatched spring-design/load-capacity spring assemblies are installed.	Install the correct spring assemblies as originally specified for the vehicle.
A frame rail is bent or twisted.	Check the frame rails for bends and twists. Correct as needed.

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**.
Caster is incorrect.	Install correct caster shims. Refer to **Group 33** for specifications.
Steering gear is not centered.	Adjust steering using the instructions in **Group 46**.
Drive axle is out of alignment.	Align the drive axle using the instructions in **Group 35**.

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**.
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 the torque table in **Specifications 400**.
Worn or damaged spring pin bushings are allowing spring end-play.	Replace the spring pin and bushing.

Troubleshooting

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.

Problem—Rough Ride

Problem—Rough Ride	
Possible Cause	**Remedy**
Refer to the applicable suspension section in this manual.	

Specifications

Front Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Shackle Bracket-to-Frame Locknut	3/4–10	240 (325)
Spring Shackle Pinch-Bolt Locknuts	1/2–13	Aluminum Shackles: 45 (61) Steel Shackles: 70 (95)
Spring Pin Retainer Hexbolts	1/2–13	60–76 (81–103)
Forward Spring-Eye Bolt	3/4–10	240 (325)
Upper and Lower Shackle Bolt	3/4–10	240 (325)
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: 180–230 (245–313)
	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)
Shock Absorber Upper and Lower Mounting Locknuts	3/4–10	140 (190)

Table 1, Front Suspension Fastener Torque Values

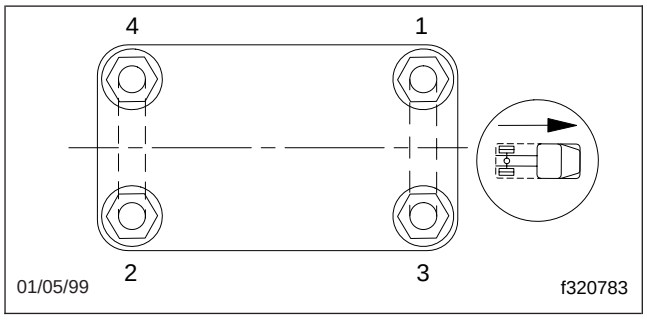


Fig. 1, Tightening Pattern for U-Bolt High Nuts

General Information

The rear leaf-spring suspension for the S2 Chassis uses either 60-inch taper-leaf or 52-inch multi-leaf springs with varying capacities. See **Fig. 1**, **Fig. 2**, **Fig. 3**, or **Fig. 4**.

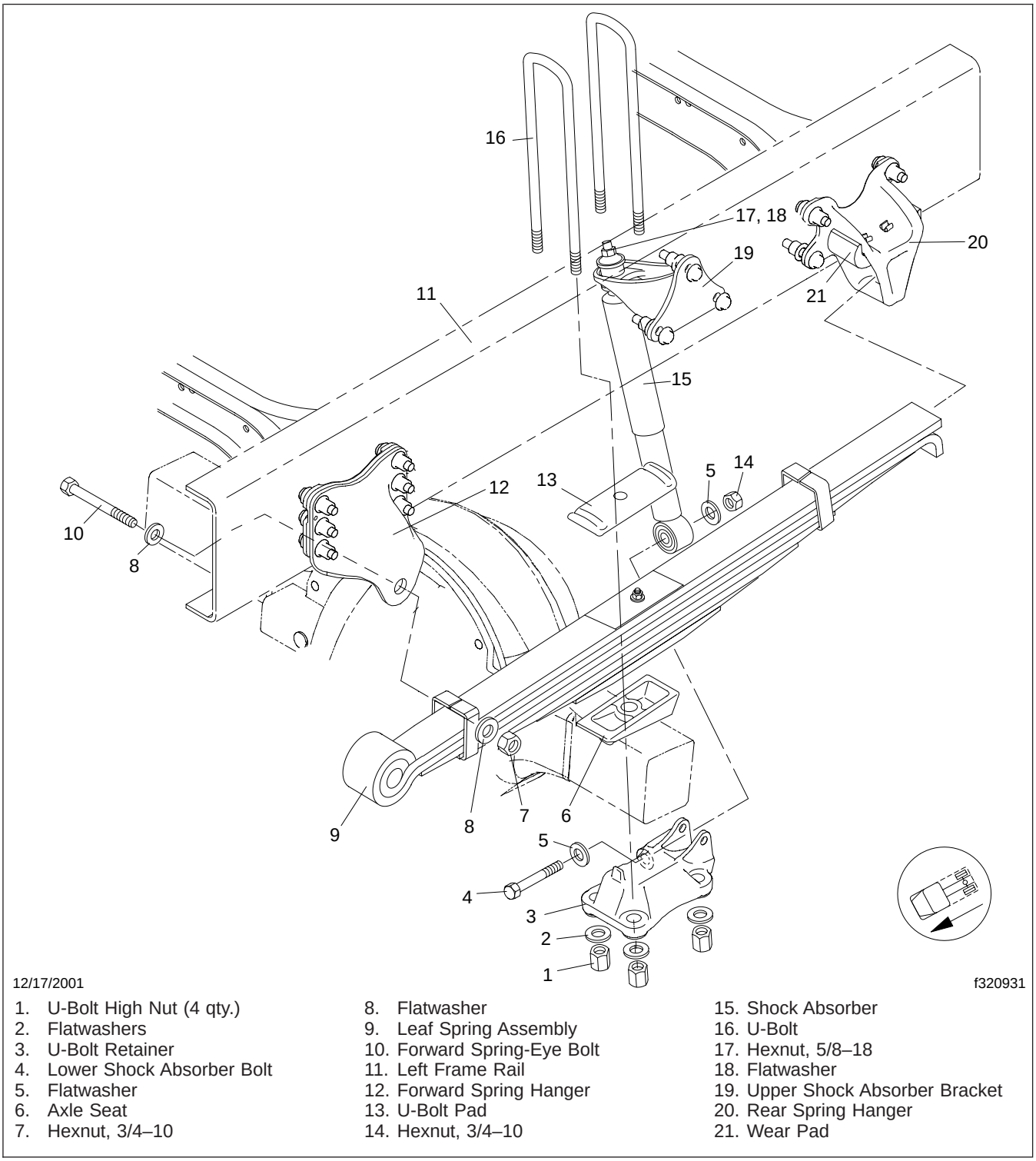
Taper-leaf springs have shackles and pins to secure the rear spring end, while multi-leaf spring applications use a slip spring design in which the rear spring end rides in a cast iron bracket mounted on the frame rail.

The 52-inch multi-leaf spring suspension is available with a rubber or leaf-spring helper. A rubber helper is standard with the 60-inch taper-leaf spring suspension.

Both types of helper provide additional spring rate for extra load-carrying capacity and increased roll stability.

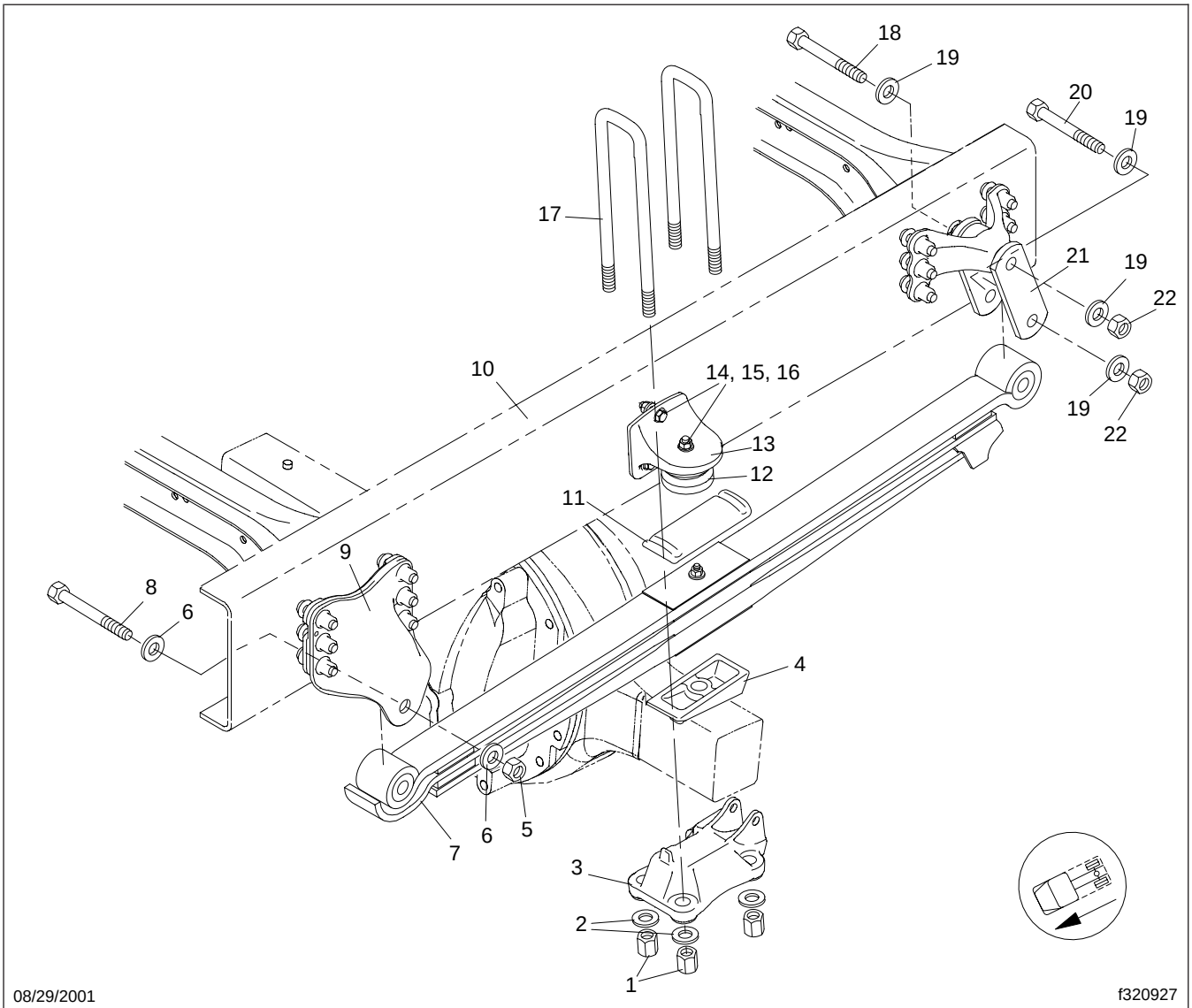
Both types of spring assemblies are attached to the axle with U-bolt assemblies. Shock absorbers are optional with the 52-inch multi-leaf suspension, and are standard with the 60-inch taper-leaf suspension.

General Information



1. U-Bolt High Nut (4 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Lower Shock Absorber Bolt
5. Flatwasher
6. Axle Seat
7. Hexnut, 3/4–10
8. Flatwasher
9. Leaf Spring Assembly
10. Forward Spring-Eye Bolt
11. Left Frame Rail
12. Forward Spring Hanger
13. U-Bolt Pad
14. Hexnut, 3/4–10
15. Shock Absorber
16. U-Bolt
17. Hexnut, 5/8–18
18. Flatwasher
19. Upper Shock Absorber Bracket
20. Rear Spring Hanger
21. Wear Pad

Fig. 1, 52-Inch Multi-Leaf Spring Suspension (with optional shock absorbers)

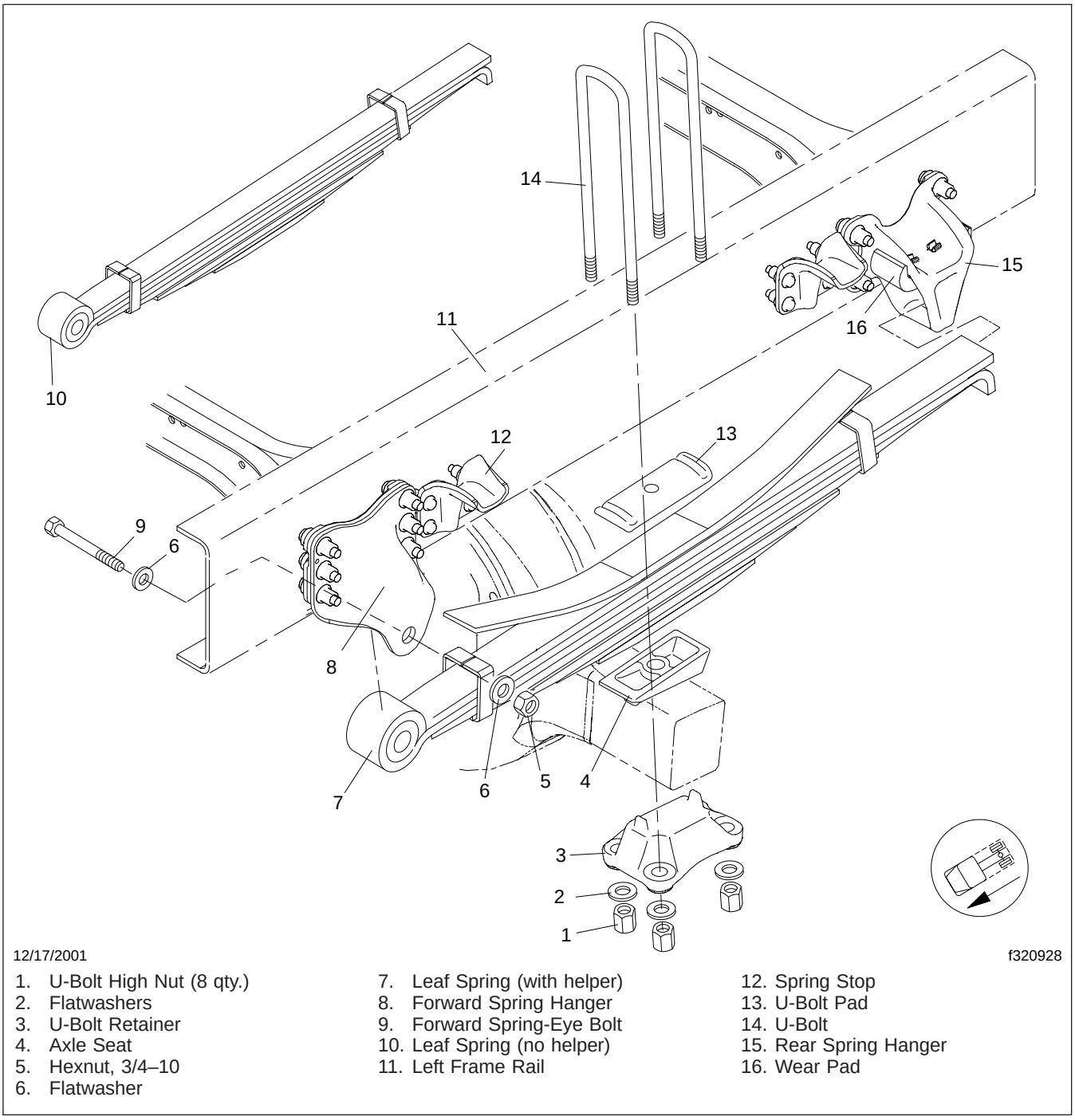


NOTE: Shock absorbers (standard with this suspension) not shown.

1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt Pad
12. Rubber Helper
13. Helper Bracket
14. Hexbolt, 1/2–13
15. Hexnut, 1/2–13
16. Flatwasher
17. U-Bolts
18. Upper Shackle Bolt
19. Flatwasher
20. Lower Shackle Bolt
21. Rear Spring Shackle
22. Hexnut, 3/4–10

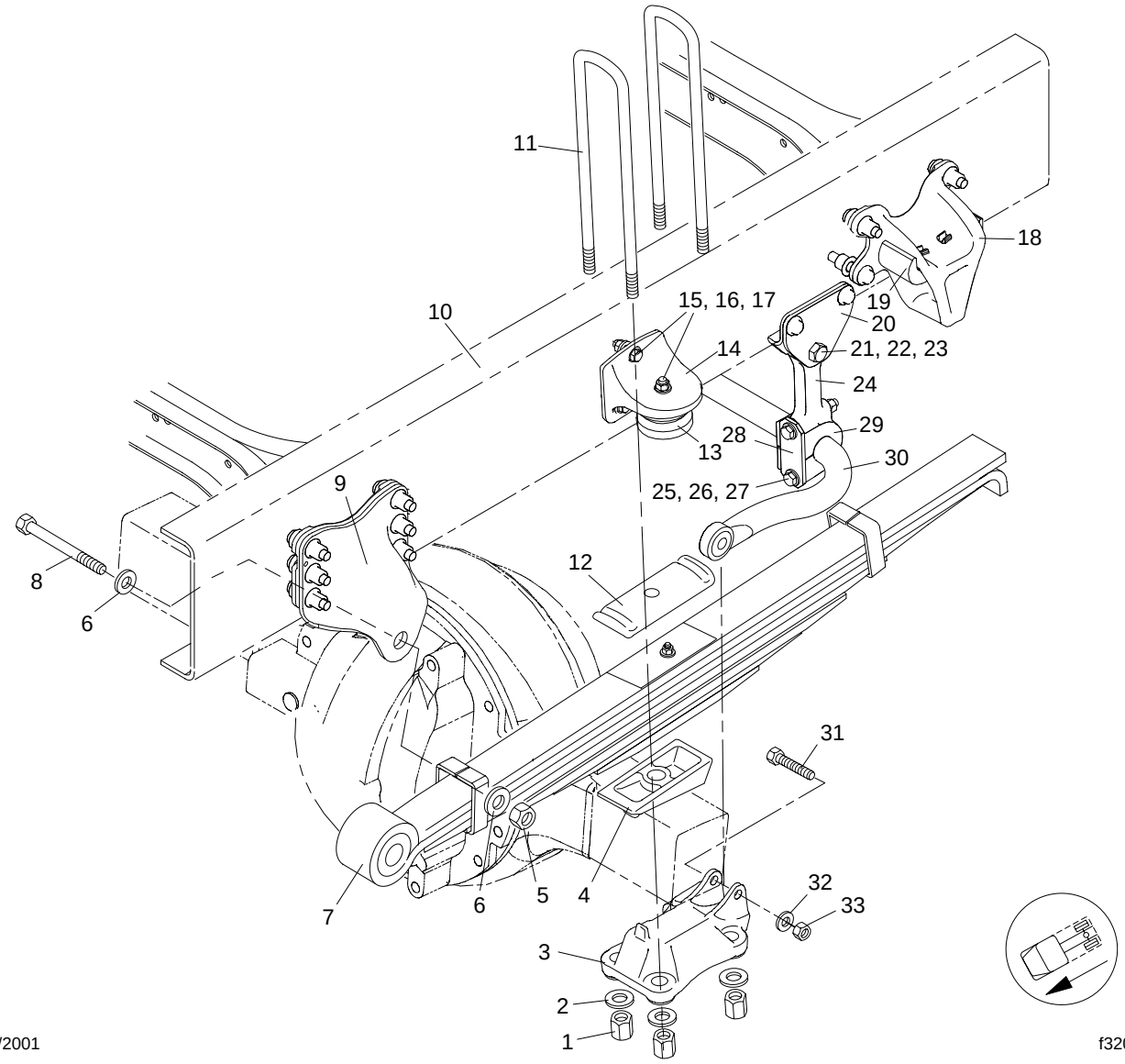
Fig. 2, 60-Inch Taper-Leaf Spring Suspension

General Information



1. U-Bolt High Nut (8 qty.)
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring (with helper)
8. Forward Spring Hanger
9. Forward Spring-Eye Bolt
10. Leaf Spring (no helper)
11. Left Frame Rail
12. Spring Stop
13. U-Bolt Pad
14. U-Bolt
15. Rear Spring Hanger
16. Wear Pad

Fig. 3, 52-Inch Multi-Leaf Spring Suspension



1. U-Bolt High Nuts
2. Flatwashers
3. U-Bolt Retainer
4. Axle Seat
5. Hexnut, 3/4–10
6. Flatwasher
7. Leaf Spring Assembly
8. Forward Spring-Eye Bolt
9. Forward Spring Hanger
10. Left Frame Rail
11. U-Bolt
12. U-Bolt Pad
13. Rubber Helper
14. Helper Bracket
15. Hexnut, 1/2–13
16. Hexbolt, 1/2–13
17. Flatwasher
18. Rear Spring Hanger
19. Wear Pad
20. Stabilizer Link Bracket
21. Hexbolt, 5/8–11
22. Hexnut, 5/8–11
23. Flatwasher
24. Stabilizer Bar Link
25. Hexbolt, 1/2–13
26. Hexnut, 1/2–13
27. Flatwasher
28. Strap
29. Stabilizer Bar Bushing
30. Stabilizer Bar
31. Hexbolt, 5/8–11
32. Flatwasher
33. Hexnut, 5/8–11

Fig. 4, 52-Inch Multi-Leaf Spring Suspension (with optional rubber helper and stabilizer bar)

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the front tires.
2. Remove the rear tires. For instructions, see **Group 40**.

⚠ WARNING

Use safety stands to securely support all axle and frame weight during suspension repairs. Unsecured components may drop when fasteners are loosened or removed, causing component damage and serious personal injury.

3. Lift the rear axle and support it with safety stands. Lift the vehicle frame to take weight off the rear springs.
4. Remove the U-bolt high nuts, then remove the U-bolts.
5. Remove the spring assembly, as follows.
   - 5.1 If the vehicle is equipped with the optional helper spring, lift it off.
   - 5.2 If equipped with rear shackles, remove the lower shackle bolt.
   - 5.3 Remove the front spring-eye bolt.
   - 5.4 Slide the leaf spring assembly forward and remove it from the vehicle.
6. For 52-inch multi-leaf suspensions, inspect the wear pads for wear. Replace them if needed. For instructions, see **Subject 120**.
7. Install the new spring assembly, as follows.
   - 7.1 *For 52-inch multi-leaf springs only,* slide the rear end of the spring into the rear spring hanger.
   - 7.2 Position the new spring on the axle seat.

   NOTE: It may be necessary to raise the frame slightly.
   - 7.3 Lower the frame or raise the axle until the front spring eye lines up with the hole in the forward spring bracket.
   - 7.4 Install the foward spring-eye bolt, nut, and washers. Make sure the bolt is inboard. Tighten the nut 240 lbf·ft (325 N·m).
   - 7.5 If equipped with the optional helper leaf spring, place it on the main spring.
   - 7.6 For 60-inch taper-leaf springs, raise the spring assembly until the rear spring eye is lined up with the lower shackle holes. Install the shackle fasteners, making sure the bolt head is inboard. Tighten the nuts 240 lbf·ft (325 N·m).
8. Install the U-bolts and the U-bolt retainer. Make sure the taller end of the retainer is toward the front of the vehicle.
9. Install the U-bolt high nuts, but don't tighten yet.
10. Tighten the U-bolt high nuts in sequence. See **Specifications 400** for complete instructions.
11. Install the rear tires. For instructions, see **Group 40**.
12. Raise the vehicle, remove the jack or safety stands from the rear axle and the frame, then lower the vehicle.
13. Remove the chocks from the tires.

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.
2. Remove the locknut, retainers, and bushings (if applicable) from the shock absorber lower mount.
3. Remove the fasteners from the shock absorber upper mount.
4. Remove the shock absorber.
5. Install the replacement shock absorber.
6. Install the bolt and locknut in the upper mount. Hand-tighten them at this time.
7. Install the replacement bushings, retainers, and locknut.

⚠ WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be pushed over the nut and be ejected violently, possibly causing personal injury and property damage.

8. Tighten the shock absorber upper mounting locknut until the rubber bushings expand to the same size as the retainer washer.
9. Tighten the shock absorber lower mounting fasteners to 240 lbf·ft (325 N·m).
10. Remove the chocks from the tires.

Replacement

NOTE: Wear pads, used only on 52-inch multi-leaf suspensions, can be replaced without removing the leaf spring assemblies. They are located on the rear spring hangers.

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the front tires.
2. Using a floor jack or a crane, take the weight off the frame rail so there is no contact between the spring and the wear pad.
3. Using a suitable pair of pliers, pinch the tabs of the wear pad together and push them out of the slot in the upper part of the rear spring hanger. Remove and discard the wear pad.
4. Install the new wear pad so that the thicker portion of the pad is toward the axle. Pinch the tabs together so they fit through the slot in the spring hanger. Push the wear pad up into place.
5. Lower the frame rail.
6. Remove the chocks from the tires.

Specifications

Torque Values			
Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Forward Spring Bolt*	3/4–10	—	240 (325)
Rear Spring Shackle Bolts*	3/4–10	—	240 (325)
Axle U-Bolt High Nuts Tighten in a diagonal pattern as shown in **Fig. 1**.	5/8–18 (10k to 16k lb ratings)	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 180 to 230 (245 to 313)
	7/8–14 (18k to 23k lb ratings)	C	Stage 1: Hand tighten Stage 2: 60 (81) Stage 3: 200 (271) Stage 4: 420 to 500 (570 to 678)
Helper Bracket Hexbolts	1/2–13	—	68 (92)
Shock Absorber Lower Locknuts†	—	C	240 (325)

* Cadmium-plated, wax-coated nuts, and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.

† See **Subject 110** for shock absorber upper locknut tightening instructions.

Table 1, Torque Values

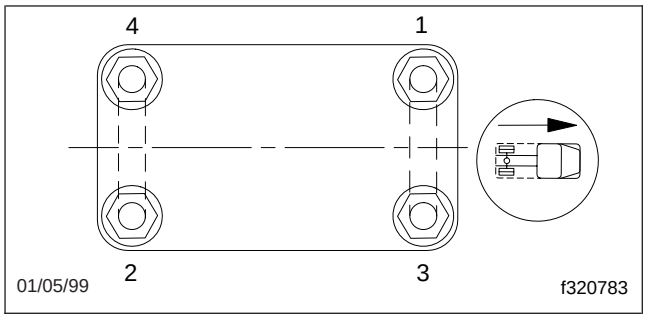


Fig. 1, Tightening Pattern for U-Bolt High Nuts

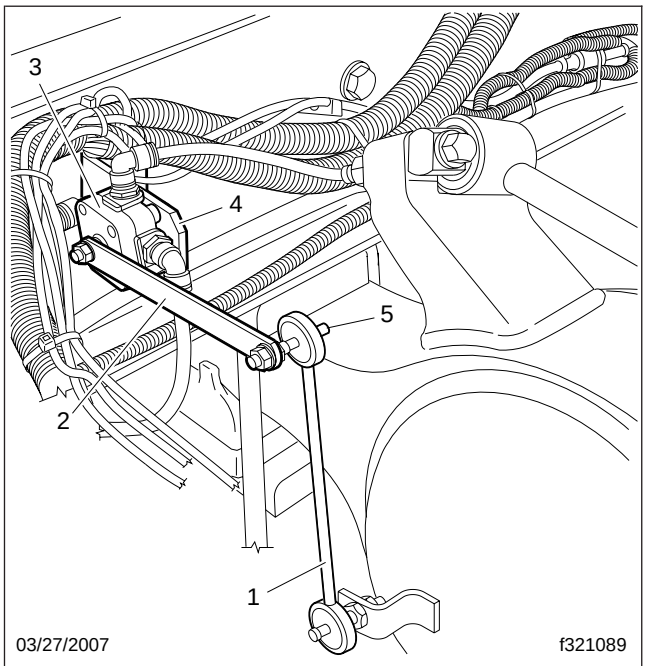
General Information

The Freightliner AirLiner suspension is a combination of air and leaf springs. 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) 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, locates 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. See **Fig. 1**. As the air spring compresses or expands, changes in the clearance between the vehicle frame and the differential housing activate the height control valve.

A 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. Linkage Rod
2. Overtravel Lever
3. Height Control Valve
4. Valve Mounting Bracket
5. Stud Bolt

Fig. 1, Height Control Valve Assembly

General Guidelines

To keep the air suspension system operating reliably, the air system must be kept free of any oil, moisture, or foreign material. Inspect and maintain the air system components regularly. Refer to **Group 42** of the *S2 Chassis Maintenance Manual* for maintenance operations.

⚠ CAUTION

Failure to take precautions against the entry of moisture, oil, or other foreign material into the air suspension system could eventually lead to sludge forming in the air system. Sludge could adversely affect the operation of the air suspension system and other air system components.

Use only SAE grade 8 hexbolts and grade G prevailing torque locknuts to attach spring hangers and brackets to the frame.

For suspension component inspecting, lubricating, and fastener torque checking intervals and instructions, refer to the maintenance schedule in **Group 00** and the suspension coverage in **Group 32** of the *S2 Chassis Maintenance Manual*.

General Information

Adjust the height control valve with the vehicle on a level surface.

CAUTION

Failure to adjust the height control valve could adversely affect driveline angles. If the air springs are set too low, rapid wear of suspension parts could result.

Valve Height Control Adjustment

1. Park the vehicle on a level surface, using a light application of the brakes. Do not apply the parking brakes. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.
2. Mark the location of the front and rear tires on the floor; then chock the tires on one axle only.

IMPORTANT: Before checking the suspension height, make sure there is no load on the chassis. Trucks must be empty.

3. Measure the distance between the top of the U-bolt and the bottom of the axle stop. See **Fig. 1**, **Fig. 2** and **Table 1**.

   If the measurement is acceptable, no more work is necessary.

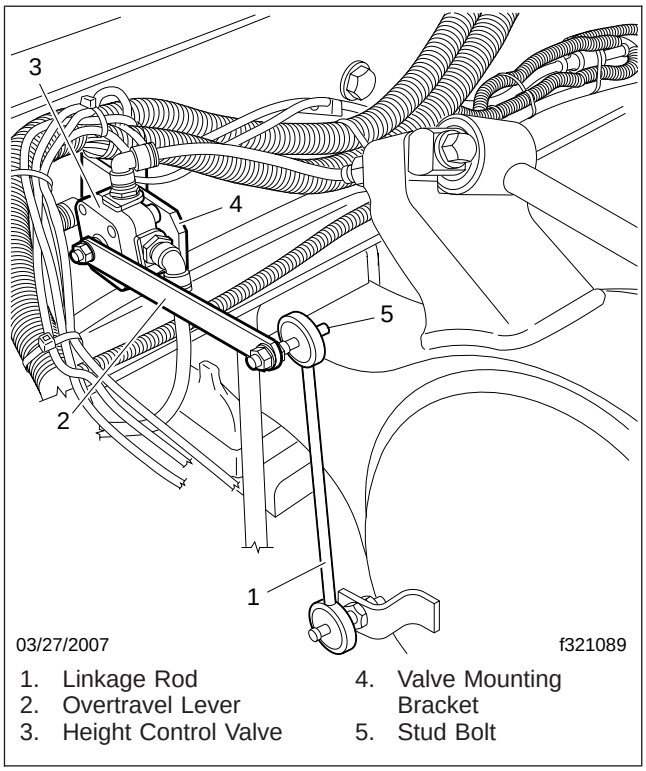
   If the measurement is not acceptable, go to the next step.

4. Adjust the suspension height, as follows. See **Table 1** for the correct distances.

   4.1 Loosen the two nuts that attach the valve to the valve mounting bracket.

   4.2 Adjust the position of the valve body until the distance from the bottom of the left axle stop to the top of the axle U-bolt pad is correct.

   4.3 Center the overtravel lever on the valve by inserting a 5/32-inch (4-mm) pin into the hole in the overtravel lever and aligning the hole with the valve body.



1. Linkage Rod
2. Overtravel Lever
3. Height Control Valve
4. Valve Mounting Bracket
5. Stud Bolt

Fig. 1, Height Control Valve Installation

   4.4 Tighten the two fasteners that attach the valve to the mounting bracket.

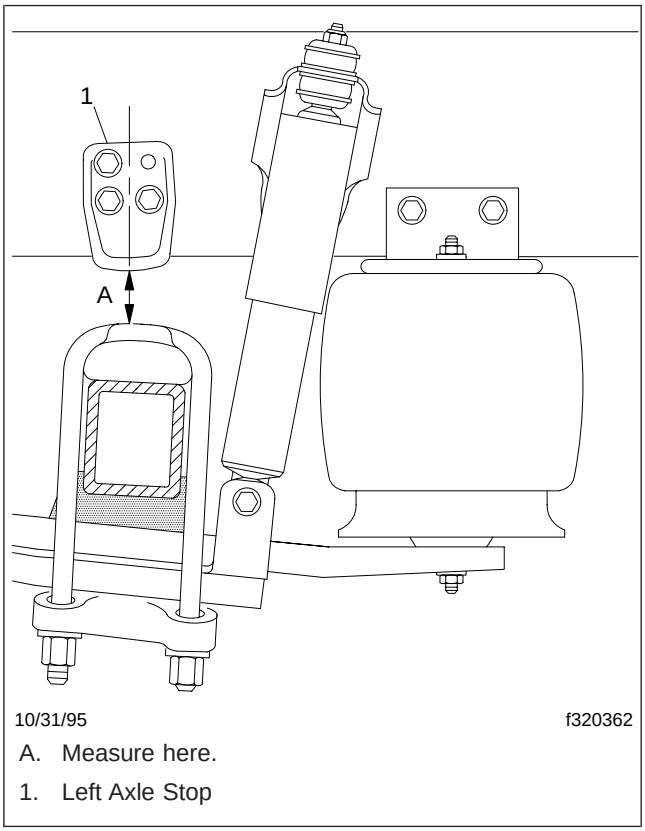
   4.5 Remove the pin from the hole in the overtravel lever.

5. Drive the vehicle unloaded for about 1/4 mile (1/2 km), then stop the vehicle in the exact location (as previously marked) of the original measurement.

   Park the vehicle using a light brake application. Chock the tires on one axle only, and put the transmission in neutral. Do not apply the parking brakes.

6. Check the distance between the bottom of the left axle stop and the top of the U-bolt.
7. If the distance is not correct, repeat the adjustment procedure.

Height Control Valve Adjustment



A. Measure here.
1. Left Axle Stop

Fig. 2, Height Control Valve Adjustment Measurement

Suspension Height Adjustment Distances			
Suspension Type	**Distance: in (mm)**		
	Minimum	**Target**	**Maximum**
20k AirLiner	2-3/8 (60)	2-5/8 (67)	2-7/8 (73)
23k AirLiner	2-3/4 (70)	3 (76)	3-1/4 (83)
Low/Mid-Ride Height AirLiner	2-1/4 (57)	2-1/2 (64)	2-3/4 (70)
10/12/15k Mid-Ride Height	2-3/8 (60)	2-1/2 (64)	2-7/8 (73)
10/12/15k Low/Extra-Low Ride Height	2-1/8 (54)	2-1/4 (58)	2-5/8 (67)

Table 1, Suspension Height Adjustment Distances

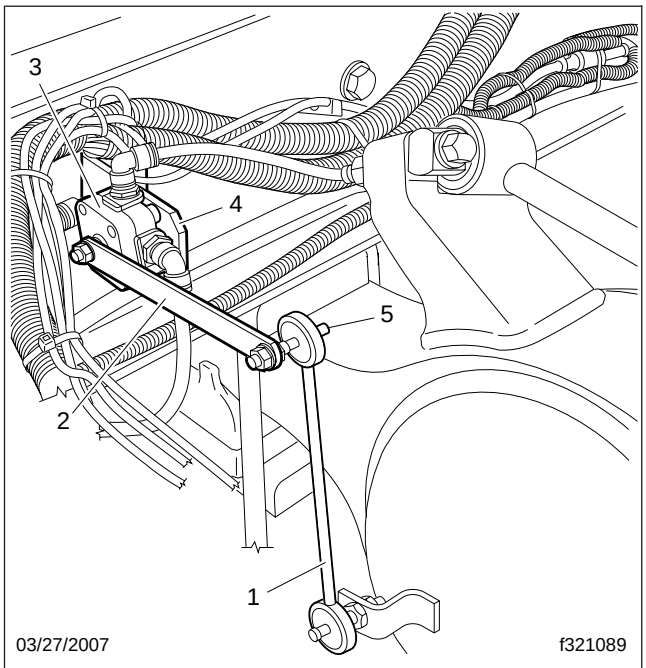
Height Control Valve Checking

The height control valve responds to changes in height, and is the control center of any air suspension system. When correctly adjusted, it maintains the correct suspension ride height.

Carefully check the valve before replacing it. Do the following steps to see if a valve is working correctly.

1. Disconnect the height control valve linkage from the overtravel lever. See **Fig. 1**.
2. Pull the overtravel lever up about 45 degrees. If air passes through the valve, that section of the valve is working.
3. Return the valve to the neutral position. Air should stop flowing. If so, that section of the valve is working.
4. Push the overtravel lever down about 45 degrees. If air exhausts from the valve, that section of the valve is working.
5. Return the valve to the neutral position. If the air stops again in the neutral position, the valve is working correctly.
6. If the valve works as stated in all of the above steps, then no further checking is necessary. Connect the height control valve linkage to the overtravel lever. Secure the linkage with a cotter pin.

   If the valve needs adjusting, see **Subject 110**. If the valve needs replacing, see **Subject 130**.

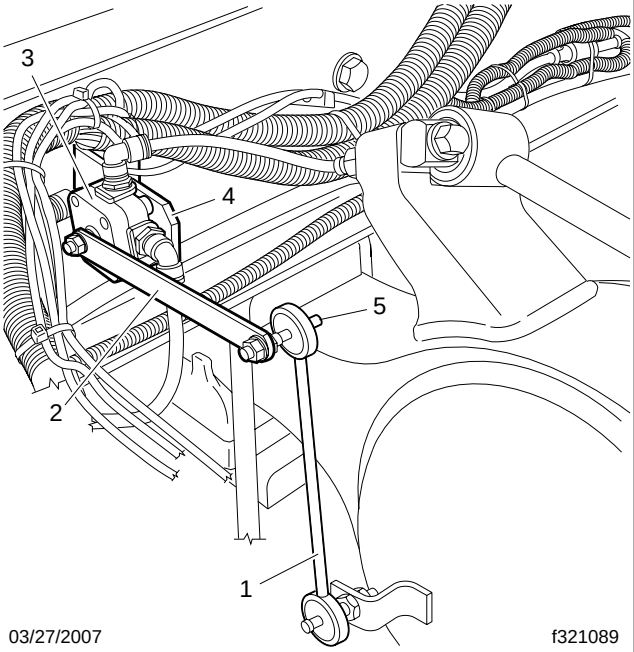


1. Linkage Rod
2. Overtravel Lever
3. Height Control Valve
4. Valve Mounting Bracket
5. Stud Bolt

Fig. 1, Height Control Valve Assembly

Replacement

1. Park the vehicle on a level surface, set the parking brakes, and chock the tires.
2. Drain the air reservoirs.
3. Disconnect the linkage from the overtravel lever. See **Fig. 1**. Exhaust all air from the air springs by moving the overtravel lever down.



1. Linkage Rod
2. Overtravel Lever
3. Height Control Valve
4. Valve Mounting Bracket
5. Stud Bolt

Fig. 1, Height Control Valve Installation

4. 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.
5. Remove the height control valve mounting bolts and nuts, and remove the height control valve from the bracket.
6. Attach the new height control valve to the bracket. Tighten the valve mounting bolt nuts 14 lbf·ft (19 N·m).
7. 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.
8. Close the drain cocks on all reservoirs.
9. Build up normal operating pressure in the air system. Check all air lines and connections for leaks. Eliminate all leaks.
10. Adjust the height control valve. For instructions, see **Subject 110**.

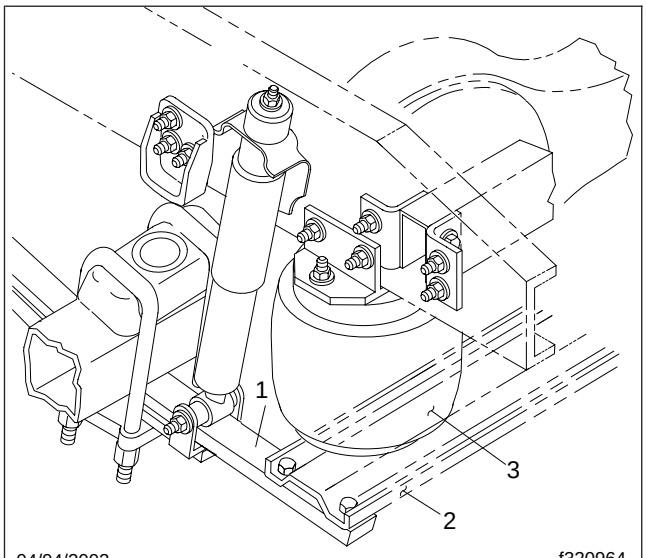
Shock Absorber Replacement

1. Chock the tires.
2. Remove the locknut, bolt, and spacer from the shock absorber lower mounting bracket. See **Fig. 1**.
3. Remove the nut, upper retainers, and upper bushings from the top of the shock absorber.
4. Pull the shock absorber out of the upper mounting bracket, and remove the retainers and bushings.
5. Install the replacement shock absorber, making sure the new bushings and retainers are correctly positioned. See **Fig. 1**.

WARNING

Use only the retainers included with the replacement shock absorber. Do not use washers. They can be extruded over the nut and be ejected violently, possibly causing personal injury and property damage.

6. Tighten the shock absorber lower mounting locknut 170 lbf·ft (230 N·m).
7. Tighten the shock absorber upper mounting nut to compress the bushings to the dimension as shown in **Fig. 1**.

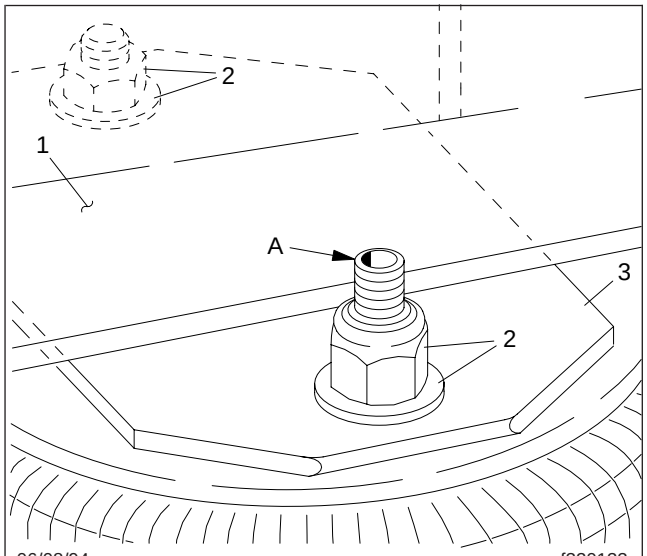


1. Leaf Spring
2. Crossbar
3. Air Spring

Fig. 1, Shock Absorber Installation

Air Spring Replacement

1. Chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs. The leveling valve automatically releases air from the air springs when all weight is removed from the suspension.
2. 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.
3. Remove the locknuts and washers that connect the air spring to the upper mounting bracket, or to the frame rail flange. See **Fig. 1** and **Fig. 2**.



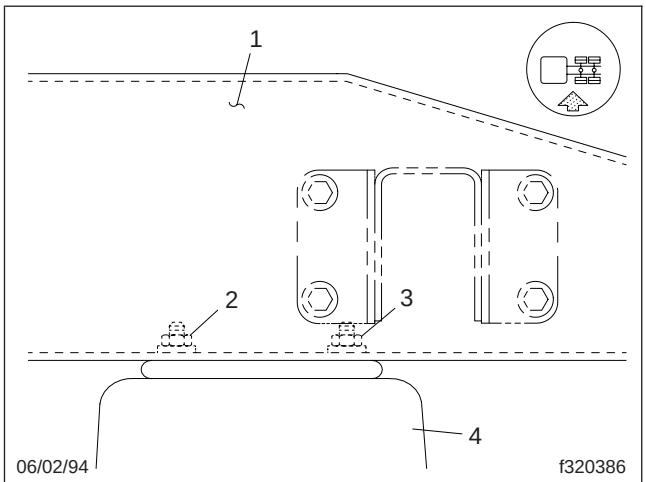
A. Air line connects here.

1. Right Frame Rail Flange
2. Locknut and Washer
3. Upper Mounting Bracket

Fig. 1, Bracket-Mounted Air Spring

4. Remove the capscrews and lockwashers that connect the air spring to the rear of the leaf spring. Remove the air spring. See **Fig. 3**.

NOTE: Suspensions manufactured to a 23,000-pound (10 433 kg) weight rating have a different leaf spring, and an additional crossbar attached between the air spring and rear of the leaf spring. See **Fig. 4**.



1. Frame Rail (left)
2. 3/4–16 Locknut and Washer
3. 1/2–13 Locknut and Washer
4. Air Spring

Fig. 2, Flange-Mounted Air Spring

5. Place the new air spring on the rear of the leaf spring (or the crossbar on the 23,000-lb suspensions), and install the washer and locknut that hold the air spring (and crossbar) in place. See **Fig. 3**. Tighten the locknut 55 lbf·ft (75 N·m).
6. *For bracket-mounted air springs:* Attach the air spring to the upper mounting bracket, using the 1/2–13 locknut on the outside of the frame rail and the 3/4–16 locknut on the inside. See **Fig. 1**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).

   For flange-mounted air springs: Attach the air spring to the frame rail flange, using the 3/4–16 locknut on the forward stud of the air spring, and the 1/2–13 locknut on the rear stud. See **Fig. 2**. Tighten the 3/4–16 locknut 45 lbf·ft (61 N·m); tighten the 1/2–13 locknut 23 lbf·ft (31 N·m).
7. 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.
8. Remove the safety stands, and lower the vehicle. Remove the chocks from the tires.

Air Spring Replacement

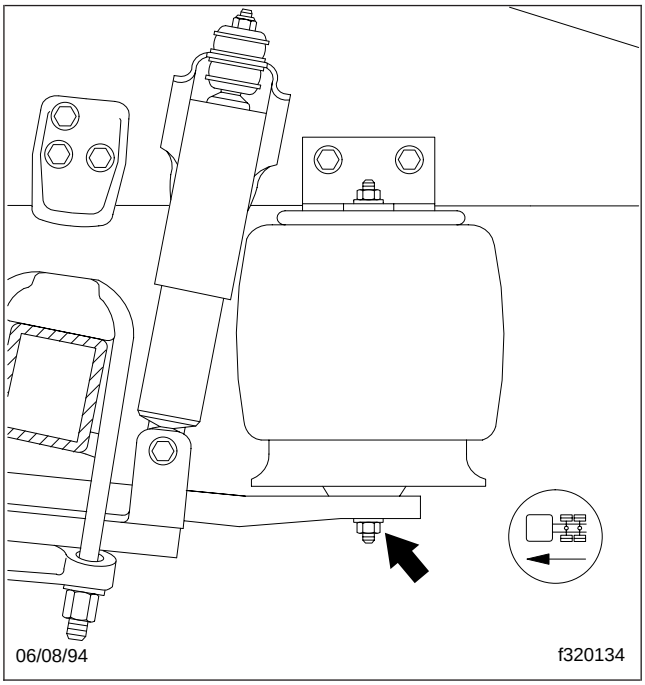
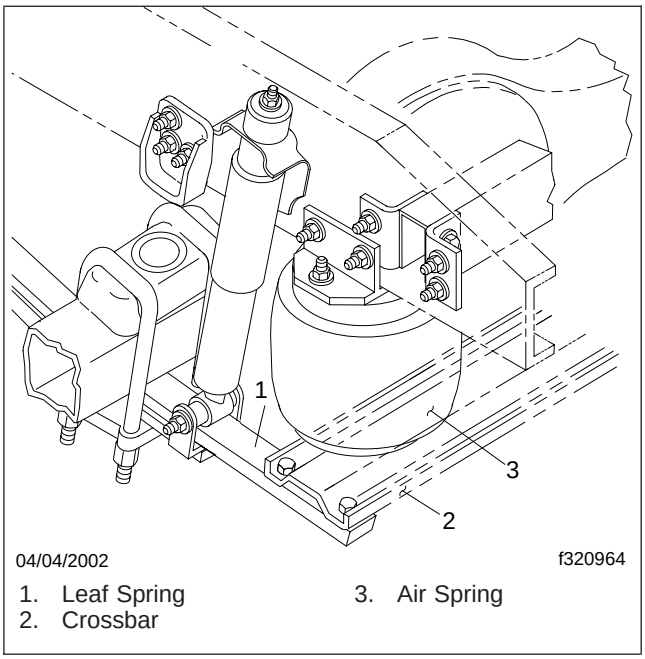


Fig. 3, Bolt Connecting Leaf Spring and Air Spring



1. Leaf Spring
2. Crossbar
3. Air Spring

Fig. 4, Leaf Spring and Air Spring Assembly (23,000-pound suspensions)

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs.

IMPORTANT: Do not disconnect the shock absorbers while the vehicle frame is raised. They limit downward suspension travel, preventing the piston from being pulled out of the air bag.

2. Exhaust all air from the air springs by disconnecting the height control valve linkage and holding the overtravel lever down.
3. Using a dull instrument, pry the air spring bead off the piston lip. Be careful not to damage the piston.
4. Disconnect the air supply line and, if so equipped, 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.
5. Remove the locknuts and washers that connect the air spring bag to the upper mounting bracket.
6. Remove the air spring bag.
7. Check the piston for residue and remove any if found.
8. When space is limited, it may be easier to remove the piston from the leaf spring and assemble the bag and piston on a workbench. Secure the air spring mounting bracket, which is attached to the bag, in a vise. Fully extend the air bag and plug the air supply port. Apply a soap-and-water solution to the piston lip and air bag bead, and, using a twisting motion, push the piston onto the air bag until the piston is fully seated. Inspect the circumference of the bag-to-piston connection to make sure there is less than 1/8 inch (3 mm) of clearance between the air bag and the piston shoulder. The gap should be uniform around the assembly. After inspecting, remove the plug in the air supply port and push the piston into the air bag so that it rolls over the piston. Then, install on the vehicle.

⚠ WARNING

Do not add air pressure to the air spring assembly when it is not mounted on a vehicle. Doing so could cause components to eject from the assembly, which could cause serious personal injury or property damage.

9. Attach the new air spring bag to the upper mounting bracket, using the 1/2–13 locknut on the outside of the frame rail, and the 3/4–16 locknut on the inside. Tighten 3/4–16 locknuts 45 lbf·ft (61 N·m); tighten 1/2–13 locknuts 23 lbf·ft (31 N·m).
10. 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.
11. Make sure the air spring bag is fully extended alongside the piston so there are no folds in the bag near the bead. See **Fig. 1**.
12. Fold the air spring bag so the bead is fully parallel with the piston lip. See **Fig. 2**.
13. Apply a soap-and-water solution to the bead and piston lip.
14. Pull the rear of the air spring bag over the piston lip making sure the bead is the lowest part of the bag—none of the bag should droop over the piston. Then, work the front of the bag over the piston lip like a button in a buttonhole. See **Fig. 3**.
15. Feeling the bead through the folds of the air spring bag, partially inflate the bag. This will cause snapping of the bead over the piston lip so it seats fully. A snapping sound confirms correct seating of the bead.

NOTE: The air bag should seat from 10 to 40 psi (69 to 276 kPa). Do not overinflate it to try to force it to seat. If there is no snapping sound before reaching 50 psi (345 kPa), release the air pressure and realign the air bag bead and piston. Then, try again to seat the bag using air pressure.

16. Inspect the circumference of the bag-to-piston connection to make sure there is less than 1/8 inch (3 mm) of clearance between the air bag

Air Spring Bag Replacement

and the piston shoulder. The gap should be uniform around the assembly.

17. Connect the height control valve and inflate the air spring bag. As it's inflating, the bag should roll into position over the piston. See **Fig. 4**.
18. Remove the safety stands, and lower the vehicle.
19. Check the suspension ride height. See **Subject 110** for instructions.
20. Remove the chocks from the tires.

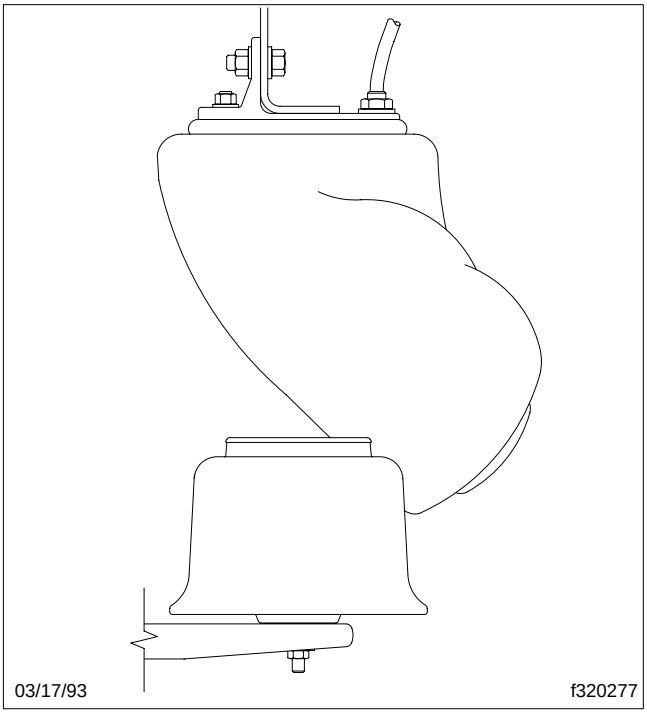


Fig. 1, Air Spring Bag Extended

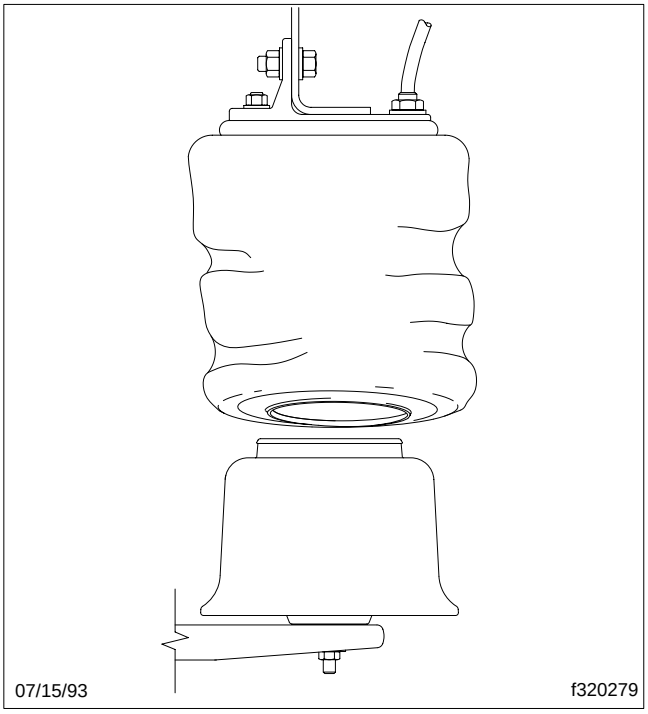


Fig. 2, Air Spring Bag Folded

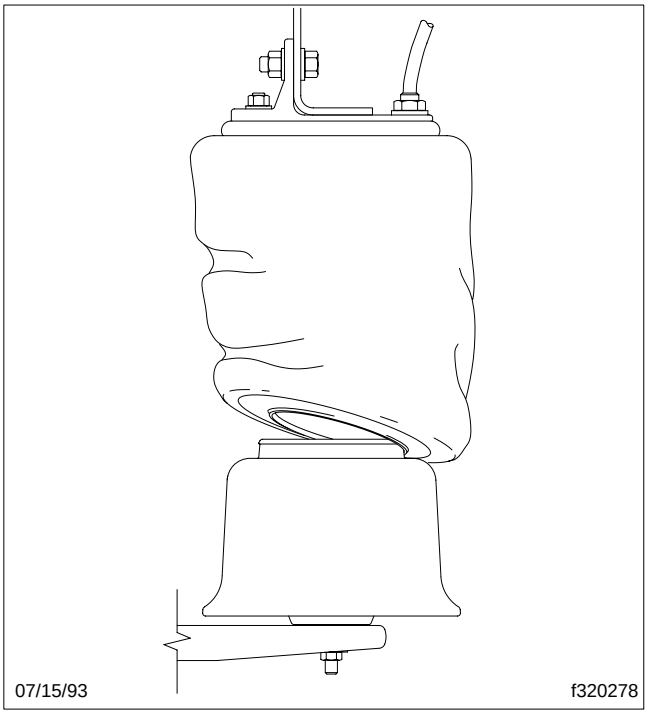


Fig. 3, Air Spring Bag Aligned With Piston

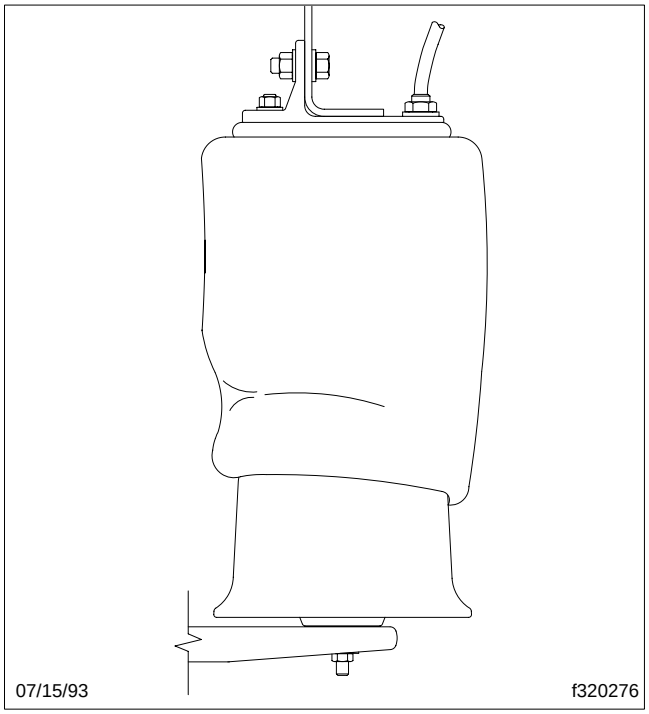


Fig. 4, Air Spring Bag Rolling Onto Piston

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 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** for instructions.
3. Remove the nut, bolt, and washers from the shock absorber lower mounting bracket. Remove the high nuts, flatwashers, and axle clamp from each U-bolt. Support the leaf spring assembly with a jack.
4. If the air spring mounts to the leaf spring, disconnect the bottom of the air spring from the leaf spring.

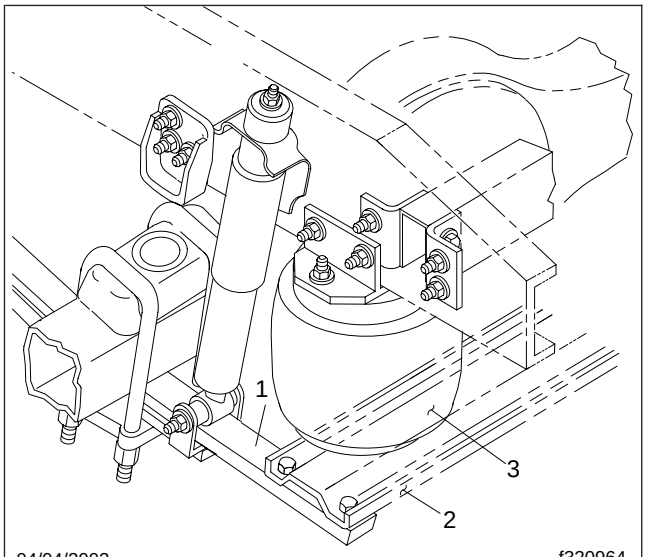
   If the air spring mounts to a crossbar, disconnect the crossbar from the leaf spring by removing the bolts, nuts, and washers. See **Fig. 1**.
5. Note the number and position of the alignment shims on the spring mounting bolt. See **Fig. 2**.
6. Remove the hexnut, washers, alignment shim(s), spring mounting bolt, and wear shoe clip from the spring hanger. See **Fig. 2**.

WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

7. Remove and discard the leaf spring assembly.
8. 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.
9. 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 bolts attach in the forwardmost holes; the shorter bolts attach in the aft holes.
10. 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.



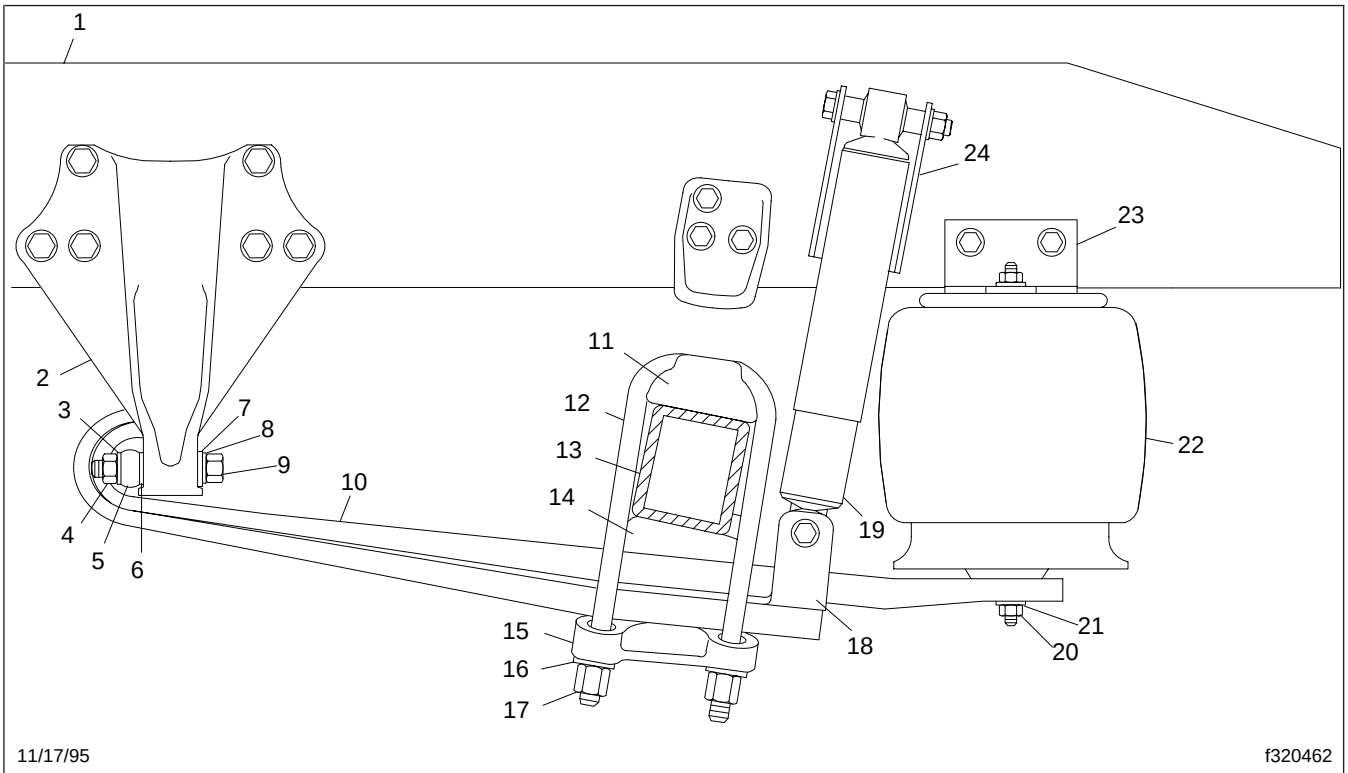
1. Leaf Spring
2. Crossbar
3. Air Spring

Fig. 1, Leaf Spring and Air Spring Assembly (23,000-pound suspensions)

NOTE: On axles angled 5 degrees, the arrow on the U-bolt pads must point to the front of the axle housing. See **Fig. 3**. On axles angled 3 degrees, there is no arrow. Make sure that the axle bump stop on the U-bolt pad is positioned toward the vehicle centerline. See **Fig. 4**.

With both 5- and 3-degree axle angles, the arrow on the bottom of the axle clamp must point toward the rear of the vehicle. See **Fig. 2**.

Leaf Spring Replacement



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1. Frame Rail
2. Spring Hanger
3. Washer
4. Hexnut
5. Spring Mounting Eye 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. 2, AirLiner Leaf Spring Assembly

11. 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, torque to the final value of 400 to 460 lbf·ft (542 to 624 N·m).

    For the 23,000-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).

12. Install the bolt, washers, and hexnut to connect the shock absorber to its lower mounting bracket. Tighten the hexnut 170 lbf·ft (230 N·m).

13. Tighten the locknut on the bottom of the air spring 55 lbf·ft (75 N·m).

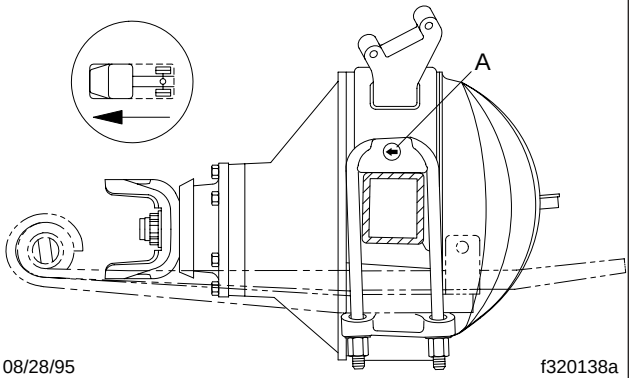
    On 23,000-pound suspensions, tighten the locknuts on the bottom of the crossbar 241 lbf·ft (327 N·m).

14. Tighten the hexnuts at the front of the leaf spring 170 lbf·ft (230 N·m).

15. Install the wheel and tire assembly. For instructions, refer to **Group 40**. Remove the safety stands, and lower the vehicle.

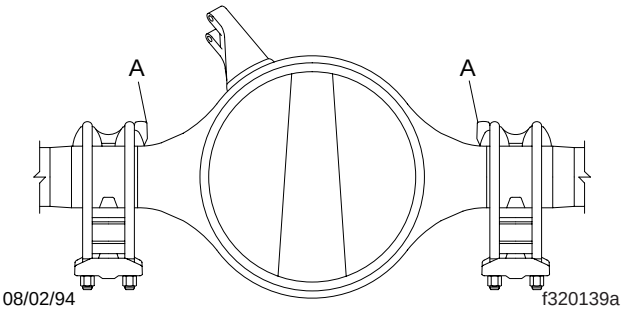
16. Check the rear axle alignment. For instructions, refer to the rear axle section in this manual. If

necessary, adjust the rear axle alignment using the instructions in **Subject 180**.



A. Arrow on U-Bolt Pad

Fig. 3, U-Bolt Pad Arrow Positioning



A. Axle Bump Stop

Fig. 4, Axle Bump Stop Positioning

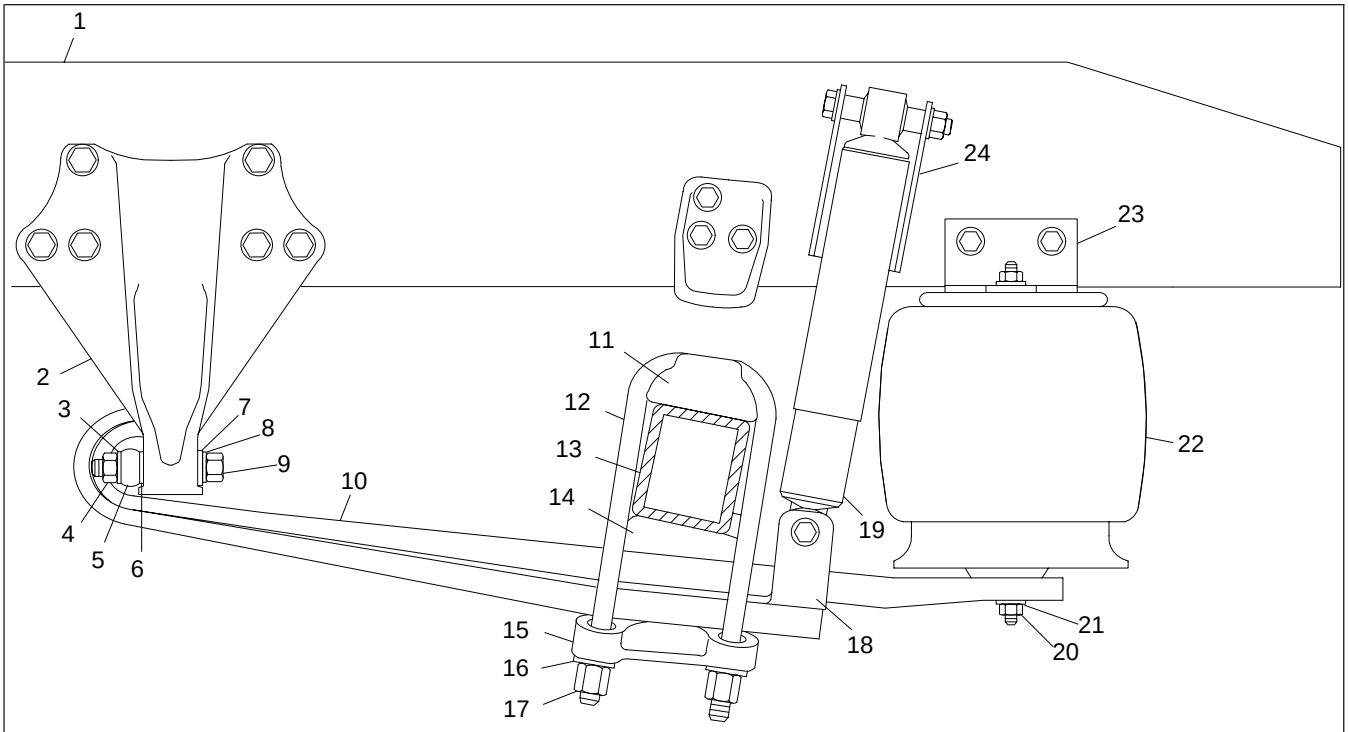
Rear Axle Alignment Adjusting

Follow the instructions in **Group 35** 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. See **Fig. 1**.
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 both ends of the spring pin.

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.



11/17/95 f320462

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 Alignment

Rear Axle Tracking Adjustment

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**.

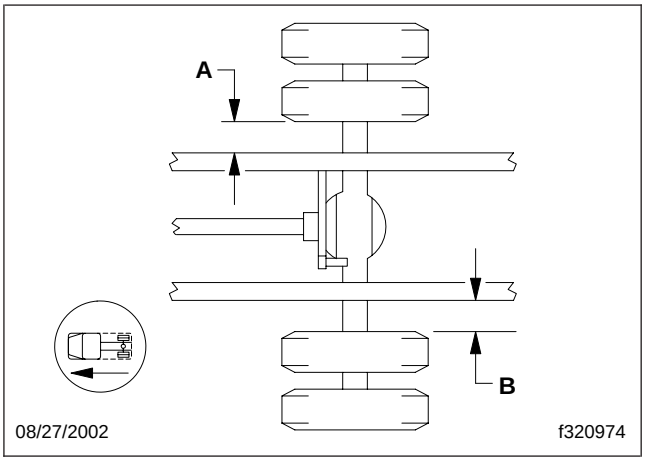


Fig. 2, Rear Axle Tracking Measurements

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**.

IMPORTANT: 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. For bar-pin style torque rods, tighten the fasteners 136 lbf·ft (184 N·m).

   For taper-pin style torque rods, tighten the fasteners 165 lbf·ft (224 N·m). See **Fig. 3**.

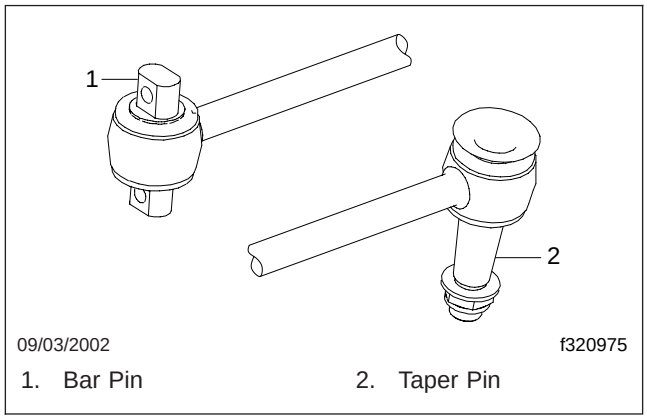
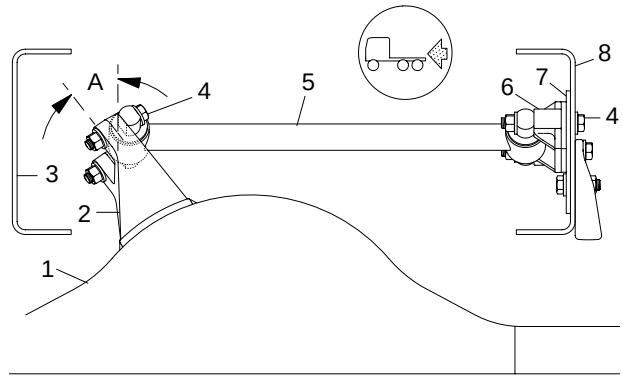


Fig. 3, Control Rod Types

Replacement

1. Shut down the engine, and apply the parking brakes.
2. Chock the tires. 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 fasteners from the axle end (control rod axle bracket) of 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**.



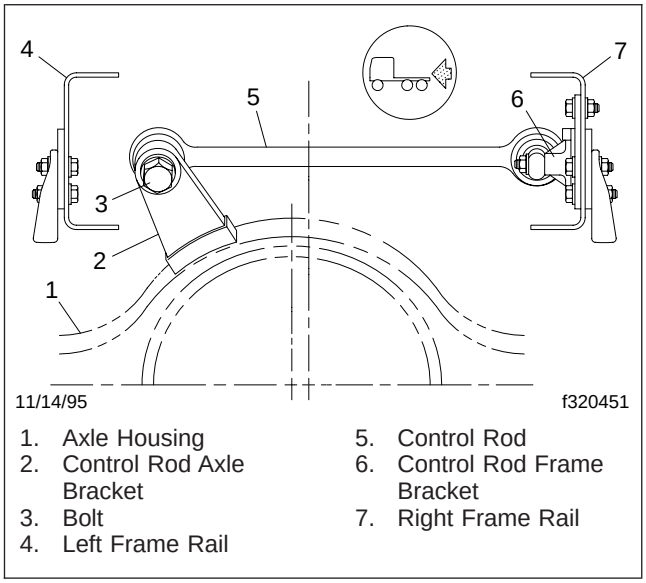
A. Angle: 35 degrees

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

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. Remove the jack stands. Lower the vehicle. Remove the tire chocks.

NOTE: Control rods on suspensions manufactured to a 23,000-pound (10 433 kg) weight rating are larger and are attached to the axle bracket with a single bolt. Tighten the fasteners that attach the control rod frame bracket to the frame rail 160 to 170 lbf·ft (217 to 230 N·m), and the bolt that connects the control rod to the axle housing 175 to 225 lbf·ft (237 to 305 N·m). See **Fig. 2**.



1. Axle Housing
2. Control Rod Axle Bracket
3. Bolt
4. Left Frame Rail
5. Control Rod
6. Control Rod Frame Bracket
7. Right Frame Rail

Fig. 2, Control Rod Installation on 23,000-pound AirLiner Suspensions

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front tires.
2. Raise the rear of the vehicle, and support the rear axle 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 170**.

⚠ WARNING

The leaf spring assembly is heavy. Use care when handling it to prevent injury.

5. Remove the bushing from the leaf 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 leaf spring eye, as follows.

   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 RC–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-pound (3490 kg) pushout force.

7. Install the leaf spring assembly. See the information in **Subject 170**.
8. Install the wheel and tire assembly. For instructions, see **Group 40**. Remove the safety stands and 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 **Group 35**.
10. Remove the chocks from the tires.

Specifications

Torque Values for AirLiner Suspension			
Description	**Size**	**Torque**	
		lbf·ft (N·m)	**lbf·in (N·cm)**
Height Control Valve Adjustment Nut	1/4–20	—	62 (700)
Height Control Valve Mounting Bolt Nuts	5/16–18	14 (19)	—
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)	—
Axle U-Bolt High Nuts (tighten in a diagonal pattern as shown in **Fig. 1**)	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

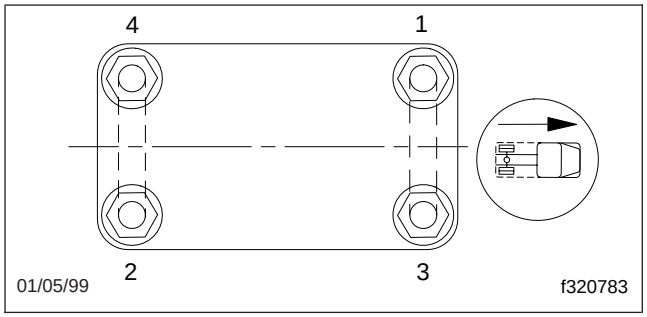


Fig. 1, Tightening Pattern for U-Bolt High Nuts

General Description

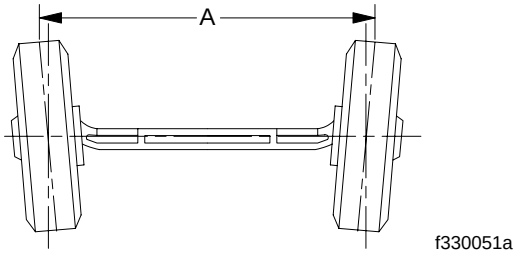
NOTE: For front axle troubleshooting procedures, refer to **Section 33.01, Subject 300**.

The front axle requires periodic servicing to maintain accurate wheel alignment. If the front axle is damaged enough to affect the camber angle it must be replaced. For axle removal and installation instructions, see **Subject 130**.

Correct front axle wheel alignment is needed to ensure long tire life, ease of handling, and steering stability.

Three factors are involved in wheel alignment: camber angle, caster angle, and wheel toe-in.

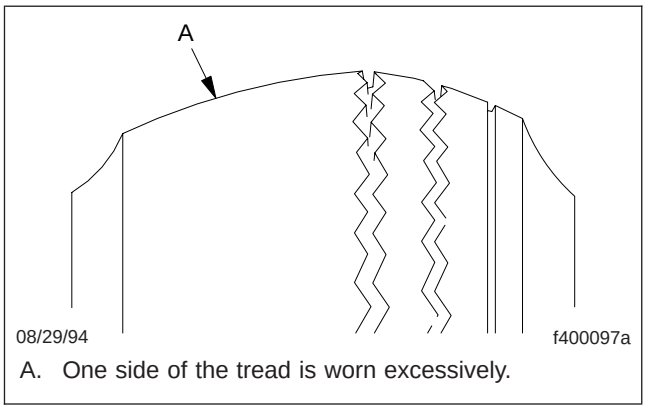
Camber angle is the vertical tilt of the wheel as viewed from the front of the vehicle. See **Fig. 1**. Camber angle is measured in degrees, and is not adjustable. Positive camber is the outward tilt of the wheel at the top. Excessive positive camber in one wheel causes the vehicle to pull in the opposite 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 to the same side 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**.



A. Camber (Positive)

Fig. 1, Camber Angle (front view)

Caster angle is the tilt of the knuckle pin (or kingpin) as viewed from the side. See **Fig. 3**. Caster angle is measured in degrees and it 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.



A. One side of the tread is worn excessively.

Fig. 2, Tire Damage Due to Excessive Camber

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. 4**. 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**.

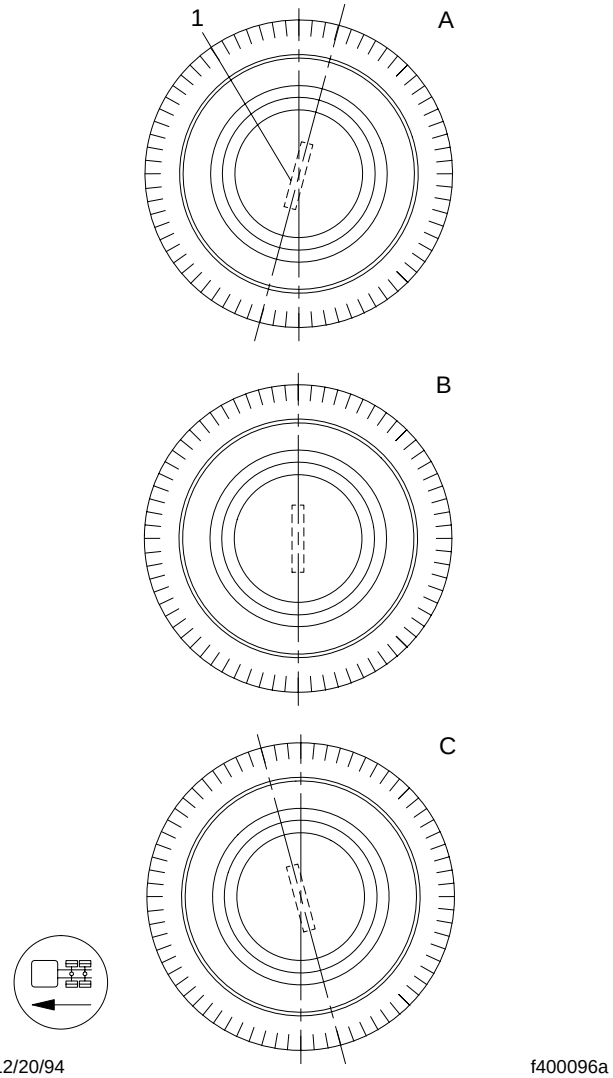
Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

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.

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; refer to **Section 33.01, Subject 300** for other possible causes.

If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires. For

General Information

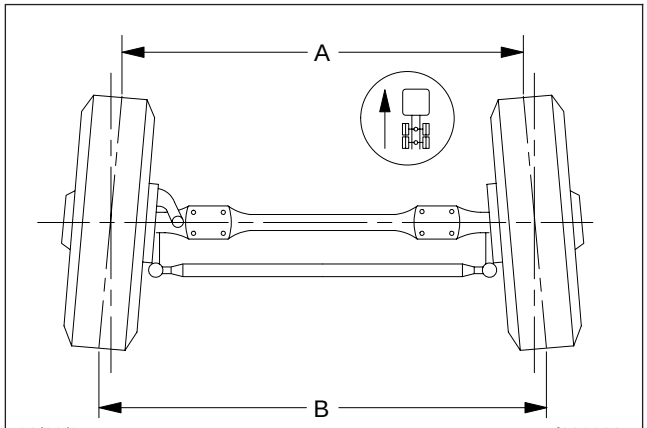


A. Positive Caster
B. Zero Caster
C. Negative Caster

1. Knuckle Pin (King Pin)

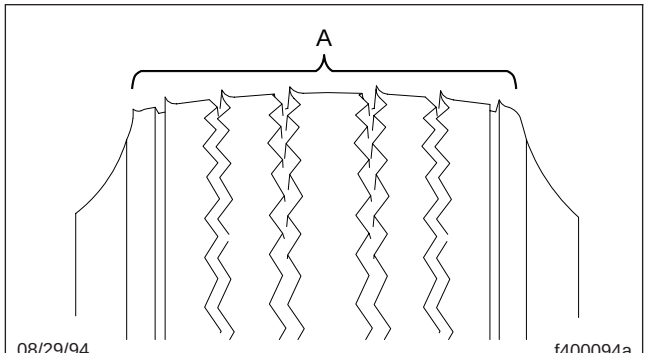
Fig. 3, Caster Angle

minimum tread wear specifications, refer to **Group 40** of the *S2 Chassis Maintenance Manual*.



NOTE: B minus A equals toe-in.

Fig. 4, Wheel Toe-In (overhead view)



A. Feathered Edges

Fig. 5, Tire Damage Due to Excessive Toe-In or Incorrect Drive Axle Alignment

Preliminary Checks

IMPORTANT: When aligning the front axle, it is essential that the rear axle be checked for correct alignment at the same time. Alignment of the rear axle has a direct impact on how the vehicle tracks. Refer to **Section 35.00, Specifications 400**.

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 for 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** of this manual and **Group 40** of the *S2 Chassis Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to **Group 40** of 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**.

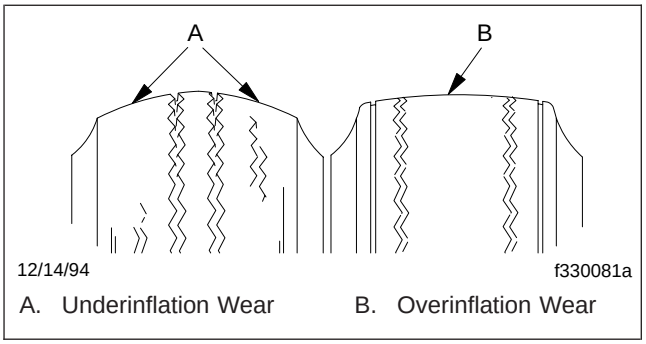
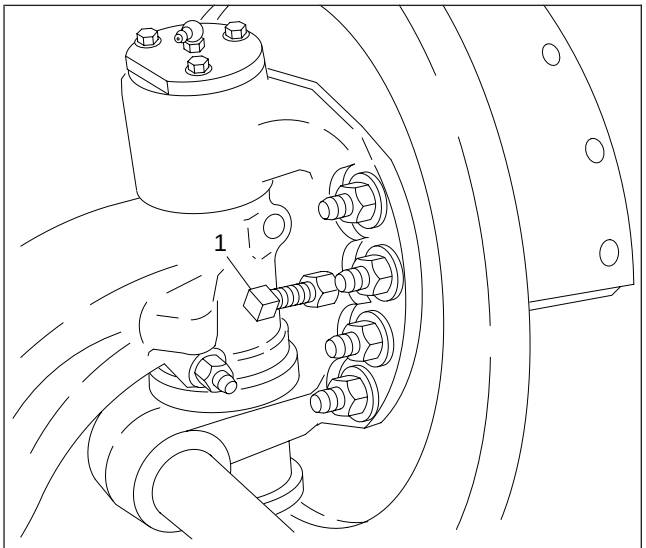


Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels, rims, or 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 **Group 32** of this manual.
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, using the instructions in **Group 46** of this manual.
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 46** of the *S2 Chassis Maintenance Manual* for instructions.
10. 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 axle stops, which are located on the rear side of each front axle spindle. See **Fig. 1**.



1. Stopscrew and Locknut

Fig. 1, Axle Stop

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. Dealers must have proof of this calibration history.

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 **Group 46**. Bottoming of the steering gear must not occur when making an extreme right or left turn.
2. If using stationary turn-plates or turntables, drive the vehicle on the plates; the tires must be exactly straight ahead. See **Fig. 2**. 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.

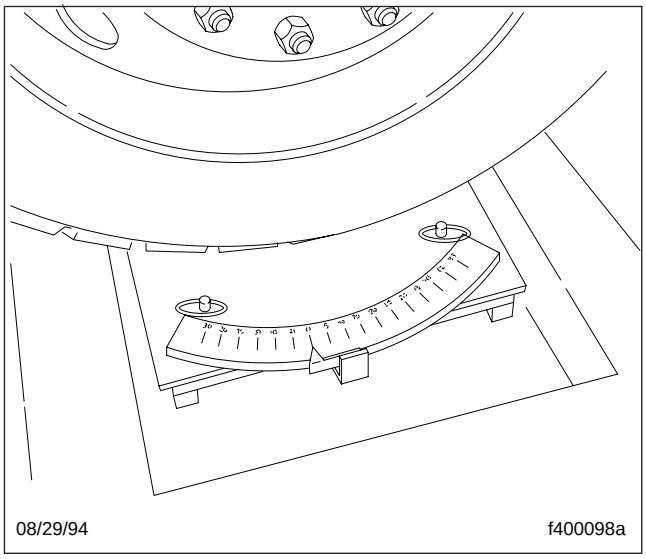


Fig. 2, Turn-Plate (Turntable), Stationary Type

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 under **Specifications 400**.

Steering Angle Checking and Adjusting

5. Repeat the step above with the steering wheel turned counterclockwise. Adjust the axle stop as needed.
6. If equipped with power steering, 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 and Adjusting Front Axle Wheel Alignment Angles

Measuring and Adjusting

Precision instruments and equipment are needed for accurately measuring and adjusting wheel alignment. Use the calibrated equipment whenever measuring and adjusting the front-axle wheels. Refer to the operating instructions provided by the wheel alignment equipment manufacturer.

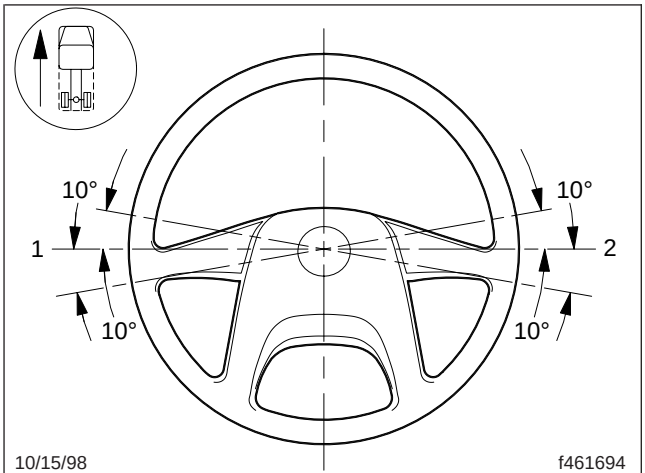
Before checking or correcting wheel alignment, make sure the vehicle is at curb weight. Curb weight is the weight of the unloaded vehicle complete with accessories and full fuel tanks.

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 steering gear is centered, the steering wheel spokes should be at the 3 and 9 o'clock positions, or within 10 degrees of that position. See **Fig. 1**.

If there are any problems, refer to **Section 33.01**.



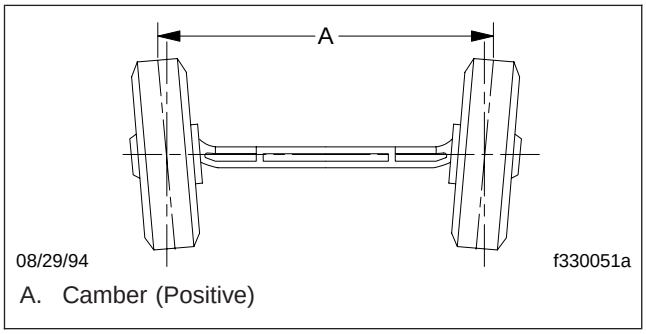
1. 9 o'Clock
2. 3 o'Clock

Fig. 1, Steering Wheel Position

Camber Angle Checking

IMPORTANT: Do all the preliminary checks in **Subject 100** before checking the camber angle.

Camber angle is the vertical tilt of the wheels as viewed from the front of the vehicle. See **Fig. 2**.



A. Camber (Positive)

Fig. 2, Camber Angle

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. Dealers must have proof of this calibration history.

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, frame, and front axle.
3. Before measuring camber, check the front wheel bearings for wear and incorrect adjustment. Try moving the wheel on the axle spindle (steering knuckle) either by grasping the front tire on the top and bottom, or by using a bar for leverage. If movement between the brake drum and the backing plate or other axle-mounted reference point is 0.05 inch (1 mm) or more, the bearings may be worn or incorrectly adjusted. Inspect the wheel bearings for damage using the instructions in **Section 33.01**. If needed, replace or adjust the bearings.
4. Remove the safety stands, and lower the vehicle to the ground.

Measuring and Adjusting Front Axle Wheel Alignment Angles

5. Using the alignment equipment manufacturer's instructions, measure the front wheel camber.
6. 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.

⚠ WARNING

Do not attempt to straighten any twisted or bent front axle component. This could crack or weaken the component, possibly resulting in a collapsed front axle, loss of a wheel, and serious personal injury.

7. Remove the chocks from the tires.

Caster Angle Checking and Adjusting

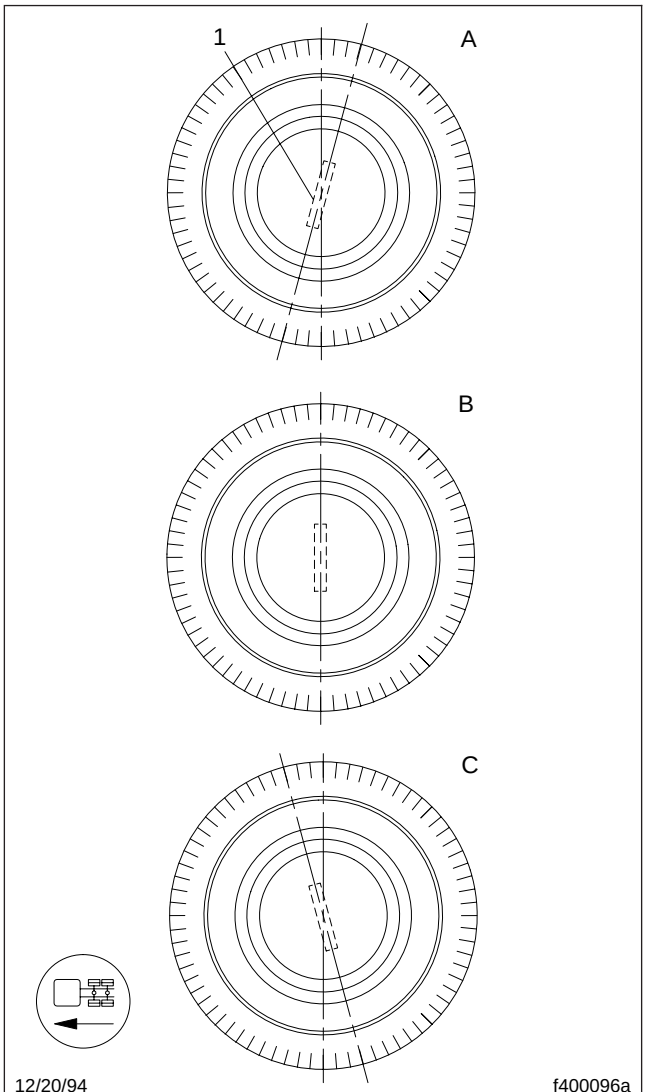
IMPORTANT: Do all the preliminary checks in **Subject 100** before checking the caster angle.

Caster angle is the tilt of the knuckle pin (or kingpin) as viewed from the side. See **Fig. 3**.

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. 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



A. Positive Caster
B. Zero Caster
C. Negative Caster

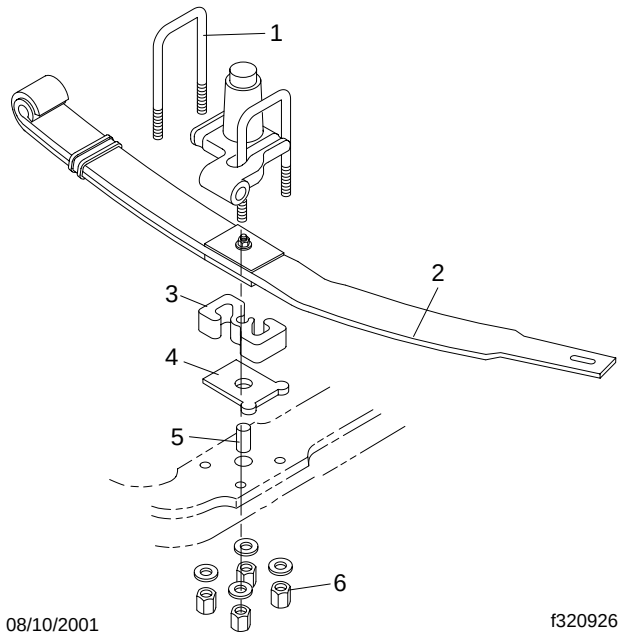
1. Knuckle Pin (Kingpin)

Fig. 3, Caster Angle

shims between the axle spacer and the axle beam, as follows. See **Fig. 4**.

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

Measuring and Adjusting Front Axle Wheel Alignment Angles



1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 4, Axle Spring Installation (typical)

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. 4**.
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. See **Fig. 4**.

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 32** of the *S2 Chassis Maintenance Manual* for recommended intervals.

CAUTION

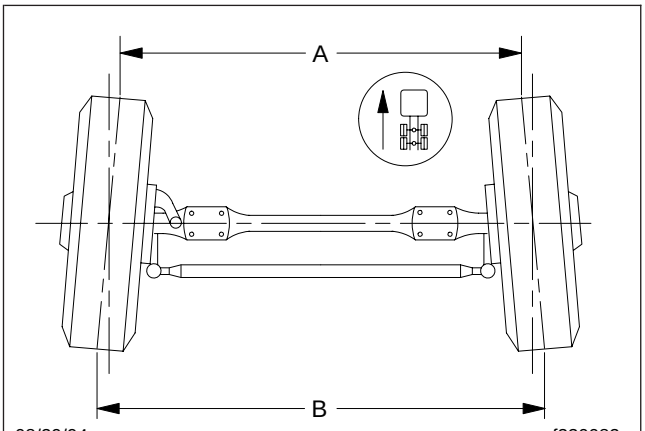
Failure to periodically retighten the U-bolt nuts could result in spring breakage and abnormal tire wear.

7. Using the steps above, replace the shim on the other side of the axle.
8. Do a final caster angle check.
9. Remove the chocks from the tires.

Wheel Toe-In Checking and Adjusting

IMPORTANT: When checking wheel toe-in, it is essential that the rear axle be checked for correct alignment at the same time. Alignment of the rear axle has a direct impact on how the vehicle tracks. Refer to **Section 35.00, Specifications 400**.

Using the alignment equipment manufacturer's operating instructions, measure the wheel toe-in. See **Fig. 5**. Compare the measurement with that shown in the appropriate table in **Specifications 400**. If corrections are needed, go to the applicable (tie rod adjustment) step below.



NOTE: B minus A equals toe-in.

Fig. 5, Wheel Toe-In (Overhead View)

Measuring and Adjusting Front Axle Wheel Alignment Angles

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. Dealers must have proof of this calibration history.

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 body, 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 6 feet (2 meters).

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. 6**. Adjust the scale end so that the pointers line up with the scribe lines. See **Fig. 7**.
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 step.
9. 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 6 feet (2 meters). This is important when setting the toe-in on vehicles equipped with radial tires.

   Do a final wheel toe-in check to make sure that it is correct.

   Make sure the steering wheel is centered.

   Tighten the clamp nuts to the values in the appropriate table in **Specifications 400**.
10. If not already done, remove the chocks from the rear tires. Road test the vehicle.

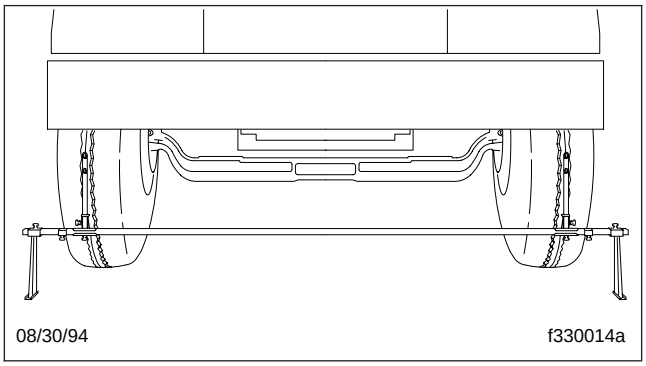


Fig. 6, Trammel Bar Positioning

Measuring and Adjusting Front Axle Wheel Alignment Angles

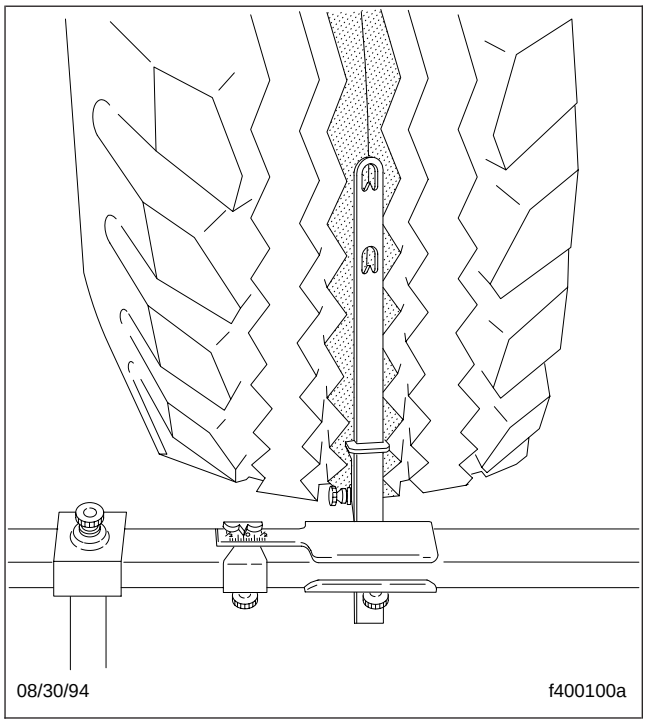


Fig. 7, Calculating Wheel Toe-In

Front Axle Replacement

Replacement

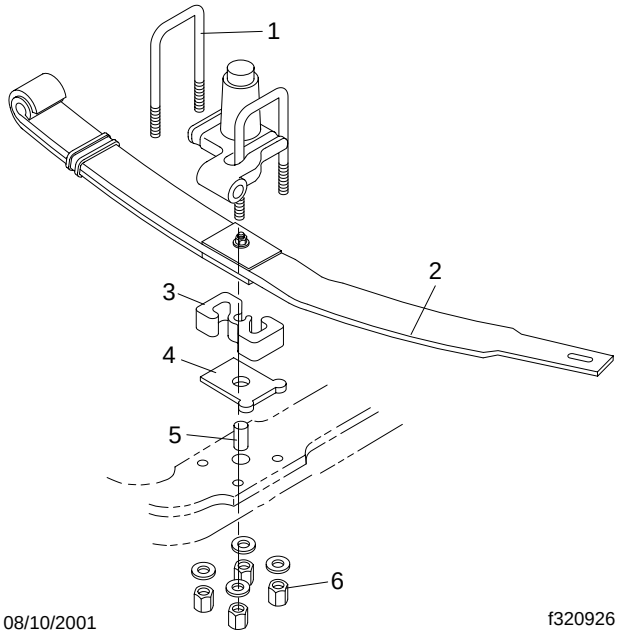
NOTE: This procedure involves removing the axle from underneath the front of the vehicle. If you cannot support the vehicle high enough for the axle to clear the bumper, then you will need to remove the bumper.

1. Park the vehicle on a level surface, set the parking brakes, then chock the rear tires.
2. Tilt the hood.
3. If needed, remove the front bumper. See **Group 31** for instructions.
4. Raise the vehicle, then support the frame rails with safety stands.

⚠ 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 while working on the air brake system can cause personal injury.

5. Drain the air tanks.
6. Remove the front tires.
7. If so equipped, disconnect the ABS sensors from the axle knuckles. Pull the sensors straight out.
8. For a vehicle with air brakes, disconnect the air lines from the front brake chambers.
9. For a vehicle with air brakes, remove the brake drums. For a vehicle with hydraulic disc brakes, without disconnecting the hydraulic lines from the front brake calipers, remove and support both calipers. See **Group 42** for instructions.
10. Remove the hubs, or hubs and rotors. Refer to the applicable subject in **Section 33.01** for instructions.
11. Disconnect the steering drag link from the axle steering arm. See **Group 46** for instructions.
12. Remove the U-bolts and nuts that hold the axle to the leaf springs, as follows. See **Fig. 1**.
    - 12.1 Take the weight off the leaf springs by raising the axle.
    - 12.2 On one side of the axle, remove all the U-bolt nuts and washers, then remove the two U-bolts.
    - 12.3 Repeat the procedure on the other side of the axle.
13. Remove the axle stops from the top of the leaf springs.
14. Remove the axle spacers from the top of the axle beam.
15. Using a suitable axle jack, remove the axle by sliding it out from the front of the vehicle.
16. For a vehicle with air brakes, remove the brake shoes, cam, and spider. See **Group 42** for instructions.
17. From the front of the vehicle, and using a suitable axle jack, roll the axle into place under the leaf springs.
18. Install the axle spacers.



1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 1, Axle Removal

Front Axle Replacement

19. Slowly raise the axle up to the bottom of the leaf springs, making sure the dowels on top of the axle beam line up with the holes in the axle spacers.
20. Install the axle stops onto the tops of the leaf springs.
21. Install the U-bolts, as follows.
    - 21.1 Using a suitable clamp (such as a large C-clamp) compress one of the U-bolts, then install it on one side of the axle. Do the same for the second U-bolt.
    - 21.2 Install the U-bolt nuts and washers. Tighten the nuts finger-tight.
    - 21.3 Repeat the procedure on the other side of the axle.
22. Tighten the U-bolt nuts.

    For 3/4–16 U-bolt nuts: In a diagonal pattern, tighten the U-bolt nuts successively 80 lbf·ft (108 N·m), 200 lbf·ft (270 N·m), then 300 lbf·ft (406 N·m).

    For 7/8–16 U-bolt nuts: In a diagonal pattern, tighten the U-bolt nuts successively 60 lbf·ft (81 N·m), 200 lbf·ft (270 N·m), then 460 lbf·ft (624 N·m).
23. For a vehicle with air brakes, install the brake spider, cam, and brake shoes. See **Group 42** for instructions.
24. If so equipped, install the ABS sensors in the axle knuckles.
25. For a vehicle with air brakes, connect the air lines to the brake chambers.
26. Install the hubs, or hubs and rotors. Refer to the applicable subject in **Section 33.01** for instructions.
27. For a vehicle with air brakes, install the brake drums. For a vehicle with hydraulic disc brakes, install both brake calipers. See **Group 42** for instructions.
28. Connect the drag link to the steering arm. See **Group 46** for instructions.
29. Install the tires.
30. If it was removed, install the bumper. See **Group 31** for instructions.
31. Raise the vehicle, then remove the safety stands.
32. Lower the vehicle.
33. Do all the alignment procedures, including caster, camber, wheel toe-in, and rear axle alignment. Refer to **Subject 120** for instructions. For rear axle alignment procedures, refer to **Section 35.00**.
34. Lower the hood.
35. Remove the chocks from the rear tires.

Specifications

IMPORTANT: When aligning the front axle, it is essential that the rear axle be checked for correct alignment at the same time. Alignment of the rear axle has a direct impact on how the vehicle tracks. Refer to **Section 35.00, Specifications 400**.

Camber and Toe-In					
Axle Manufacturer	**Axle Model**	**Left Camber: degrees**	**Right Camber: degrees**	**Toe-In Limits: inch (mm)**	**Toe-In Target: inch (mm)**
Freightliner	All	0 ± 7/16	0 ± 7/16	0 to +1/8* (0 to +3.2)	+1/16 (+1.6)

* If adjustment is required, set the toe-in as close as possible to +1/16 inch.

Table 1, Camber and Toe-In

Caster					
Axle Model	**Beissbarth: degrees**	**Bee Line**		**Hunter: degrees**	**Target, All Models: degrees**
		Except LC 4000: degrees	**LC 4000: degrees**		
Freightliner	+3 to +6-1/2	+3 to +6-1/2	+2-1/4 to +4-3/4	+1-1/2 to +5	Left +3-1/2; Right +4
IMPORTANT: Caster settings for the left and right sides *must* be within 1/2 degree of each other. It is necessary for only one side to be within the specifications given in this table.					

Table 2, Caster

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)**
Freightliner	All	5/8–11	40–60 (54–81)	40–60 (54–81)

* All torque values in this table apply to parts lightly coated with rust-preventive type oil.

Table 3, Tie Rod Clamp Nut Torque Values

Miscellaneous Torque Values	
Fastener Description	**Torque: lbf·ft (N·m)**
7/8–14 U-Bolt Nuts	400 (542)
7/8–16 U-Bolt Nuts	460 (624)
3/4–16 U-Bolt Nuts	300 (406)
5/8–18 U-Bolt Nuts	200 (271)
Stopscrew Locknut	50–65 (68–88)

Table 4, Miscellaneous Torque Values

General Information

These vehicles are equipped with the traditional hub and bearings.

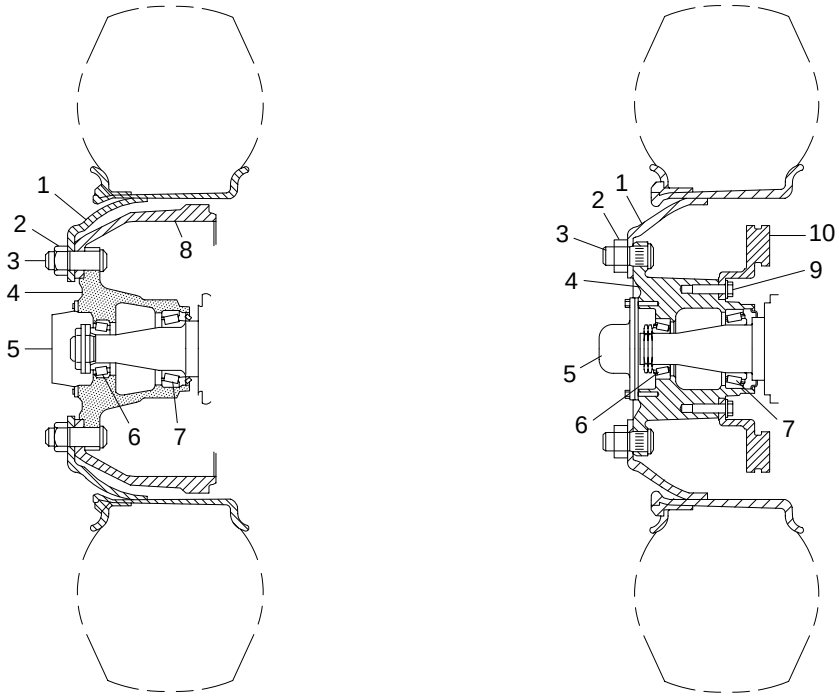
With traditional wheel ends, the bearings and oil seal must be assembled with the hub when the hub is installed on the axle spindle. First the oil seal is placed on the spindle (some brands of oil seal are installed in the hub bore), then the inner bearing and the hub are mounted on the axle spindle. Then, the outer bearing is mounted in the hub bore. A nut is installed on the axle spindle end and tightened and loosened to adjust the bearings. Finally, a locking device and jam nut are installed to secure the hub and bearings on the axle. For instructions, see **Subject 130**.

All wheel hub assemblies consist of the following components. See **Fig. 1**.

- Wheel Bearings
- Wheel Hub
- Wheel Studs
- Brake Rotor or Brake Drum

Tapered Wheel Bearings

A traditional 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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A. Disc Wheel Assembly with Drum Brakes

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

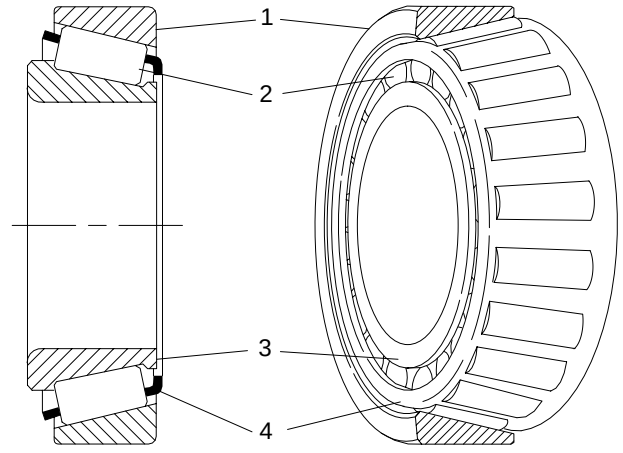
B. Disc Wheel Assembly with Disc Brakes

1. Disc Wheel
2. Wheel Nut
3. Wheel Stud
4. Hub
5. Hub Cap
6. Outer Wheel Bearing
7. Inner Wheel Bearing
9. Rotor Bolt
10. Brake Rotor

Fig. 1, Hub and Wheel Assemblies

General Information

Each hub has a set of inner and outer tapered wheel bearing assemblies. On traditional hub and bearing assemblies, the bearing setting is locked in place on the axle spindle (steering knuckle) by an adjusting nut, a locking device such as a lockring or nut-lock, and a jam nut, or a Pro-Torq nut. See **Fig. 3**.



1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly

Wheel Hub

The wheel and the brake drum are mounted on an aluminum or iron wheel hub. See **Fig. 4**.

Both the inner and outer wheel bearing cups and the wheel studs are press-fit in the hub.

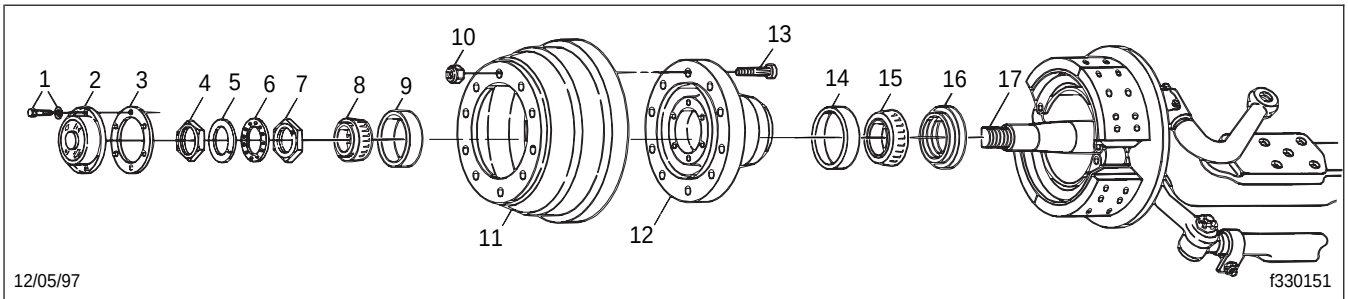
Wheel Studs

A headed wheel stud is used on front 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. 5**.

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.

The brake drum is mounted on the outboard face of the hub and fits over the wheel studs. See **Fig. 3**.



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Gasket
4. Jam Nut
5. Nut-Lock
6. Lockring
7. Adjusting Nut
8. Outer Wheel Bearing
9. Outer Bearing Cup
10. Wheel Nut
11. Brake Drum
12. Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Spindle

Fig. 3, Typical Wheel and Axle Assembly (four-piece bearing system shown)

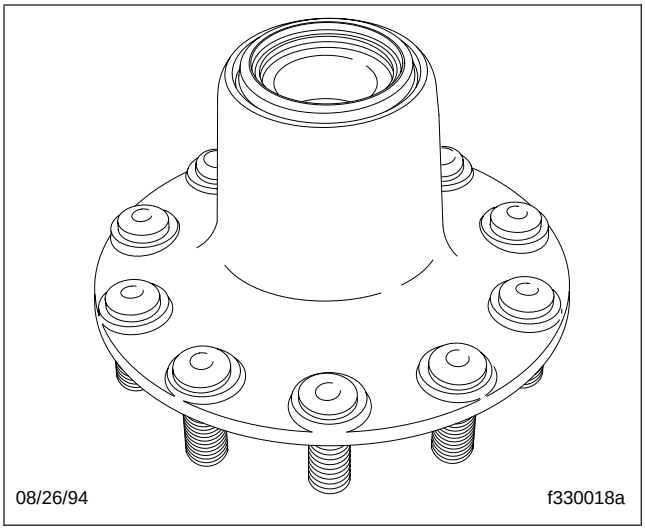
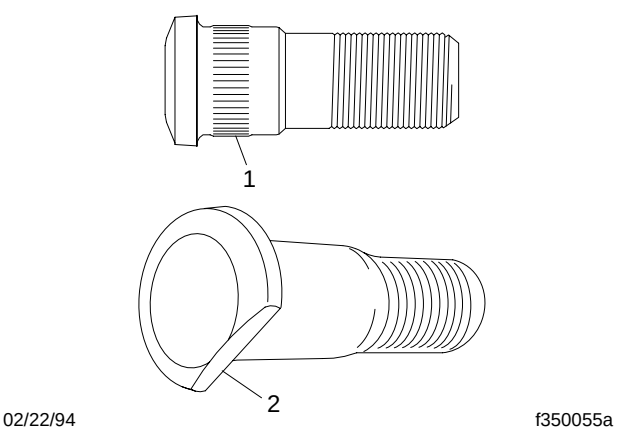


Fig. 4, Front Axle Wheel Hub for Drum Brakes



1. Serrations
2. Clipped Head

Fig. 5, Typical Wheel Studs

Removal

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.

WARNING

Never work under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall. This could result in a person being pinned under or crushed by the vehicle, causing severe personal injury or death. Always use safety stands to support the vehicle.

3. Back off the slack adjuster to release the front 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 the wheel and tire assembly. See **Group 40** for instructions.
5. Remove the brake drum. For instructions, see **Subject 160**.

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. Discard the oil.

6. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket. See **Fig. 1**.
7. Remove the jam nut, locking device(s), and adjusting nut, as follows. See **Fig. 1**.

CAUTION

When moving the hub, be careful not to let the outer wheel bearing drop from the axle spindle. If the wheel bearing is dropped, cage warpage or roller damage can occur. 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.

7.1 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).

7.2 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.

CAUTION

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.

7.3 Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.

7.4 Remove the inner wheel bearing from the axle; handle the bearings with clean, dry hands. Wrap the bearings in clean, oil-proof paper or lint-free rags. Occasionally, the inner wheel bearing will remain in the hub after the hub is removed. In those cases, place a protective cushion where it will catch the bearings. Use a hardwood drift and a light hammer to gently tap the bearing (and seal, if necessary) out of the cup.

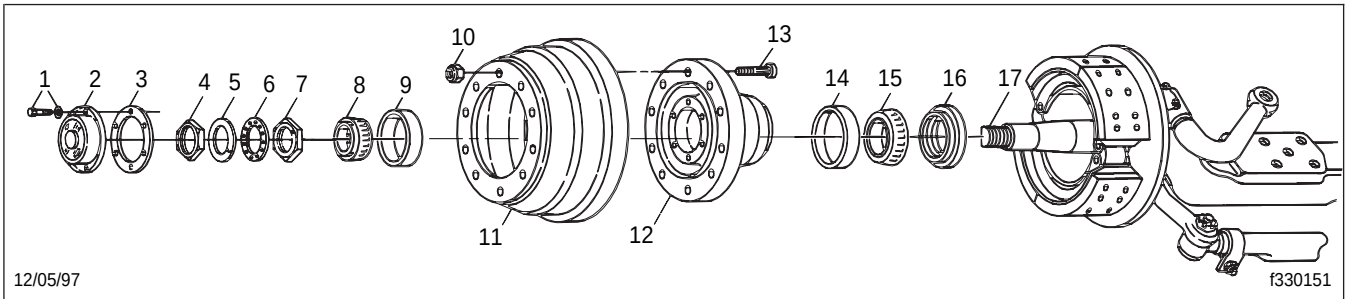
7.5 Remove the oil seal from the axle spindle, if not already removed. See **Section 33.02** for additional information.

Installation

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,

Hub Assembly Removal and Installation



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Gasket
4. Jam Nut
5. Nut-Lock
6. Lockring
7. Adjusting Nut
8. Outer Wheel Bearing
9. Outer Bearing Cup
10. Wheel Nut
11. Brake Drum
12. Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Spindle

Fig. 1, Typical Wheel and Axle Assembly (four-piece bearing system shown)

starting with removal of the wheels and continuing through assembly.

1. Remove the old oil from the axle spindle (steering knuckle) and the disassembled parts. Follow the solvent manufacturer's warnings and cautions when using it. Allow the parts to dry or dry them with a clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.
2. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.

⚠ CAUTION

Make sure 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.

3. 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.
4. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.

⚠ CAUTION

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.

5. Mount the hub assembly on the axle spindle.
6. Adjust the wheel bearings. For instructions, see **Subject 130**.
7. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews to the torque values in the torque table in **Specifications 400**.
8. 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.

9. Install the brake drum on the wheel hub. For instructions, see **Subject 160**.

⚠ 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 wheel and tire assembly. See **Group 40** for instructions.
11. Adjust the front axle brakes.
12. Raise the vehicle and remove the safety stands from under the axle. Lower the vehicle.
13. Remove the chocks from the rear tires.

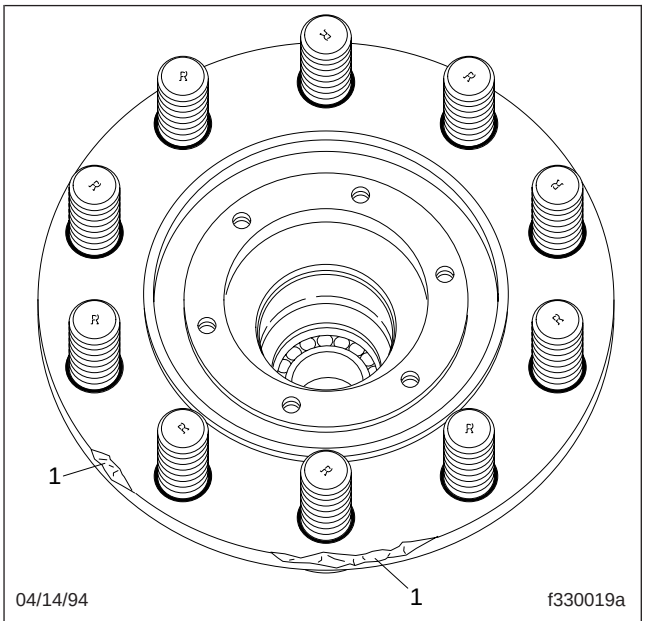
Wheel Hub Assembly Inspection

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.

2. Remove all of 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.

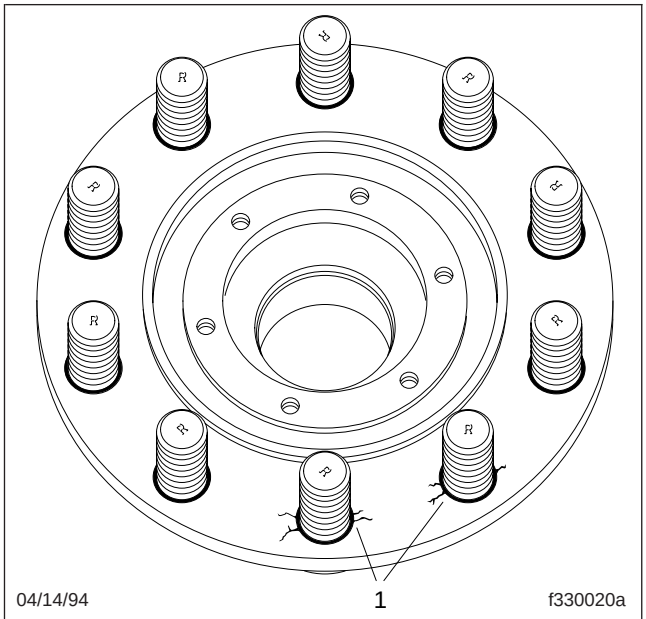
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the wheel bearing cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. For instructions, see **Subject 120**.



1. Wear Spots

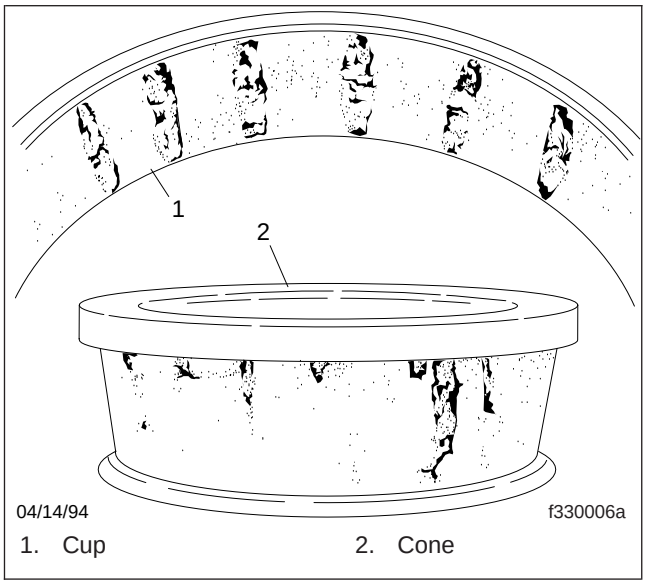
Fig. 1, Damaged Front Axle Wheel Hub

4. Inspect the wheel studs. Replace studs that are stripped, broken, bent, or otherwise damaged. For instructions, see **Subject 160**.



1. Cracked Stud Grooves

Fig. 2, Damaged Front Axle Wheel Hub



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

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 kerosene or diesel fuel oil, and a stiff brush. Before inspecting, clean the bearings.

1. Remove the wheel hub and bearing cones. For instructions, see **Subject 100**.
2. Clean all old oil from the bearings and hub cavity with kerosene or diesel fuel and a stiff brush. Don't 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.

⚠ CAUTION

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.

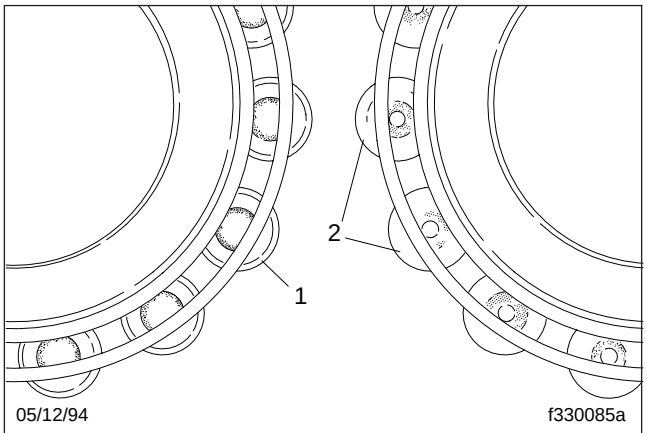
4. After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the following conditions exist, replace the bearing assemblies:

   4.1 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**.

   4.2 Visible step wear, particularly at the small end of the roller track. Deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 5**.

   4.3 Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 6**.

   4.4 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.



1. New Bearing
2. Worn Bearing Rollers

Fig. 4, Wheel Bearing Roller Wear

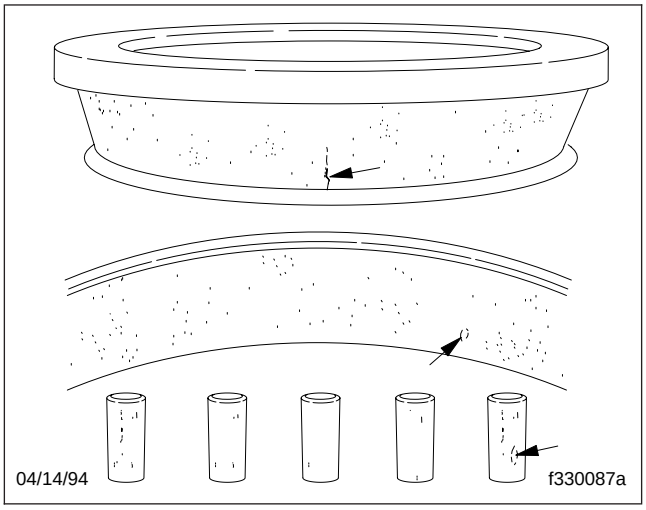


Fig. 5, Indentations, Cracks, or Breaks in Bearing Surfaces

   4.5 Etching or pitting on functioning surfaces. See **Fig. 7**.

   4.6 Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, brush the bearings with fresh axle lubricant.

Brake Drum Inspection

NOTE: For disc brake rotors and calipers, see the *Bosch Pin Slide Disc Brakes Service*

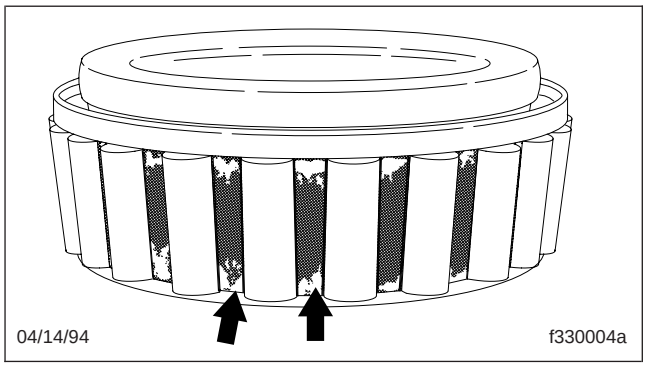


Fig. 6, Rubbing Marks on Bearing Cage

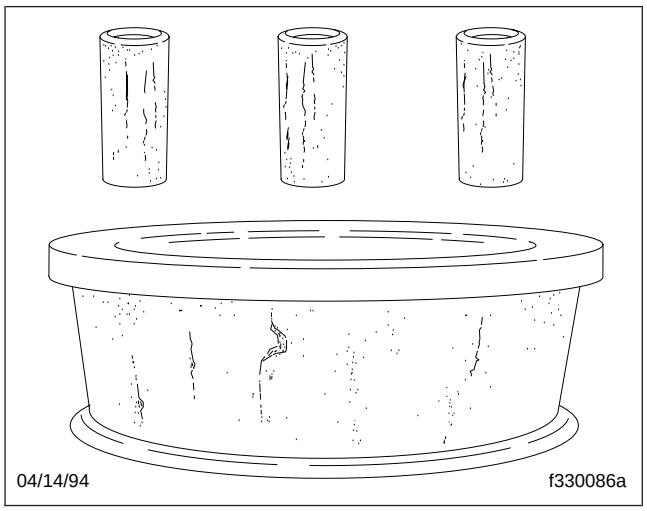
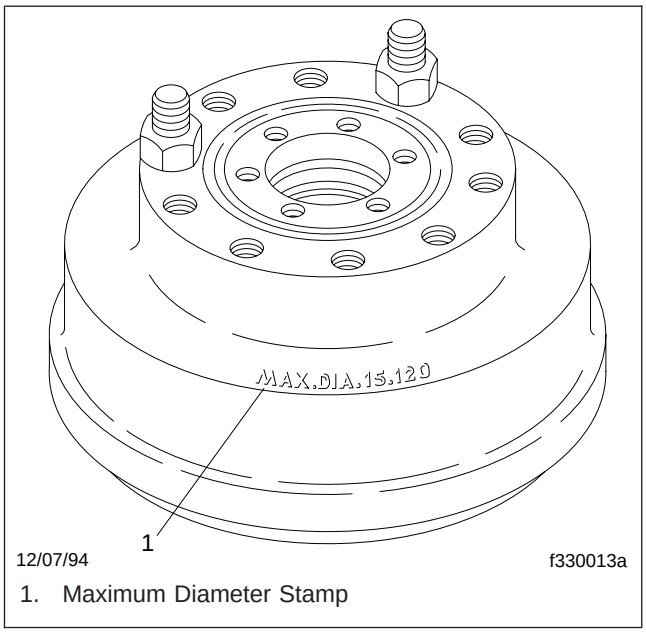


Fig. 7, Etching (Pitting) on Bearing Surfaces

Manual for brake rotor and caliper inpsection procedures.

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 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.



1. Maximum Diameter Stamp

Fig. 8, Outboard Mounted Hub and Drum Assembly

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.

⚠ CAUTION

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate 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

Axle Components Cleaning and Inspection

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.

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.
5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums.
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.

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.

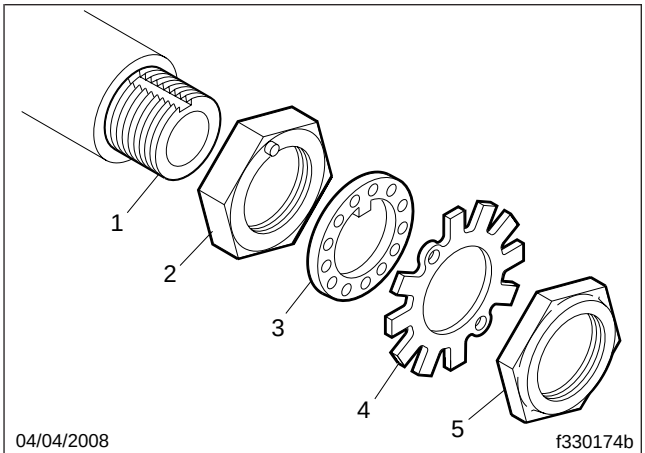
Installation

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 replacement bearing cup hub contact surface 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.

Four-Piece Wheel Bearing System Installation and Adjustment

Installation and Adjustment

1. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.
2. Fill the hub cavity with oil, then install the outer wheel bearing. Handle the bearings with clean, dry hands. Be careful not to damage the bearings, as they are seated in the bearing cups.
3. Install the wheel bearing adjusting nut. See **Fig. 1**.



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1. Axle Spindle
2. Adjusting Nut
3. Lockring
4. Bend-Type Locking Washer
5. Jam Nut

Fig. 1, Four-Piece Spindle Nut Set

3.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

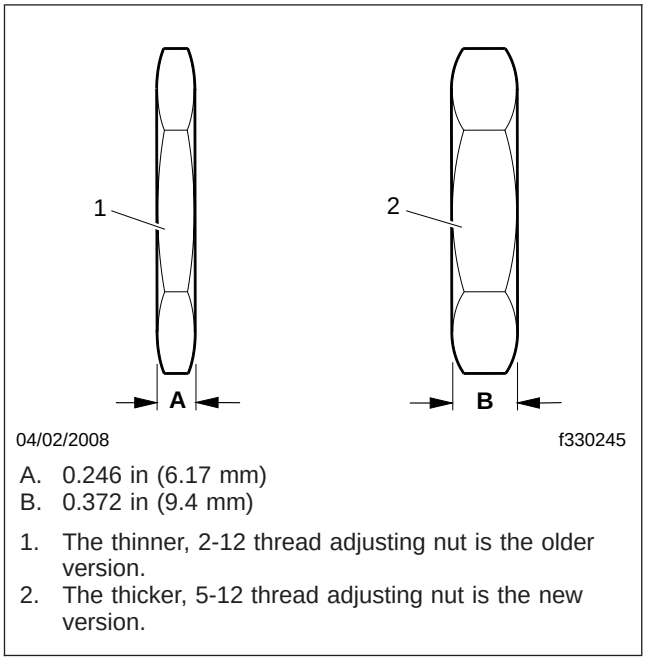
3.2 While rotating the wheel hub assembly, tighten the adjusting nut 100 lbf·ft (136 N·m).

3.3 Back off the adjusting nut completely.

IMPORTANT: The new adjusting nut is thicker, and requires the torque listed below. **Figure 2** shows both the old and new adjusting nut.

3.4 For the new thicker, 5-12 thread adjusting nut, tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

For the old thinner, 2-12 thread adjusting nut, tighten the adjusting nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.



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A. 0.246 in (6.17 mm)
B. 0.372 in (9.4 mm)

1. The thinner, 2-12 thread adjusting nut is the older version.
2. The thicker, 5-12 thread adjusting nut is the new version.

Fig. 2, Wheel-Bearing Adjusting Nuts

3.5 Back off the adjusting nut one-third turn (two flats of the adjusting nut) for Freightliner axles.

Back off the adjusting nut 45 degrees for Meritor axles.

4. Install the locking device and jam nut.

4.1 Install the locking device.

NOTE: If no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If still no hole aligns with the dowel, loosen the adjusting nut just enough to align the dowel with a hole in the lockring.

4.2 Then install the jam nut, and tighten it to the applicable torque value in **Table 1**.

5. With the jam nut installed and tightened, adjust the bearings.

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub.

Four-Piece Wheel Bearing System Installation and Adjustment

You cannot accurately adjust or measure bearing end play with the wheel mounted on the hub.

5.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

If using aluminum hubs, you may have to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot, then adjust the brake or have someone apply the brakes, to hold the drum securely, while you secure the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

NOTE: If using a stud-piloted hub and a steel drum, install 1-1/4 inch washers between the nuts and the drum.

5.2 Release the brakes, if you used them to hold the drum for installation.

5.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

5.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

5.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

6. 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.

6.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

6.2 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.

6.3 Once the end play is correct, bend two tabs of the nut-lock over opposing flats on the jam nut.

6.4 Rotate the hub in both directions. It should turn freely with no dragging or binding. End play should be between 0.001 and 0.005 inch (0.03 to 0.13 mm).

Torque Values		
Retention Method	**Size**	**Torque: lbf·ft (N·m)**
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, or Bendable Lockwasher)	1-1/8	Target: 175 (235) Permissible Range: 150–225 (205–305)
	1-1/2 to 2-1/2	Target: 250 (340) Permissible Range: 200–300 (270–405)
	2-5/8 or Larger	Target: 310 (420) Permissible Range: 250–400 (340–540)

Table 1, Torque Values

Outboard-Mounted Drum Removal and Installation

Removal

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.

1. Chock the rear tires to prevent vehicle movement. Apply the parking brakes.
2. Raise the front of the vehicle until the tires clear the ground. Then place safety stands under the axle.

WARNING

Never work under a vehicle that is supported only by a jack. Jacks can slip, causing the vehicle to fall. This could result in a person being pinned under or crushed by the vehicle, causing severe personal injury or death. Always use safety stands to support a vehicle.

3. Back off the slack adjuster to release the front 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 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 particulate air (HEPA) filter. 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 110** for instructions.

Installation

1. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.
2. Install the brake drum on the wheel hub. See **Fig. 1**.

   2.1 Position the brake drum on the top step of the pilot pad. One of the hub's pilot pads should be at the 12 o'clock (top center) position. See **Fig. 2**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are torqued.

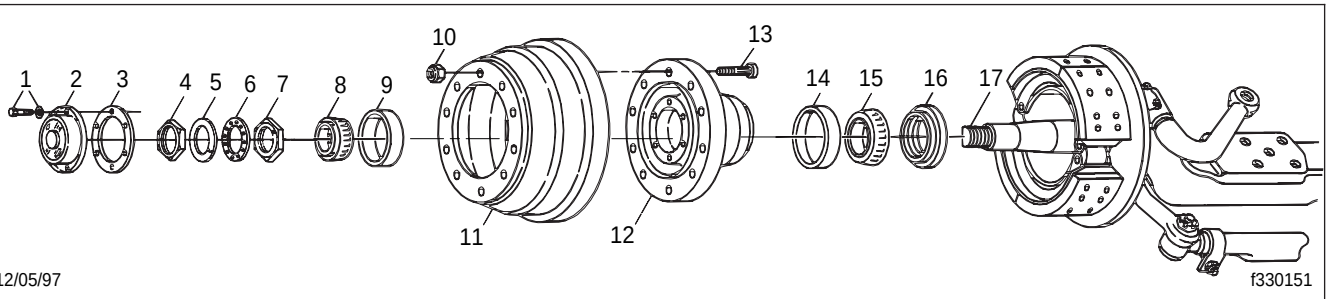
   2.2 Make sure that the pilot pads securely center the drum (space between drum and hub is equal all around the hub).

   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.
3. 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**.

WARNING

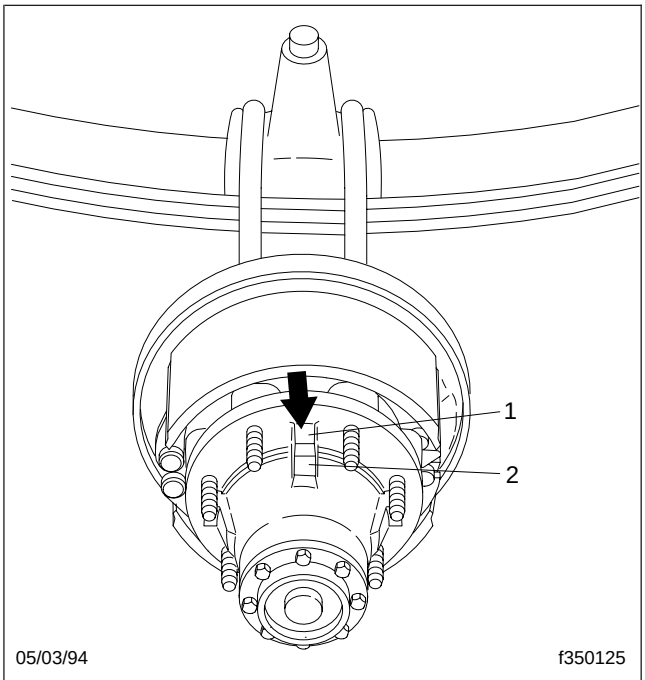
If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking ability, and the hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel

Outboard-Mounted Drum Removal and Installation



1. Hub Cap Capscrew and Washer
2. Hub Cap
3. Gasket
4. Jam Nut
5. Nut-Lock
6. Lockring
7. Adjusting Nut
8. Outer Wheel Bearing
9. Outer Bearing Cup
10. Wheel Nut
11. Brake Drum
12. Hub
13. Wheel Stud
14. Inner Wheel Bearing Cup
15. Inner Wheel Bearing
16. Oil Seal
17. Spindle

Fig. 1, Typical Wheel and Axle Assembly (four-piece bearing system shown)



NOTE: Pilot pad at 12 o'clock position

1. Drum Pilot
2. Wheel Pilot

Fig. 2, Hub Pilot Pads

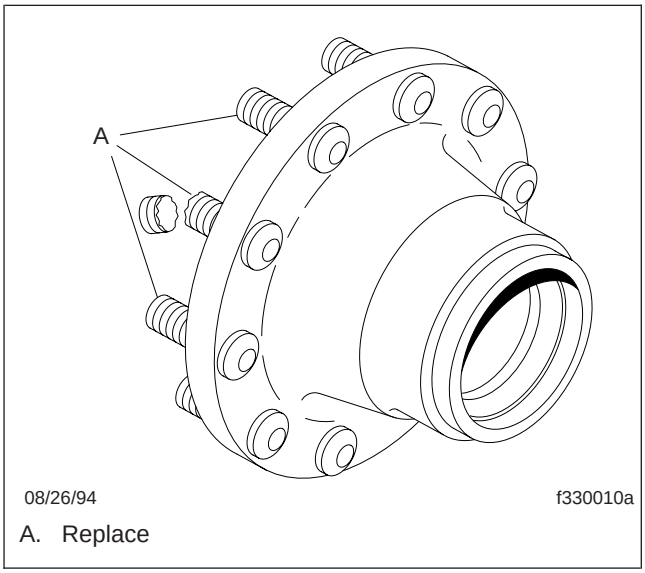
hub assembly when the conditions described above exist, could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

4. Adjust the front axle brakes.
5. Raise the vehicle and remove the safety stands from under the axle. Lower the vehicle.
6. Remove the chocks from the rear tires.

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

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.

CAUTION

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.*

CAUTION

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.

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

Troubleshooting Tables

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil was used on the bearings, or the wrong type of oil was used.	Clean, then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil.
Foreign matter or corrosive agents entered the bearing assembly. Dirt or metallic debris from the bearings was not removed.	Clean, then inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle, and any other component in contact with the bearing lubricant.
An incorrect adjustment of the wheel bearings is causing noise and wear.	Adjust the wheel bearings following the applicable instructions in this section.
Flat spots or dents on the roller surface were caused by skidding of the roller or improper handling of the wheel bearing during installation.	Clean, then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil.

Problem—Broken Wheel Studs

Problem—Broken Wheel Studs	
Possible Cause	**Remedy**
The wheel nuts were overtightened.	Replace the wheel studs. See **Group 40** for the wheel nut tightening sequence.
An incorrect nut tightening sequence was used.	
The wrong brake drums were installed.	Install new brake drums.
Wheels are mismatched (hub-piloted wheels are mixed with stud-piloted wheels).	Install properly matched wheels.
The vehicle is being overloaded.	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
(Cracked hub) Local surface of an aluminum hub was heated higher than 350°F (177°C) during bearing cup removal.	Replace the hub assembly. When removing the bearing cup, oven-heat the hub.
(Bent flange) Incorrect installation of the wheel studs, such as using a hammer and drift, or the hub flange was not fully supported on the press during wheel stud replacement.	Replace the hub assembly. Replace the wheel studs.
The wrong brake drums were installed.	Install new brake drums.
Insufficient tightening of the wheel nuts to the wheel hub.	Replace the hub assembly and tighten the wheel nuts to the values in the torque table in **Specifications 400**.

Troubleshooting

Problem—Loss of Lubricant from the Wheel Hubs

Problem—Loss of Lubricant from the Wheel Hubs	
Possible Cause	**Remedy**
The seals or gaskets are worn or damaged.	Replace worn or damaged parts.

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**
Dirt or grease has built up on the brake linings (glazing), or the brake linings have worn excessively.	Install new brake linings or brake pads on both sets of axle brake shoes or brake calipers. Clean, turn, or replace the drums or discs.
The brake drums are worn, heat-checked, or cracked.	Install new brake drums.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
For detailed information, see **Group 42**.	

Problem—Poor Lining-to-Drum Contact

Problem—Poor Lining-to-Drum Contact	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Install new brake drums or turn the drums.
The brake shoes are stretched or bent.	Replace the brake shoes.
Undersized linings were installed.	Install new brake linings on both sets of axle brake shoes.
An incorrect grind was used on the brake linings.	
The wrong brake drums were installed.	Install new brake drums.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the applicable instructions in this section.

Problem—Brake Linings Are Tapered Across the Width

Problem—Brake Linings Are Tapered Across the Width	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the drums.
The brake shoes are bent.	Replace the brake shoes.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the applicable instructions in this section.

Troubleshooting

Problem—Brake Shoes on the Same Brake Are Wearing Unequally

Problem—Brake Shoes on the Same Brake Are Wearing Unequally	
Possible Cause	**Remedy**
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 on both sets of axle brake shoes. Clean, turn, or replace the drums.
The brake shoes are stretched.	Replace the brake shoes.

Problem—Shoes on Each Side of the Axle (Side-to-Side Brakes) Are Wearing Unequally

Problem—Shoes on Each Side of the Axle (Side-to-Side Brakes) Are Wearing Unequally	
Possible Cause	**Remedy**
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 on both sets of axle brake shoes. Clean, turn, or replace the drums.
The inside surface of the brake drum is in poor condition.	Turn or replace the drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.

Problem—Edge of the Lining Is Showing Wear

Problem—Edge of the Lining Is Showing Wear	
Possible Cause	**Remedy**
The brake lining is too wide.	Install new brake linings on both sets of axle brake shoes.
The brake linings are misaligned because of incorrectly drilled brake lining holes.	
Undersized brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.
There is an incorrect fit of the wheel onto the spindle due to the wrong wheel bearings.	Install new wheel bearings and adjust them following the applicable instructions in this section.
The brake shoes are bent.	Replace the brake shoes.

Problem—Brake Linings Are Scored or Grooved

Problem—Brake Linings Are Scored or Grooved	
Possible Cause	**Remedy**
Worn or scored brake drums have been causing poor contact with the brake linings.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
There is abrasive material between the lining and the drum.	

Troubleshooting

Problem—Brake Linings Are Loose

Problem—Brake Linings Are Loose	
Possible Cause	**Remedy**
The rivet holes in the brake shoes are too large.	Replace the brake shoes.
Incorrectly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem—Brake Lining Is Cracked at the Rivet Holes or Bolt Holes

Problem—Brake Lining Is Cracked at the Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
Overtightening of the lining bolts is causing cracks.	Install new brake linings. Replace the rivets or bolts with the correct size.
The wrong size counter bore for the rivet holes was made.	
The wrong rivets or bolts were used.	Replace the rivets or bolts with the correct size.
Incorrectly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem—Out-of-Round Rivet Holes or Bolt Holes

Problem—Out-of-Round Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
The rivets or bolts are loose.	Replace the brake shoes or linings.

Problem—Brake Drums Are Heat-Checked

Problem—Brake Drums Are Heat-Checked	
Possible Cause	**Remedy**
The brake drums are out-of-round.	Turn or replace the brake drums.
The wrong brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the applicable instructions in this section.
The brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The lining friction material for the operation of the vehicle is incorrect.	

Problem—Brake Drums Are Heavily Scored

Problem—Brake Drums Are Heavily Scored	
Possible Cause	**Remedy**
The brake linings are damaged.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
There is excessive wear on the linings.	
On the last brake reline, the drums were not turned.	Turn the brake drums.

Problem—Hard Steering

Problem—Hard Steering	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate tires to the correct pressure.
Binding in the steering gear due to a lack of lubrication.	Test the steering system for binding with the front tires off the ground. For instructions, see **Group 46**.
Too much caster angle in the front wheels.	Check the caster angle and adjust as needed.
The front suspension is sagging due to a damaged spring.	Repair or replace the spring as needed. For instructions, see **Group 32**.
The axle spindle is bent.	Replace the spindle.
The frame is misaligned.	Check the frame alignment; correct, as needed.

Problem—Erratic Steering When the Brakes are Applied

Problem—Erratic Steering When the Brakes are Applied	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more front axle spring U-bolt nuts are loose.	Check the U-bolt nuts for looseness. If loose, check the U-bolt for damage. Replace damaged parts; tighten loose nuts.
The brakes are not adjusted evenly.	Adjust the brakes on all axles. Also, check the operation of the slack adjusters.
Grease or oil contamination of the brake linings is reducing brake effectiveness.	Replace the brake linings and clean the drums. Find and correct the cause of grease or oil contamination.
The caster angle is wrong.	Check, and adjust as needed.
An axle spindle is bent.	Replace the axle spindle.
The front axle wheel bearings are worn or were incorrectly adjusted.	Check the bearings for wear or damage; replace as needed.

Troubleshooting

Problem—Vehicle Pulls to One Side During Operation

Problem—Vehicle Pulls to One Side During Operation	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more of the alignment measurements are incorrect.	Check all the alignment measurements. Correct as needed.
The wheels or tires are out-of-round.	Inspect the wheels and tires. Replace out-of-round parts.
The front axle wheel bearings are too tightly adjusted.	Check the bearings for wear or other damage. Replace the bearings if needed.
The front suspension is sagging due to a damaged spring.	Repair or replace the spring as needed. For instructions, see **Group 32**.
The axle spindle is bent.	Replace the spindle.
The frame is misaligned.	Check the frame alignment; correct as needed.
The rear axle is out of alignment.	Check, and if needed, adjust the rear axle alignment.

Problem—Front Wheel Wander

Problem—Front Wheel Wander	
Possible Cause	**Remedy**
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for out-of-round brake drums; correct as needed.
One of the front springs is weak or broken.	Repair or replace the spring as needed. For instructions, see **Group 32**.

Problem—Front Wheel Shimmy

Problem—Front Wheel Shimmy	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for out-of-round brake drums; correct or replace as needed.
One or more tires are out-of-round or bulged.	Replace the tire.
The front axle wheel bearings are worn or were incorrectly adjusted.	Check the bearings for wear or other damage. Replace the bearings if needed.
Parts of the steering gear or linkage are worn.	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.
The axle spindle is bent.	Replace the spindle.
One or more of the alignment measurements are incorrect.	Check all alignment measurements and correct as needed.
The knuckle pin is loose due to worn bushings.	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts as needed.
Shock absorbers are worn or damaged.	Check the shock absorbers and replace if needed.

Problem—Vehicle Wanders

Problem—Vehicle Wanders	
Possible Cause	**Remedy**
Tire pressure is low in one or both front tires.	Inflate the tires to the correct pressure.
One or more of the alignment measurements are incorrect.	Check all of the alignment measurements; correct as needed.
The rear axle is out of alignment.	Check the rear axle alignment and adjust as needed.
Parts of the steering gear or linkage are worn.	Test for play in the steering gear and linkage with the front tires off the ground. Replace parts as needed.
A knuckle pin is loose due to worn bushings.	Inspect the knuckle pin and bushings for damage. Replace worn or damaged parts.
The axle spindle is bent.	Replace the spindle.

Problem—Cupped Tires

Problem—Cupped Tires	
Possible Cause	**Remedy**
Tire pressure is too low or too high in one or both front tires.	Inflate or deflate the tires to the correct pressure.
One or more wheels or brake drums are out-of-balance.	Balance the wheels. Check for eccentric brake drums; correct or replace as needed.
The wheel toe-in is not correct.	Adjust the wheel toe-in.
The brakes are not adjusted evenly.	Adjust the brakes on all axles. Also, check the operation of the slack adjusters.
The front axle wheel bearings are worn or were not adjusted correctly.	Check the bearings for wear or other damage; replace them if needed.
The camber angle is not within specifications.	Check the front wheel camber angle. If not correct, find and replace the damaged axle component.

Problem—Steering Wheel Spokes Do Not Point at the 3 and 9 o'clock Positions

Problem—Steering Wheel Spokes Do Not Point at the 3 and 9 o'clock Positions	
Possible Cause	**Remedy**
The steering gear is not centered.	Center the steering gear.
If adjustable, the drag link is out of adjustment.	Adjust the drag link.
The steering wheel was not installed (positioned) correctly on the steering column.	Reposition the steering wheel on the steering column.
The pitman arm is not correctly aligned with the timing mark on the steering gear output shaft.	Reposition the pitman arm on the steering gear output shaft. For instructions, see **Group 46**.

Specifications

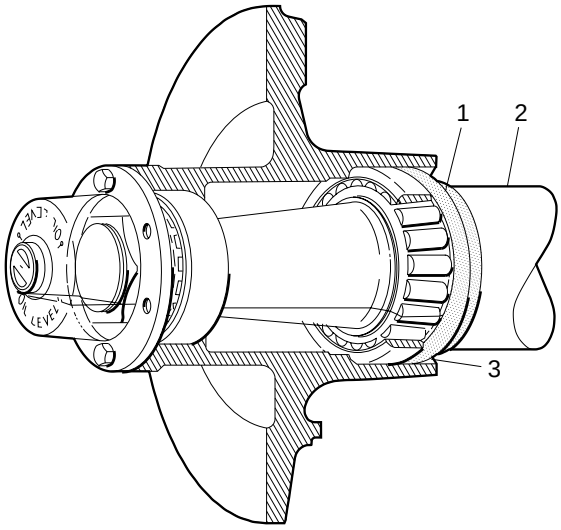
Torque Values		
Application	**Size (grade 8)**	**Torque: lbf·ft (N·m)**
Hub Cap Capscrews	5/16–18	15 (20)
Wheel-Bearing Inner Nut, 4-Piece System, Standard Hub	—	1. Initial: 200 (271) 2. Back Off 1 Turn 3. 50 (68) While Rotating Hub 4. Back Off 1/4 Turn
Wheel-Bearing Jam Nut, 4-Piece System, Standard Hub	1-1/8-inch to 2-1/2-inch	200 to 300 (271 to 407)
	2-5/8-inch or larger	250 to 400 (339 to 542)
Axilok® Wheel Bearing Nut, Preset Bearings	—	300 (407)
Axilok Wheel Bearing Nut, Standard Bearings	—	1. 90 to 110 (122 to 149) While Spinning Hub in Both Directions 2. Loosen to Zero 3. 50 (68) While Spinning Hub in Both Directions 4. Back Off 1/6 Turn

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 fits between the hub bore and the axle spindle, and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub. See **Fig. 1**.



1. Wheel Oil Seal
2. Axle Spindle
3. Wheel Hub Bore

Fig. 1, Spindle-Mounted Wheel Oil Seal (typical)

Most wheel oil seals consist of four basic parts. See **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.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip (called the "primary lip") keeps the oil inside the hub cavity. The outermost lip (called the "secondary lip") keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

Chicago Rawhide Scotseal® and Scotseal Plus® are used on this vehicle.

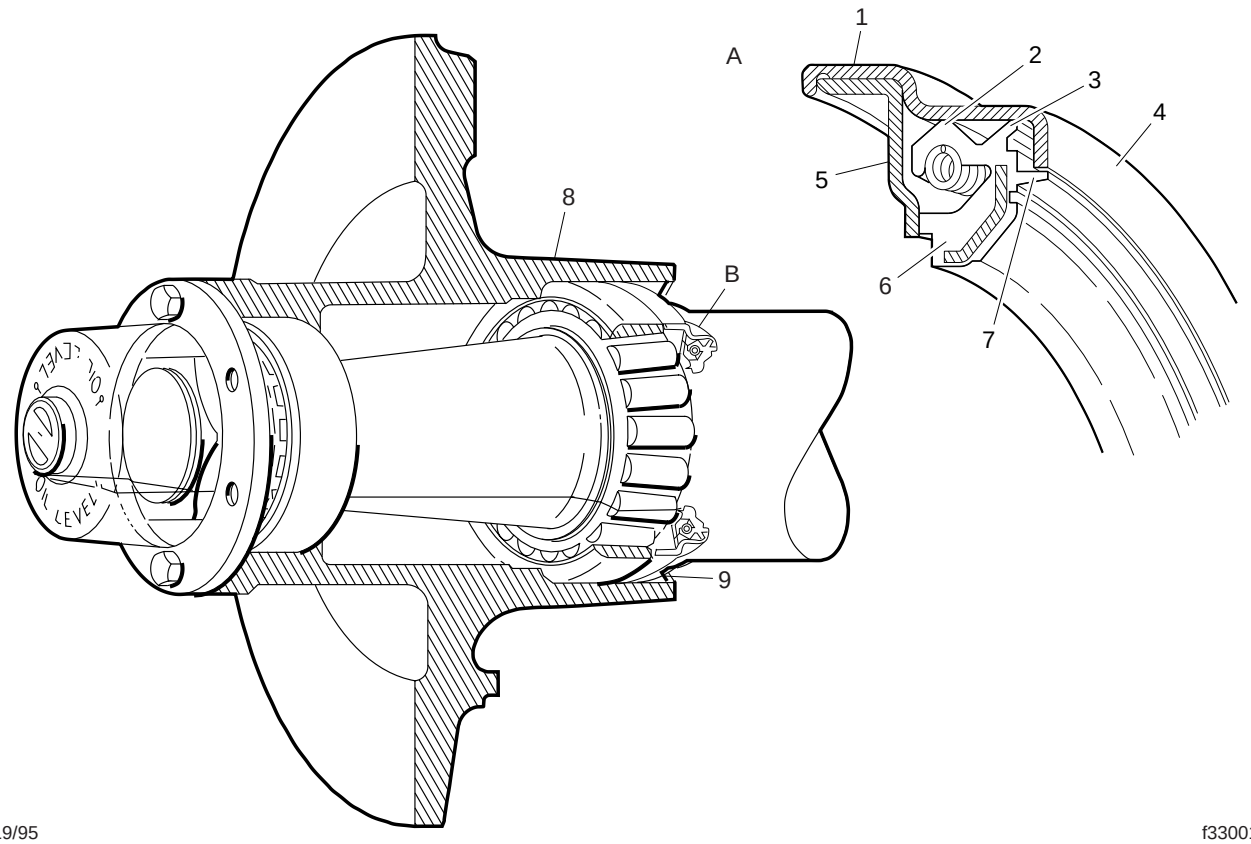
Chicago Rawhide

The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 2**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

Although you install the Scotseal 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.

The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.

General Information



A. Detail A
B. Oil Seal (See detail A)

1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

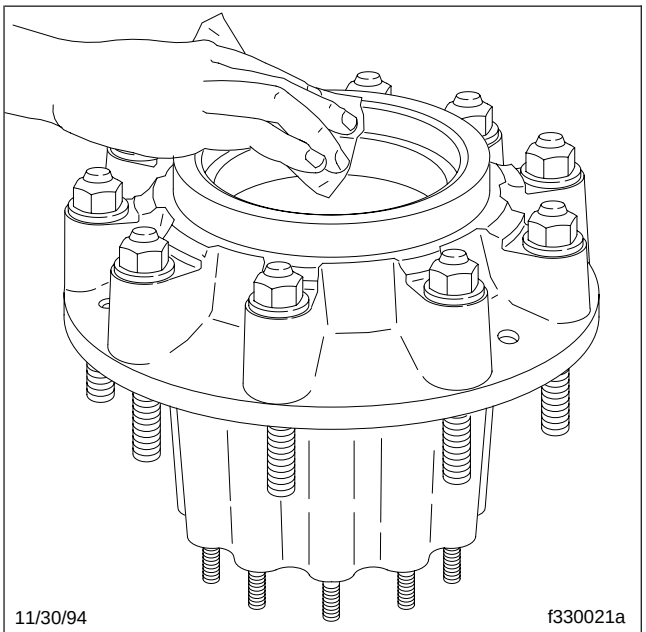
Fig. 2, Chicago Rawhide Scotseal

Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 33.01, Subject 100**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. 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 seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.



NOTE: Rear hub shown.

Fig. 1, Cleaning the Hub

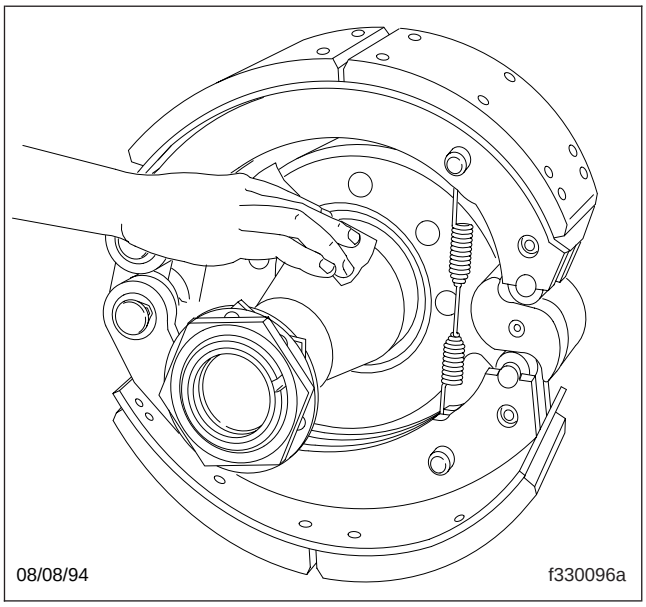


Fig. 2, Cleaning the Spindle

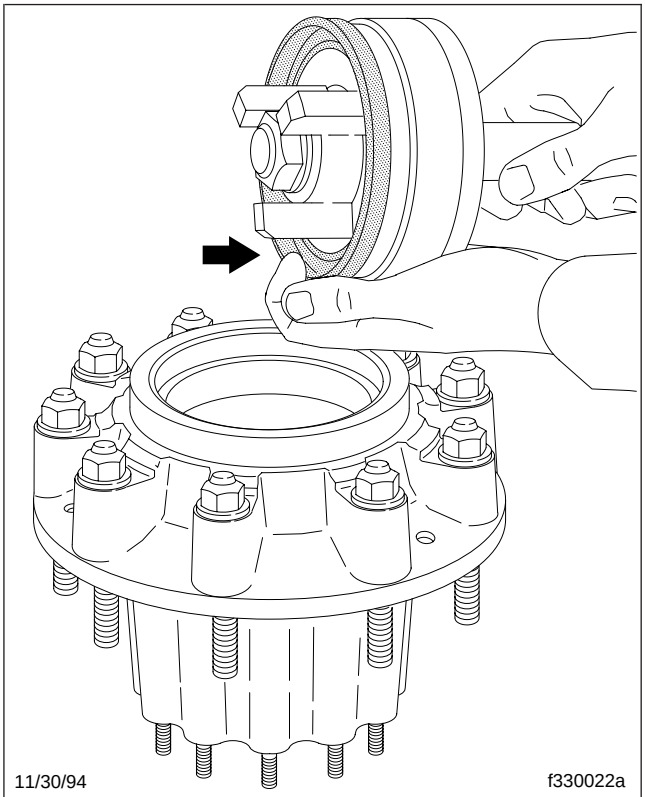
CAUTION

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.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

Seal Replacement, Chicago Rawhide



NOTE: Rear hub shown.

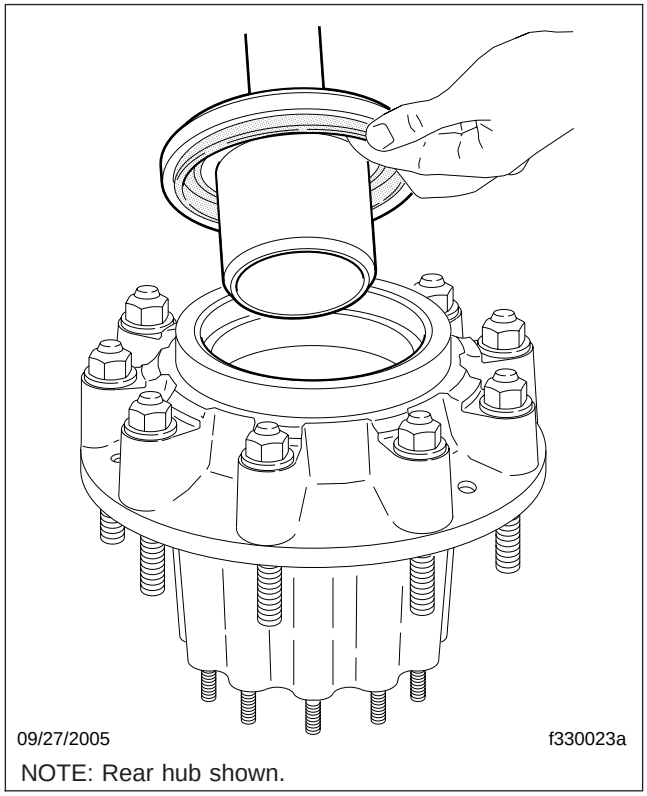
Fig. 3, Placing the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

12. 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.
13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 33.01, Subject 100**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

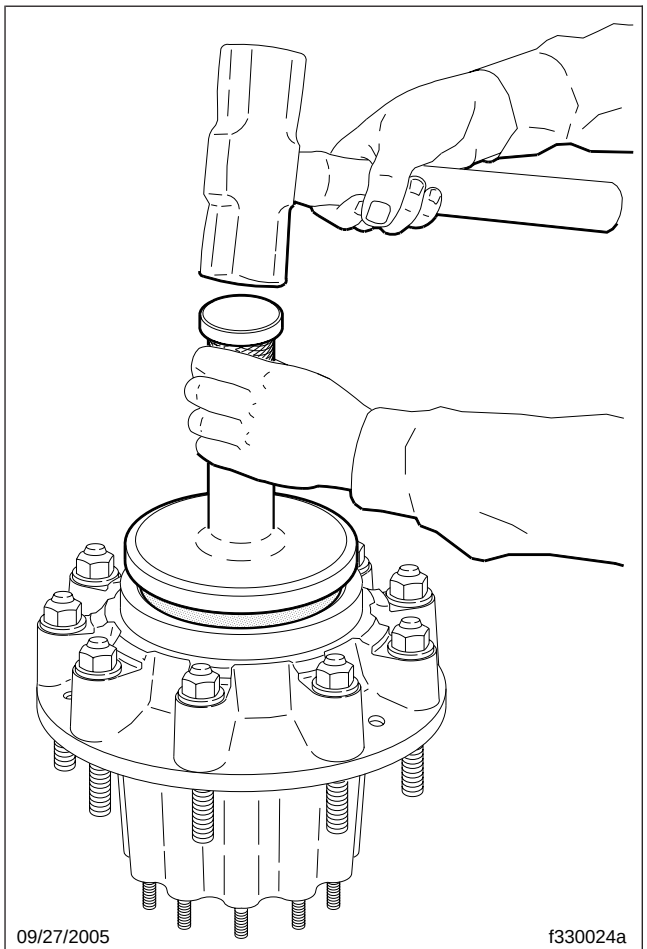
14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).
15. Fill the hub with oil to the level shown on the hubcap. See **Fig. 6**. Do not overfill.



NOTE: Rear hub shown.

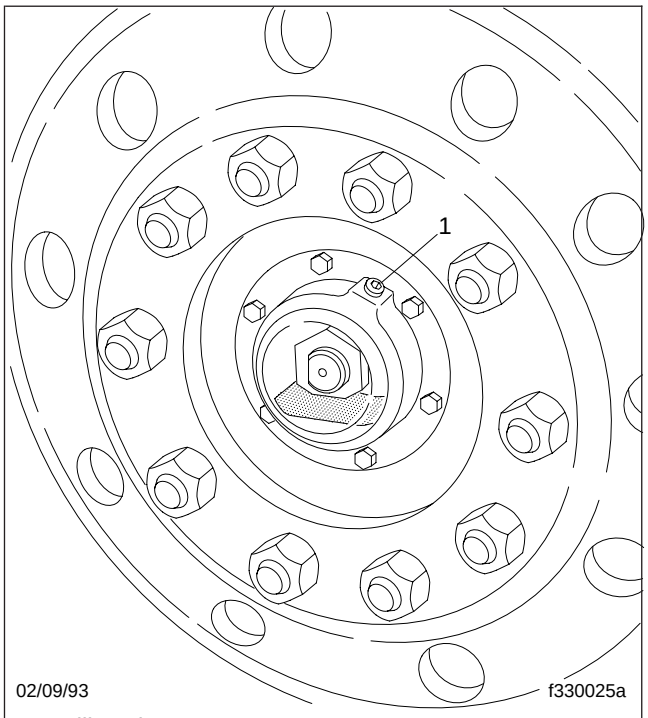
Fig. 4, Inserting the Tool in the Hub Bore

16. Spin the wheel and check the oil level.
17. Adjust the brake shoe-to-drum clearance.



NOTE: Rear hub shown.

Fig. 5, Striking the Tool



1. Filler Plug

Fig. 6, Hub Filled with Oil

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

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. Raise the front of the vehicle and support it with safety stands.
3. Release the pressure from the air system.
4. Remove the front wheel and tire assemblies. For instructions, see **Section 40.00**.
5. Remove the brake drums. For instructions, see **Group 42**.
6. Remove the front hubs from the axle. For instructions, see **Section 33.01**.
7. Remove the brake shoes. For instructions, see **Group 42**.
8. Remove the ABS sensors and wiring from the brake anchor plates.
9. Remove the brake air chambers and the slack adjusters. For instructions, see **Group 42**.
10. Remove the brake anchor plates from the axle. For instructions, see **Group 42**.
11. Disconnect the drag link from the axle steering arm. For instructions, see **Group 46**.
12. Disconnect the sway bar from the axle brackets.
13. Using a suitable jack, support the front axle.
14. Remove the nuts that hold the axle beam to the leaf springs and the air bag brackets. There are four nuts on each side.
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.

    For instructions on replacing the steering knuckles, see **Subject 110**.

Installation

1. With the axle on a suitable jack, position it under the vehicle.
2. Raise the axle so that the holes in the beam line up with the bolts that hold the air bags to the leaf springs. Install the nuts and washers, and tighten the nuts to 220 lbf·ft (298 N·m).

   For vehicles with a leaf-spring suspension, install the U-bolts and nuts. For instructions on tightening U-bolt nuts, see **Group 32**.
3. Connect the sway bar to the axle brackets. Tighten the fasteners 100 lbf·ft (136 N·m).
4. Connect the drag link to the steering arm. For instructions, see **Group 46**.
5. Install the brake anchor plates on the axle ends. For instructions, see **Group 42**.
6. Install the brake air chambers and slack adjusters on the axle. For instructions, see **Group 42**.
7. Install the ABS sensors.
8. Install the brake shoes. For instructions, see **Group 42**.
9. Install the hubs and adjust the wheel bearings. For instructions, see **Section 33.01**.
10. Install the brake drums.
11. Adjust the slack adjusters. For instructions, see **Group 42**.
12. Install the tire and wheel assemblies. For instructions, see **Section 40.00**.
13. Raise the vehicle, remove the safety stands, then lower the vehicle.
14. Start the engine and build the air pressure.
15. Check that the suspension air bags are inflating correctly.
16. Put the transmission in park. Remove the chocks from the rear tires.

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.

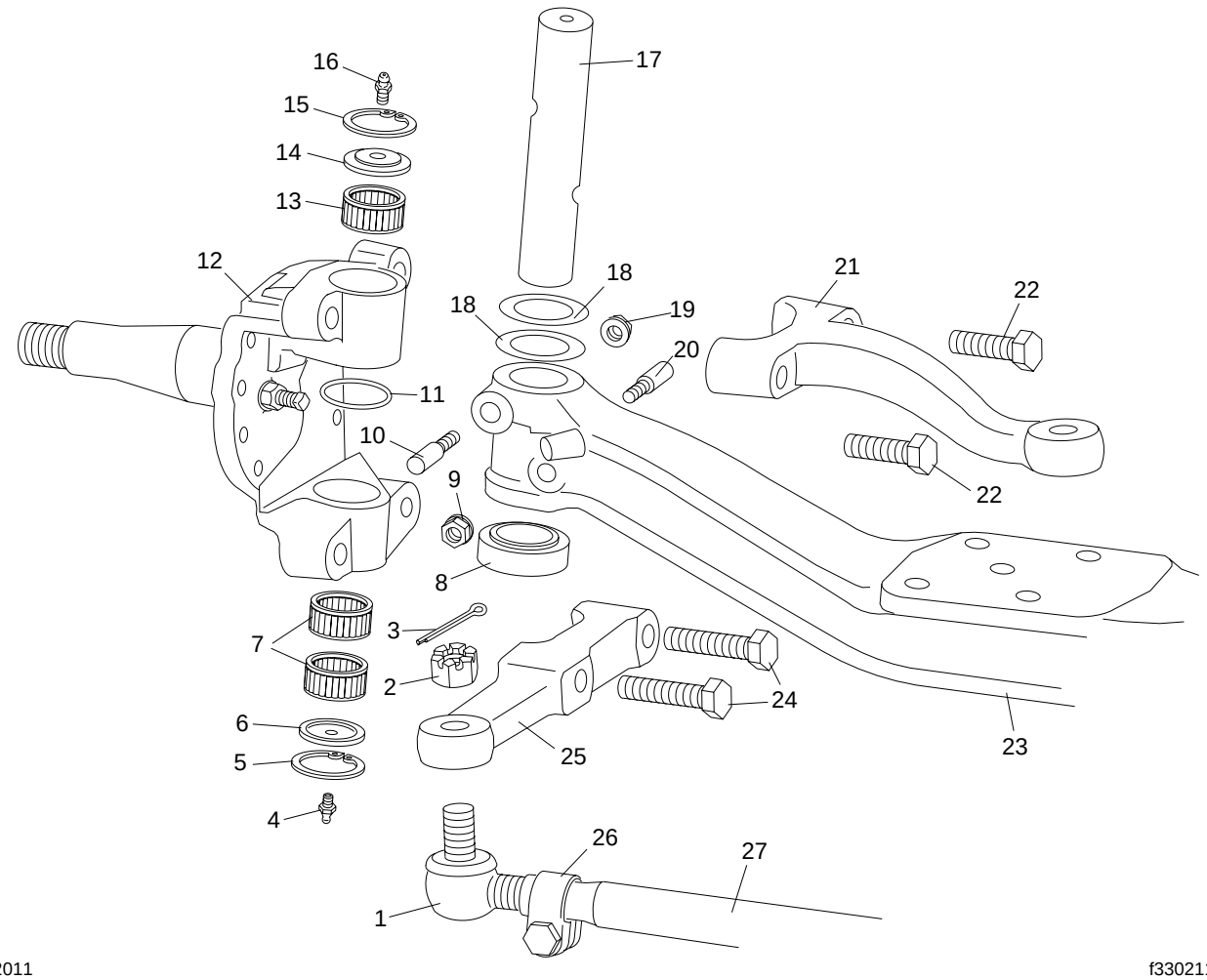
8. Remove the thrust friction bearing (driver side) or the thrust roller bearing (passenger side) from the top of the lower steering knuckle bore.

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.

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. Alignment specifications for Hunter and Bee Line alignment equipment are in **Specifications, 400.**

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 *S2 Chassis 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.**

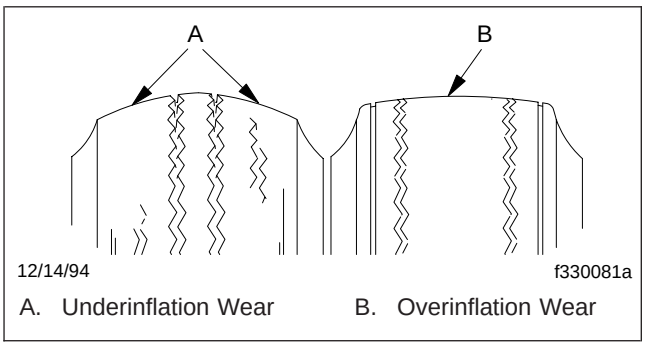


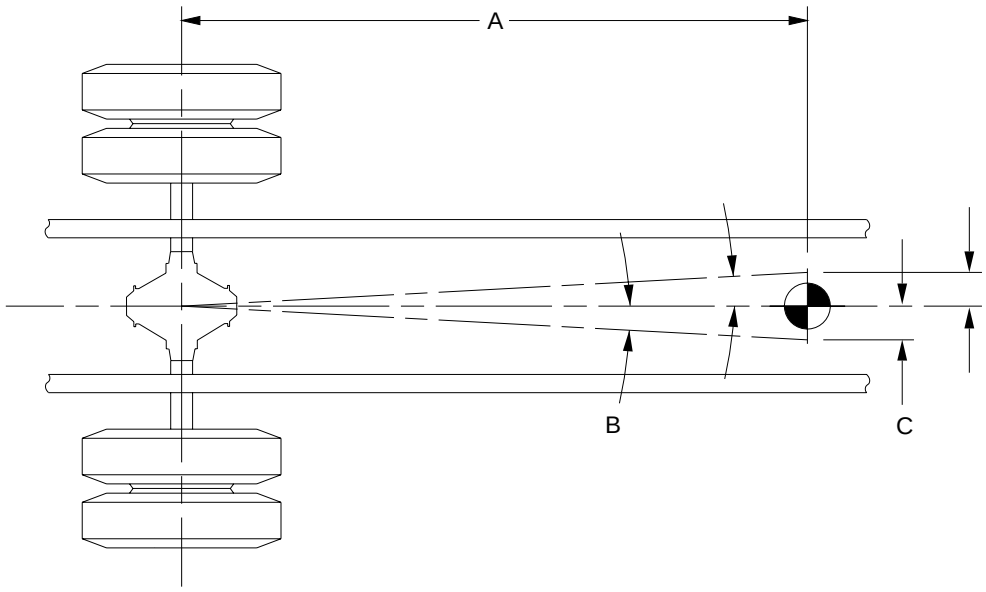
Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

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. 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**.



For items A and C, see **Specifications 400**.

A. Distance from Rear Axle to Target (using Bee Line Alignment Tools)
B. Maximum Allowable Tolerance if Aligned with Hunter Tools = ±0.18 degree
C. Maximum Allowable Tolerance if Aligned with Bee Line Tools

Fig. 1, Alignment Measurements

Specifications

Maximum Tolerance from Perpendicular, Hunter Equipment	
Method	**Maximum Tolerance ± from Perpendicular**
Hunter*	±0.25 degree

* To use Hunter alignment equipment, refer to the applicable Hunter service literature.

Table 1, Maximum Tolerance from Perpendicular, Hunter Equipment

Maximum Tolerance from Perpendicular at Target, Bee Line Equipment	
Distance from the Rear 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 2, Maximum Tolerance from Perpendicular at Target, Bee Line Equipment

General Information

These vehicles are equipped with one of two different wheel end assemblies:

- The traditional hub and bearings

  With traditional wheel ends, the bearings and oil seal must be assembled with the hub when the hub is installed on the axle spindle. First the inner bearing is installed in the hub. The oil seal is pressed into the hub bore. The inner bearing and the hub are then mounted onto the axle spindle. Then the outer bearing is mounted in the hub bore. A nut is installed on the axle spindle end and tightened and loosened to adjust the bearings. Finally, a locking device and jam nut are installed to secure the hub and bearings on the axle. For instructions, see **Subject 140**.

- The Con Met PreSet® hub

  This wheel end has the bearings and oil seal pre-installed in a hub. To install a new hub, mount it on the axle spindle, and secure it with an Axilok® nut. For instructions, see **Subject 180**. A spacer between the inner and outer bearings adjusts the bearings to near zero end-play and preload when you tighten the retaining nut.

All wheel end assemblies consist of the following components. See **Fig. 1** and **Fig. 2**.

- Wheel Bearings
- Axle Spindle
- Wheel Hub
- Disc Brake Rotor with Caliper and Brake Pads, or Brake Drum with Brake Shoes
- Wheel Studs

Tapered Wheel Bearings

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. 3**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

Each hub has a set of inner and outer tapered wheel bearing assemblies. On traditional hub and bearing assemblies, the bearing setting is locked in place on the axle spindle by an adjusting nut, a locking device such as a lockring or nut-lock, and a jam nut. See **Fig. 4**.

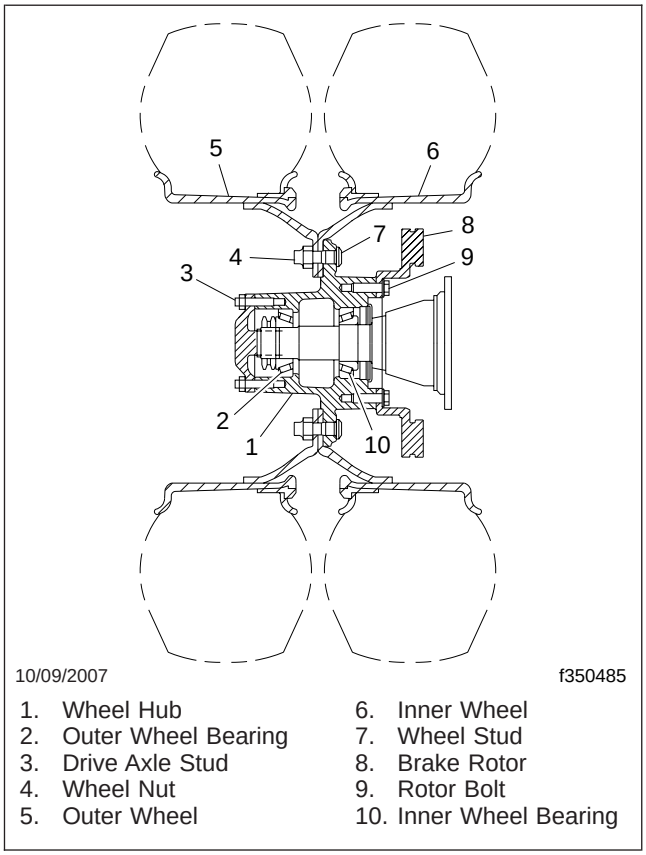


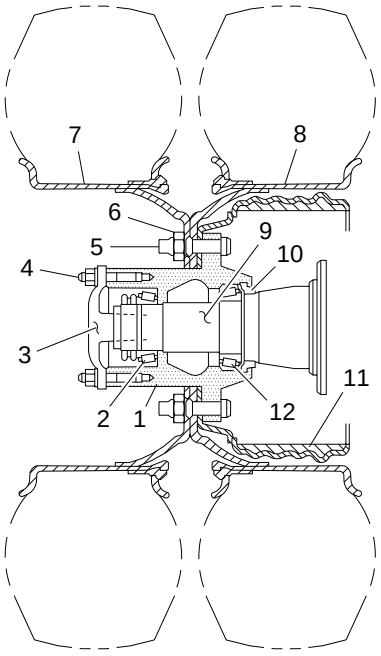
Fig. 1, Traditional Wheel End Assembly with Disc Brakes

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 a locking assembly.

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.

General Information



10/11/2007 f350136a

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

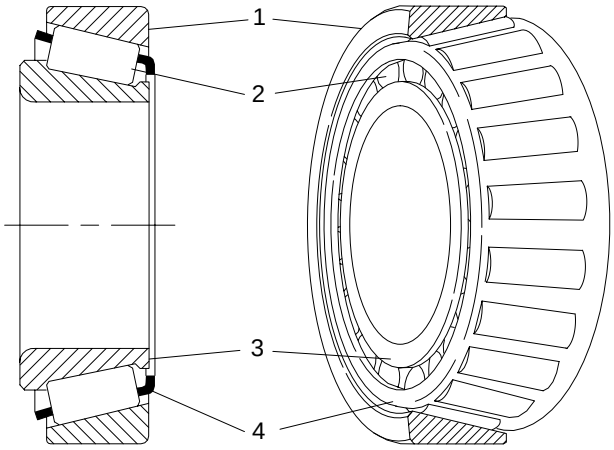
Fig. 2, Traditional Wheel End Assembly with Drum Brakes

CAUTION

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.

Wheel Hub

The dual hub-piloted disc wheels, and the inboard-mounted disc-brake rotor or the outboard-mounted brake drum are mounted on an aluminum or iron wheel hub. See **Fig. 4** and **Fig. 5**. Both the inner and outer bearing cups and certain types of wheel studs are press-fit in the hub. The hub is also the interconnecting point for the drive axle shaft and wheels.



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1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 3, Tapered Wheel Bearing Assembly

Disc Brake Rotor and Caliper

The disc brake rotor, caliper, and brake pads work together, with the disc brake rotor responsible for both heat absorption and dissipation. Brake pad performance and life largely depend on the condition of the disc brake rotor and whether it can adequately absorb and dissipate heat generated by braking action. See **Fig. 5**.

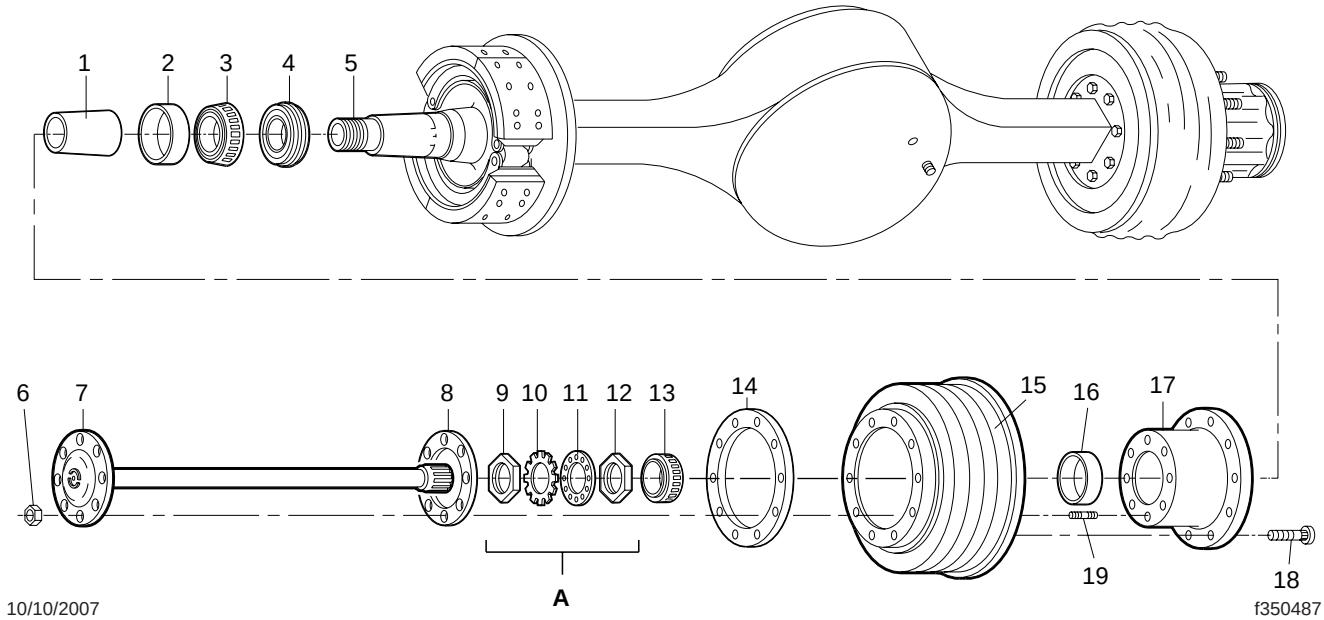
Brake Drum

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.

The brake drum is mounted on the outboard face of the hub and fits over the wheel studs. See **Fig. 4**.

Wheel Studs

A headed wheel stud is used on rear axle disc wheel hub assemblies and has either serrations on the stud



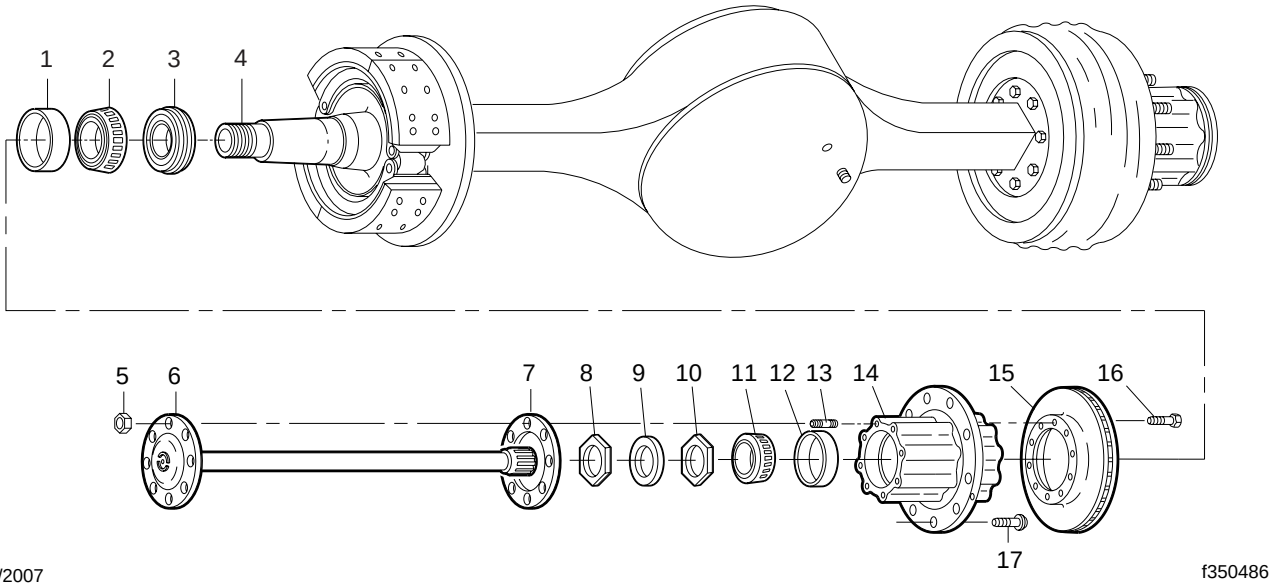
A. Four-piece bearing-lock system shown; an Axilok® locking nut is used with ConMet PreSet hubs.

1. Bearing Spacer (used only with ConMet PreSet hubs)
2. Inner Wheel Bearing Cup
3. Inner Wheel Bearing
4. Oil Seal
5. Axle Spindle
6. Drive Axle Stud Nut
7. Drive Axle Flange and Shaft
8. Gasket
9. Jam Nut
10. Nut-Lock
11. Lockring
12. Adjusting Nut
13. Outer Wheel Bearing
14. Hub Spacer
15. Brake Drum
16. Outer Wheel Bearing Cup
17. Hub
18. Wheel Stud
19. Drive Axle Stud

Fig. 4, Typical Drive Axle and Hub Assembly (exploded view)

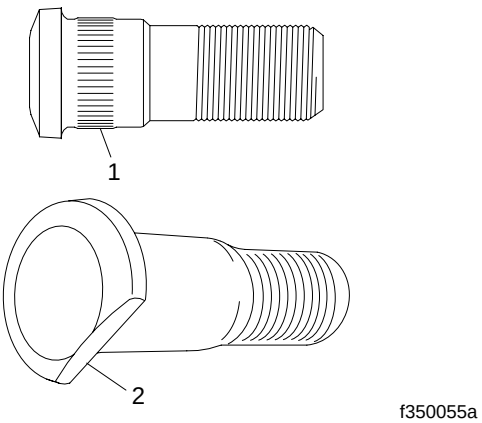
body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 6**.

General Information



1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Wheel Hub
15. Brake Rotor
16. Rotor Bolt
17. Wheel Stud

Fig. 5, Typical Drive Axle and Disc Brake Assembly (exploded view)



1. Serrations
2. Clipped Head

Fig. 6, Typical Headed Wheel Studs

Removal

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. If the vehicle has air 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. If the vehicle has air brakes, remove the brake drum. See **Fig. 1** and **Fig. 2**. For instructions, see **Subject 150**.

NOTE: Oil will spill as the drive axle shaft and the wheel hub are removed. Place a suitable container under the drive axle flange to catch any spilled oil. Discard the oil.

6. Remove the drive axle stud nuts and washers. See **Fig. 3**.

⚠ CAUTION

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.

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. For outboard-mounted hubs on vehicles with disc brake applications, tilt the caliper up so the outboard brake pad clears the rotor. Slide the caliper off the anchor plate rails. See **Fig. 4**. Be careful not to stretch the brake hose.

    The inboard brake pad will stay in place between the upper and lower rails of the anchor plate.
12. Remove the wheel bearing locking device.

    If the hub is equipped with a four-piece wheel-bearing-lock system, see **Subject 140**; then go to the next step.

    If the vehicle has ConMet PreSet hubs, see **Subject 180**; then go to the step below that says "remove the hub."
13. 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).

⚠ CAUTION

When moving the hub, be careful not to let the outer wheel bearing drop from the axle spindle. If the wheel bearing is dropped, cage warpage or roller damage can occur. 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.

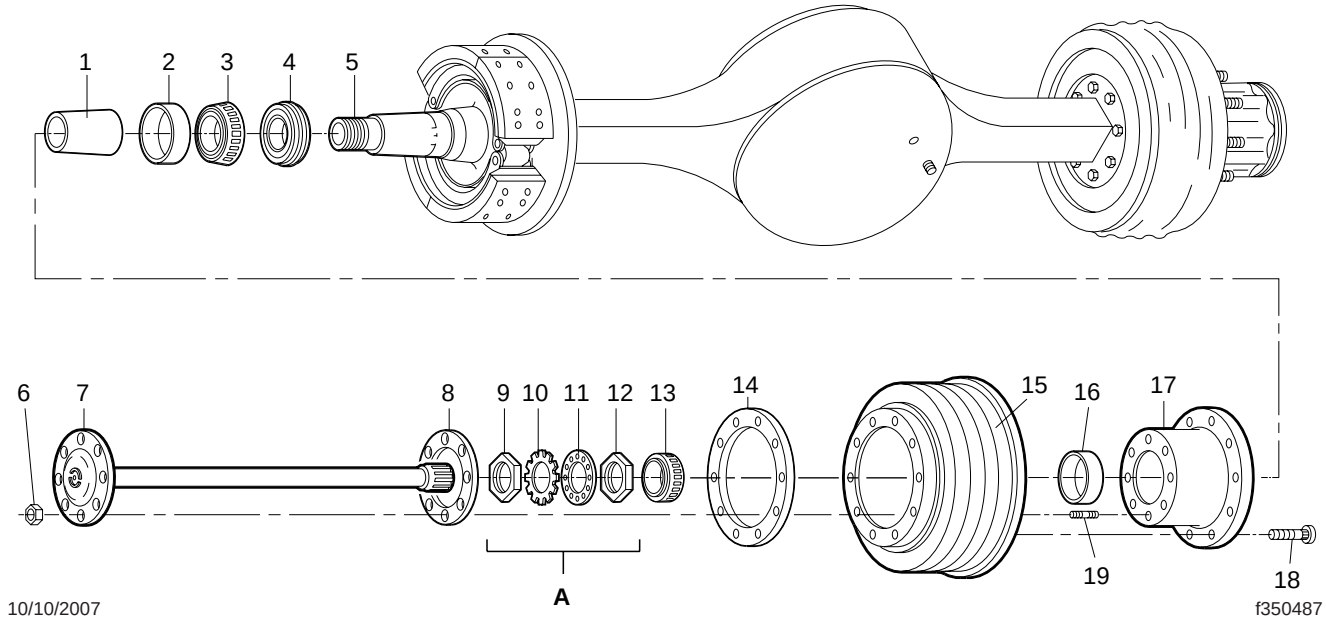
14. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap the bearings in either clean oil-proof paper or lint-free rags.

⚠ CAUTION

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.

15. Remove the hub. Be careful not to damage the axle spindle threads as the assembly is removed.

Hub Assembly Removal and Installation



A. Four-piece bearing-lock system shown; an Axilok® locking nut is used with ConMet PreSet hubs.

1. Bearing Spacer (used only with ConMet PreSet hubs)
2. Inner Wheel Bearing Cup
3. Inner Wheel Bearing
4. Oil Seal
5. Axle Spindle
6. Drive Axle Stud Nut
7. Drive Axle Flange and Shaft
8. Gasket
9. Jam Nut
10. Nut-Lock
11. Lockring
12. Adjusting Nut
13. Outer Wheel Bearing
14. Hub Spacer
15. Brake Drum
16. Outer Wheel Bearing Cup
17. Hub
18. Wheel Stud
19. Drive Axle Stud

Fig. 1, Typical Drive Axle and Hub Assembly (exploded view)

16. Remove the oil seal from the hub.
17. If the hub is equipped with a four-piece wheel-bearing-lock system, remove the inner wheel bearing from the hub. Handle the bearings with clean, dry hands, then wrap the bearings in either clean oil-proof paper or lint-free rags. Occasionally, the inner wheel bearing will remain in the hub after the oil seal is removed from the hub. In those cases, place a protective cushion where it will catch the bearings. Then use a hardwood drift and a light hammer to gently tap the bearing out of the cup.

Installation

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 a clean, absorbent, and lint-free cloth or paper. Wrap a protective layer of friction tape on the axle spindle threads.

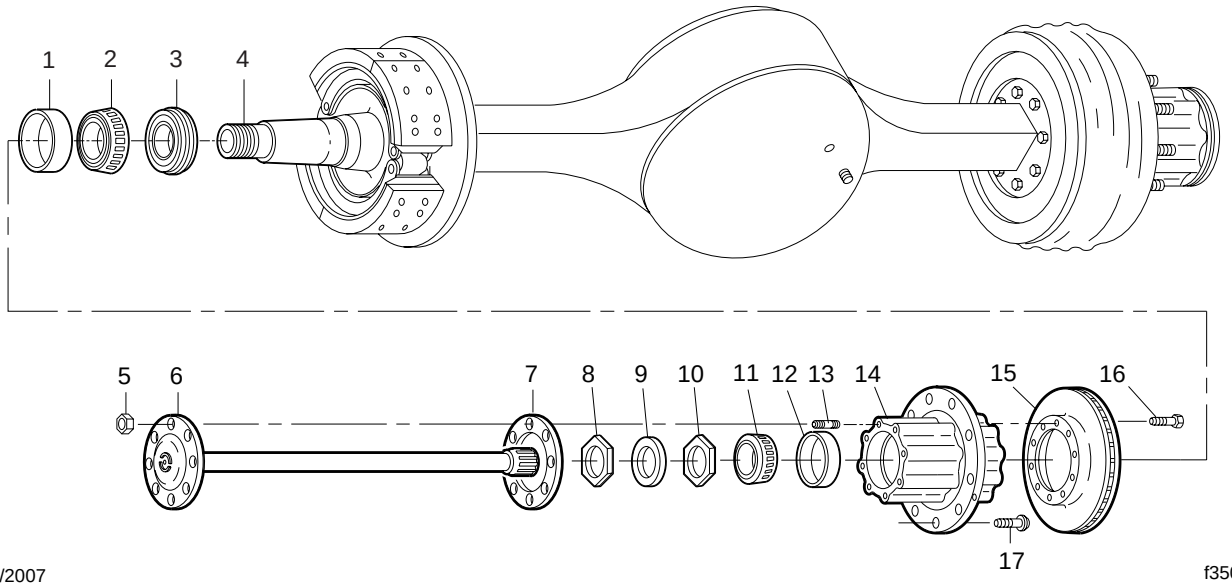
IMPORTANT: Be sure to follow all the manufacturer's warnings and instructions when using any solvent.

2. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic compound or an equivalent.
3. If the vehicle has air brakes, coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal. Handle the bearings with clean, dry hands. See **Section 35.02** for oil seal installation instructions.

⚠ CAUTION

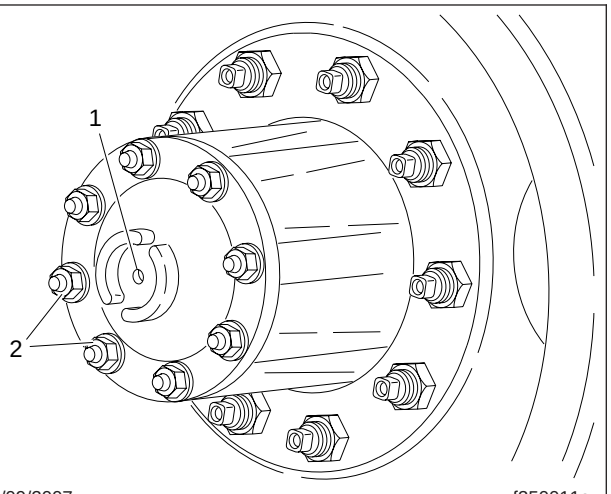
Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both

Hub Assembly Removal and Installation



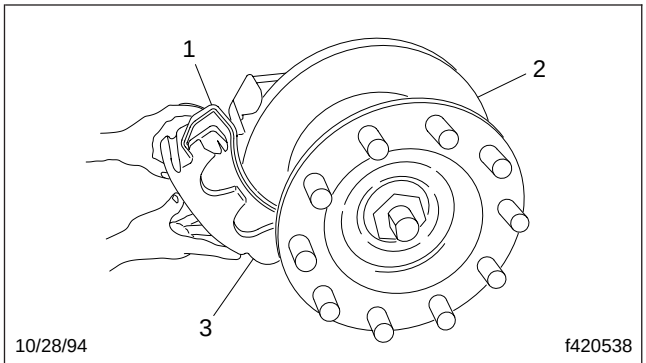
1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjusting Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Wheel Hub
15. Brake Rotor
16. Rotor Bolt
17. Wheel Stud

Fig. 2, Typical Drive Axle and Disc Brake Assembly (exploded view)



1. Center Portion of Drive Axle Flange
2. Drive Axle Studs and Nuts

Fig. 3, Wheel Hub and Drive Axle Flange



1. Outboard Brake Pad
2. Rotor
3. Caliper

Fig. 4, Tilting the Caliper

are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.

4. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.

Hub Assembly Removal and Installation

CAUTION

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.

5. Mount the bearings and hub on the spindle. Then adjust and secure the bearings.

   If the hub is equipped with a four-piece wheel-bearing-lock system, see **Subject 140**; then go to the next step.

   If the vehicle has ConMet PreSet hubs, see **Subject 180**; then go to the next step.

6. For outboard-mounted hubs on vehicles with disc brake applications, tilt the caliper housing so that the outboard brake pad will fit over the rotor. Push the caliper down onto the anchor plate rails. See **Fig. 4**.
7. Install a new gasket on the drive axle studs.
8. Install the drive axle shaft. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.
9. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle nuts. Using the sequence shown in **Fig. 5**, tighten the nuts to the torque values in the torque table in **Specifications 400**.

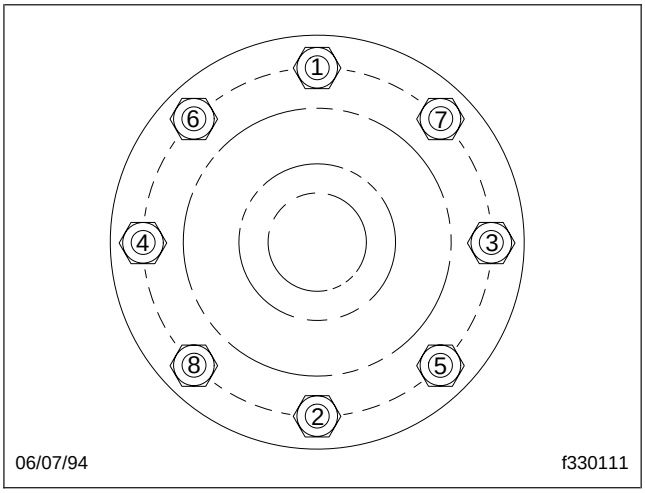


Fig. 5, Axle Shaft Flange Nut-Tightening Sequence

10. If the vehicle has air brakes, install the brake drum on the wheel hub. For instructions, see **Subject 150**.

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.

11. 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.

12. Pour the recommended drive axle lubricant through the axle housing filler hole. Tighten the oil filler plug 35 lbf·ft (47 N·m).

    Tilt the axle to the left and right, by jacking the opposite side. Hold the tilted position for one minute 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 2 extra pints (1 L) will be needed, to bring the level even with the base of the filler hole.

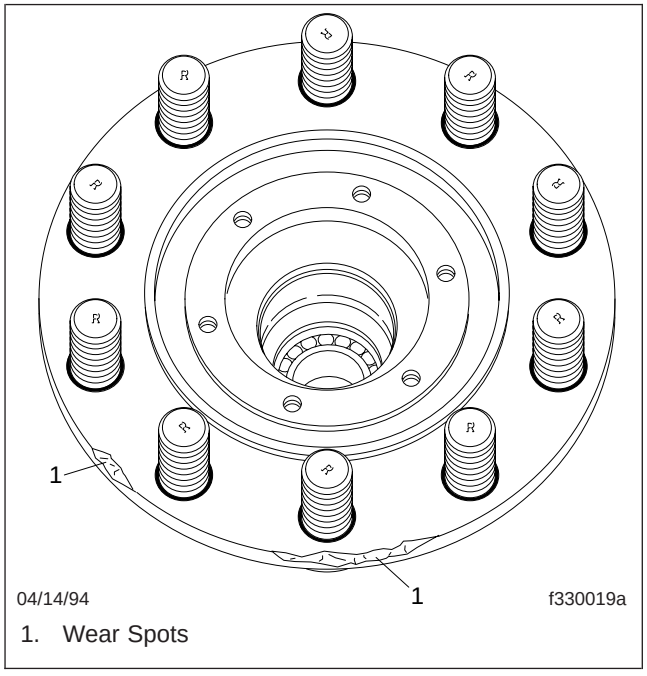
NOTE: Drive axle wheel bearings are lubricated by oil drawn from the axle housing bowl. This method ensures good exchange of heat, prevents stagnation, and minimizes maintenance required on bearings and hub assemblies.

13. Adjust the rear axle brakes. For instructions, see **Group 42**.
14. Remove the safety stands from under the axle, then lower the vehicle.
15. Apply the parking brakes, then remove the chocks from the front tires.

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.

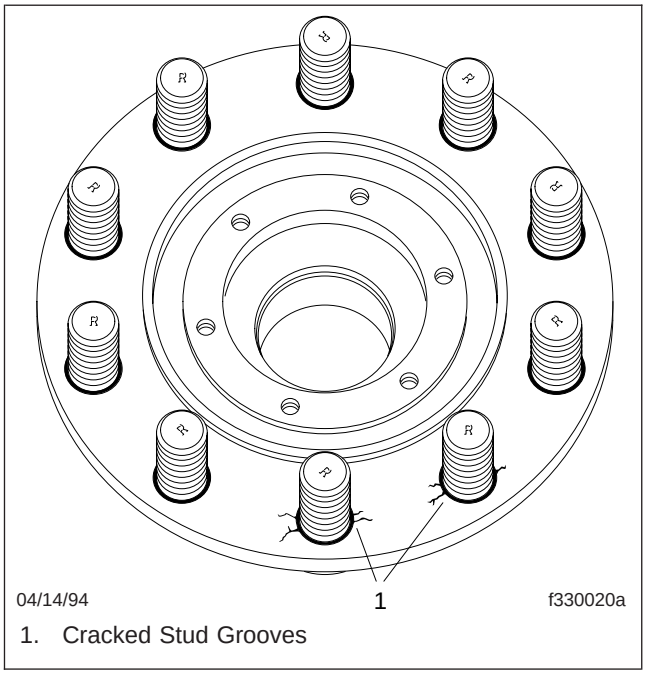
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

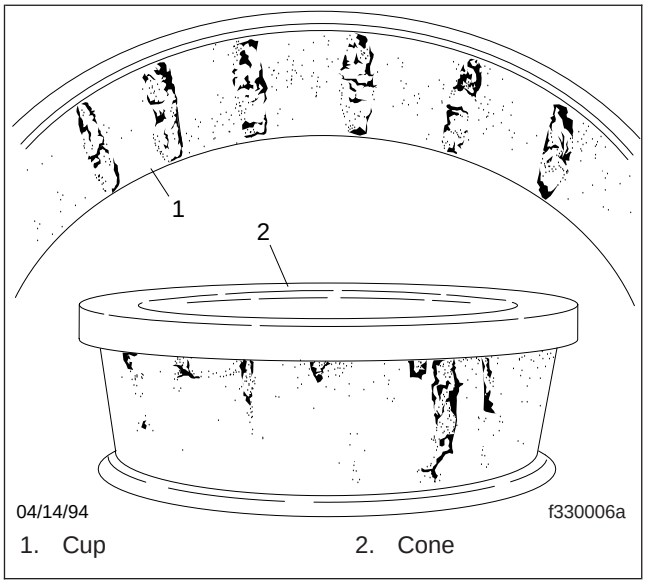
Fig. 1, Damaged Front Axle Wheel Hub

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. For instructions, see **Subject 120** 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 nuts on disc wheel installations. Damaged nuts are usually caused by inadequate tightening and must be replaced with new ones.

Axle Components Cleaning and Inspection

5. Inspect the wheel studs. Replace studs that are stripped, broken, bent, or otherwise damaged. For instructions, see **Subject 170**.

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 kerosene or diesel fuel oil, and a stiff brush. Before inspecting, clean the bearings.

1. Remove the wheel hub and bearing cones. For instructions, see **Subject 100**.
2. Clean all old oil from the bearings and hub cavity with kerosene or diesel fuel and a stiff brush. Don't 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 which is wet with kerosene or diesel fuel, and the kerosene or diesel fuel may dilute the lubricant.

⚠ CAUTION

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.

   4.1 If the large ends of the rollers are worn flush with the recess, or the radii at the large ends of the rollers are worn sharp. These are indications of advanced wear. See **Fig. 4**.

   4.2 If there is visible step wear, particularly at the small end of the roller track. If there are deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 5**.

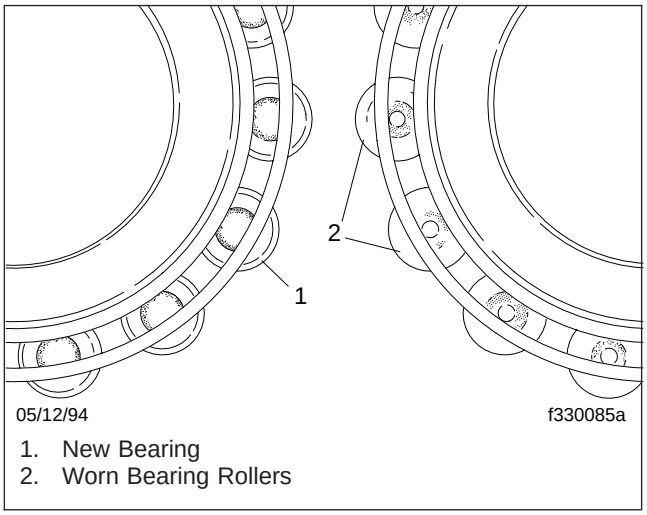
   4.3 If there are bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 6**.

   4.4 If there is 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.

   4.5 If there is etching or pitting on functioning surfaces. See **Fig. 7**.

   4.6 If there is spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, brush the bearings with fresh axle lubricant.



1. New Bearing
2. Worn Bearing Rollers

Fig. 4, Wheel Bearing Roller Wear

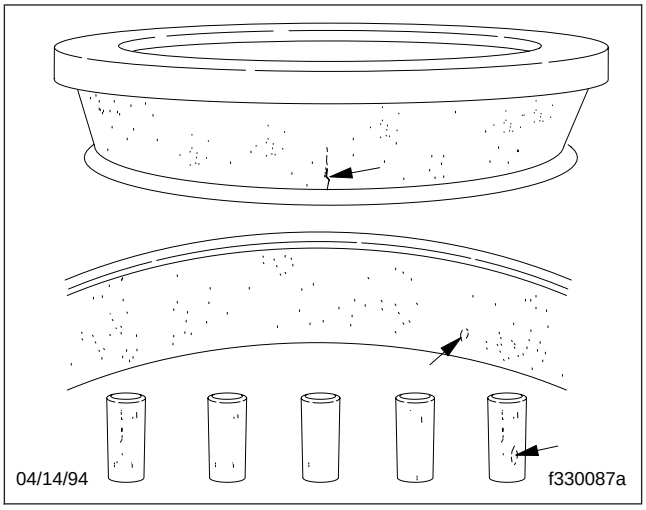


Fig. 5, Indentations, Cracks, or Breaks in Bearing Surfaces

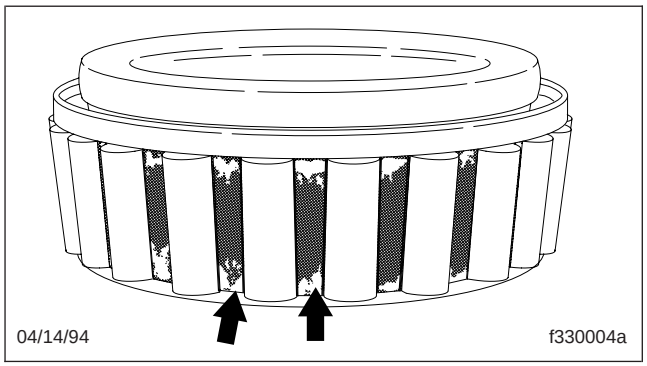


Fig. 6, Rubbing Marks on Bearing Cage

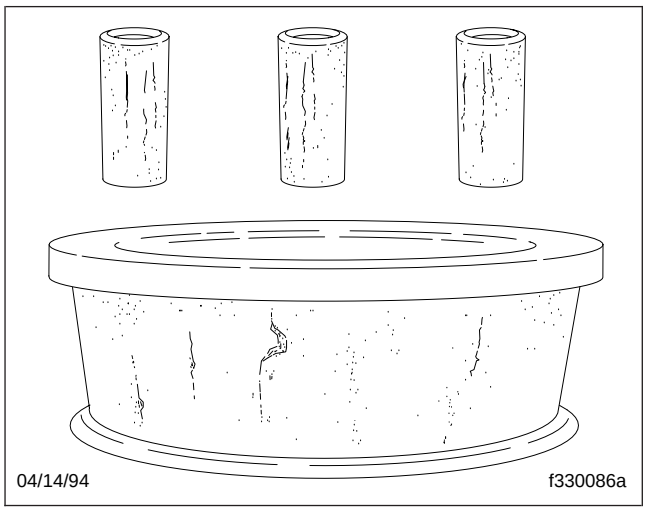


Fig. 7, Etching (Pitting) on Bearing Surfaces

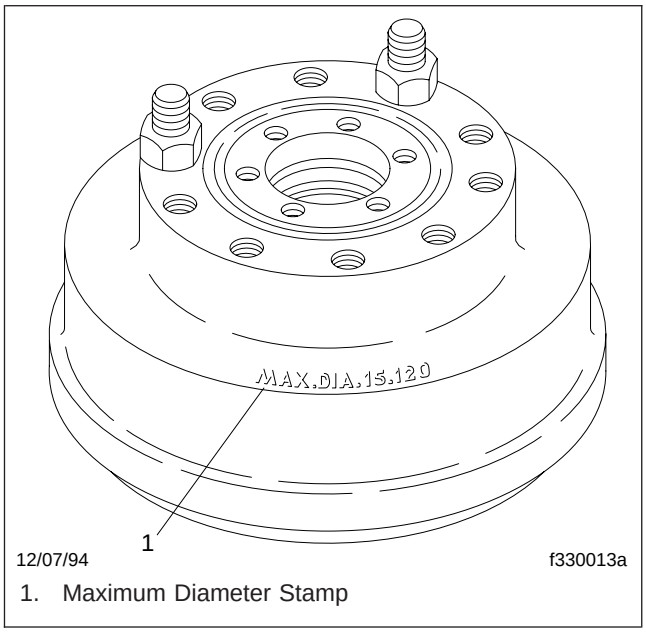
Brake Rotor Inspection

If the vehicle has disc brakes, see the "Bosch Pin Slide Disc Brakes Service Manual" for brake rotor inspection procedures and replacement requirements.

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 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.



1. Maximum Diameter Stamp

Fig. 8, Outboard-Mounted Hub and Drum Assembly

NOTE: Drums that have been turned should then be cleaned by using fine emery cloth followed with a hot water wash. Also, for drums that have been renewed using emery cloth, follow with a hot-water wash.

⚠ CAUTION

Failure to replace drums when worn or turned to limits exceeding the maximum allowable diameter will cause drum weakness and reduced braking capacity, which can lead to distortion, higher drum temperatures, and ultimate 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.

Axle Components Cleaning and Inspection

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.

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. 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.
5. Check for a variation in gauge readings at different points on the radius of the drum's working surface. If the variation is more than 0.010 inch (0.25 mm) at any point, the drum is out-of-round to unacceptable limits. Remachine or replace the same-axle drums.
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.

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 replacement bearing cup hub contact surface 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.

⚠ WARNING

To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury or property damage if ignited.

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

1. Remove the wheel hub from the axle. For instructions, see **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.

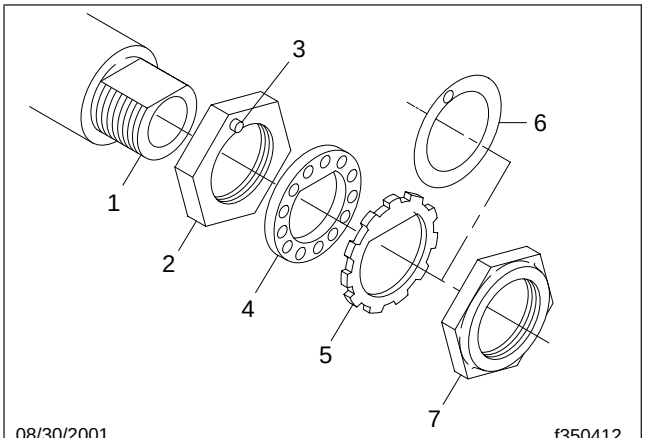
   2.2 Do not drill more than 1.25 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel hub. Drilling through the bottom of the drive axle stud could damage the hub. If the wheel hub is drilled into, replace it.

   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 **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, see **Subject 100** for installation instructions.

Four-Piece Wheel-Bearing-Locking System Installation and Adjustment

Installation and Adjustment

1. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.
2. Fill the hub cavity with oil, then install the outer wheel bearing; handle the bearings with clean, dry hands. Use care not to damage the bearings as they are seated in the bearing cups. Remove the friction tape from the axle spindle threads.
3. Install the wheel bearing adjusting nut, as follows. See **Fig. 1**.



1. Axle Spindle
2. Adjusting Nut
3. Dowel
4. Lockring
5. Nut-Lock
6. Retaining Washer (may be used in place of nut-lock)
7. Jam Nut

Fig. 1, Axle With Nut-Lock (or washer) and Lockring

3.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner adjusting nut finger-tight.

3.2 While rotating the wheel hub assembly, tighten the adjusting nut 100 lbf·ft (136 N·m).

3.3 Back off the adjusting nut completely.

3.4 Tighten the adjusting nut 20 lbf·ft (27 N·m) while rotating the wheel hub assembly.

3.5 Back off the adjusting nut one-third turn.

4. Install the locking device and jam nut, as follows.

4.1 Install the locking device.

NOTE: If no hole in the lockring aligns with the dowel on the adjusting nut, remove the lockring, turn it over and install it again. If a hole still doesn't align with the dowel, loosen the adjusting nut, but only enough to align the dowel with a hole in the lockring.

4.2 Then install the jam nut, and tighten it to the applicable torque value in **Table 1**.

5. With the jam nut installed and tightened, adjust the bearings, as follows.

IMPORTANT: Do not adjust the wheel bearings with the wheel mounted on the hub. You cannot accurately adjust or measure bearing end play with the wheel mounted on the hub.

5.1 Attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

If using aluminum hubs, you may have to install the brake drum on the hub to provide a steel base for the magnet of the dial indicator. Mount the drum on the hub's drum pilot, then adjust the brake or have someone apply the brakes to hold the drum securely while you secure the drum using the stud at the 12 o'clock position, then the studs at about the 4 o'clock and 8 o'clock positions.

5.2 Release the brakes if you used them to hold the drum while installing it.

Torque: lbf·ft (N·m)		
1-1/8 Inch Jam Nuts	**1-1/2 to 2-1/2 Inch Jam Nuts**	**2-5/8 Inch or Larger Jam Nuts**
150–225 (205–305)	200–300 (271–407)	250–400 (339–542)

Table 1, Jam Nut Torques

Four-Piece Wheel-Bearing-Locking System Installation and Adjustment

5.3 Grip the sides of the hub at the three o'clock and nine o'clock positions. Push in on the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

5.4 Once again, grip the sides of the hub at the three o'clock and nine o'clock positions. This time, pull out on the hub (and drum, if applicable). Read the dial indicator, and note the end play.

5.5 Push the hub back in to confirm that the needle of the dial indicator returns to zero.

6. 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.

   6.1 Remove the jam nut and locking device, and back off or tighten the inner adjusting nut.

   6.2 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.

7. Once the end play is correct, bend two tabs of the nut-lock over opposing flats on the jam nut.

8. Rotate the hub in both directions. It should turn freely with no dragging or binding. End play should be between 0.001 and 0.005 inch (0.03 to 0.13 mm).

Outboard-Mounted Drum Removal and Installation

Removal

⚠ 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.

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.

⚠ 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 assemblies. 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 particulate air (HEPA) filter. 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. See **Fig. 1**.

Installation

1. On brake drum assemblies with an aluminum hub, coat the hub and drum contact surfaces with Alumilastic® compound or an equivalent.
2. Install the brake drum on the wheel hub, as follows.

   2.1 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. 2**.

   IMPORTANT: If the drum is not positioned correctly, the pilot pad could be damaged when the wheel nuts are tightened.

   2.2 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.

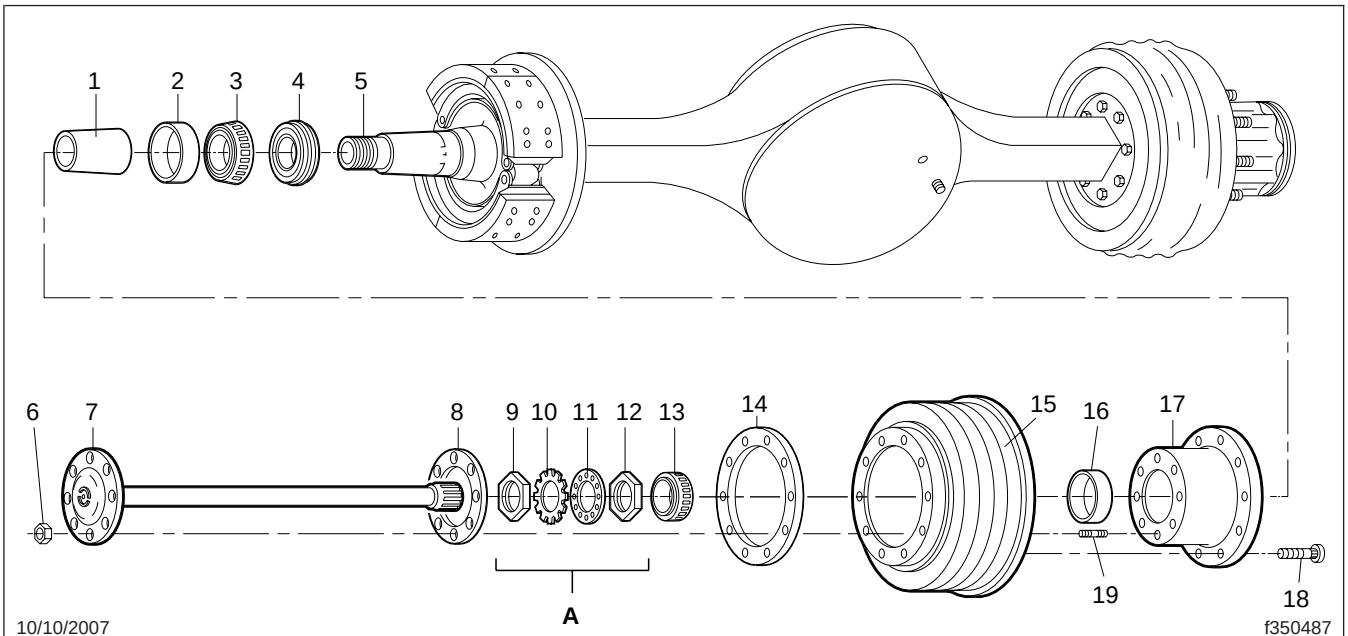
3. Install the wheel and tire assemblies. To ensure that the drum does not slip off the pilot pad, follow the correct nut tightening sequence. For instructions, see **Group 40**.

⚠ 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.

4. Adjust the rear axle brakes. For instructions, see **Group 42**.
5. Remove the safety stands from under the axle; lower the vehicle.

Outboard-Mounted Drum Removal and Installation

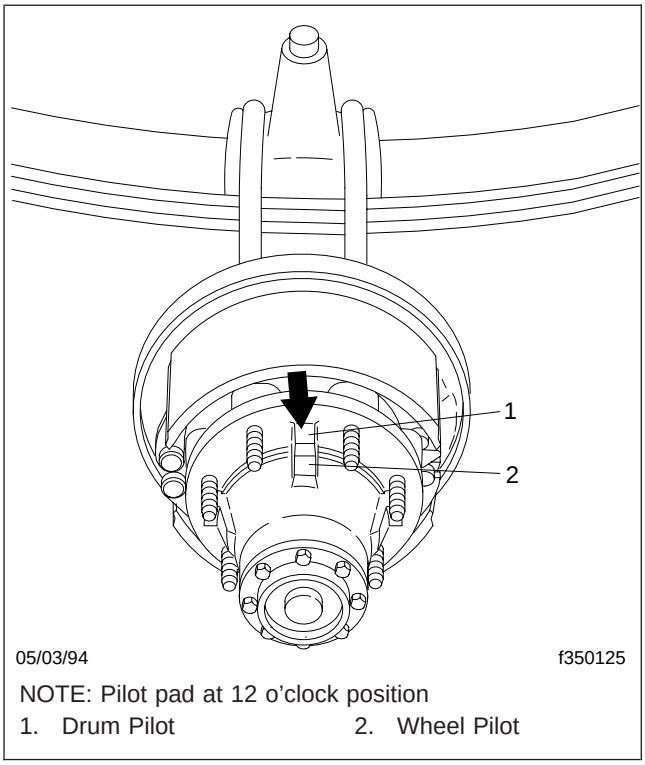


A. Four-piece bearing-lock system shown; an Axilok® locking nut is used with ConMet PreSet hubs.

1. Bearing Spacer (used only with ConMet PreSet hubs)
2. Inner Wheel Bearing Cup
3. Inner Wheel Bearing
4. Oil Seal
5. Axle Spindle
6. Drive Axle Stud Nut
7. Drive Axle Flange and Shaft
8. Gasket
9. Jam Nut
10. Nut-Lock
11. Lockring
12. Adjusting Nut
13. Outer Wheel Bearing
14. Hub Spacer
15. Brake Drum
16. Outer Wheel Bearing Cup
17. Hub
18. Wheel Stud
19. Drive Axle Stud

Fig. 1, Typical Drive Axle and Hub Assembly (exploded view)

Outboard-Mounted Drum Removal and Installation



NOTE: Pilot pad at 12 o'clock position

1. Drum Pilot
2. Wheel Pilot

Fig. 2, Hub Pilot Pads

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 by heating the hub in an oven (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.

IMPORTANT: Be sure to follow all the manufacturer's warnings and instructions when using any solvent.

2. Oven-heat the hub to a temperature range of 240 to 280°F (116 to 138°C). Make sure the oven thermostat is accurately set; 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. Place the hub on a suitable press so that the base is fully supported. Quickly press out the bearing cups.

Installation

To install the bearing cups, aluminum hubs must again be temporarily expanded using oven heating. When the hub is properly heated, the bearing cup and hub can be press-fit together, using a suitable press.

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. Oven-heat the hub to a temperature range of 240 to 280°F (116 to 138°C). Make sure the oven thermostat is accurately set; 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 replacement bearing cup hub contact surface with a film of grease.
5. Wearing heavy protective gloves, remove the hub from the oven.
6. Place the hub on a suitable press so that the base is fully supported. Quickly press-fit the bearing cups into the wheel hub until they are 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.

Wheel Bearing Cup Removal and Installation, Aluminum Hubs

⚠ WARNING

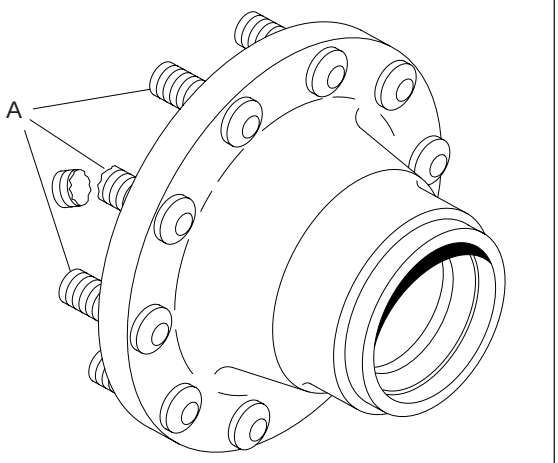
To prevent skin irritation, wear chemical-resistant gloves when using kerosene or diesel fuel. Also, do not expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible and could cause personal injury or property damage if ignited.

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.

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.



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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.

CAUTION

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.*

CAUTION

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.

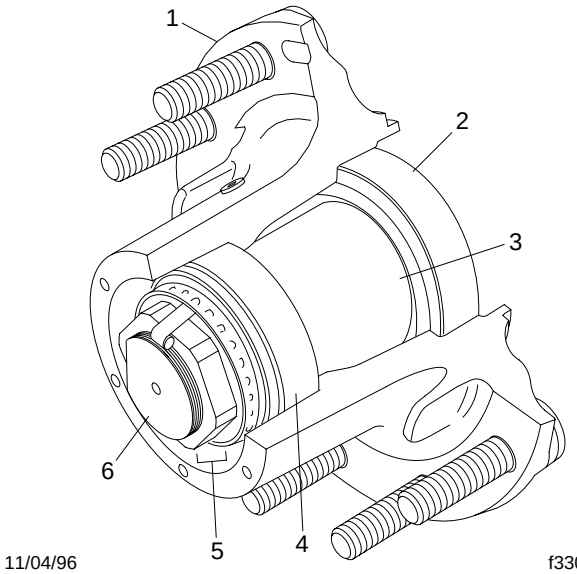
9. Wipe off any grease on the wheel studs and wheel hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Con Met PreSet® Hub Installation and Adjustment

General Information

Con Met PreSet® drive axle hubs are equipped with a special tubular spacer inside the hub, between the inner and outer bearings. See **Fig. 1**.

Wheel bearing adjustment is unnecessary when installing these hubs, because the spacer, together with specially toleranced bearings, automatically sets the bearing end-play to zero. Rear axle PreSet hubs can be identified by the part number NP840302 stamped on the outer bearing cone. The outer bearing cone is visible when the retaining nut is removed. See **Fig. 2**.



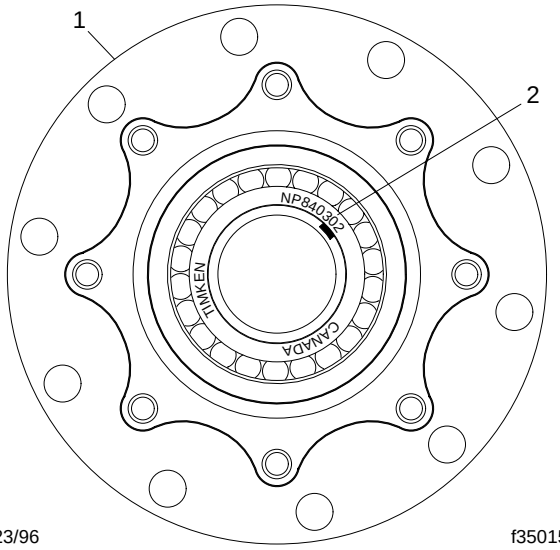
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NOTE: Front axle hub shown.

1. Hub
2. Inner Bearing
3. Bearing Spacer
4. Outer Bearing
5. Axilok® Retaining Nut
6. Axle Spindle

Fig. 1, Con Met PreSet Hub, Cut-Away View

NOTE: If you are replacing the bearings for a PreSet hub, and the required bearings are not available, use standard wheel bearings. Remove the bearing spacer and adjust the bearings manually. See the installation instructions for "Standard Bearings," under "Installation."



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1. Rear Axle Hub
2. Outer Bearing Cone and Part Number

Fig. 2, Identifying a Con Met PreSet Hub

⚠ CAUTION

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.

Con Met PreSet hubs use Axilok® retaining nuts. See **Fig. 3**. Axilok retaining 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 dis-

Con Met PreSet® Hub Installation and Adjustment

engage the nut's locking clips, allowing it to spin freely by hand. See **Fig. 4**. Use an accurately calibrated torque wrench to tighten the nut to its final torque value.

- After the nut is installed, always make sure that both locking clips are present and engaged in the retainer cage. See **Fig. 4**. If the locking clips are not engaged, the nut is not locked in position and can rotate freely.

Installation

Using Preset Bearings

1. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
2. If present, remove the temporary plastic bearing cover from the front of the hub.
3. Install the PreSet hub assembly all the way onto the axle spindle. 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.

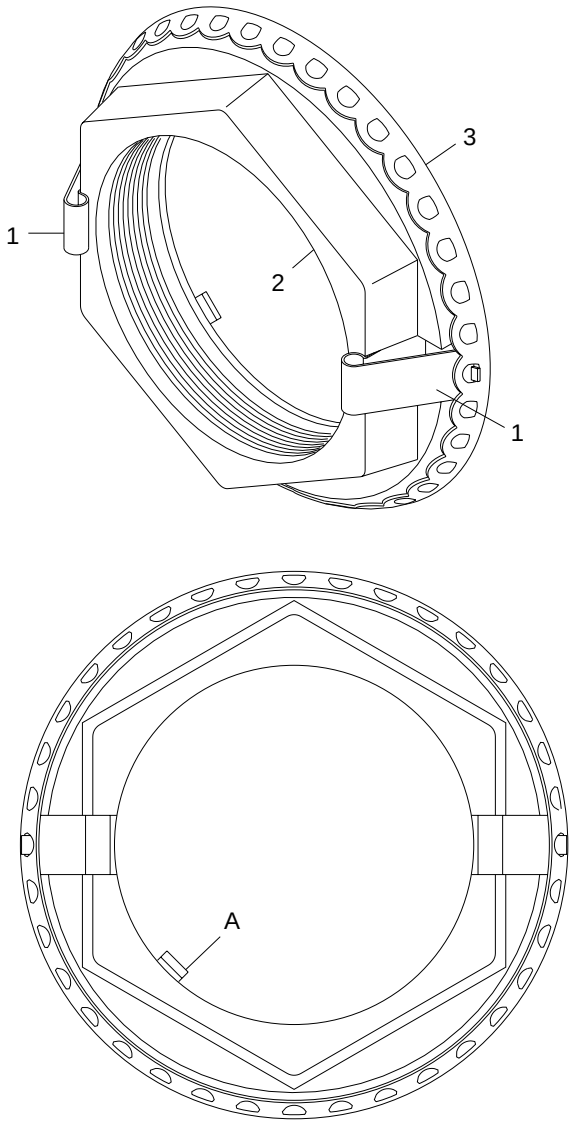
⚠ CAUTION

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.

⚠ 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.

4. Install the Axilok retaining nut onto the axle spindle. See **Fig. 3**.
5. Tighten the retaining nut 250 lbf·ft (339 N·m). Do not back off the retaining nut. The nut should lock in place when you remove the wrench. If it does not, advance it until it does.



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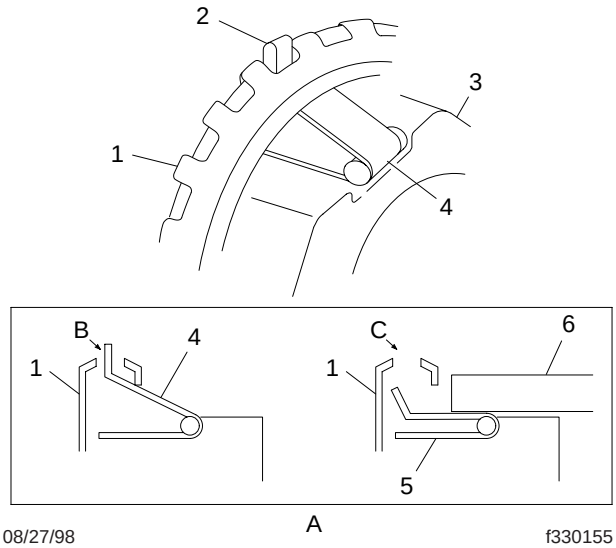
A. The retainer tab must engage the keyway of the axle spindle.

1. Locking Clip
2. Nut
3. Retainer

Fig. 3, Rear Axle Axilok Nut

6. Install the axle shaft, using a new gasket. See **Subject 100** for instructions.

Con Met PreSet® Hub 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. 4, Axilok Nut, Checking the Position of the Locking Clip

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.

7. Pour the recommended drive axle oil through the axle housing filler hole.

Using Standard Bearings

1. If not already done, remove the tubular spacer from inside the hub. Save it for future use to convert the hub back to the PreSet system.
2. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
3. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal in the hub. See **Section 35.02** for instructions on installing the various types of oil seals.
4. Install the hub with the inner bearing and oil seal onto the axle spindle. Be careful not to unseat the inner bearing or oil seal.
5. Fill the hub cavity with oil, and install the outer wheel bearing.

CAUTION

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.

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.

6. Adjust the wheel bearings.
   - 6.1 Install the Axilok nut and turn it against the bearing while spinning the wheel. See **Fig. 3**.
   - 6.2 Tighten the nut 90 to 110 lbf·ft (122 to 149 N·m) while spinning the wheel in both directions.
   - 6.3 Loosen the nut to zero torque and spin the wheel a few turns.
   - 6.4 Tighten the nut 50 lbf·ft (68 N·m) while spinning the wheel in both directions. Back off the nut one-eighth to one-sixth turn.
   - 6.5 Remove the wrench from the nut. The Axilok nut should automatically lock in place. If it does not, advance it until it does.
7. Install the axle shaft, using a new gasket. See **Subject 100** for instructions.

Con Met PreSet® Hub Installation and Adjustment

⚠ 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.

8. Remove the fill plug from the axle housing, then pour the recommended drive axle oil through the axle housing filler hole. Install the filler plug.

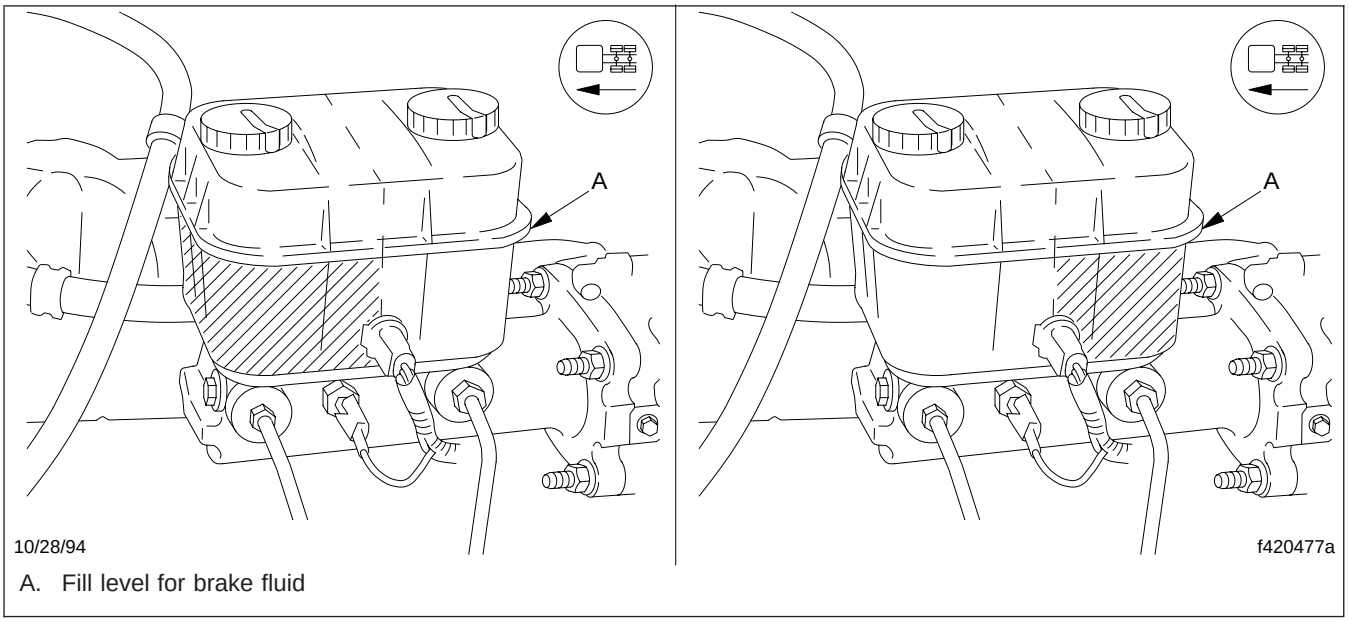
Disc Brake Rotors Removal and Installation

Removal

1. Shut down the engine and chock the tires.
2. Open the hood.
3. Remove about half of the brake fluid from the front section (if removing a front-axle rotor) or the rear section (rear-axle rotor) of the master cylinder reservoir. See **Fig. 1**.

Installation

1. Position the rotor on the hub as shown in **Fig. 3**. Make sure the holes in the rotor are lined up with those of the hub.
2. Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 4**.



A. Fill level for brake fluid

Fig. 1, Master Cylinder Reservoir

4. Chock the front or rear tires, as required.
5. Jack up the vehicle. Support the axle with jackstands.
6. Remove the tire.
7. Remove the brake caliper from the rotor.
8. Remove the hub and rotor assembly from the axle. See **Subject 100**. Put the hub on the floor, so the rotor is facing up.
9. Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 2**. Lift the brake rotor off the hub.

3. Install the hub and the rotor assembly on the axle. See **Subject 100**.
4. Install the brake caliper on the rotor.
5. Install the tire.
6. Remove the jackstands. Lower the vehicle.
7. Fill the applicable section of the master cylinder reservoir with new DOT 3 approved brake fluid. The brake fluid level should be even with the raised seam on the outside circumference of the reservoir. See **Fig. 1**.
8. Close the hood.
9. Remove the chocks from the tires.

Disc Brake Rotors Removal and Installation

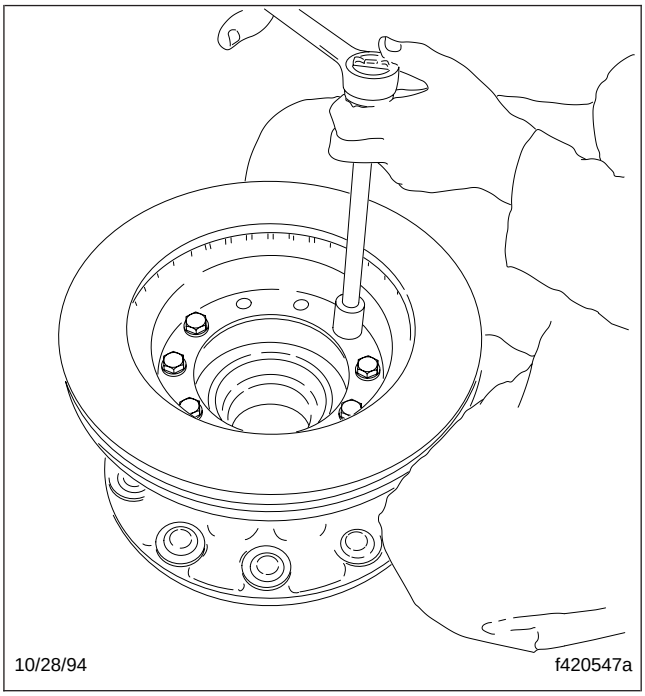


Fig. 2, Rotor-to-Hub Fasteners

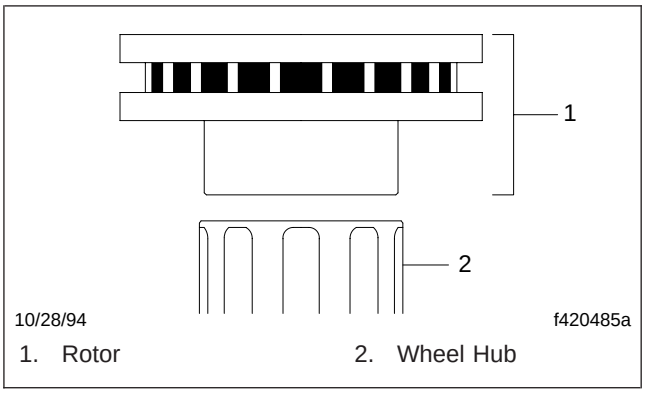


Fig. 3, Rotor-to-Hub Position

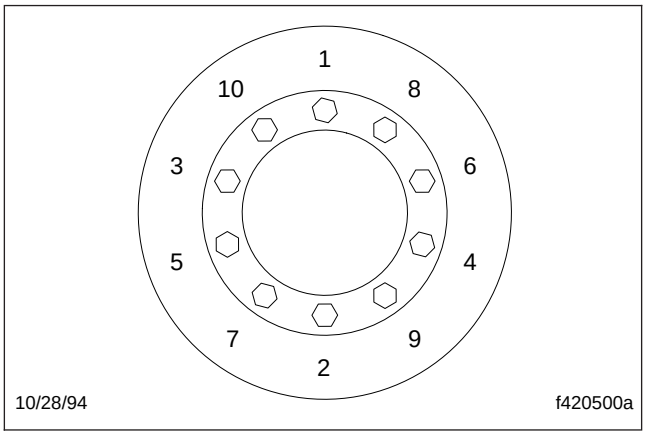


Fig. 4, Tightening Pattern

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.

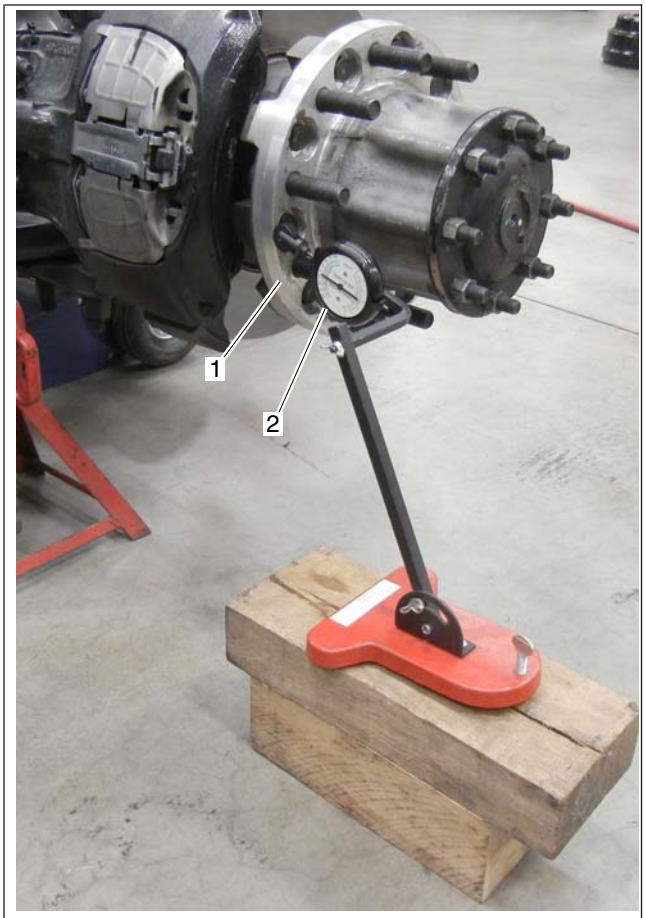
⚠ WARNING

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 150** 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.

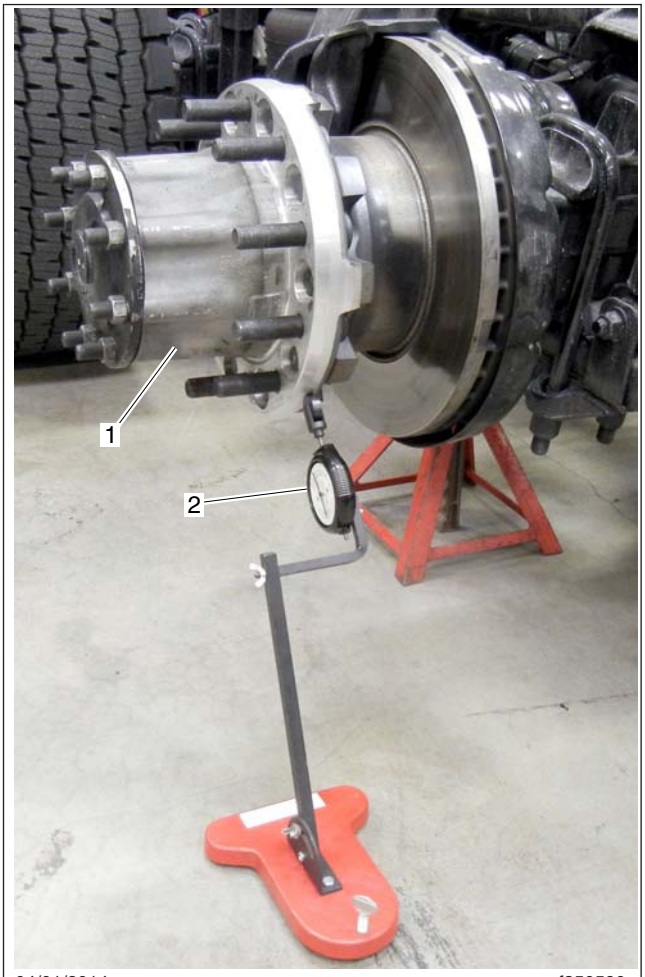


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1. Hub
2. Dial Indicator (with roller point)

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

Troubleshooting Tables

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil was used on the bearings, or the wrong type of oil was used.	Clean, then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil. For lubricant specifications, see **Specifications 400**.
Foreign matter or corrosive agents entered the bearing assembly. Dirt or metallic debris from the bearings was not removed.	Clean, then inspect the bearings for wear. Replace worn seals. Also clean the wheel hub, the axle spindle, and any other component in contact with the bearing lubricant.
An incorrect adjustment of the wheel bearings is causing noise and wear.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.
Flat spots or dents on the roller surface were caused by skidding of the roller or improper handling of the wheel bearing during installation.	Clean, then inspect the bearing rollers. Replace the bearing if damaged. Coat the replacement bearings with fresh oil. For lubricant specifications, see **Specifications 400**.

Problem—Broken Wheel

Problem—Broken Wheel	
Possible Cause	**Remedy**
The wheel nuts were overtightened.	Replace the wheel. See **Group 40** of the *S2 Maintenance Manual* for the wheel nut tightening sequence.
An incorrect nut tightening sequence was used.	
The wrong brake drums were installed.	Install new brake drums.
Wheels are mismatched (hub-piloted wheels are mixed with stud-piloted wheels).	Install properly matched wheels.
The vehicle is being overloaded.	Do not exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
(Cracked hub) Local surface of an aluminum hub was heated higher than 350°F (177°C) during bearing cup removal.	Replace the hub assembly. When removing the bearing cup, oven-heat the hub.
(Bent flange) Incorrect installation of the wheel studs, such as using a hammer and drift, or the hub flange was not fully supported on the press during wheel stud replacement.	Replace the hub assembly. Replace the wheel studs as instructed in **Subject 170**.
The wrong brake drums were installed.	Install new brake drums.
Insufficient tightening of the wheel nuts to the wheel hub.	Replace the hub assembly and tighten the wheel nuts to the values in **Specifications 400**.

Troubleshooting

Problem—Loss of Lubricant From the Wheel Hubs

Problem—Loss of Lubricant From the Wheel Hubs	
Possible Cause	**Remedy**
The drive axle studs are loose.	Tighten the nuts to the torque values in **Specifications 400**. Add lubricant to the axle housing or to the wheel hub.
The seals or gaskets are worn or damaged.	Replace worn or damaged parts.
Minor burrs or rough spots are on the inboard portion of the drive axle flange.	Use fine-grit emery cloth to remove the burrs or rough spots. If they cannot be removed, replace the drive axle shaft.

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 brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The disc brakes are glazed (dirt or grease build-up) or are worn unevenly.	Install new disc brakes.
The brake drums are worn, heat-checked, or cracked.	Install new brake drums.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
The drum could be out of round if it was not correctly positioned on the drum pilot tabs before the wheel was installed.	Position one of the hub-piloted tabs in the top position before placing the drum on the hub. When doing so, be sure the drum is located flat against the hub and on the largest-diameter portion of the pilot tabs. After placing the wheel(s) on the studs, firmly hand-tighten the nut on the stud closest to the top position. Proceed with the other nuts.
See the air brake system troubleshooting section in **Group 42**.	

Problem—Poor Lining-to-Drum Contact

Problem—Poor Lining-to-Drum Contact	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
The brake shoes are stretched or bent.	Replace the brake shoes.
Undersized linings were installed.	Install new brake linings on both sets of axle brake shoes.
An incorrect grind was used on the brake linings.	
The wrong brake drums were installed.	Install new brake drums.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.

Problem—Brake Linings Are Tapered Across the Width

Problem—Brake Linings Are Tapered Across the Width	
Possible Cause	**Remedy**
The inside surface of the brake drum is scored or grooved.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
The brake shoes are bent.	Replace the brake shoes.
An incorrect adjustment of the wheel bearings is causing wheel instability.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.

Problem—Brake Shoes on the Same Brake Are Wearing Unequally

Problem—Brake Shoes on the Same Brake Are Wearing Unequally	
Possible Cause	**Remedy**
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 on both sets of axle brake shoes. Clean, turn, or replace the drums.
The disc brakes are not a matched set. Different friction codes or different brands of disc brakes are installed.	Install a new matched set of disc brakes.
The inside surface of the brake drum is in poor condition.	Turn or replace the brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.

Problem—Edge of the Lining Is Showing Wear

Problem—Edge of the Lining Is Showing Wear	
Possible Cause	**Remedy**
The brake lining is too wide.	Install new brake linings on both sets of axle brake shoes.
The brake linings are misaligned because their holes were incorrectly drilled.	
Undersized brake drums were installed.	Install new brake drums.
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.
There is an improper fit of the wheel onto the spindle due to the wrong wheel bearings or cone.	Install and adjust the new wheel bearings and cone.
The brake shoes are bent.	Replace the brake shoes.

Troubleshooting

Problem—Brake Linings Are Scored or Grooved

Problem—Brake Linings Are Scored or Grooved	
Possible Cause	**Remedy**
Worn or scored brake drums have been causing poor contact with the brake linings.	Install new brake linings on both sets of axle brake shoes. Turn or replace the brake drums.
There is abrasive material between the lining and the drum.	

Problem—Brake Linings Are Loose

Problem—Brake Linings Are Loose	
Possible Cause	**Remedy**
The rivet holes in the brake shoes are too large.	Replace the brake shoes.
Improperly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem—Brake Lining is Cracked at the Rivet Holes or Bolt Holes

Problem—Brake Lining is Cracked at the Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
Overtightening of the lining bolts is causing cracks.	Replace the brake linings. Replace the rivets or bolts with the correct size.
The wrong size counter bore for the rivet holes was made.	
The wrong rivets or bolts were used.	Replace the rivets or bolts with the correct size.
Improperly crimped rivets are working loose and allowing the linings to move.	Replace the rivets.
Rust has built up on the shoe table.	Clean the brake shoe table of all rust, dirt, scale, and paint.

Problem—Out-of-Round Rivet Holes or Bolt Holes

Problem—Out-of-Round Rivet Holes or Bolt Holes	
Possible Cause	**Remedy**
The rivets or bolts are loose.	Replace the brake shoes or linings.

Problem—Brake Drums Are Heat-Checked

Problem—Brake Drums Are Heat-Checked	
Possible Cause	**Remedy**
The brake drums are out-of-round.	Turn or replace the brake drums.
The wrong brake drums were installed.	Install new brake drums.

Problem—Brake Drums Are Heat-Checked	
Possible Cause	**Remedy**
The wheel bearings are out of adjustment.	Adjust the wheel bearings following the instructions in **Subject 140** or **Subject 180**.
The brake linings are glazed (dirt or grease build-up) or are worn unevenly.	Install new brake linings on both sets of axle brake shoes. Clean, turn, or replace the drums.
The lining friction material for the operation of the vehicle is incorrect.	

Problem—Brake Drums Are Heavily Scored

Problem—Brake Drums Are Heavily Scored	
Possible Cause	**Remedy**
The brake linings are damaged.	Install new brake linings on both sets of axle brake shoes. Turn or replace the drums.
There is excessive wear on the linings.	
On the last brake reline, the drums were not turned.	Turn the brake drums.

Specifications

Torque Values		
Application	**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 (locking)	5/8–18	150–170 (203–230)
Drive Axle Stud Nuts (non-locking)	5/8–18	150–170 (203–230)
Disc Brake (rotor to hub)	—	130 (175)
Wheel-Bearing Inner Nut, 4-Piece System, Standard Hub	—	1. Initial: 100 (136) 2. Back Off Completely 3. 20 (27) While Rotating Hub 4. Back Off 1/3 Turn
Wheel-Bearing Jam Nut, 4-Piece System, Standard Hub	1-1/8-inch to 2-1/2-inch	200–300 (271–407)
	2-5/8-inch or larger	250–400 (339–542)
Axilok® Retaining Nut	—	250 (339)
Axilok® Wheel Bearing Nut, Standard Bearings	—	1. 90–110 (122–149) While Spinning Hub in Both Directions 2. Loosen to Zero 3. 50 (68) While Spinning Hub in Both Directions 4. Back Off 1/6 Turn

Table 1, Torque Values

Freightliner Drive Axle Recommended Lubricants		
Recommended Lubricant Type	**Ambient Temperature**	**SAE Viscosity Grade**
Hypoid Gear Oil API Service Classification GL–5	+10°F (–12.2°C) and up*	85W–140
	–15°F (–26.1°C) and up*	80W–140
	–15°F (–26.1°C) and up*	80W–90
	–40°F (–40°C) and up*	75W–90
	–40°F (–40°C) to +35°F (+2°C)	75W
	–40°F (–40°C) and up*	75W–140
Synthetic Gear Oil	–40°F (–40°C) and up*	75W–90
	–40°F (–40°C) and up*	75W–140

* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 250°F (121°C).

Table 2, Freightliner Drive Axle Recommended Lubricants

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 fits between the hub bore and the axle spindle, and the sealing element either turns with the wheel (*hub-mounted seals*) and seals against the axle spindle, or the sealing element stays stationary with the axle spindle (*spindle-mounted seals*) and seals against the turning hub.

Most wheel oil seals consist of four basic parts:

- 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 tight 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.

The sealing element is usually molded rubber, leather, or a synthetic such as nitrile or silicone. The element is molded into lips which will seal against the axle spindle or against the outside or inside edge described above. The innermost lip (called the "primary lip") keeps the oil inside the hub cavity. The outermost lip (called the "secondary lip") keeps dirt out of the hub cavity.

The garter spring is a coiled wire spring with its ends connected to make a loop. On hub-mounted seals, the spring runs around the outside of the sealing element to press the element inwards against the sealing surface. On spindle-mounted seals, the spring runs around the inside of the sealing element to press the element outward against the sealing surface.

These vehicles use Chicago Rawhide (Scotseal® and Scotseal Plus®) rear oil seals.

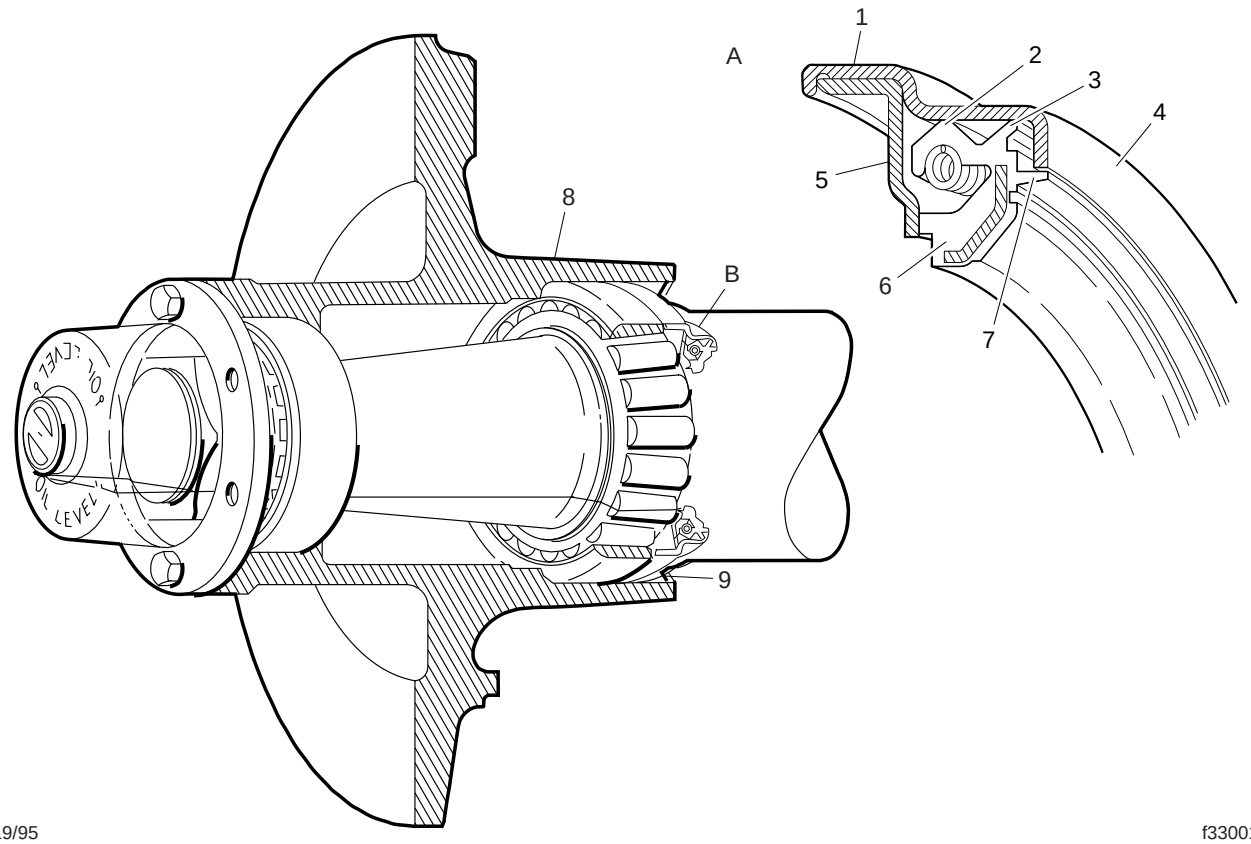
Chicago Rawhide

The Chicago Rawhide Scotseal is a unitized, one-piece design consisting of a sealing element (packing) that is assembled between metal outer and inner cups. See **Fig. 1**. The sealing element consists of three sealing lips; a spring-loaded primary sealing lip that is factory pre-lubed and two dirt exclusion lips. The seal is press fit into the hub bore using Scotseal service installation tools. *Do not install the Scotseal directly onto the axle spindle.*

Although you install the Scotseal 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.

The Chicago Rawhide Scotseal maintains a metal-to-metal contact between the outer cup and the hub bore surface as well as a metal-to-metal contact between the sealing element inside edge and the axle spindle.

General Information



A. Detail A
B. Oil Seal (See detail A)

1. Bore-Tite® Coating
2 Primary Sealing Lip
3. Dirt Lip
4. Outer Cup
5. Inner Cup
6. Sealing Element (Packing)
7. Bumper Lip
8. Hub
9. Hub Bore

Fig. 1, Chicago Rawhide Scotseal

Seal Replacement, Chicago Rawhide

Replacement

NOTE: This procedure applies to the Chicago Rawhide Scotseal®.

1. Remove the wheel, drum, and hub from the axle. For instructions, see **Section 35.01, Subject 100**.
2. Remove the oil seal from the hub.
3. Remove the inner wheel bearing assembly from the hub. 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 seal is removed. In those cases, place a protective cushion to catch the bearing assembly. Using a hardwood drift and a light hammer, gently tap the bearing out of the inner wheel bearing cup.
4. Clean the spindle, spindle threads, seal bore, and the hub cavity. See **Fig. 1** and **Fig. 2**.
5. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. Clean any metal filings from the components.

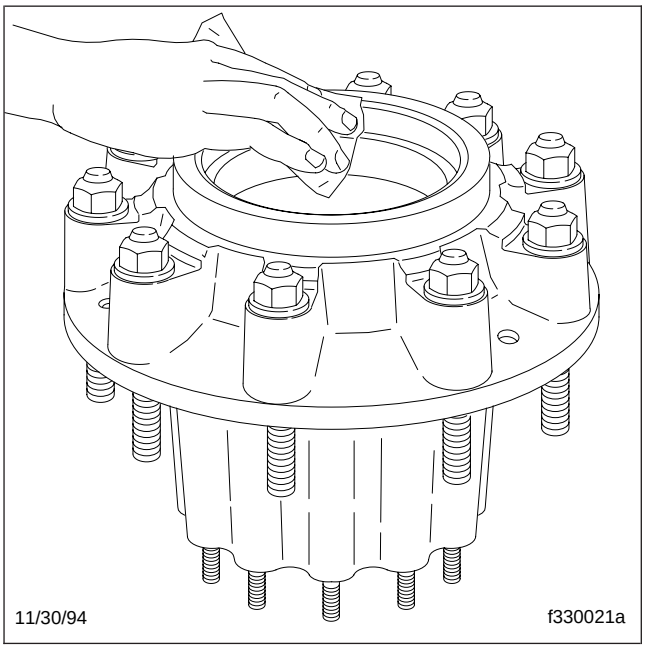


Fig. 1, Cleaning the Hub

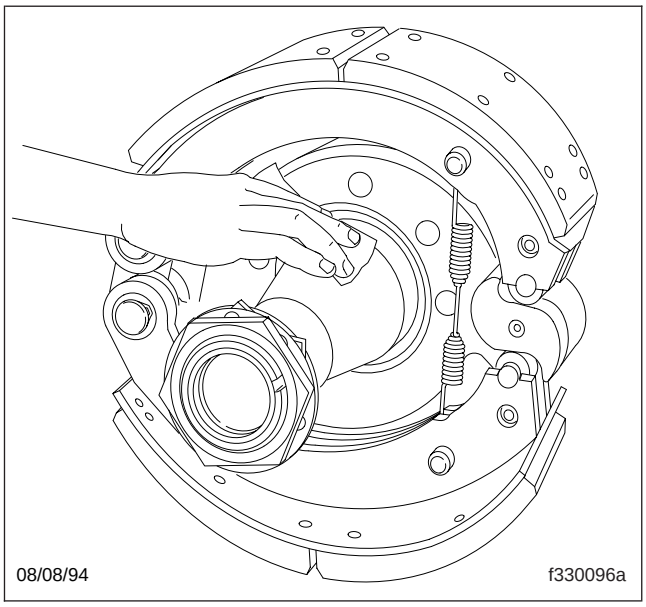


Fig. 2, Cleaning the Spindle

CAUTION

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.

6. Inspect the bearings and hub components for wear or damage. Replace any worn or damaged components as necessary.
7. Coat the wheel bearing cones with oil.
8. Install the inner wheel bearing cone in the inner wheel bearing cup.
9. Seat the small outside edge of the seal in the recess of the tool adaptor. See **Fig. 3**. The correct adaptor is identified on the box.
10. Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 4**. The plug prevents cocking of the seal in the bore.
11. Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms

Seal Replacement, Chicago Rawhide

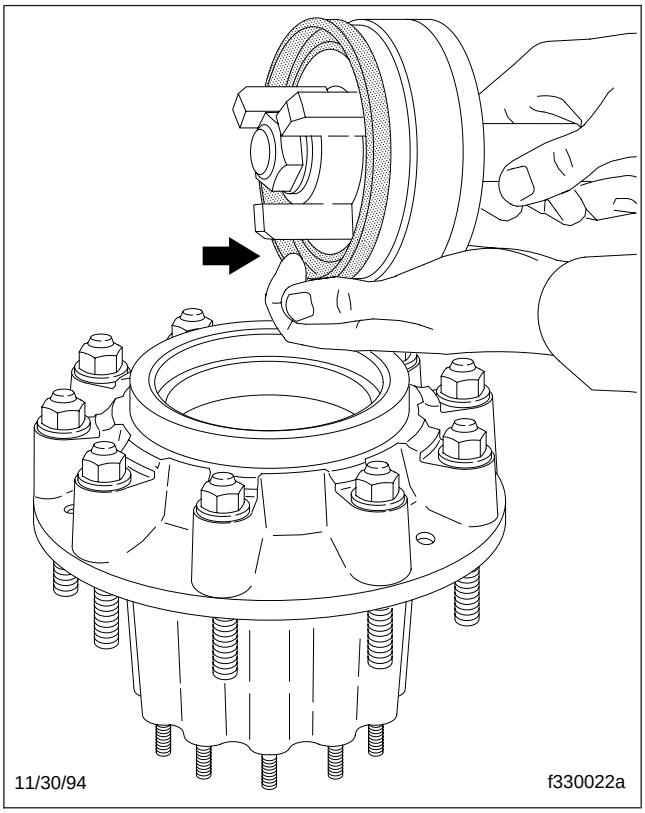


Fig. 3, Placing the Seal on the Installation Tool

out. See **Fig. 5**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

12. 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.
13. Install the wheel hub on the axle, and adjust the wheel bearings. For instructions, see **Section 35.01, Subject 100**.

IMPORTANT: When starting the wheel on the spindle, center the hub carefully to avoid seal damage from the leading edge of the spindle.

14. Place the hubcap and a new gasket in position, then install the capscrews. Tighten the capscrews 15 lbf·ft (20 N·m).
15. Top off the differential carrier oil. Then raise the axle at each wheel, and allow the oil to drain to the hubs. Finally, top off the oil to the differential carrier. Do not overfill.
16. Adjust the brake shoe-to-drum clearance. For instructions, see **Group 42** of the *S2 Chassis Workshop Manual*.

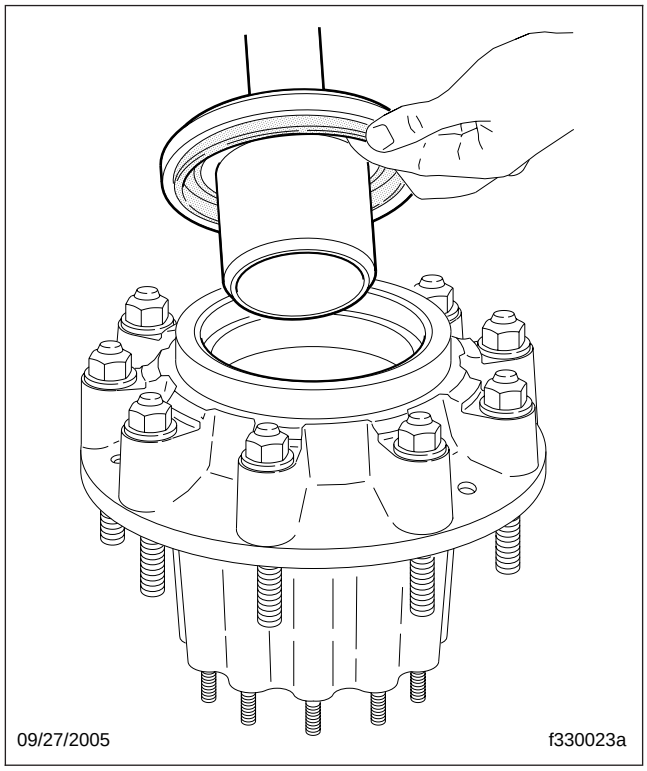


Fig. 4, Inserting the Tool in the Hub Bore

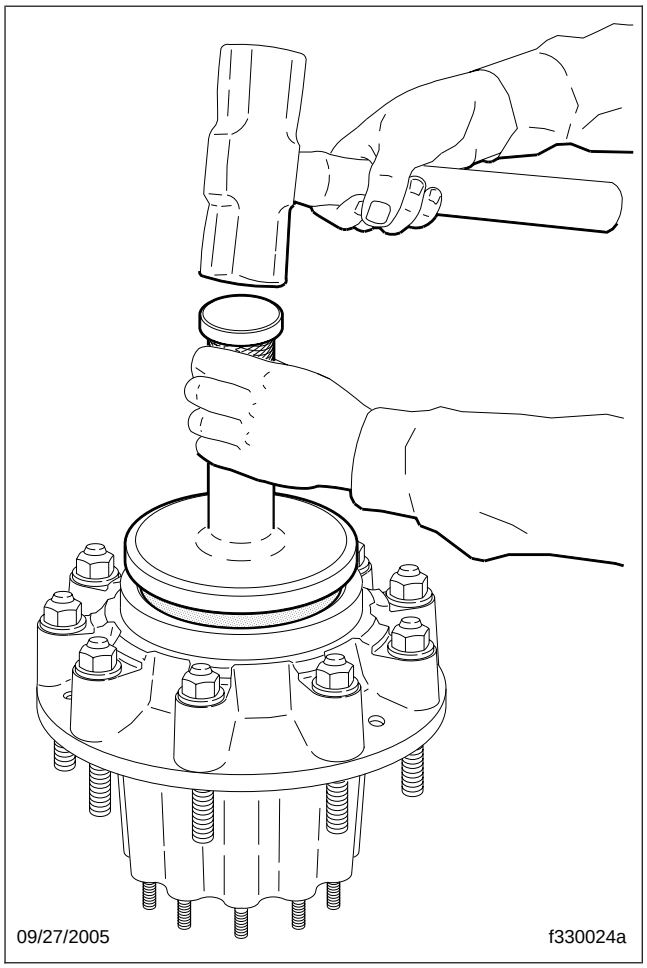


Fig. 5, Striking the Tool

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: ARS-19.0-2

- *ARS* = single rear axle
- *19.0* = weight rating (times 1000 lb)
- *2* = basic model number

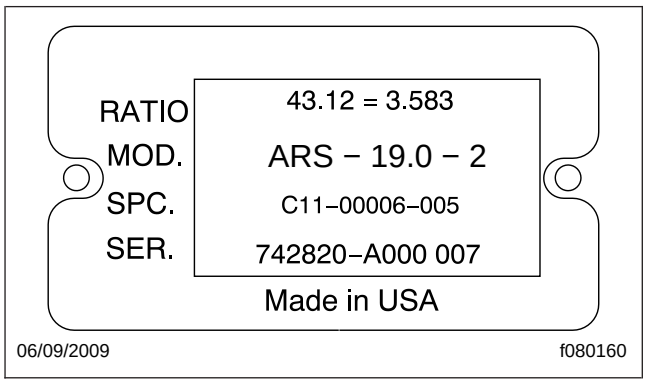


Fig. 1, Rear Axle ID Tag

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."

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**

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 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.
4. Continue to raise the vehicle evenly until there is room to fit a stand underneath the axle housing.

⚠ WARNING

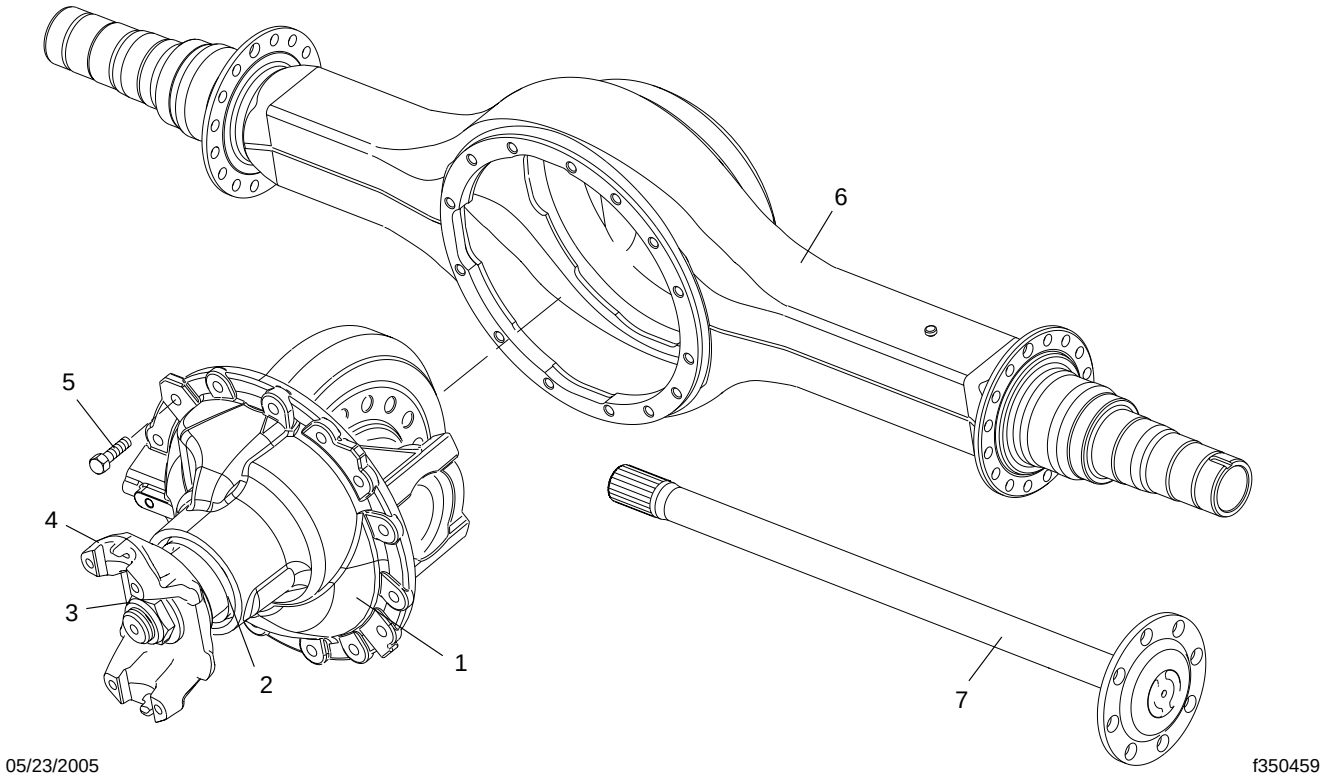
Never work around or under a vehicle that is supported only by a jack. Always support the vehicle with safety stands. Jacks can slip, allowing the vehicle to fall, which could result in serious injury or death.

5. Support the vehicle with safety stands.
6. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
7. Remove the oil drain plug from the bottom of the differential housing and drain the oil. Install the drain plug after emptying.
8. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 110**. 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.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being removed.

12. Place a basin under the axle shaft flanges to catch any oil, then remove the axle shafts. For instructions, see **Subject 120**.
13. Drain the air system, if installed.
14. If installed, disconnect the DCDL air line from the carrier housing.
15. If necessary, back off the slack adjusters. Remove the brake drums.
16. Remove the hubs from the axle spindles. For instructions, 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. If installed, disconnect the air lines from the rear brake chambers. Then remove the brake air chambers and the slack adjusters from the axle housing. For instructions, see **Group 42**.
20. Remove the brake spiders from the axle flanges.
    - 20.1 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.
    - 20.2 Remove the ABS sensors and wiring.
    - 20.3 Remove the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
21. Using a suitable jack, support the axle housing.
22. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
23. 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.
24. Lower the axle enough to clear the suspension components.
25. Remove the axle from the vehicle.
26. If you are going to replace the differential carrier, place the axle on a secure axle stand.

Single 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 Axle Components

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 driveshaft to the differential carrier yoke. For instructions, see **Section 41.00, Subject 110**.
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 (if removed) 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 small amount of oil trickling out of the back of the hub (fill with about 0.8 quart, or 0.75 liter). Install the hubs on the axle spindles, and adjust the wheel bearings. For instructions, see **Section 35.01**.

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.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

11. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
12. Install the brake drums on the hubs.
13. Install the tire and wheel assemblies. 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**.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

17. If the hubs are dry, 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.

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 operation of the DCDL, if installed.
22. 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.
23. Set the parking brake, then remove the chocks from the front tires.

Single 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 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 stand underneath the axle housing.
4. Remove the tire and wheel assemblies. For instructions, see **Group 40**.
5. Remove the oil drain plug from the bottom of the rear axle housing and drain the oil. Install the drain plug after emptying.
6. 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.
7. Disconnect the driveshaft from the carrier input yoke. For instructions, see **Section 41.00, Subject 110**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
8. Place a basin under the axle shaft flanges, then remove the axle shafts. For instructions, see **Subject 120**.
9. Do the steps under the heading, "Axle Removed from Vehicle."

Axle Removed from Vehicle

⚠ 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.

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.
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.

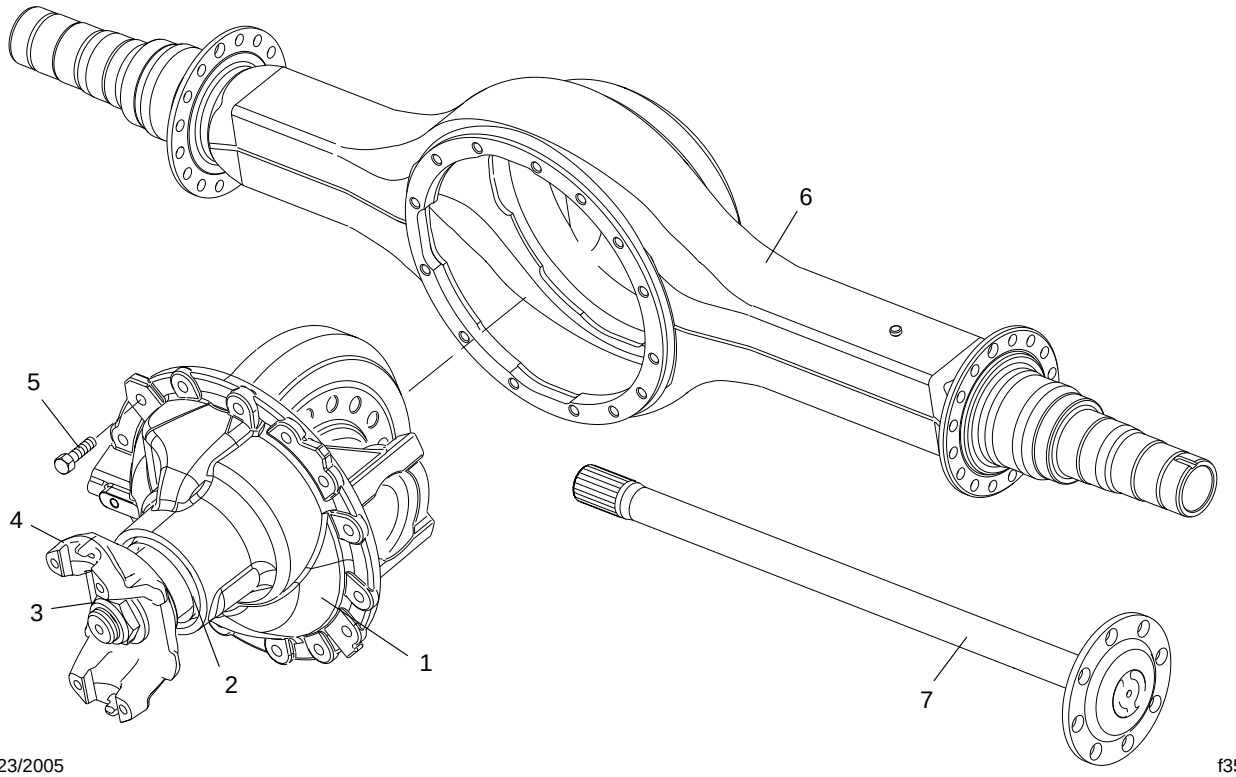
NOTE: Alignment dowels for installing the differential carrier can be made by sawing off the heads of two M12 x 1.5 x 100 mm bolts (for Model 2 axles) or M16 x 1.5 x 100 mm bolts (for Model 4 axles).

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

Single 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 Axle Components

the carrier when it is not centered or straight may cause damage to the carrier.

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.

   7.3 In a star pattern, gradually tighten the carrier capscrews to the values given.

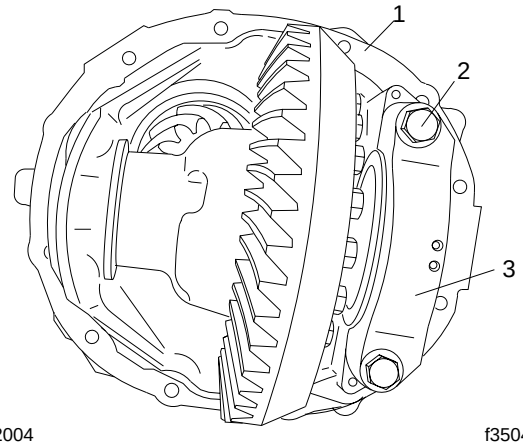
   - M12 capscrews: 115 lbf·ft (156 N·m)
   - M16 capscrews: 200 lbf·ft (270 N·m)

8. If removed, install the axle on the vehicle. For instructions, see **Subject 100**.

   If the axle is already on the vehicle, go to the next step.

9. Connect the driveshaft to the carrier input yoke. For instructions, see **Section 41.00, Subject 110**.
10. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.

Single Axle Differential Carrier Removal and Installation



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

11. Install the tire and wheel assemblies. For instructions, 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**.

Approved Single Rear Axle Oil Type and Capacity				
Model	Oil Type		Capacity: quarts (liters)	
	Mineral	Synthetic	Hubs Full	Hubs Dry
2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
4			10.6 (10.0)	12.2 (11.5)

Table 1, Approved Single Rear Axle Oil Type and Capacity

13. 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.

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.
18. Remove the chocks from the front tires.

Axle Shaft Removal and Installation

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 rear wheels and 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.

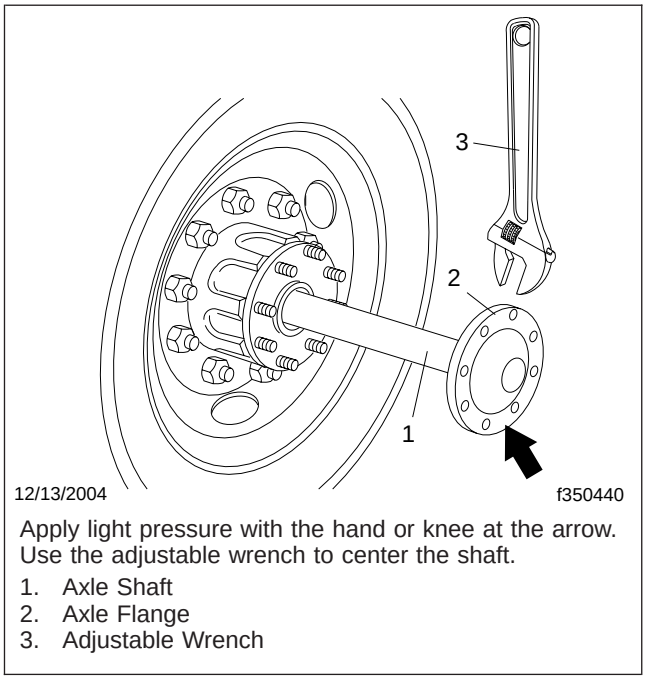
6. Remove the drive axle stud nuts that attach the axle shaft to the wheel hub.
7. If DCDL is installed on the vehicle, use the DCDL switch in the cab to engage the lock. An indicator light comes on when the differential lock is engaged. Turn the appropriate wheels to ensure the lock is fully engaged.
8. 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.

IMPORTANT: The wheel lock must be fully engaged to prevent the possibility of damage to wheel lock components while the axle shafts are being installed.

3. Install the axle shaft, as follows. See **Fig. 1**.
   - 3.1 Carefully raise the axle with the 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.



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

   - 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)
4. If removed, install the rear wheels and tires. 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.
7. Remove the chocks from the front tires.

Single Axle Yoke and Seal Replacement, Model 4 Axles

Special Tools

Special tools are required for this procedure. See **Table 1**.

NOTE: There are no special tools for model 2 axles at this time.

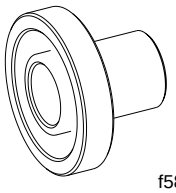
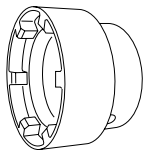
Replacement

1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 110**. 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.
6. Install the carrier yoke on the input shaft. If the yoke is damaged or worn, install a new yoke.

Special Tools for Single Axle Yoke and Seal Replacement, Model 4 Axles

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 for Single Axle Yoke and Seal Replacement, Model 4 Axles

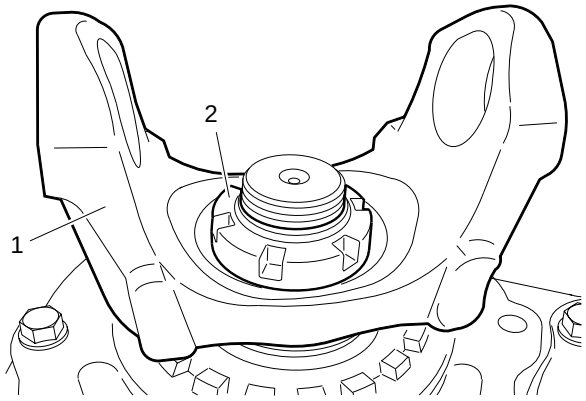
Single Axle Yoke and Seal Replacement, Model 4 Axles

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 110**.

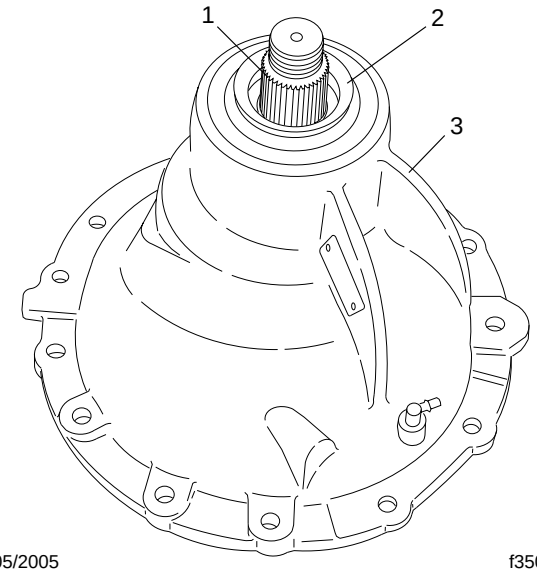


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NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

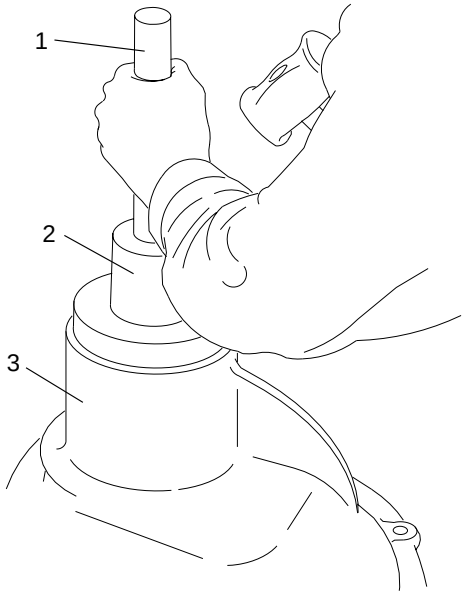
Fig. 1, Yoke Nut on the Carrier



05/05/2005 f350450

1. Input Shaft
2. Rear Pinion Seal
3. Carrier Housing

Fig. 2, Rear Pinion Seal



05/12/2005 f350448

1. Universal Handle
2. Rear Pinion Seal Installer
3. Carrier Housing

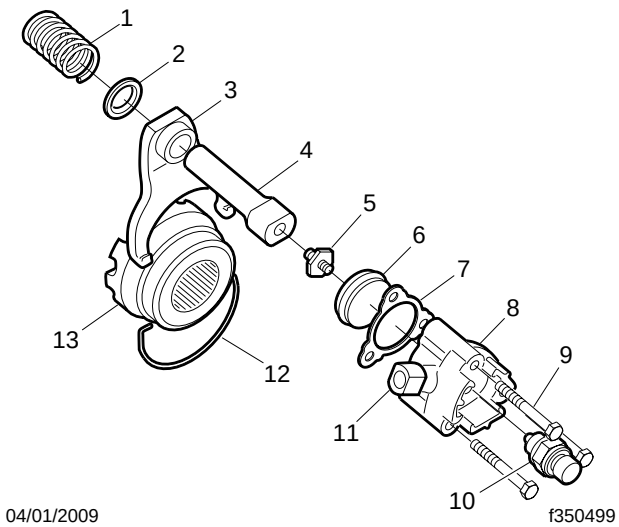
Fig. 3, Installing the Rear Pinion Seal

Main Differential Lock Disassembly and Assembly, Model 2 Axles

General Information

Commonly known as DCDL (Driver-Controlled Differential Lock), a main differential lock is available on single rear axles. The following procedures only apply to Model 2 rear axles equipped with the optional DCDL.

Each part of the main differential lock is replaceable. See **Fig. 1**.



1. Spring
2. Spacer
3. Shift Fork
4. Shift Shaft
5. Adjustment Screw (with locknut)
6. Piston (with O-Ring)
7. Gasket
8. Differential Lock Cover
9. Capscrew
10. DCDL Control Switch
11. Air Interface Connection
12. Retaining Clip
13. Clutch Collar

Fig. 1, DCDL Components, Model 2 Axles

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 Model 2 axle differential carrier, see **Subject 110**.
3. Remove the capscrews that attach the differential lock cover to the carrier housing. See **Fig. 1**.
4. Remove the DCDL control switch.
5. Remove the differential lock cover (including the air interface connection).
6. Remove the gasket, piston, and adjustment screw.
7. Unlatch the retaining clip, and remove it.
8. Remove the clutch collar.
9. Carefully remove the shift shaft from the bore in the carrier housing.
10. Due to spring tension, carefully remove the shift fork, spacer, and spring from the carrier housing.

Assembly

1. Install the spring in the carrier housing, and compress it to install the spacer and shift fork in the housing. Ensure that the spring is centered in the bore.
2. Install the shift shaft into the bore in the carrier housing and through the shift fork, spacer, and spring, being careful to properly align it in the bore. Do not force the shift shaft into the bore.
3. Install the clutch collar, and secure it by installing the retaining clip on the shift fork.
4. Install the adjustment screw as follows.

   4.1 Press the shift shaft in until the clutch collar teeth are fully engaged with the ring gear.

   4.2 Install the adjustment screw, and tighten it until the outer end of it is 0.02 – 0.06 inch (0.5 – 1.5 mm) below the top of the bore in the carrier housing. The screw advances 0.04 inch (1.0 mm) per full revolution, so one complete turn should be sufficient. Use an inside micrometer or depth micrometer to measure the gap.

   4.3 Hold the shift shaft and adjustment screw in a fixed position, and tighten the locknut on the adjustment screw to 18 lbf·ft (24 N·m).
5. Grease the o-ring on the piston.
6. Place the gasket on the differential lock cover, and press the flat side of the piston into the differential lock cover.

Main Differential Lock Disassembly and Assembly, Model 2 Axles

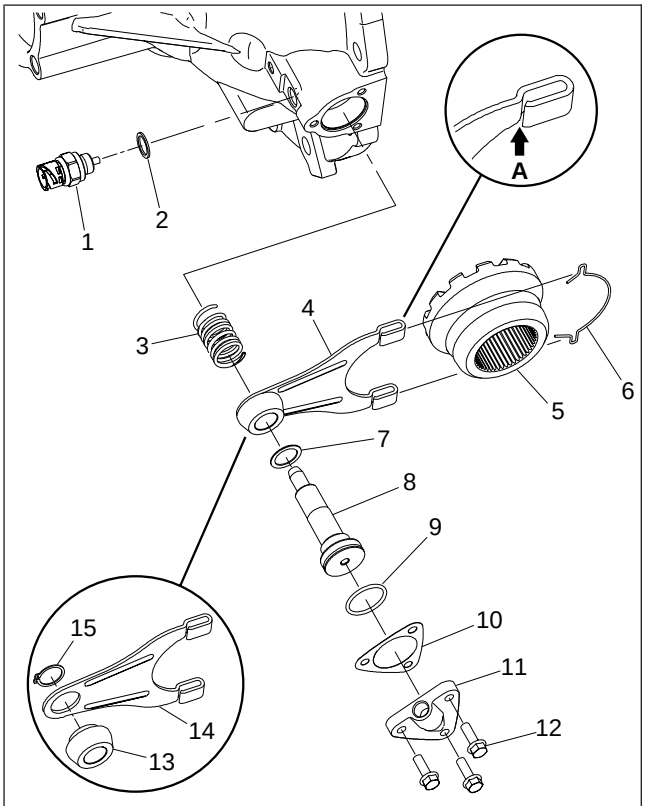
7. Place the differential lock cover over the capscrew bores in the carrier housing, and install the DCDL control switch. Tighten the nut 21 lbf·ft (28 N·m).
8. Install the differential lock cover, and in a regular sequence that seats the cover evenly, tighten the capscrews 18 lbf·ft (24 N·m).
9. Connect 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.
10. Install the differential carrier; for instructions, see **Subject 110**.

Main Differential Lock Disassembly and Assembly, Model 4 Axles

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**.



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A. Opening in fork loop faces away from the clutch collar as shown.

1. Sending Unit
2. Sending Unit Seal
3. Spring
4. Shift Fork Assembly
5. Clutch Collar
6. Retaining Clip
7. Shim(s)
8. Shift Shaft Piston
9. O-Ring
10. Air Interface Gasket
11. Air Interface
12. Capscrew
13. Alignment Boss
14. Fork
15. Snap Ring

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 axle differential carrier, see **Subject 110**.
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.
6. Install the DCDL sending unit in the carrier housing, as removed.

Main Differential Lock Disassembly and Assembly, Model 4 Axles

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.

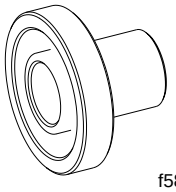
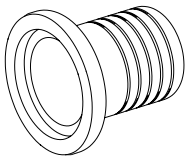
   For instructions on installing a single axle differential carrier, see **Subject 110**.
10. Remove the chocks.

Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Detroit Axles (all models)		
Carrier Capscrews	M12	115 (156)
	M16	200 (270)
Drive Axle Stud Nuts	1/2–20	75–115 (102–156)
	5/8–18	150–170 (203–230)
Pinion Nut (model 2 axles)	M40 x 1.5	370 (502)
Pinion Nut (model 4 axles)	M45 x 1.5	627 (850)

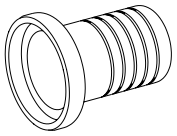
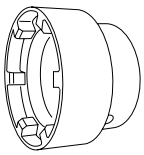
Table 1, Torque Values

Single Rear Axle Oil Type and Capacity				
Model	**Approved Oil Type**		**Capacity: quarts (liters)**	
	Mineral	**Synthetic**	**Hubs Full**	**Hubs Dry**
Model 2	80W-90	75W-90	5.8 (5.5)	7.4 (7.0)
Model 4			10.6 (10.0)	12.2 (11.5)

Table 2, Single Rear Axle Oil Type and Capacity

Special Tools for Axle Yoke and Seal Replacement, Model 4 Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 f580400	Universal Handle*	Kent-Moore	J-8092
 f580406	Rear Pinion Seal Installer*	Kent-Moore	J-47354
 f580410	Input Seal Installer*	Kent-Moore	J-47369

Specifications

Special Tools for Axle Yoke and Seal Replacement, Model 4 Axles			
Tool	**Description**	**Manufacturer**	**Part Number**
 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.

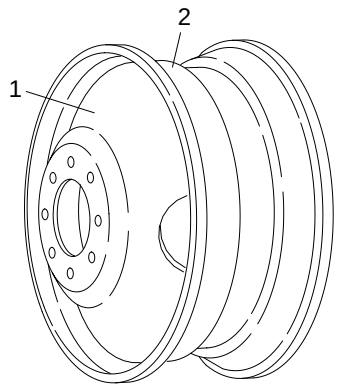
† The yoke nut socket is needed to remove the round, slotted yoke nut installed on some vehicles. It can be ordered through Paragon.

Table 3, Special Tools for Axle Yoke and Seal Replacement, Model 4 Axles

General Information

The tires support the weight of the vehicle, and are integral parts of the transmission and braking systems. The wheels serve as load carrying members between the tires and the axle.

Only hub-piloted disc wheels are used on S2 chassis. Eight-hole and ten-hole disc wheels consist 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 two-piece flange nuts.



1. Disc
2. Rim

Fig. 1, Disc Wheel

Only radial tires are used on S2 chassis. 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 and belt plies 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.

Wheels and tires operate either with or without tubes. Tubeless tires require only the tire, and a one-piece drop-center wheel. See **Fig. 1**.

IMPORTANT: Review and follow these requirements for matching and mixing tires, before installing any tire and wheel assembly on a vehicle.

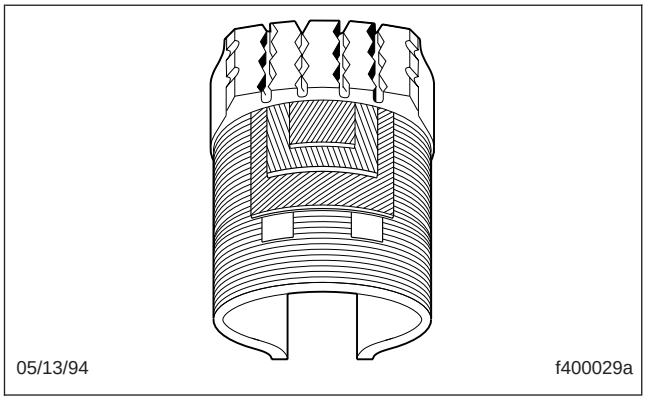


Fig. 2, Radial Ply Tire Construction

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's Gross Axle Weight Ratings (GAWR). The GVWR and each of the GAWRs are shown on a certification label (U.S.-purchased vehicles) or "Statement of Compliance" label (Canadian-purchased vehicles) attached to the left rear door post. See **Fig. 3**.

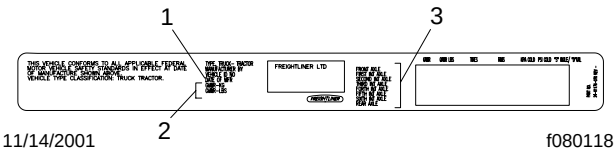
Tire and rim labels certify the minimum tire and rim combinations that can be installed on the vehicle for the given GAWRs. See **Fig. 3** and **Fig. 4**. Each GAWR is determined by considering each component of the axle system, including suspension, axle, wheels, and tires. The lowest component's capacity is the value used for the system. Therefore, the tires and rims installed on the vehicle at the time of vehicle manufacture may have a higher load capacity than that certified by the tire and rim label. Tires and rims of the minimum capacity can be installed without changing the load limitations. If tires and rims are installed that have a lower load capacity than that shown on the tire and rim label, then the tires and rims determine the load limitations (the GAWRs and GVWR will be lower).

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).

⚠ CAUTION

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

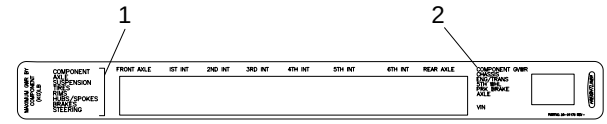
General Information



11/14/2001 f080118

1. Date of Manufacture
2. Gross Vehicle Weight Rating
3. Gross Axle Weight Rating

Fig. 3, Certification Statement, U.S.



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NOTE: Examples only. Actual specifications may vary from vehicle to vehicle.

1. Gross Weight Rating by Component
2. Gross Vehicle Weight Rating By Component in Vehicle as a Whole

Fig. 4, Tire and Rim Labels

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 straightedge 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**.

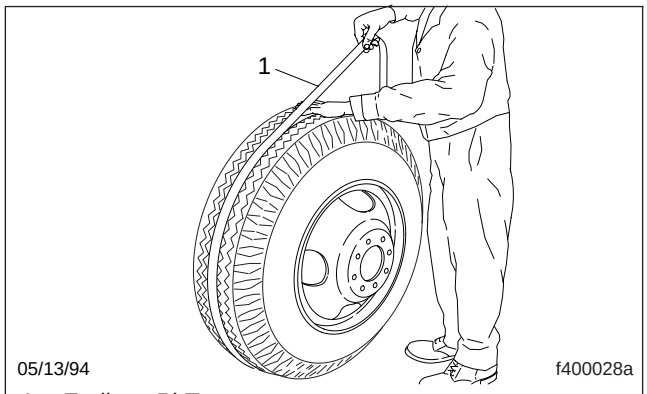
When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

⚠ 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 to within 5 psi (35 kPa) of one another. For tire inflation specifications, see **Specifications, 400**.

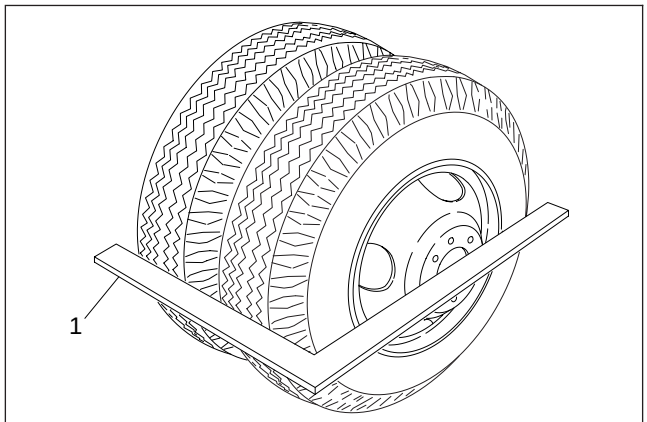
There must be sufficient space between dual tires for air to flow and cool the tires, and to prevent them



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1. Endless Pi Tape

Fig. 5, Endless Pi Tape



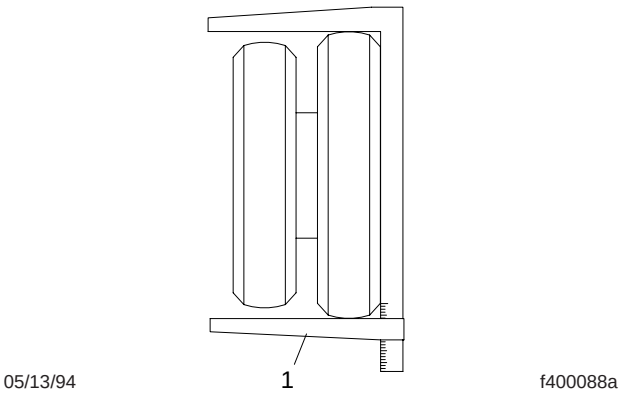
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1. Square

Fig. 6, Square

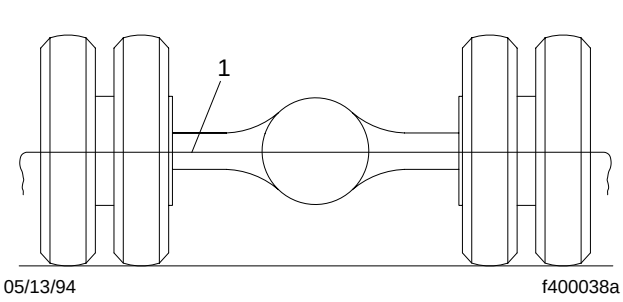
from rubbing against one another. Rims and wheels of the same size, but of different makes and types, can have different offsets, which would affect dual spacing. If there is sidewall contact between tires, or between the inside tire and the chassis, refer to the tire manufacturer's catalog to determine the minimum dual spacing. Refer to the rim or 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. However, tires with the word "Regroovable" on the sidewall, may be regrooved.



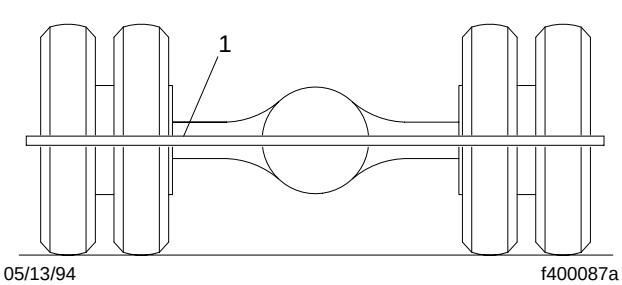
1. Matching Stick

Fig. 7, Matching Stick



1. String Gauge

Fig. 8, String Gauge



1. Tire Straightedge

Fig. 9, Tire Straightedge

CAUTION

Mixing radial and bias ply tires should be done as an emergency measure only. Some loss of steering control and premature tire wear could occur when driving under such conditions.

Better tire and vehicle performance is usually obtained by using tires of the same size and construction. Using tires of different construction is permitted if the following rules are observed:

- Do not mix radial and bias ply tires on the same axle.
- If both radial and bias ply tires are used, better handling is usually obtained by using the bias ply tires on the front axle.

Disc Wheel Removal and Installation

Removal

1. Park the vehicle on a level surface. Shut down the engine.
2. To prevent vehicle movement, chock all tires that will not be serviced. If removing the front wheels and tires, apply the parking brake.
3. Raise the end of the vehicle until the tires clear the floor. Place safety stands under the axle being serviced.
4. If the tire or wheel is damaged, or if there is reason to suspect damage, deflate the tire (or tires, on a dual assembly) being serviced by removing the valve core.
5. Turn the wheel until one hub-pilot pad is in the top-center position.
6. Leaving the top and bottom nuts until last, remove the other two-piece flange nuts.
7. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced. Remove the top and bottom nuts.

CAUTION

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 pilot pads. Keep the wheel square to the hub during removal.

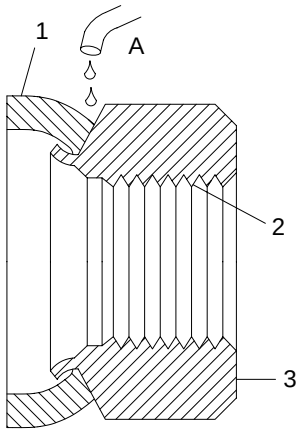
IMPORTANT: On both sides of the vehicle, the two-piece flange nuts have right-hand metric threads.

8. Remove the wheel. Do not let it drop on or drag across the stud threads.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions in **Subject 120**. Follow the tire matching and mixing requirements in **Subject 050**.

1. Clean the hub and wheel mounting surfaces, and all disc faces of dual wheels. Make sure the tire is correctly inflated. For instructions, see **Subject 130**.
2. Apply a few drops of light engine oil to the wheel studs and the area between the body and the flange of each two-piece flange nut. See **Fig. 1**. Wipe off any excess oil.



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NOTE: Apply oil here.

1. Flange
2. Nut Threads
3. Nut Body

Fig. 1, Lubricating a Two-Piece Flange Nut

CAUTION

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 pilot pads. Keep the wheel square to the hub during installation.

IMPORTANT: Before installing the wheels, make sure the drum is positioned on the raised step of the pilot pad. One of the hub's pilot pads must be at the top location. To help keep the drum in place, it may be necessary to apply the brakes before installing the wheels.

3. Locate one hub-pilot pad in the top-center position. Using a jack or wheel-and-tire dolly, position the wheel assembly (inner wheel assembly on duals) on the hub. Make sure the wheel is square to the hub and that the threads are not damaged by contact with the wheel during installation. On dual assemblies, mount the outer wheel against the inner wheel using the same procedure.

Disc Wheel Removal and Installation

4. Make sure the hub-pilot pad is still centered at the top.

IMPORTANT: Install the wheel assembly so that the balance weight(s) on the wheels are 180 degrees opposite the balance weight(s) on the brake drum. If this causes the valve stems to be in the same wheel hole on the rear wheel assemblies, mount the outer wheel so that the outer wheel balance weight(s) is on the same side as the brake drum balance weight(s).

5. Install and hand-tighten a two-piece flange nut on the top and bottom studs.

CAUTION

The two-piece flange 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.

6. Install and hand-tighten the remaining two-piece flange nuts. Tighten the nuts 50 lbf·ft (68 N·m) following the sequence in **Fig. 2** or **Fig. 3**.

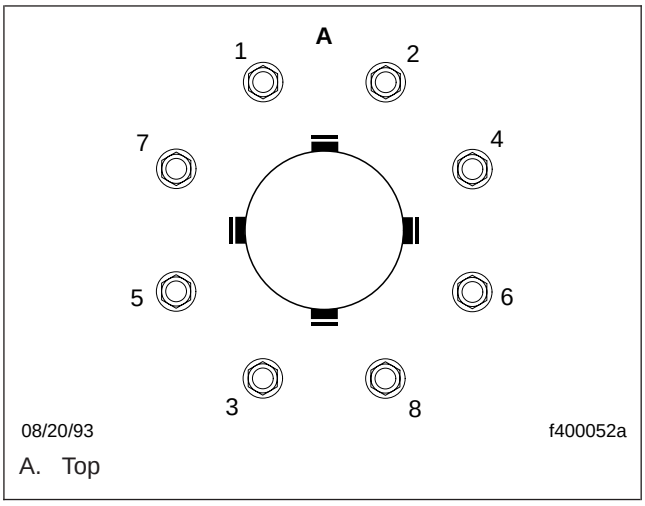


Fig. 2, 8-Stud Disc Wheel Tightening Sequence

7. Check that the wheel is correctly seated against the hub and on the hub-pilot pads.

8. Following the sequence in **Fig. 2** or **Fig. 3**, tighten the two-piece flange nuts 450 to 500 lbf·ft (610 to 678 N·m).

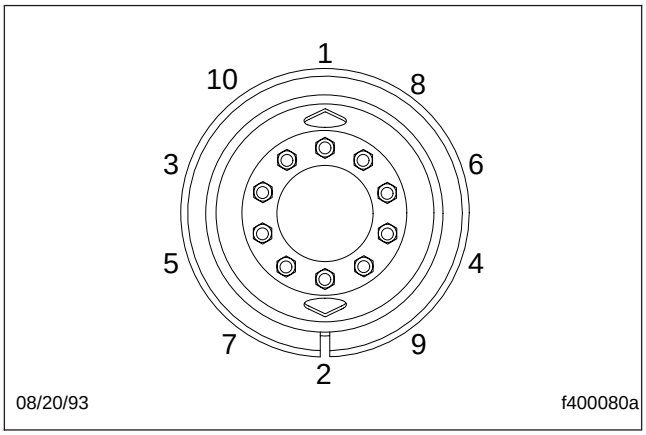


Fig. 3, 10-Stud Disc Wheel Tightening Sequence

WARNING

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 case, 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. Damaged parts must be replaced with new parts. Failure to replace damaged parts could result in the loss of a wheel or loss of vehicle control, causing property damage or personal injury.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35**.

9. Remove the safety stands, lower the vehicle and remove the chocks.

10. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the wheel nut 450 to 500 lbf·ft (610 to 678 N·m). Follow the sequence in **Fig. 2** or **Fig. 3**.

CAUTION

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. Use the specified torque values and follow the tightening sequence in Fig. 2 or Fig. 3.

Disc Wheel Removal and Installation

IMPORTANT: The two-piece flange nuts seat during vehicle operation. It is necessary to periodically tighten the wheel nuts to the specified torque. Tighten the two-piece flange nuts to the specified torque 50 to 100 miles (80 to 160 km) after service work and check the torque every 10,000 miles (16 000 km).

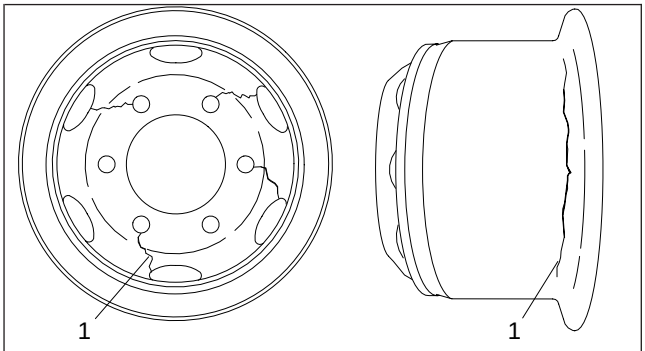
Inspection

WARNING

Inspect the tires and wheels, and correct any problems. Failure to do so could cause tire or rim damage while servicing or while in use. An incorrectly mounted tire can burst causing personal injury and equipment damage.

Examine the wheel, and all parts. Remove any grease, dirt, or rust. Using a wire brush, remove any rubber from the bead seat. Use special care when cleaning the rim gutter. Replace corroded parts. Paint the rim to prevent corrosion.

A cracked rim, wheel, or brake drum, damaged wheel nuts, or an out-of-round wheel, requires the replacement of the damaged part. See **Fig. 1**. Replace the wheel if it has out-of-round stud holes.



1. Crack

Fig. 1, Cracked Wheel and Rim

NOTE: See **Group 33** and **Group 35** for inspection and service procedures for the hub, wheel studs, wheel, and brake drum assemblies.

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. Use new parts or parts that are not cracked, broken, or otherwise damaged, and that are of the same size and type.

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 or rim damage while servicing or while in use. An incorrectly mounted tire can burst, causing personal injury and equipment damage.

Inspect the inside and outside of the tire for out-of-round, 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 (for example, due to weather checking or sidewall scuffing).

Inspect the tread for abnormal or excessive wear. Refer to **Troubleshooting, 300** for possible causes of abnormal wear. If the tires are wearing irregularly, they should be rotated. If the front axle tires become irregularly worn, they should be moved to the drive axle. The front-end alignment should be checked. In a dual assembly, if one tire wears faster than its mate, the position of the two tires should be reversed. See **Group 40** of the *S2 Chassis Maintenance Manual* for tire rotation procedures.

Government regulations require the removal of any tire with less than 2/32-inch (1.5-mm) tread remaining. Retread the tire (if possible), regroove it (only if marked "Regroovable" on the sidewall), or discard it.

Clean and inspect the tube and flap of tube-type tires. Discard tubes or flaps that are buckled or creased. Do not use an old tube in a new tire, and always mount a used flap in the same size tire and on the same size rim as the one from which it was removed. Michelin Tire Corporation recommends using only new tubes, flaps, valve cores, caps, and O-rings in a new mounting.

Tire Inflation

1. Check all parts to make sure they are correctly seated prior to inflation.

NOTE: Inflate tires in a safety cage or an approved portable restraining device. See **Fig. 1**. 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.

⚠ 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.

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.

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.

2. After placing the tire in a safety cage, or an approved portable restraining device, inflate the tire to 10 psi (69 kPa). Check the parts for correct seating. If the seating is not correct, completely deflate the tire and correct the problem. Never attempt to seat 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 to help seat tubeless tire beads:

- Metal rings, which use a blast of compressed air to seat the beads.
- 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.

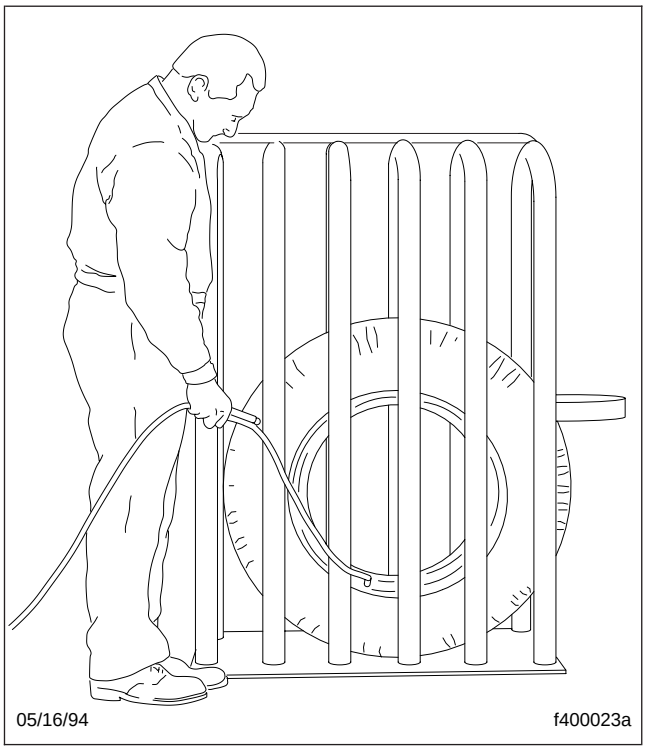


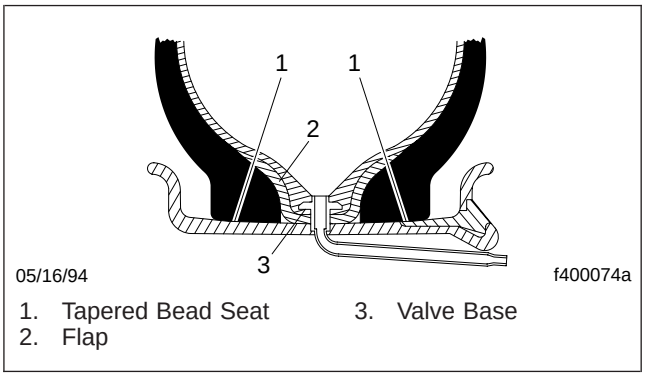
Fig. 1, Safety Cage

3. If there are no problems with the assembly at 10 psi (69 kPa), continue to inflate the tire to the recommended pressure. See **Specifications, 400** for correct cold inflation pressures. Michelin Tire Corporation recommends an initial inflation pressure of 90 to 100 psi (620 to 690 kPa) to correctly seat the tire beads.

NOTE: The position of the beads, flap, and tube with 4 to 5 psi (28 to 35 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 (140 to 275 kPa) pressure is needed to push the beads onto the bead seat. See **Fig. 3**.

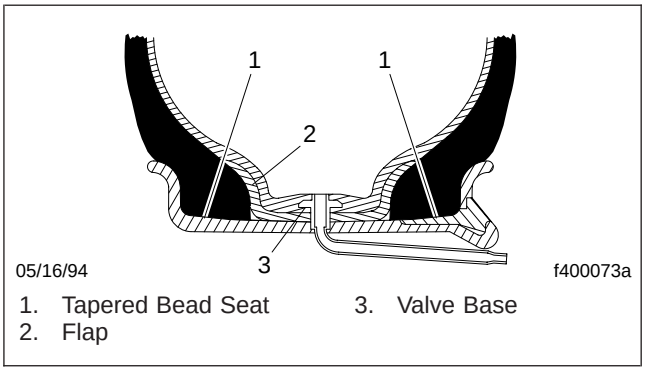
4. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating, and prevents buckling or overstretching the tube in tube-type tires. Then inflate the tire to the recommended cold inflation pressure listed in **Specifications, 400**. Install the valve caps and tighten them finger-tight.

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

⚠ CAUTION

Improperly inflating tube-type tires 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.

IMPORTANT: 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.

NOTE: Inflate the tires to the recommended pressure. Driving on overinflated tires will weaken the cords by reducing their ability to absorb road shocks, and will increase the danger of cuts, snags, and punctures. Overinflation will overstress and damage the rims. Driving on underinflated tires will generate excessive heat. This weakens the tire body, and reduces tire strength.

⚠ WARNING

Inflate tires to the specified pressure. Tire underinflation or overinflation will damage wheels and tires, and could result in a blowout, causing possible personal injury and property damage.

5. Check the inflation pressure 24 hours after mounting new tires.

NOTE: When testing a vehicle on a dynamometer, severe tire damage can occur. Because the manufacturers differ in their recommendations for preventing tire damage, refer to the manufacturer's instructions for testing a vehicle on a dynamometer.

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 causing personal injury and equipment damage.

IMPORTANT: Don't 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 mounting and demounting 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 the demounting and mounting of tires:

- Examine all wheel and tire parts as explained in **Subject 110** and **Subject 120**. Replace damaged, rusted, or worn parts.
- Make sure that tires are stored indoors, or outdoors under cover, to prevent water collecting inside the tire.
- Use special tools, as recommended by tire suppliers, for mounting and demounting tires. These tools must be smooth, and used with care, to avoid gouging the rim.
- Loosening tire beads may be difficult, since considerable force may be needed. The use of a machine designed for loosening tire beads is recommended.
- Handle the wheels on a wooden floor or rubber mat to prevent nicking or gouging the wheel.
- Lubricate the tire with an approved tire-mounting lubricant. Never use antifreeze, silicones, petroleum-based lubricants, or any flammable material (ether/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, formed by the tire and rim, before using tools to break the bead.
- Michelin also recommends applying a sufficient but sparing amount of lubricant to the entire rim face when mounting a tire on a rim, to ensure correct bead seating and ease of mounting.
- Don't reinflate a tire that has been run flat or has been run at 80 per cent or less of its recommended operating pressure. Use your spare. Before removing the low tire from the vehicle, make sure it is completely deflated. Later, have the assembly taken apart and all the parts checked for damage.

Demounting and Mounting Tubeless Tires

⚠ WARNING

Read the information in Subject 140. Failure to follow the 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 causing personal injury and equipment damage.

Five Degree Full Drop Center

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 rim by driving the flat end of the tire tool between the tire bead and the rim flange. Holding the tool upright, hammer on the neck to free the tire bead from the rim. See **Fig. 1**. Repeat at 8-inch (20 cm) intervals around the flanges, until both beads are free from the rim.
3. Place the wide side of the rim down. Lubricate the tire bead and the rim. Insert the curved end of two tire tools between the bead and the rim, and just to one side of the tire valve. Step on the side of the tire, opposite from the valve, to force the first bead into the rim well. See **Fig. 2**. Hold one of the tools in place with your foot and pry with the second tool, forcing the bead over the rim flange. Continue to work the first bead off of the rim.
4. When the first bead is off the rim, and the second bead is in the rim well, stand the assembly upright with the valve stem near the top. Lubricate the second bead and rim. Insert the straight end of the tool between the tire bead and the back rim flange, hooking the tool over the second flange. Lean the tire assembly toward the tool and use a rocking or bouncing action to pry the rim out of the tire. See **Fig. 3**.
5. Clean and inspect all parts. See **Subject 110** and **Subject 120** for procedures.

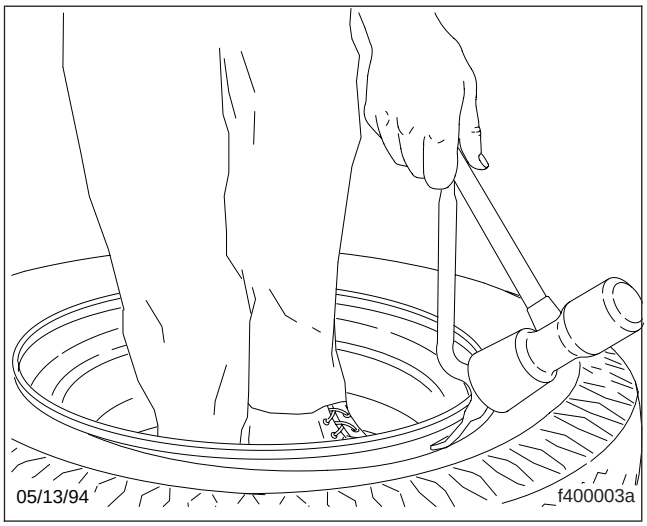


Fig. 1, Loosening the Beads

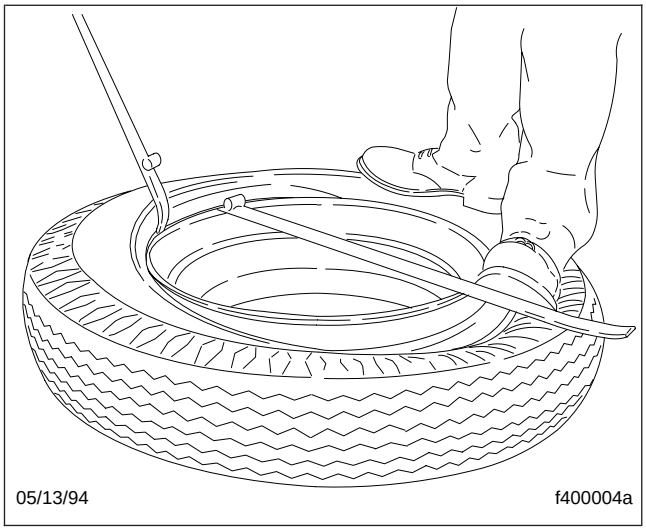


Fig. 2, Forcing Bead into the Rim Well

Mounting

1. Place the valve stem, with a rubber washer, through the valve hole from the tire side of the rim. Screw on the valve nut from the opposite side. Make sure the rubber bushing and metal

Demounting and Mounting Tubeless Tires

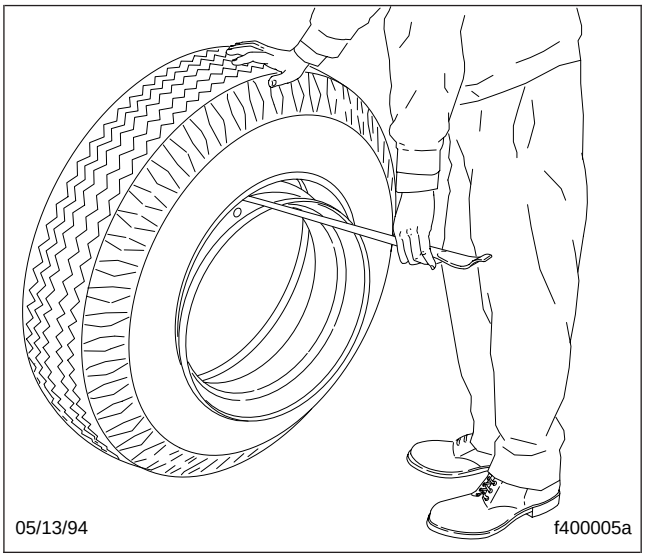


Fig. 3, Prying the Rim Out of the Tire

collar or nut are centered and fit snugly in the valve hole. See **Fig. 4**. Tighten the nut securely.

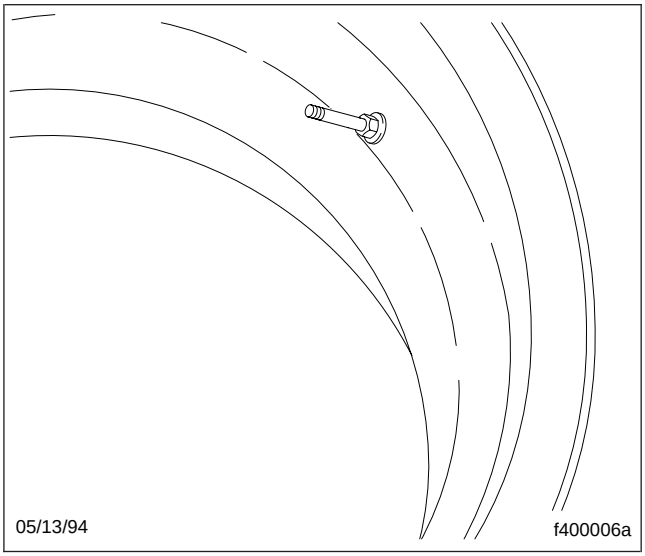


Fig. 4, Valve Stem Installation

2. Place the rim on the floor with the wide side down. Using a brush or swab, lubricate both bead seats (flanges) of the rim, and both tire beads, with an approved lubricant. Apply enough lubricant to enable correct bead seating, and to make mounting easier. Don't let excess lubricant run inside the tire.
3. Lay the tire on the rim. If there is a balance mark on the tire, line up this mark with the valve stem. Push the lower bead over the flange and into the rim well. Using the straight end of the tire tool (with the stop resting on the rim flange), take small bites to work the remaining section of the bead into the rim. See **Fig. 5**.

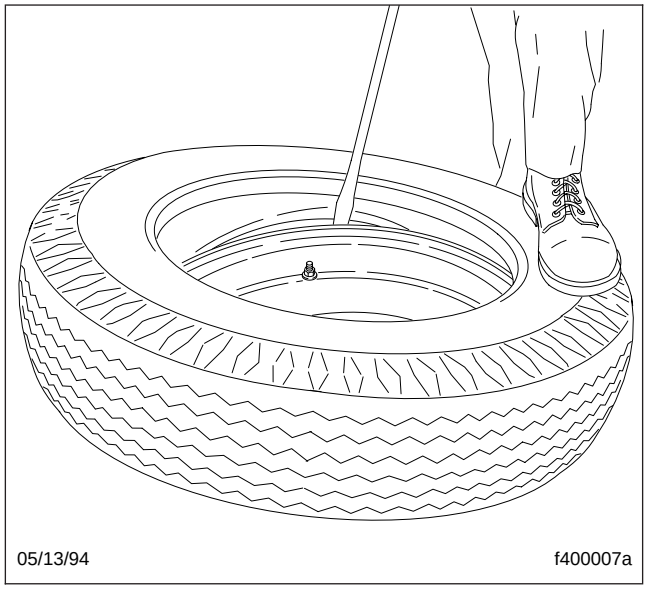


Fig. 5, Working the Lower Bead into the Rim

4. Start the upper bead over the rim flange and into the rim well by standing on the tire. If necessary, push a section of the bead into the rim well, and anchor it by attaching Vise-Grip® pliers to the rim flange (snub side toward the tire). Using the spoon end of the tire iron, with the stop toward the rim, work around the bead. See **Fig. 6**. Use small bites until the bead slips over the flange and into the rim well. If necessary, insert a second tire iron and relubricate the last 8 inches (20 cm) of bead.
5. Inflate the tire. See **Subject 130** for procedures.



Fig. 6, Working the Upper Bead into the Rim

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".

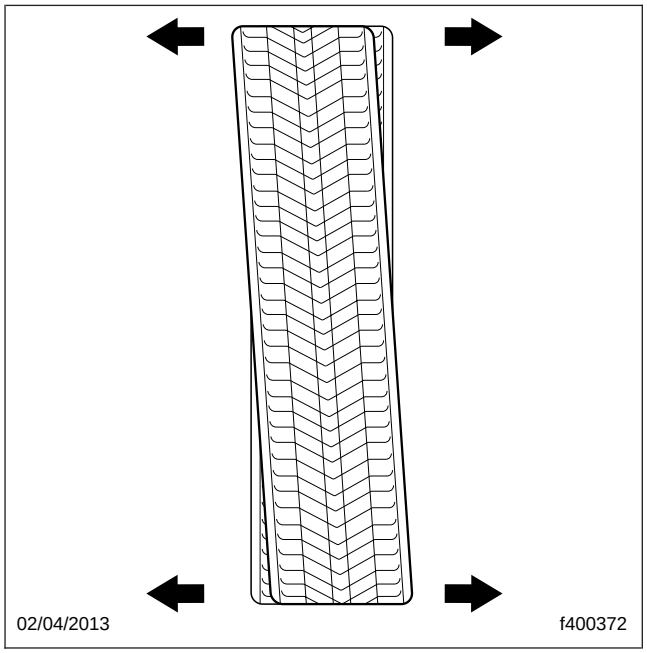


Fig. 1, Lateral Runout

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:

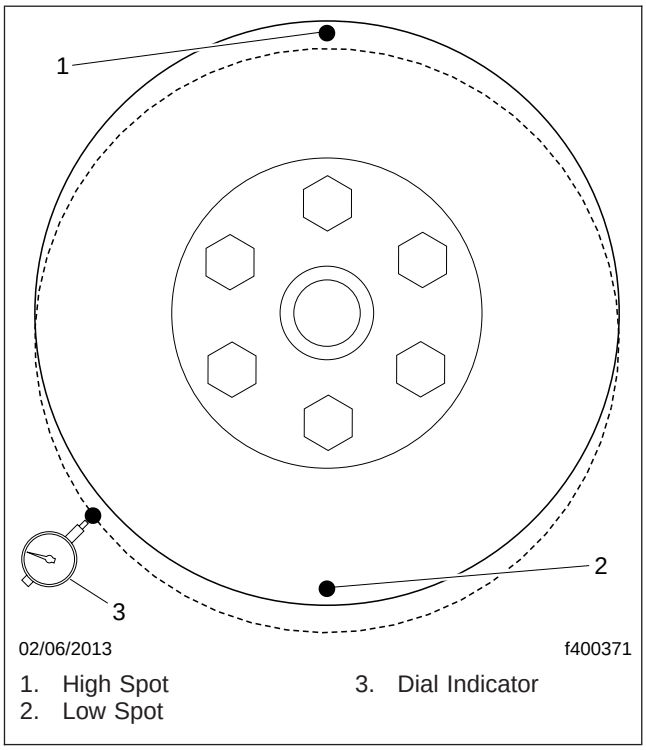


Fig. 2, Radial Runout

- 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)

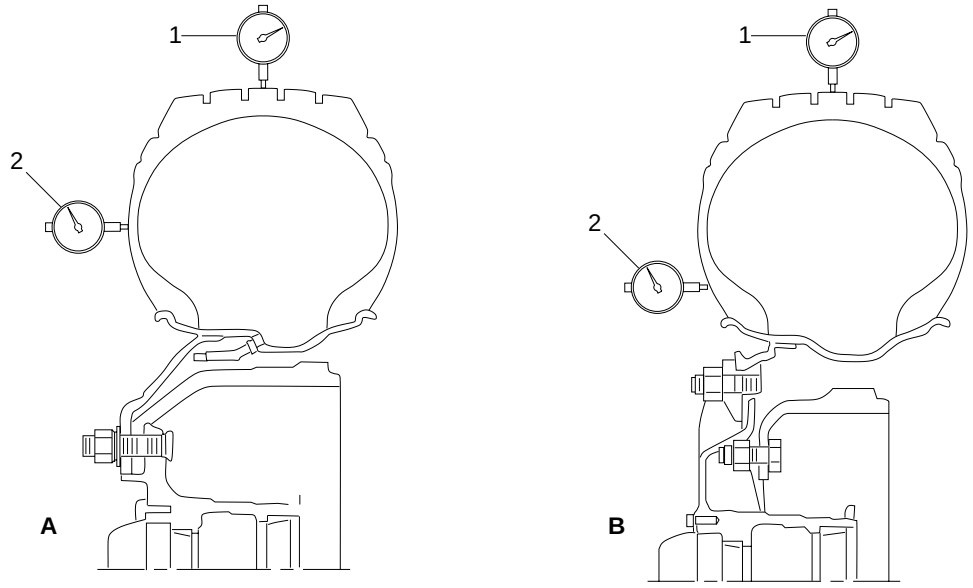
Wheel and Tire Runout Measurements

- 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 150**. 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

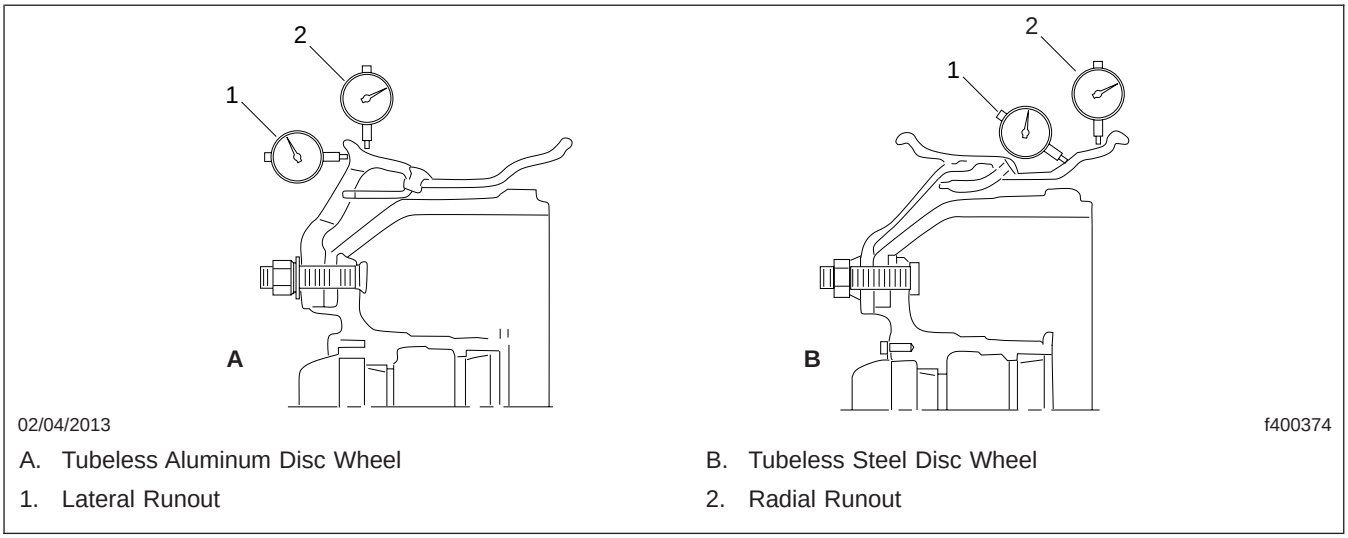


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A. Tubeless Steel Disc Wheel
1. Radial Runout
B. Tubeless Demountable Wheel
2. Lateral Runout

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. See **Specifications, 400**.
Inflation pressures in a dual assembly are unequal.	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). See **Specifications, 400** for the proper cold inflation pressures.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.
The vehicle is vibrating severely.	Follow the recommendations in the "Vehicle Vibration" troubleshooting table.
The brakes are grabbing.	Examine and adjust the brakes. See **Group 42** for instructions.
Axles are improperly aligned.	Align the axles. See **Group 33** and **Group 35** for instructions.
Wheel bearings are loose or damaged, or bushings are excessively worn.	Examine, and repair or replace the wheel bearings. See **Group 33** and **Group 35** for instructions.
Wear is uneven among tire sets.	Rotate the tires. See **Group 40** of the *S2 Chassis Maintenance Manual* for instructions.
The driver is abusing the equipment.	Caution the driver.

Problem—Vehicle Vibration

Problem—Vehicle Vibration	
Possible Cause	**Remedy**
Axles are improperly aligned.	Align the axles. See **Group 33** and **Group 35** for instructions.
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.
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, suspension, 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. See **Specifications, 400**.
Dual tires are mismatched.	Examine all tires and match them according to the specifications in this section.
Water or foreign material is inside the casing.	Clean and dry the tires and tubes 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.

Troubleshooting

Problem—Excessive On-the-Road Tire Failures	
Possible Cause	**Remedy**
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.
The vehicle is vibrating severely.	Follow the recommendations in the "Vehicle Vibration" troubleshooting table.
Parts are corroded, worn, or otherwise damaged.	Clean or replace parts as necessary.

Specifications

IMPORTANT: 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 (70 to 105 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.

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. Consult the wheel manufacturer if they are not stamped. If the load exceeds the maximum wheel capacity, the load must be adjusted or reduced.

For further data on rims and 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 on their tires. Refer to the Michelin website for additional information, www.michelin.com.

For disc wheel fastener torques, see **Table 1**.

Disc Wheel Fastener Torques			
Description	**Nut Size**	**Wheel Manufacturer**	**Torque (dry threads) lbf·ft (N·m)**
8-Hole and 10-Hole Disc Wheels With Two-Piece Flange Nuts			
Front and Rear Wheel Nut	M22 x 1.5	All	450–500 (610–678)*
Wheel Stud Retainer Nut	3/4–16	Accuride	175–200 (235–270)

* Torque values are given for lubricated threads.

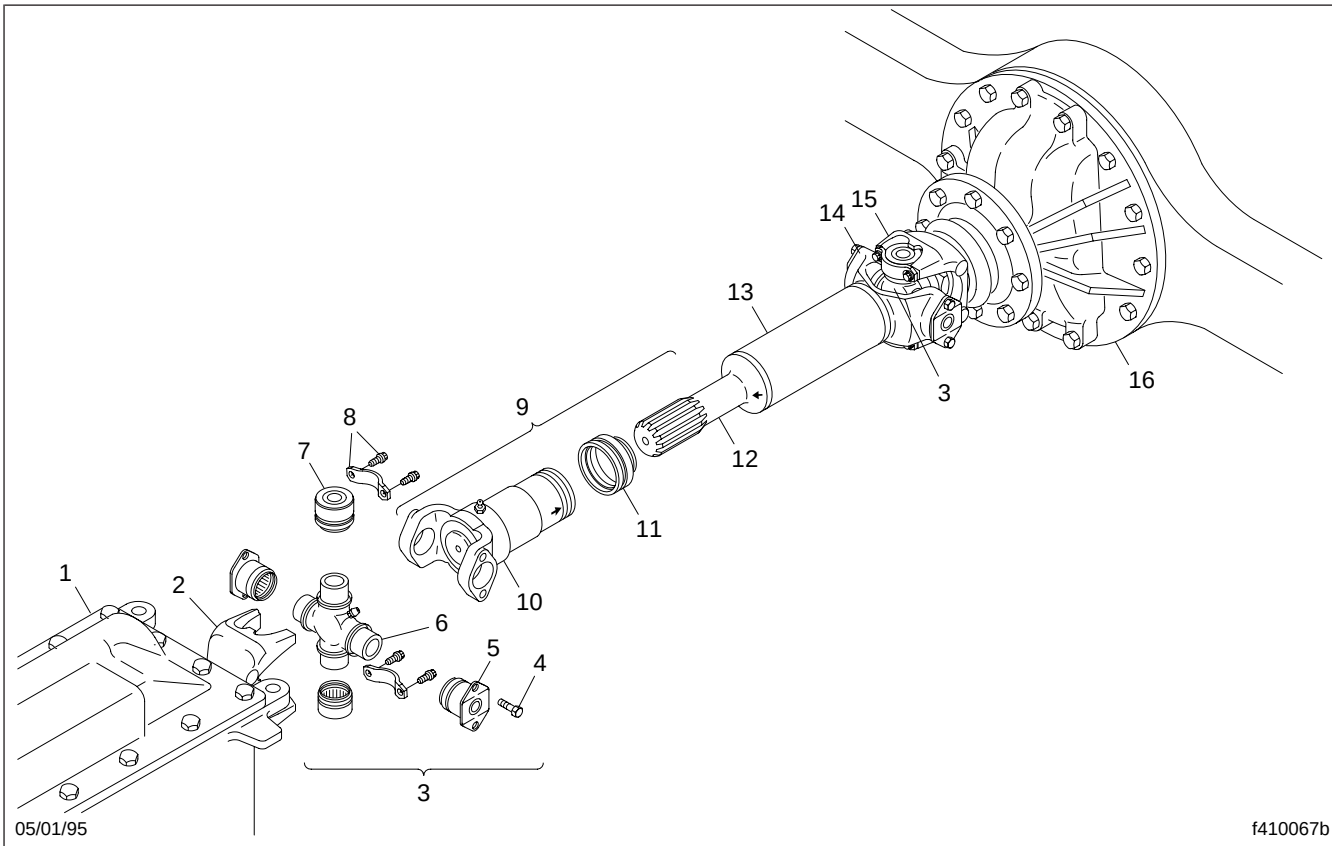
Table 1, Disc Wheel Fastener Torques

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 transmission, its type of drive axle, and its wheelbase. See **Fig. 2**. A driveline connects each driving and driven component. A driveline connecting a main transmission (or an auxiliary transmission) to a single drive axle is always referred to as a no. 2 driveline. See **Fig. 2**, examples *A*, *B*, and *C*.

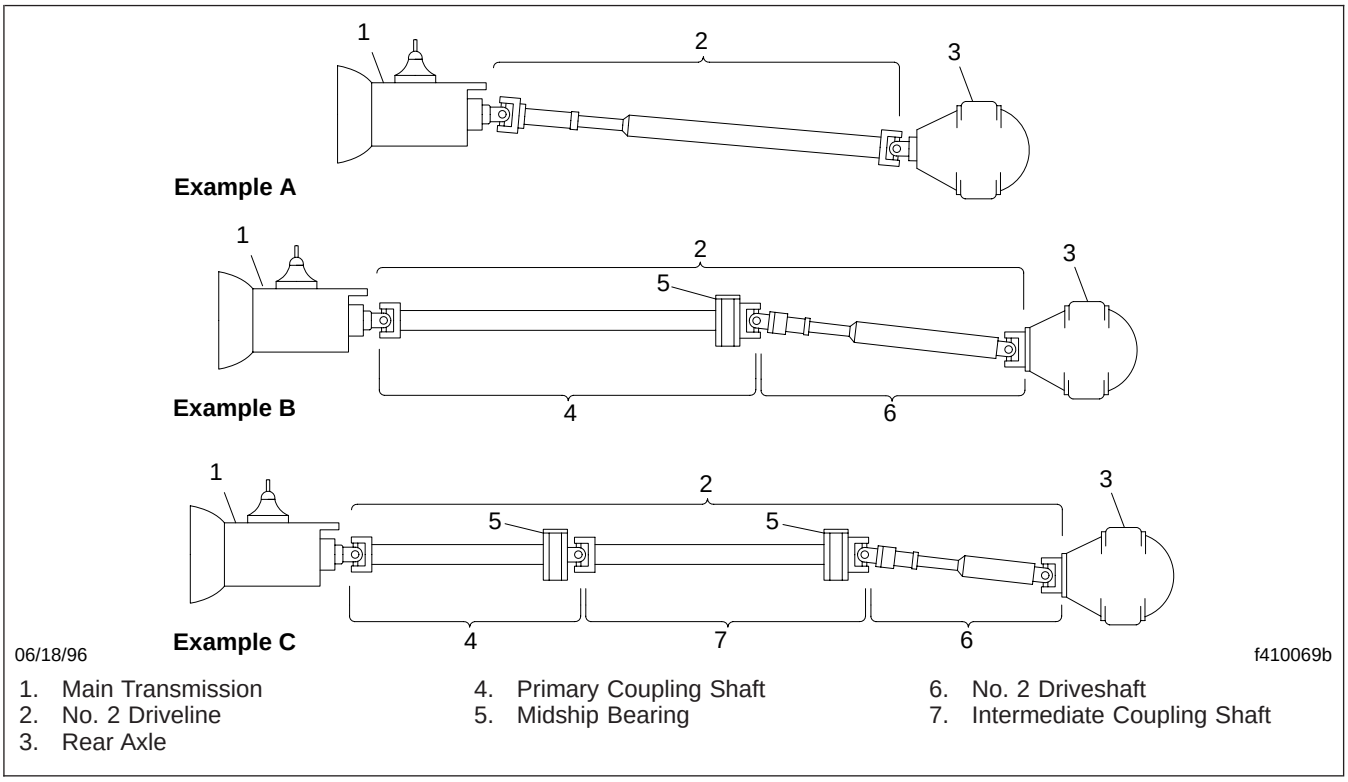


NOTE: Not all fasteners are shown.

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



1. Main Transmission
2. No. 2 Driveline
3. Rear Axle
4. Primary Coupling Shaft
5. Midship Bearing
6. No. 2 Driveshaft
7. Intermediate Coupling Shaft

Fig. 2, Driveline Configurations

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 use a midship bearing, mounted on a frame crossmember, for additional support. See **Fig. 2**, example *B*. 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.

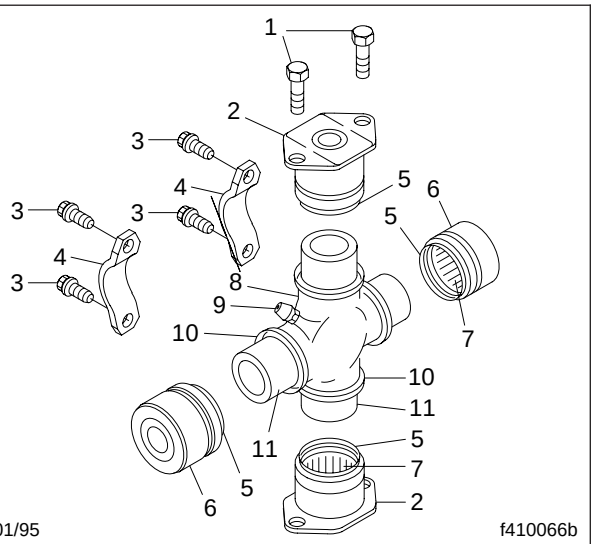
Vehicles having an even longer wheelbase use two crossmember-mounted midship bearings, allowing the no. 2 driveline to be separated into three short shafts, joined by four U-joints. See **Fig. 2**, example *C*. The first shaft is the primary coupling shaft, the second is the intermediate coupling shaft, 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 axle is not attached directly to the frame, but is suspended by springs, the axle rides 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. Slip-joints, by expanding and contracting, allow for length changes between drivetrain components.

Motion of the rear axle also causes changes to the relative angles between drivetrain components. U-joints allow transfer of torque from an output 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.



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

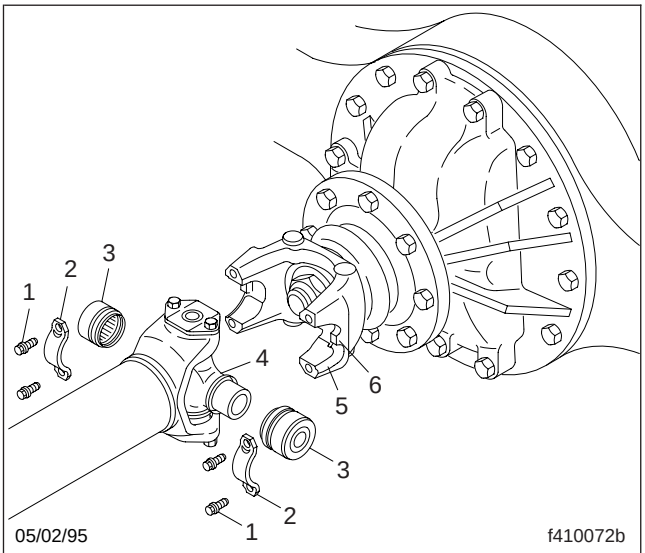
Fig. 3, Typical U-Joint

Full-round yokes are installed at the front of coupling shafts and at both ends of the driveshaft. 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.

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. As standard equipment, half-round end-yokes are installed on the transmission output shaft, on the axle input shaft and behind the midship bearing of most coupling shafts.

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. 4**.

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 installing the bearing cups into the outside of the yoke and over the ends of the trunnions. Self-locking cap-



1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

Fig. 4, Coupling of a U-Joint With a Half-Round End-Yoke

screws, inserted through a bearing plate at the back of each cup, thread into the yoke to secure the cups. See **Fig. 5**.

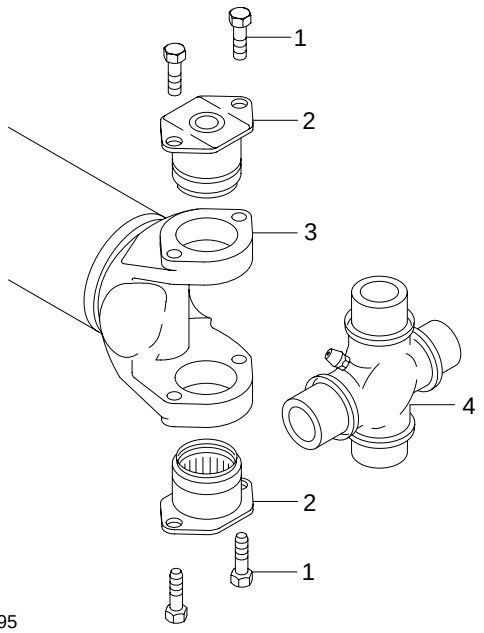
U-Joint Angles, Phasing, and Driveline Balance

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).

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 to which the U-joint connects. See **Fig. 6**. 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. 7**.

NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.



1. Bearing-Plate Self-Locking Capscrew
2. Bearing Cup (bearing-plate-type)
3. Full-Round Yoke
4. U-Joint Cross

Fig. 5, Installation of a U-Joint in a Full-Round Yoke

After manufacture, each driveline yoke is statically balanced. After assembly, the driveshaft is checked for out-of-roundness, straightened as necessary, then dynamically balanced.

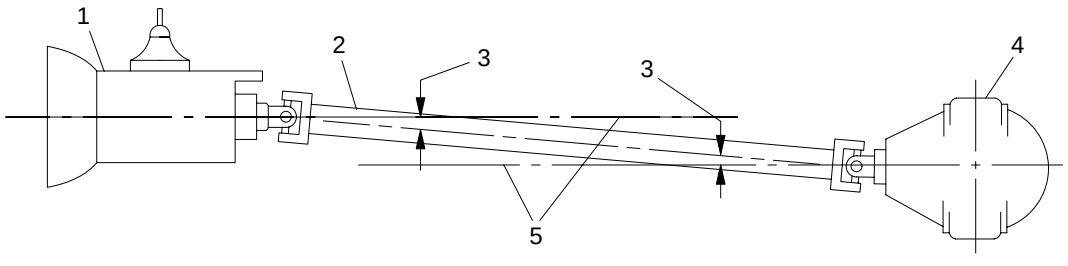
Avoiding Driveline Problems

To ensure that U-joints turn in phase, sleeve-yokes and splined 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 U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings, and worn slip-joint splines.

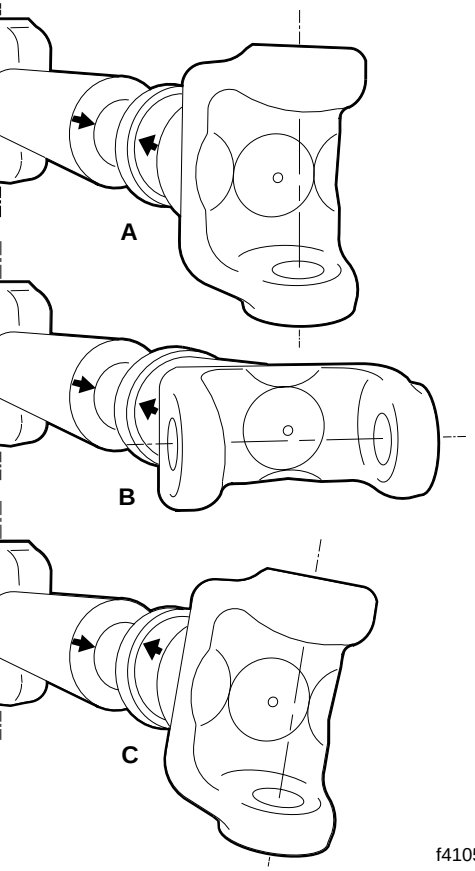
Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

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 *S2 Chassis Maintenance Manual*.



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 6, U-Joint Working Angles



A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 7, U-Joint Phasing

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

NOTE: It is easier to check driveline parts, and to replace a U-joint 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**.

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 driveshaft.

U-Joint Uncoupling

1. Roll the vehicle forward or backward as needed to turn the rearmost end-yoke until the centerline through its cross-holes is horizontal. See **Fig. 1**.
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**.
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**.
5. Remove the capscrews that secure the bearing straps to the half-round yoke. Remove the bearing straps.
6. Compress the slip-joint to remove the U-joint from the yoke.

U-Joint Coupling

1. Check and clean the end-yoke, as follows.
   - 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. 2**.
   - 1.3 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes and bearing straps. See **Fig. 3**.
   - 1.4 Turn the end-yoke until its cross-holes are horizontal. See **Fig. 1**.
2. Check, clean, and lubricate the U-joint, as follows.
   - 2.1 Remove the bearing-cup retaining wire or safety wire. See **Fig. 1**.

⚠ CAUTION

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.

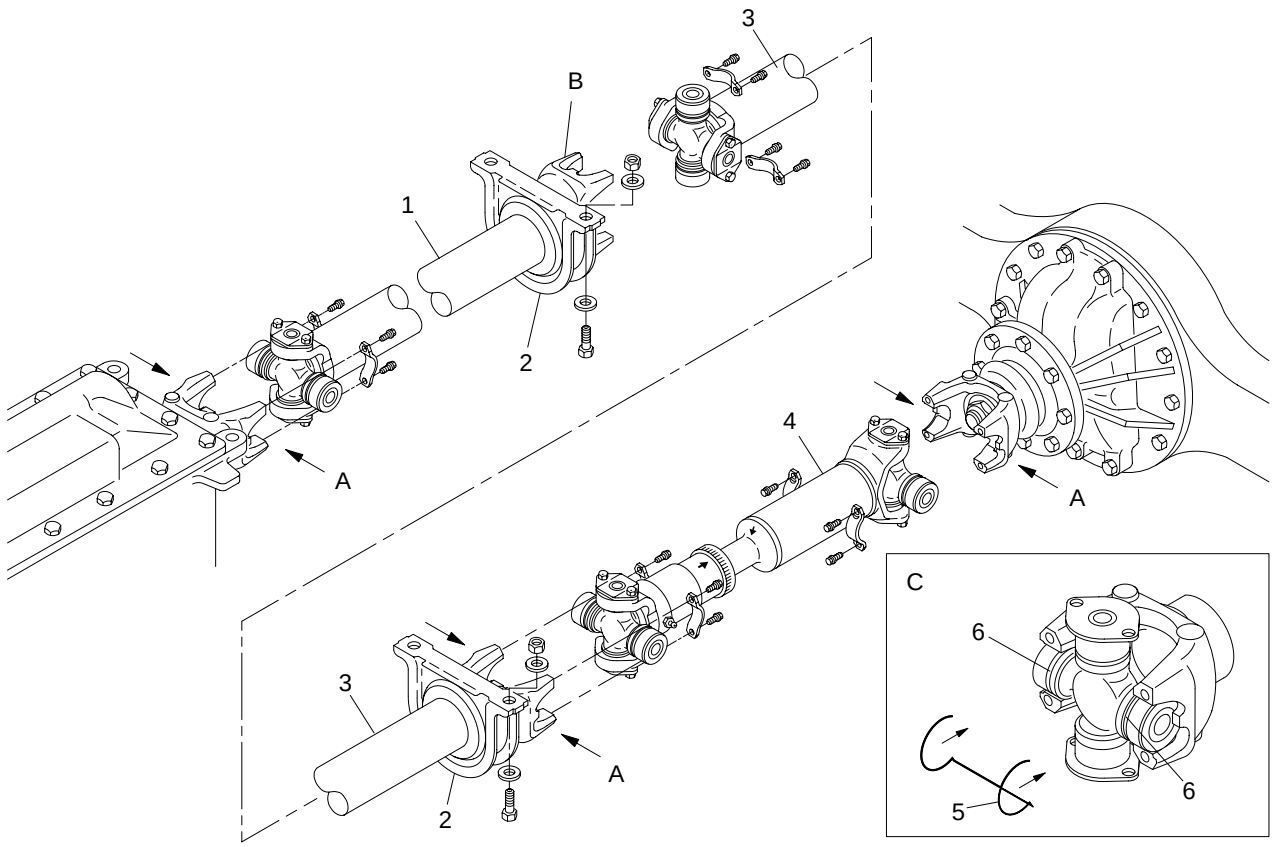
   - 2.2 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 4**.
   - 2.3 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.
   - 2.4 Using NLGI grade 2 grease with EP additives, wipe a small 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. 5**.
   - 2.6 Install the bearing cups on the cross.
   - 2.7 Install a bearing-cup retaining wire. See **Fig. 1**.
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. 6**.

⚠ CAUTION

Do not use the capscrews and bearing straps 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 over the cups, and install the new strap 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.
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

⚠ WARNING

The self-locking bearing-strap capscrews must not be reused. Replace the capscrews with new ones. Also, do not undertighten or overtighten the capscrews; use proper torque values. A loose or broken fastener at any point in the driveline weakens the driveline connection and can 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 bearing-strap capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications 400**.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

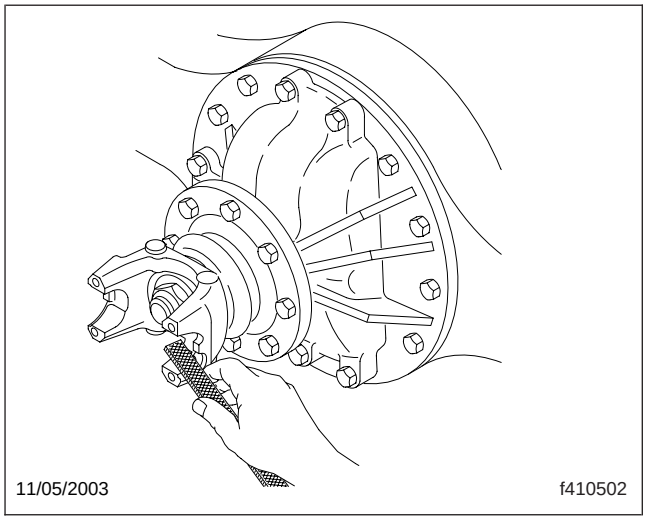


Fig. 2, Removing Burrs From a Half-Round End-Yoke Cross-Hole

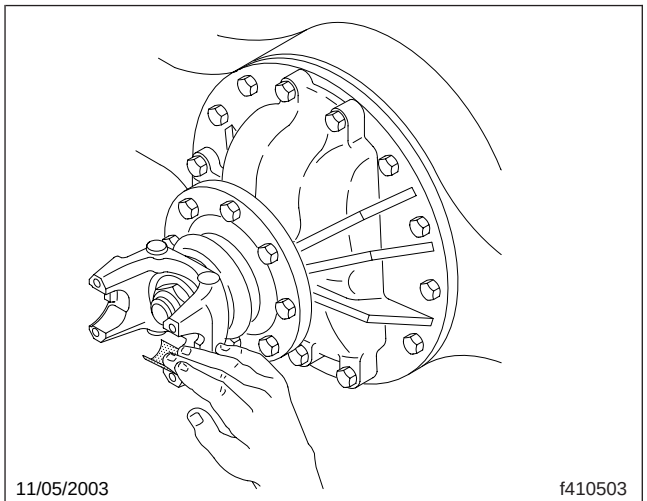


Fig. 3, Smoothing a Half-Round End-Yoke Cross-Hole

6. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).
7. Lubricate the U-joint, following the procedure in **Group 41** of the *S2 Chassis Maintenance Manual*.
8. Remove the nylon support straps, then remove the chocks.

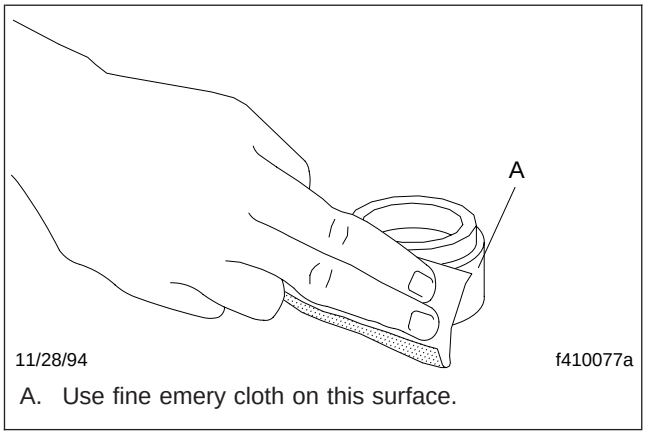


Fig. 4, Smoothing a Half-Round End-Yoke U-Joint Bearing Cup

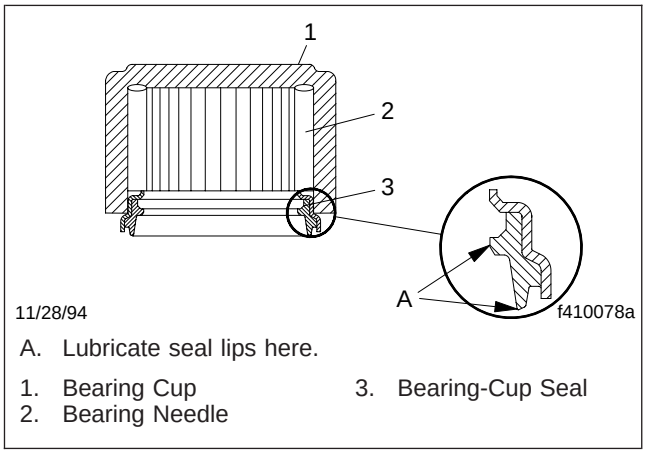
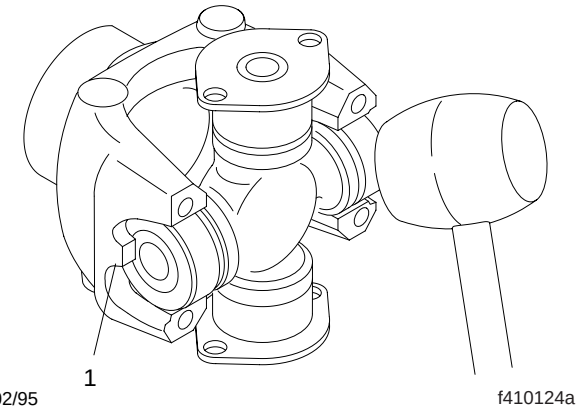


Fig. 5, Sectional View of a Half-Round Yoke U-Joint Bearing Cup

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



1. Retaining Tab

Fig. 6, Seating a U-Joint in a Half-Round Yoke

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 driveshaft; see **Subject 100** for uncoupling from a *half-round* end-yoke.

It is easier to check driveline parts, and to replace a U-joint 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. 2 Driveshaft Removal

1. Uncouple the driveshaft from the rear axle. See **Fig. 1**.
2. Uncouple the driveshaft from the transmission or coupling shaft.
3. Lift the 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. See **Fig. 2**.
3. Uncouple the intermediate coupling shaft from the primary coupling shaft. See **Fig. 3**.
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.

   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, remove the fasteners that attach the intermediate coupling shaft midship bearing to its bracket. See **Fig. 3**.
2. If not already done, uncouple the primary coupling shaft from the no. 2 driveshaft or intermediate coupling shaft.
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. 3**.
4. Uncouple the primary coupling shaft from the transmission.
5. Lift the primary coupling shaft out of the chassis.

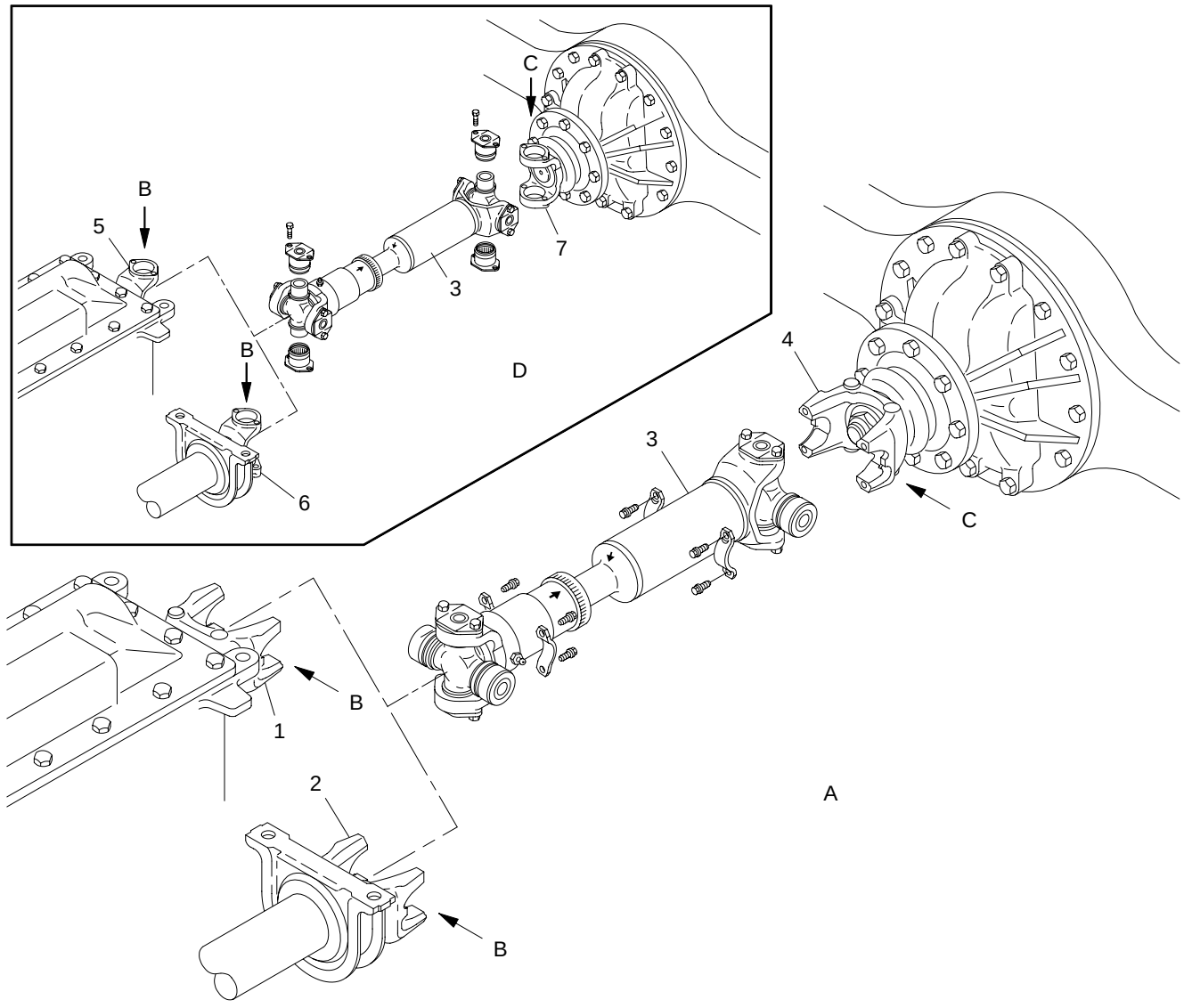
Primary Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase; see **Fig. 4**.

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. See **Fig. 3**.
3. *For a vehicle with one coupling shaft:*

   If the no. 2 driveshaft was also removed, install it, as instructed in this subject.

Driveshaft Removal and Installation



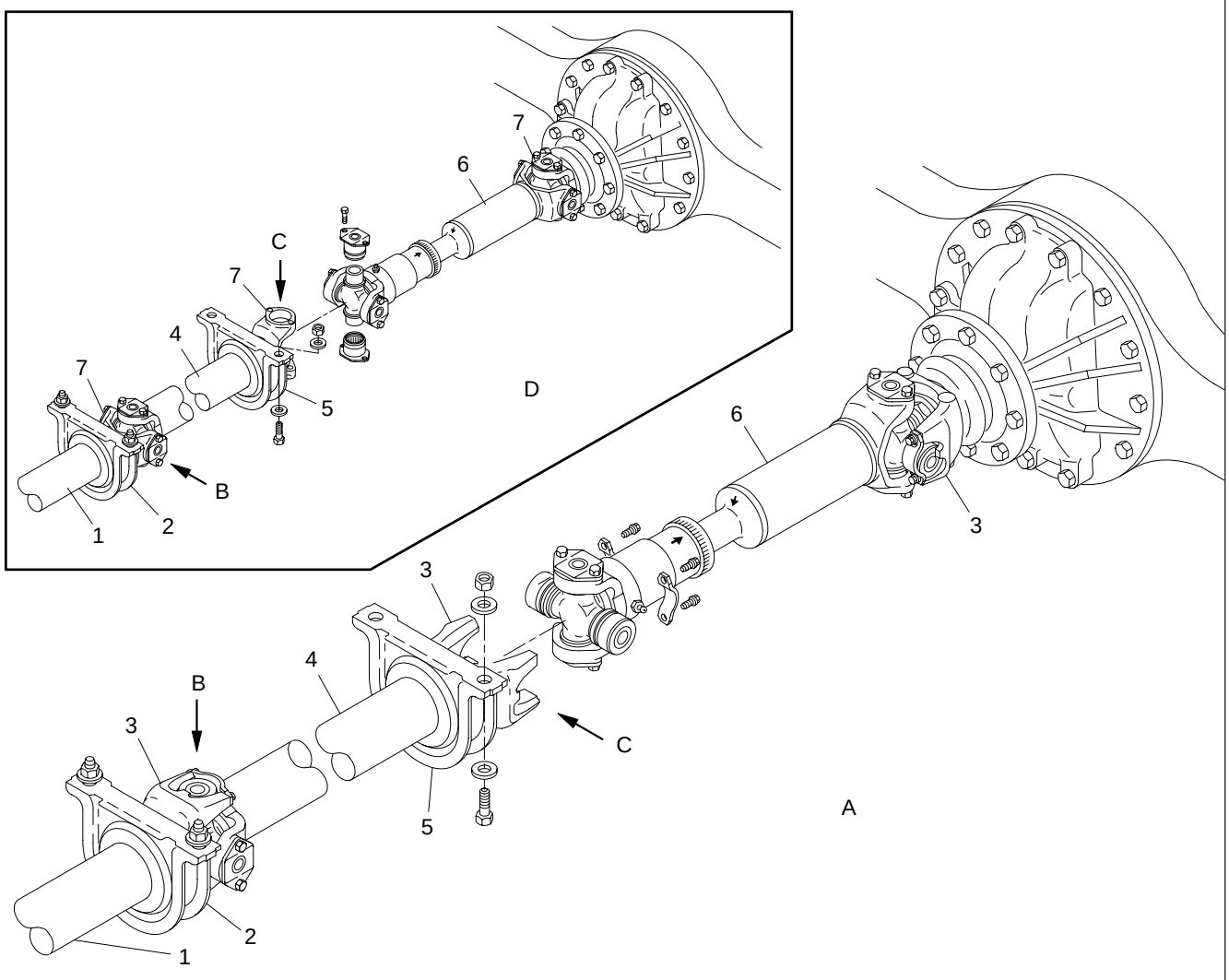
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NOTE: Not all fasteners are shown.

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. 1, Removal/Installation of a No. 2 Driveshaft



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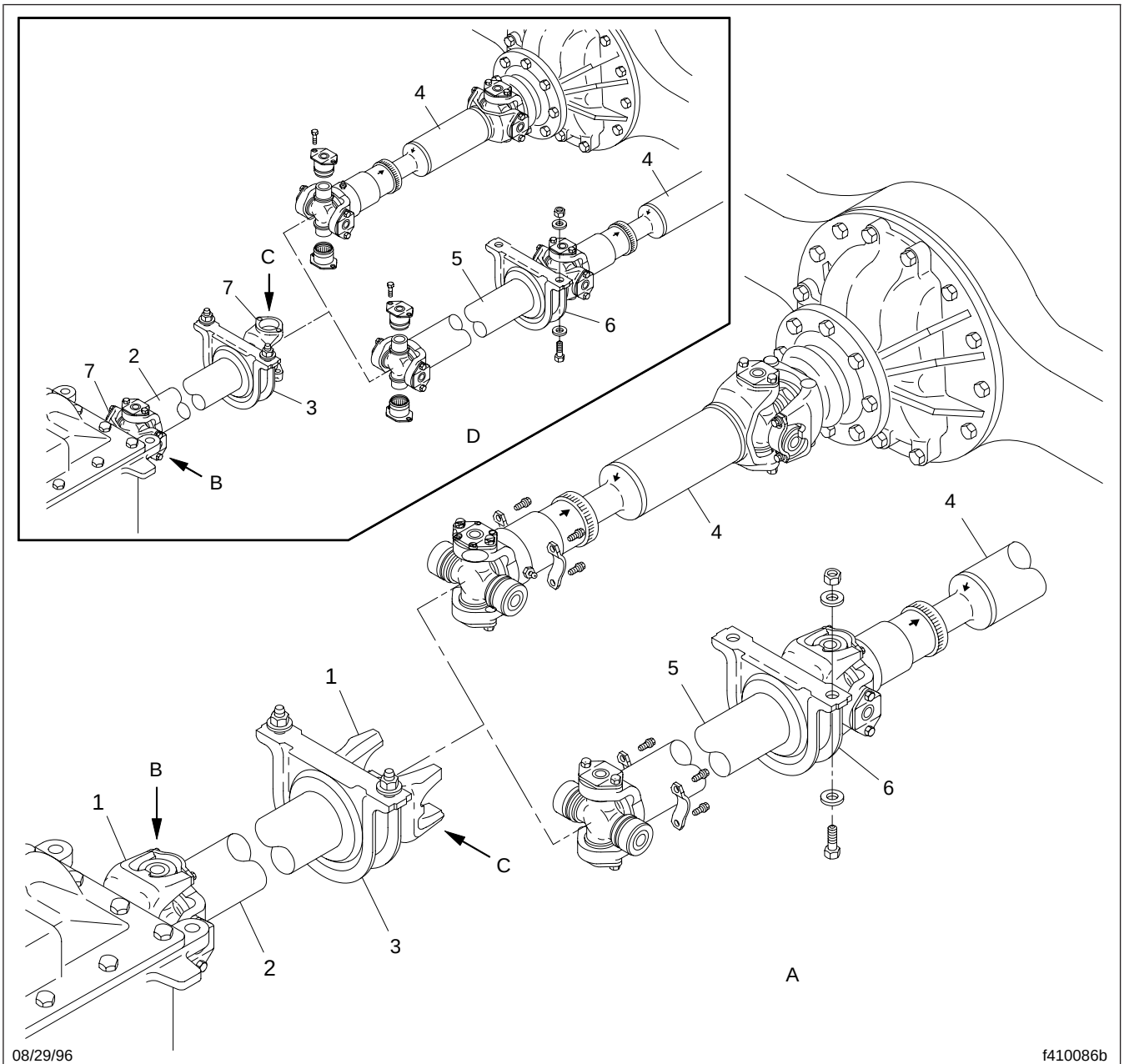
NOTE: Not all fasteners are shown.

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. 2, Removal/Installation of an Intermediate Coupling Shaft

Driveshaft Removal and Installation

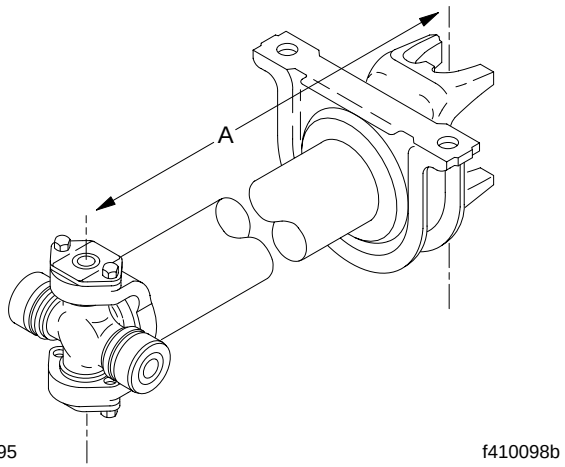


NOTE: Not all fasteners are shown.

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. 3, Removal/Installation of a Primary Coupling Shaft



A. Cross-hole centerlines of both yokes must be in alignment.

Fig. 4, U-Joint Phasing of a Coupling Shaft

If the no. 2 driveshaft was not removed, couple it to the primary coupling shaft end-yoke.

For a vehicle with two coupling shafts:

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.

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. 4**.

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 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. See **Fig. 2**.
4. 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 intermediate coupling shaft end-yoke.

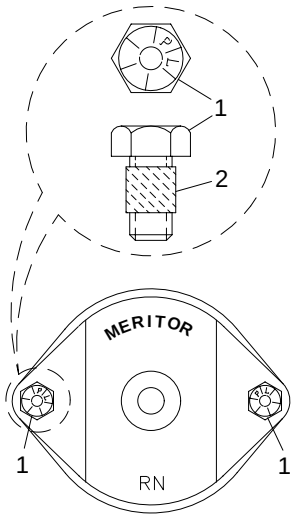
No. 2 Driveshaft Installation

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. 4**.

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.
5. Couple the no. 2 driveshaft to the axle input-shaft end-yoke. See **Fig. 1**.

U-Joint Removal

1. Remove the driveshaft from the vehicle. See **Subject 110**.
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

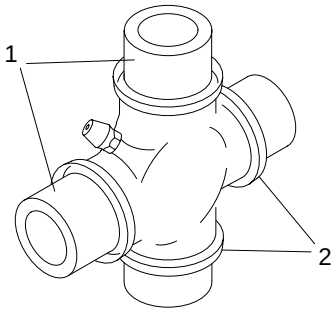
Fig. 1, Meritor U-Joint Fasteners for Full-Round Yokes

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 a U-joint puller, remove both bearing cups from the yoke cross-holes. See **Fig. 3**. Remove the cross from the yoke.

Slip-Joint Disassembly

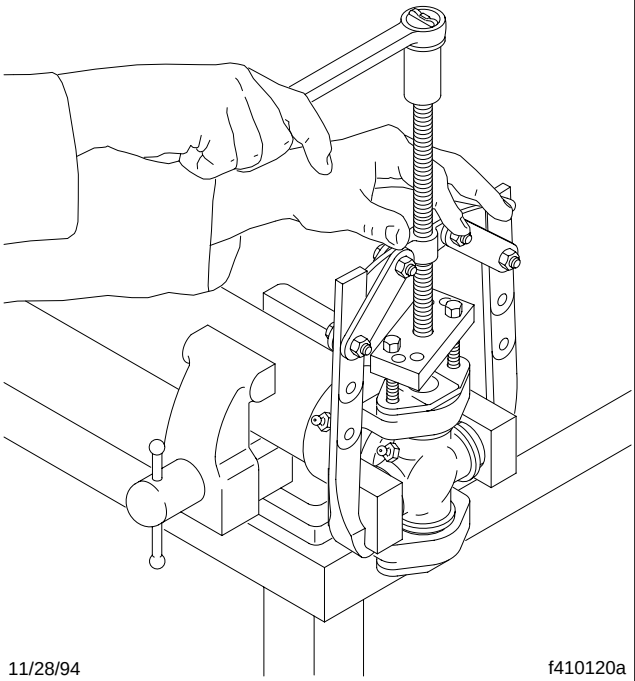
1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 4**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 5**. This will ensure proper alignment of the slip-joint components when the driveshaft is assembled.



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1. Trunnions 2. Slingers

Fig. 2, U-Joint Cross



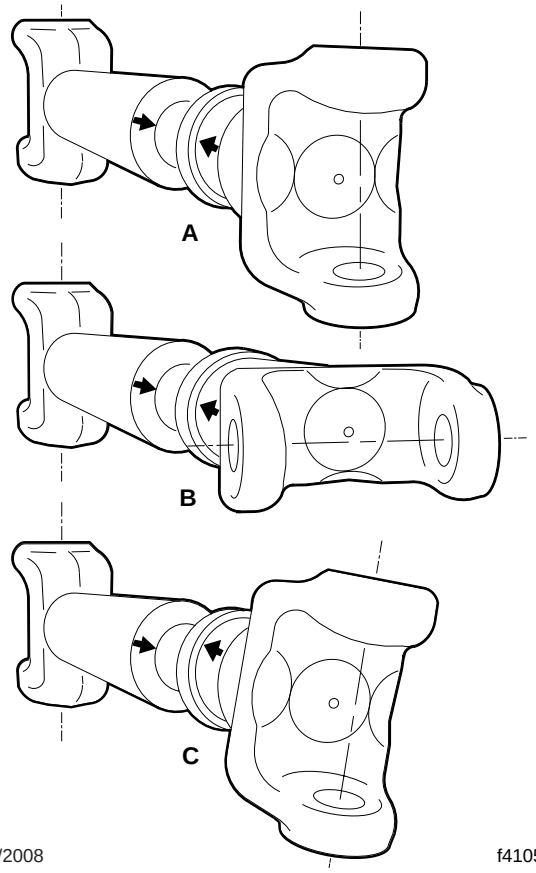
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Fig. 3, Removing a Bearing Cup From a Full-Round Yoke

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. 6**.

Driveline Component Removal/Disassembly



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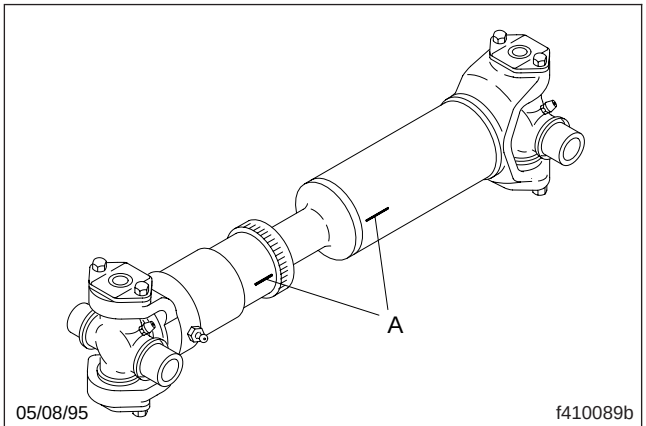
1. In Phase (parallel phased)
2. In Phase (cross phased)
3. Out of Phase

Fig. 4, U-Joint Phasing

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 130**.

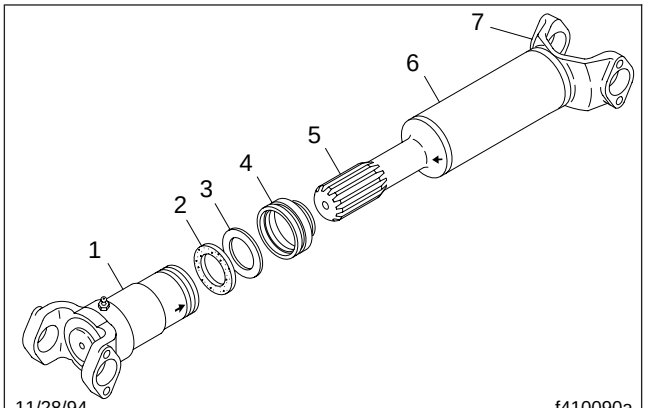
1. Uncouple the driveshaft from the end-yoke, or remove the driveshaft from the vehicle. See **Subject 100** or **Subject 110**.
2. Remove the end-yoke locknut. See **Fig. 7**.
3. Using a yoke puller, remove the end-yoke. See **Fig. 8**.



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A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks



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1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 6, Slip-Joint Components

Coupling Shaft End-Yoke and Midship Bearing Removal

1. Remove the coupling shaft from the vehicle; see **Subject 110**.
2. Clamp the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove the end-yoke (**Fig. 8**), then remove the midship bearing (**Fig. 9**), as follows.

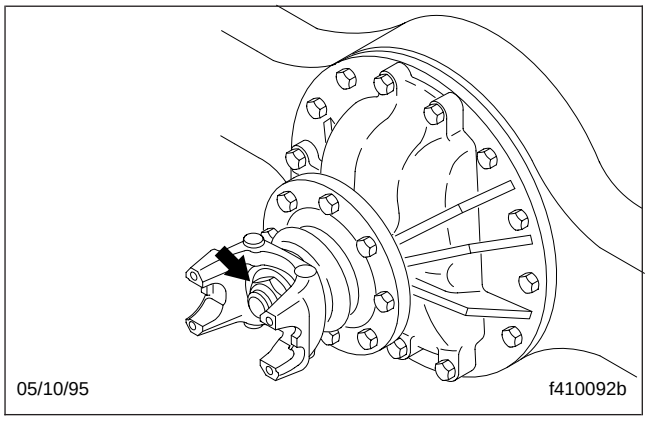


Fig. 7, Axle End-Yoke Locknut

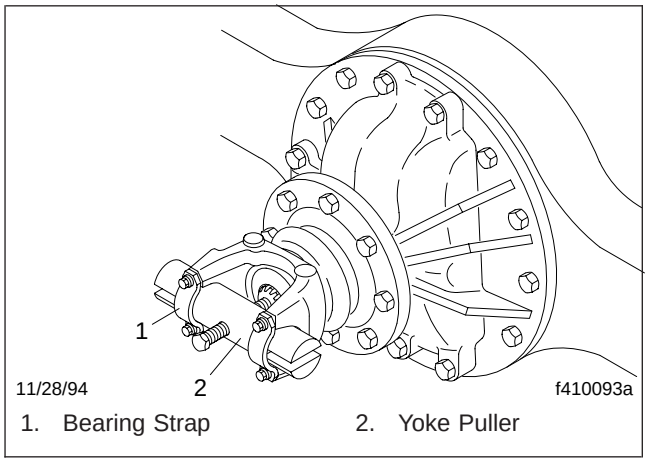


Fig. 8, Removing a Half-Round End-Yoke

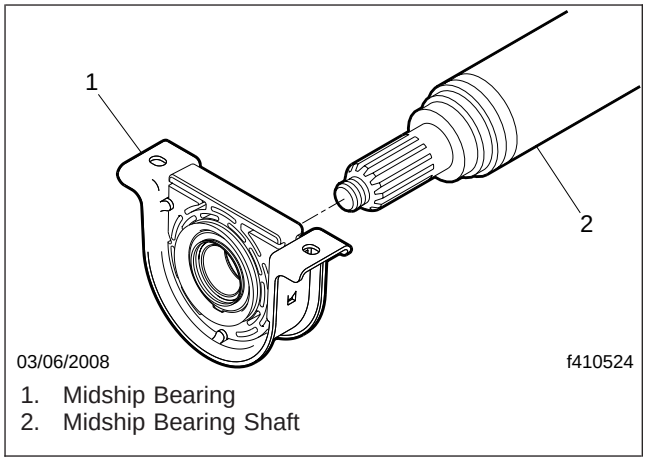


Fig. 9, Midship Bearing

3.1 Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks. See **Fig. 10**.

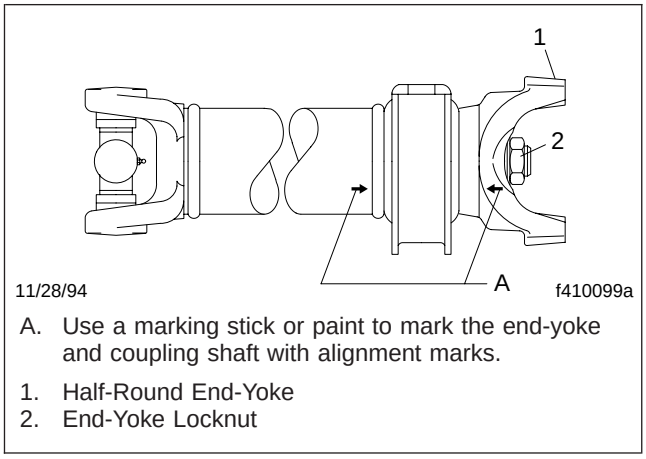


Fig. 10, Alignment Marks on a Coupling Shaft With an End-Yoke

3.2 Remove the coupling shaft end-yoke locknut.

3.3 Using a yoke puller, remove the end-yoke. See **Fig. 8** for a half-round end-yoke.

3.4 Use a hammer and a brass drift to remove the midship bearing. See **Fig. 9**.

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), and Tube-Yoke Replacement," in **Subject 140**. 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 140**. Remove any burrs or rough spots using fine emery cloth.

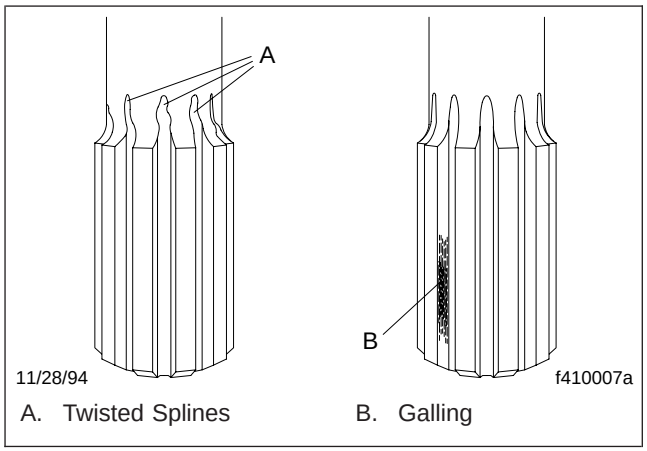


Fig. 1, Damaged Slip-Joint Splines

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**.

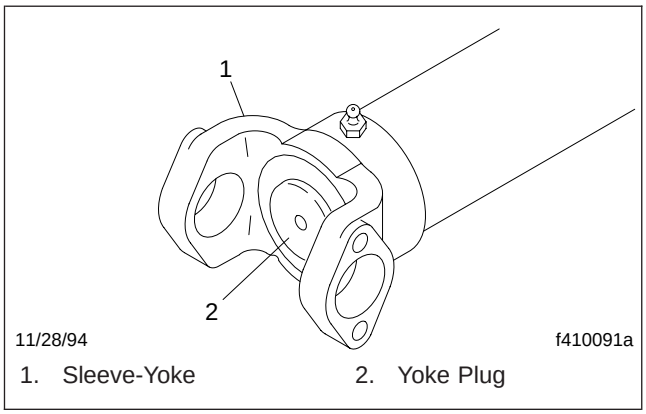


Fig. 2, Sleeve-Yoke Plug

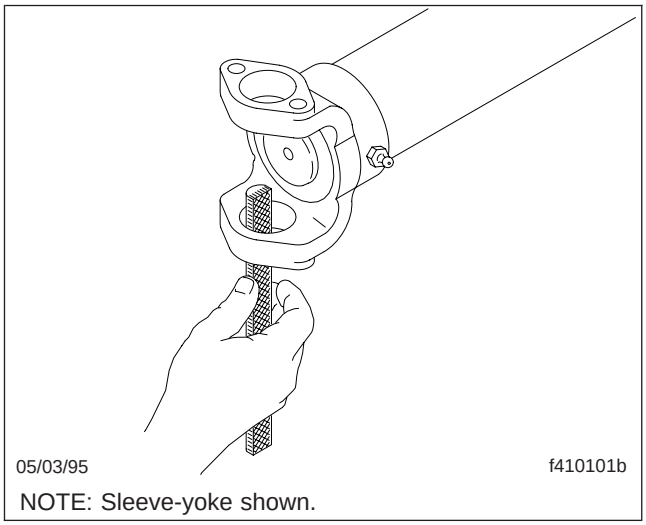


Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

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

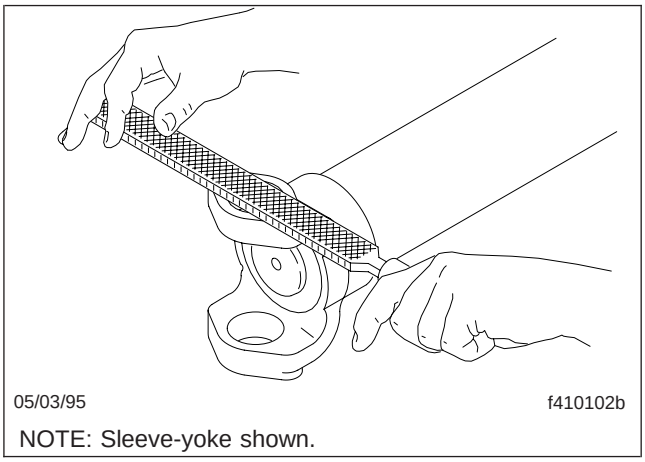


Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug

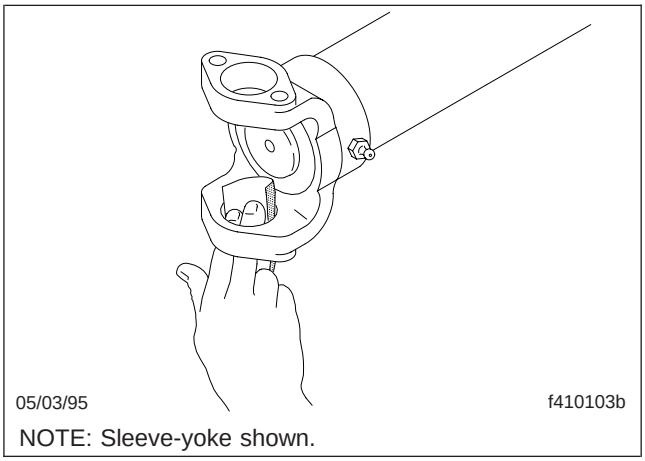


Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

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. 6**.

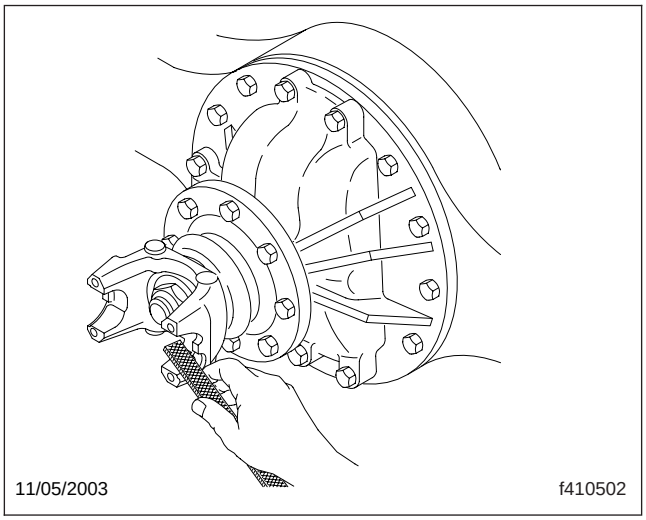


Fig. 6, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See **Fig. 7**.

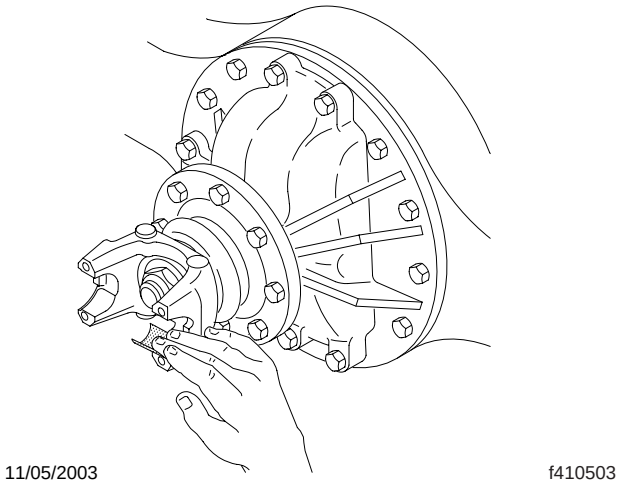
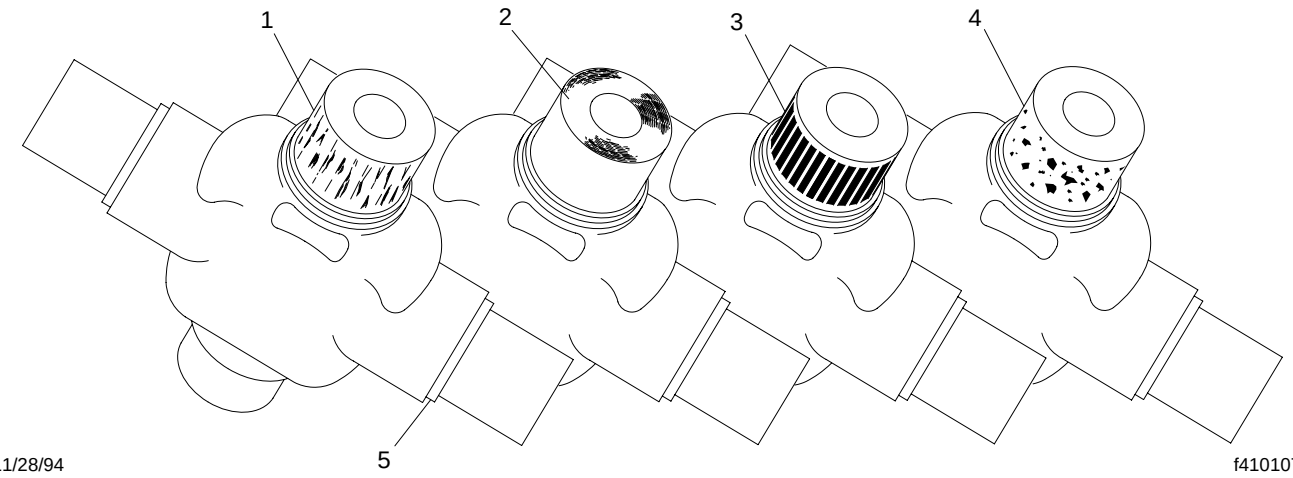


Fig. 7, Smoothing a Half-Round End-Yoke Cross-Hole

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

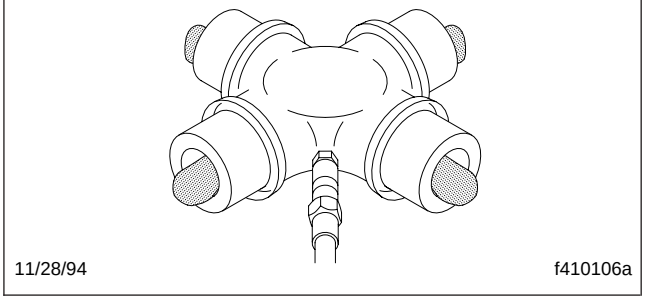
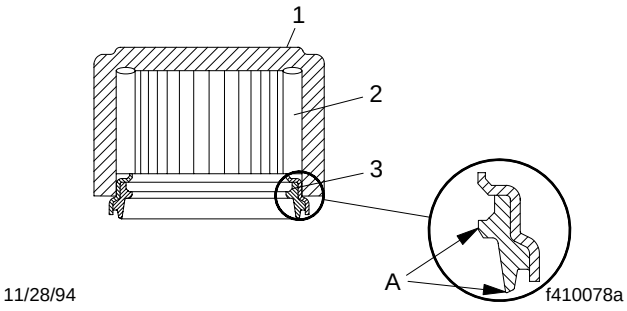


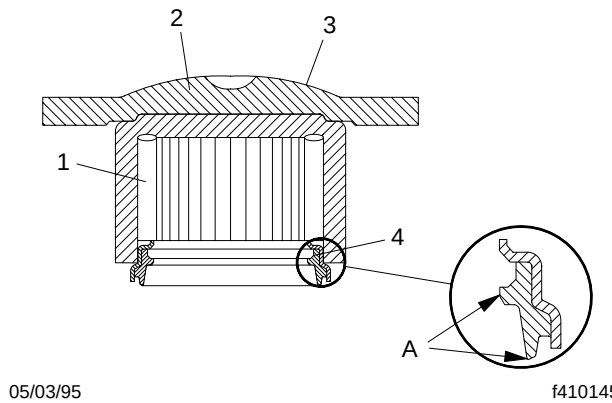
Fig. 9, Forcing Out Old Lubricant From a U-Joint Cross



A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

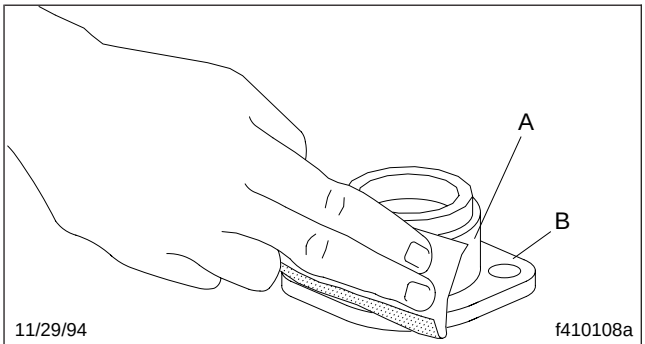
Fig. 10, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

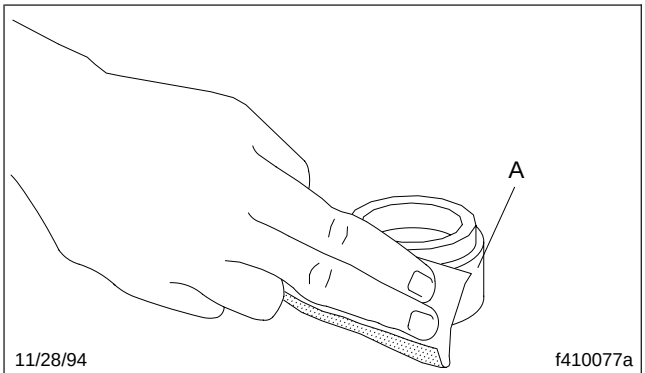
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing Cup
4. Bearing-Cup Seal

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



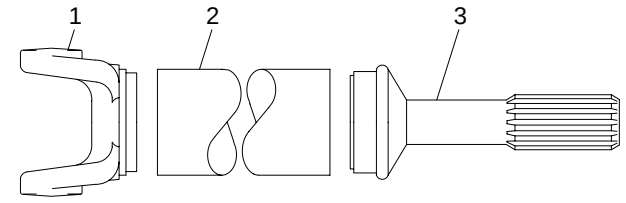
A. Use fine emery cloth on this surface.

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, the driveshaft must be chucked in a lathe, so the welds can be removed. See **Fig. 1**. 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

See **Fig. 2** for runout limits for a new (rebuilt) driveshaft. The runout limits are:

0.005 in (0.127 mm) T.I.R. (Total Indicator Reading) on the smooth portion of the stub shaft neck;

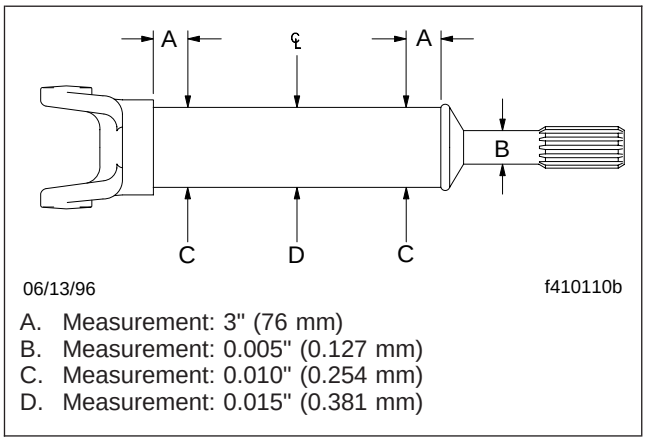
0.010 in (0.254 mm) T.I.R. on the tube 3 in (76 mm) from the front and rear welds;

0.015 in (0.381 mm) T.I.R. at the center of the tube.

Balance the rebuilt driveshaft to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

Slip-Joint Replacement or Assembly

IMPORTANT: Parts for different series drivelines must not be intermixed. Incorrectly assembled

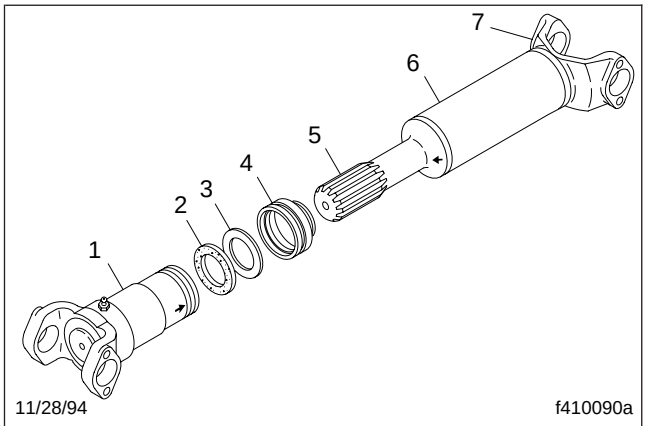


A. Measurement: 3" (76 mm)
B. Measurement: 0.005" (0.127 mm)
C. Measurement: 0.010" (0.254 mm)
D. Measurement: 0.015" (0.381 mm)

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.

1. Place the slip-joint dust cap, and (if so equipped) steel washer and cork seal, over the splined shaft. See **Fig. 3**.



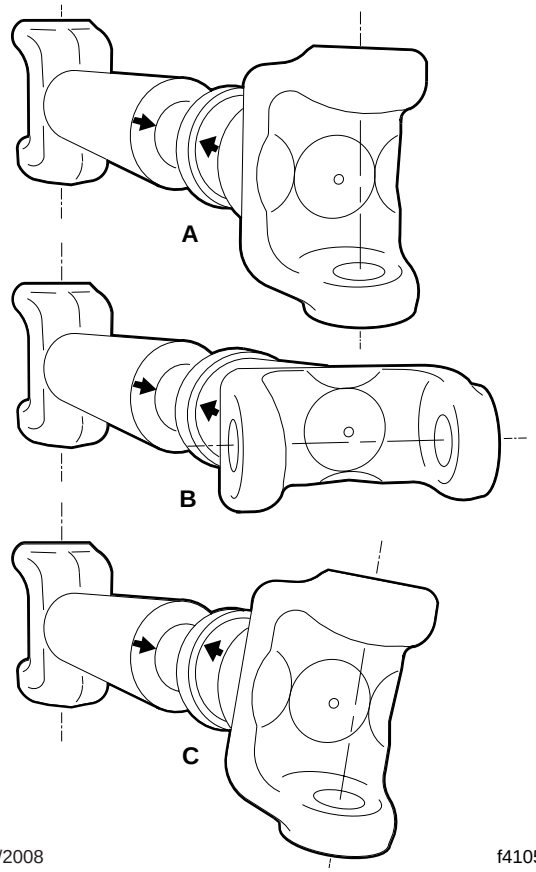
1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 3, Slip-Joint Components

2. Coat the splines of the shaft with multipurpose chassis grease.
3. Insert the splined shaft in the sleeve-yoke, so that the alignment marks are aligned, and the

Driveline Component Replacement or Installation/ Assembly

U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

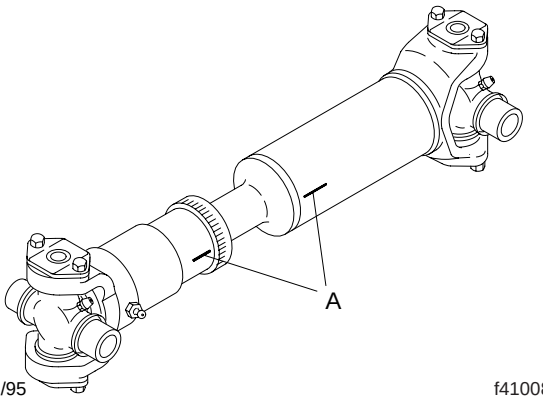


A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

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 one inch-ounce per ten pounds weight per end, at 3000 rpm.

4. Using a strap wrench, tighten 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.

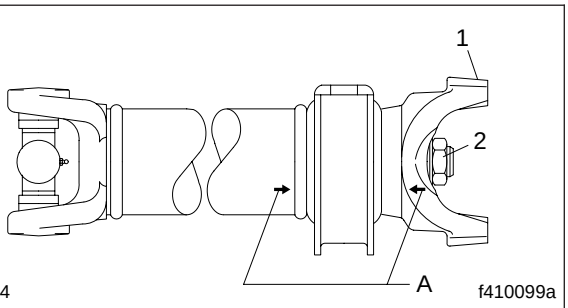
Midship Bearing and Coupling Shaft End-Yoke Replacement or Assembly

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, as follows. 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



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

yoke bores are aligned at both ends of the shaft. See **Fig. 6**.

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.

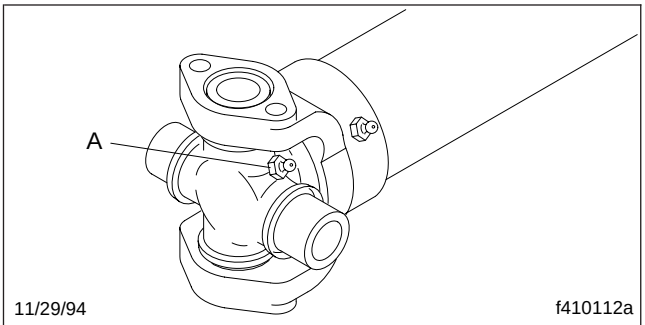
If the slip-joint has been disassembled, assemble the slip-joint before installing the U-joints.

1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. 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**.

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 130**.
4. Install the U-joint cross and bearing assemblies in the yoke, as follows.

4.1 Position the U-joint cross in the driveshaft yoke so one grease fitting points toward the driveshaft, and aligns with the grease fitting on the sleeve-yoke, if so equipped. See **Fig. 7**.



A. Install cross with grease fitting pointing toward driveshaft, and aligned with sleeve-yoke grease fitting.

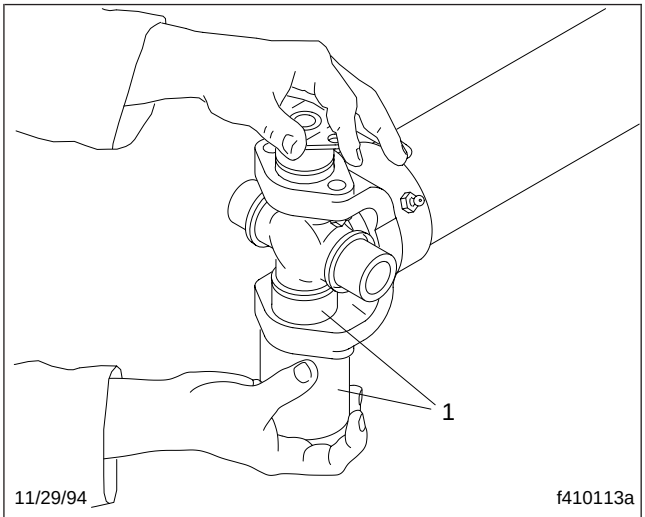
Fig. 7, U-Joint Grease Fitting Positioning

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 trunnion (journal) locator, 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**.

IMPORTANT: A 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

Driveline Component Replacement or Installation/ Assembly



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

Fig. 8, Using a U-Joint Trunnion Locator

rubber mallet; do not tap the outer edges of the plate. See **Fig. 9**.

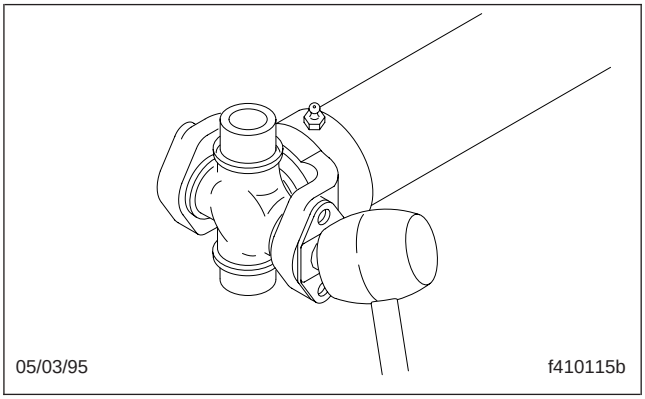
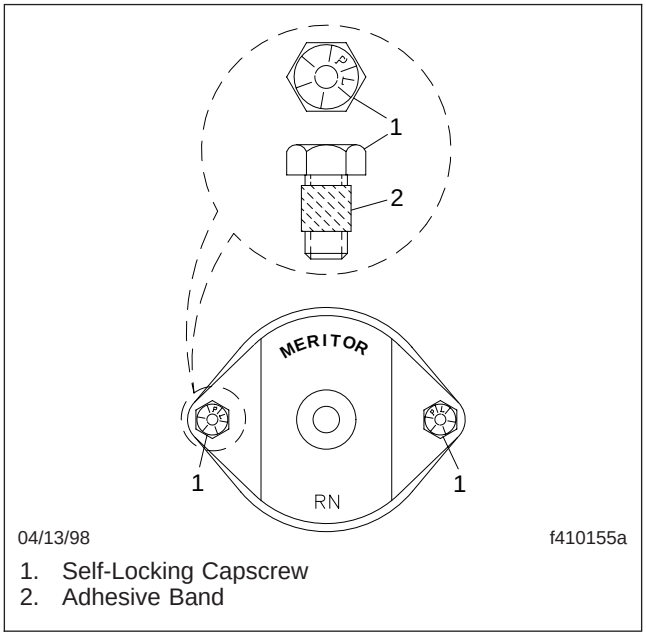


Fig. 9, Seating a U-Joint Bearing Cup In a Full-Round Yoke

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 yet tighten the capscrews to their final torque value.



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Meritor U-Joint Fasteners for Full-Round Yokes

⚠ 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.

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.

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. 11**.

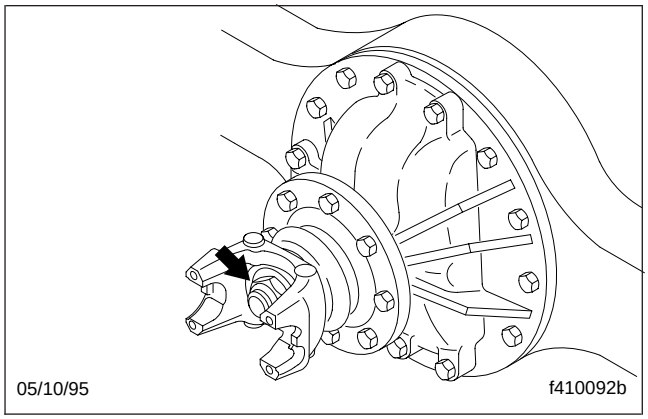


Fig. 11, Axle End-Yoke Locknut

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**.

Troubleshooting Procedure

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 axle pinion. 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 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**.

CAUTION

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.

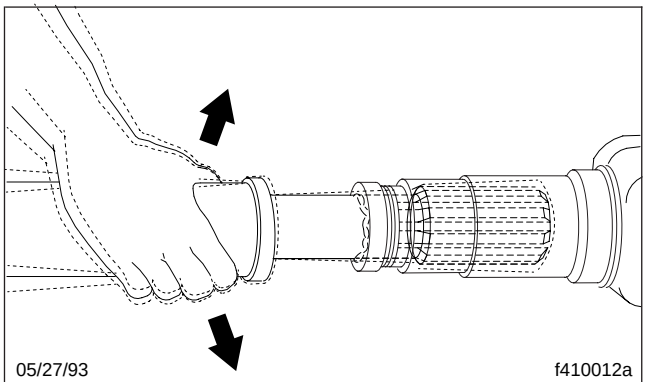
6. Check all U-joint assemblies and slip-joint splines, and midship bearings for wear, as follows.

   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, Checking for Slip-Joint Spline Wear

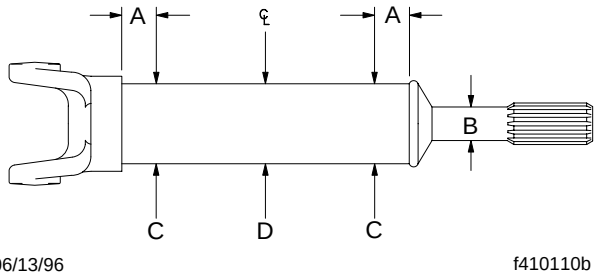
7. Check each driveshaft for an indication of missing balance weights. If any weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
8. Check each driveshaft for dents, bends, twists, or other damage.

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 in (0.38 mm) on the slip-joint seal surface of the splined shaft, 0.020 in (0.51 mm) on the tube 3 in (76 mm) from the front and the rear welds, and 0.025 in (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 140** for runout specifications for a *new* (or rebuilt) driveshaft.



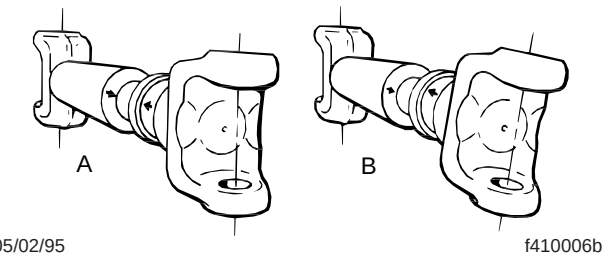
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A. Measurement: 3" (76 mm)
B. Measurement: 0.015" (0.38 mm)
C. Measurement: 0.020" (0.51 mm)
D. Measurement: 0.025" (0.635 mm)

Fig. 2, Runout Specifications for a Used Driveshaft

9. Check each driveline for proper U-joint phasing, as follows. See **Fig. 3**.

   9.1 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.



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A. In Phase B. Out of Phase

Fig. 3, U-Joint Phasing

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).

   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; then, 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.

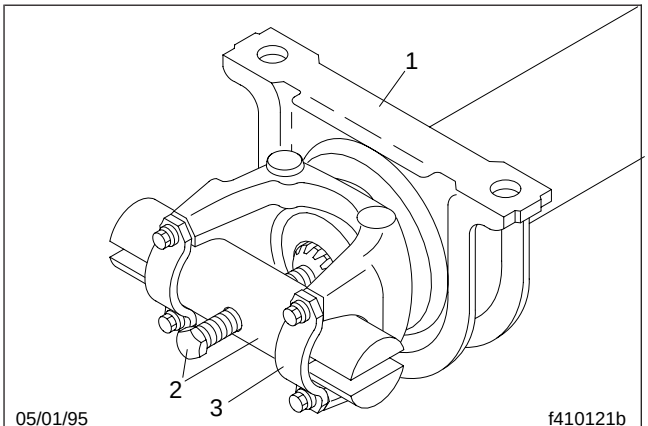
10. Check the torque on all of the end-yoke nuts in the drivetrain; see the applicable torque values in **Specifications 400**.

    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 140**.

    If the yoke is not worn, tighten the yoke nut to its torque value.

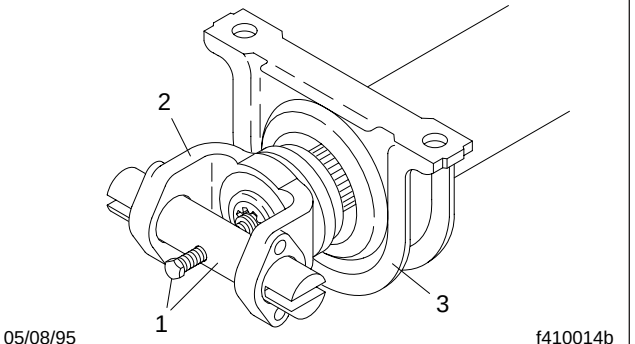
11. Have the no.2 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

12. If so equipped, balance the coupling shaft(s) to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.



1. Midship Bearing
2. Yoke Puller
3. Bearing Strap

Fig. 4, Removing a Half-Round End-Yoke From a Coupling Shaft



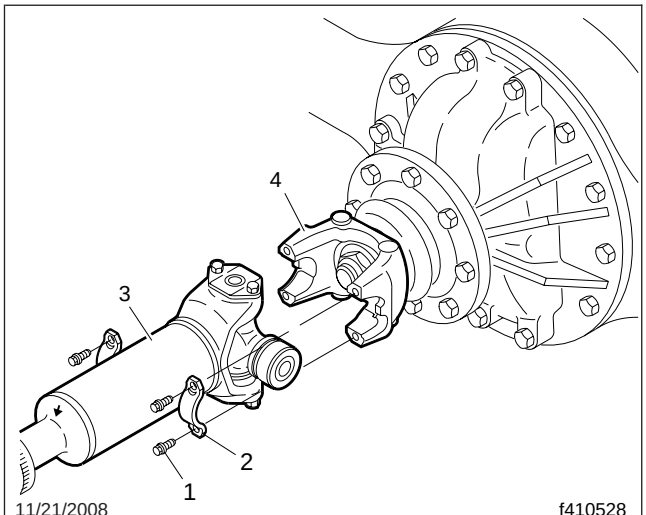
1. Yoke Puller
2. Full-Round Yoke
3. Midship Bearing

Fig. 5, Removing a Full-Round End-Yoke From a Coupling Shaft

Fastener Torques				
Description			**Size**	**Torque: lbf·ft (N·m)**
End-Yoke Nut				
Transmission Output Shaft	Fuller	FS 4205A, 4205B, 5205B, 6305A/B (all five-speeds); FS 5306A, 6306A (all six-speeds)	1-1/4–18	300–350 (405–475)
	Allison	MD Series, MD3060P	2–16	600–800 (815–1085)
	Allison	AT542/545, MT643	1/2–20	102–121 (138–164)
Midship Bearing	Spicer	SPL90, 1610, 1710	1-1/4–18	475–525 (645–710)
U-Joint Capscrew				
Bearing Strap (for half-round end-yoke)	All Brands	—	3/8-inch	45–60 (61–81)
		—	1/2-inch	115–135 (156–183)
Bearing Cap (for full-round yoke)	Spicer/ Meritor	1610, 16N	5/16–24	26–35 (35–48)
		1710, 17N	3/8–24	38–48 (52–65)

Table 1, Fastener Torques

NOTE: When installing a driveshaft with a half-round U-joint, as shown in **Fig. 1**, tighten the bearing-strap capscrews in increments of 20 lbf·ft (27 N·m), following the tightening sequence shown in **Fig. 2**.



1. Bearing-Strap Capscrew
2. Bearing Strap, Half-Round U-Joint
3. Driveshaft
4. Half-Round Yoke

Fig. 1, Half-Round U-Joint Installation

Special Tools

End-Yoke/Flange-Yoke Puller

For removing end-yokes and flange-yokes from transmission output shafts, and removing end-yokes from coupling shafts and rear-axle input and output shafts, order one of the following:

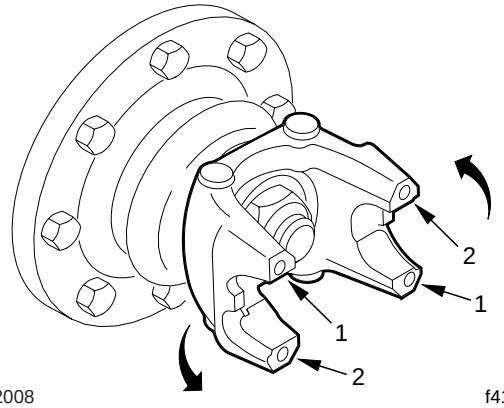
- End-Yoke Puller J 7804–01

Kent-Moore Tool Division
29784 Little Mack
Roseville, MI 48066–2298
1–800–328–6657; Telex: 244040 KMTR UR
FAX: (313) 774–9870

- Yoke and Flange Remover SP–450

G & W Tool Company
907 South Dewey
Wagoner, OK 74467

Specifications



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Tighten the capscrews in a counterclockwise sequence, starting with either number 1 position.

Fig. 2, Tightening Sequence

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 connections, 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 with a parallel arrangement. See **Fig. 1**.

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, 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. 2**.

NOTE: Some driveshafts are designed and phased with their end yokes clocked 90 degrees from each other. This is referred to as cross phasing.

To ensure that the U-joints turn in phase, the sleeve-yoke and splined shaft of driveshaft slip-joints should be marked for assembly reference before disassembly.

Driveline Balance

After manufacture, each driveline yoke is statically balanced. After assembly of the slip-joint, the driveshaft is checked for out-of-roundness, and straightened as necessary; then the 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 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.

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 driveshaft.

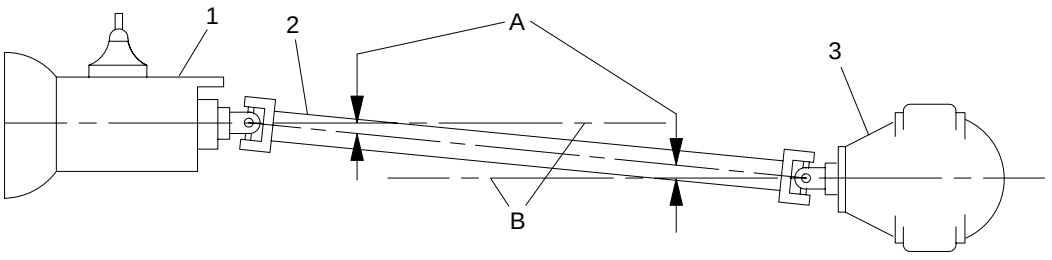
Every U-joint has a maximum working angle, determined by the design and size of its cross assembly and yokes. Exceeding the maximum working angle can cause rapid U-joint wear, or in severe cases, destruction of the U-joint. For smooth operation and long drivetrain component life, the U-joint working angles must be kept small and approximately equal.

The U-joint working angles may be made approximately equal with a parallel arrangement. See **Fig. 1**. The parallel arrangement consists of installing the drivetrain components so that of the input and output centerlines are approximately parallel.

All single-drive vehicles use the parallel arrangement.

The simplest drivetrain configuration consists of a single short driveline connecting a main transmission to a single-drive axle, in a parallel arrangement. The

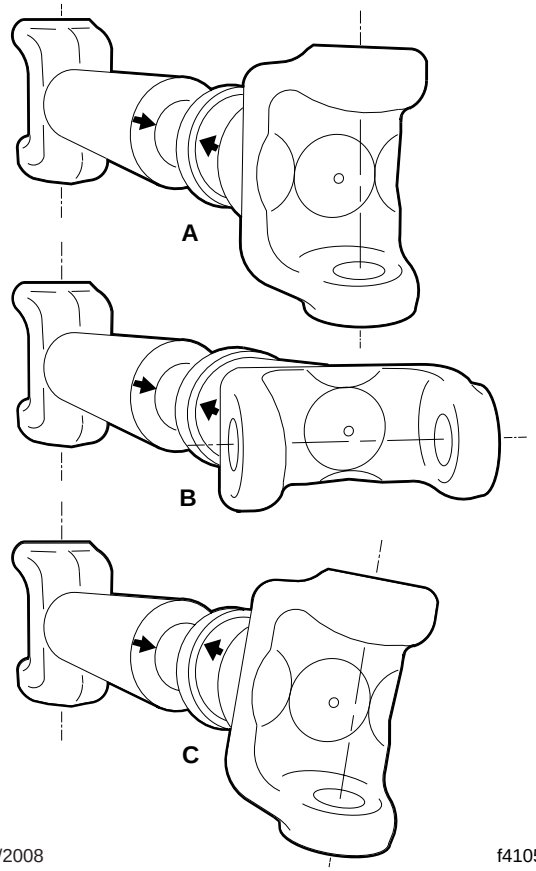
General Information



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A. Equal U-Joint Working Angles
B. Parallel Centerlines
1. Transmission
2. Driveshaft
3. Rear Axle

Fig. 1, Parallel Arrangement for Single-Drive Vehicles



05/21/2008 f410525

A. In Phase (parallel phased)
B. In Phase (cross phased)
C. Out of Phase

Fig. 2, Driveline U-Joint Phasing

parallel arrangement always used on single-drive vehicles is shown in **Fig. 1**.

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.

Engine and Pinion Angle Measurement

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), 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, measure the engine angle, driveshaft angles, and pinion angles. See **Fig. 1**. Read all angles to the nearest one-tenth of a degree (6 minutes).

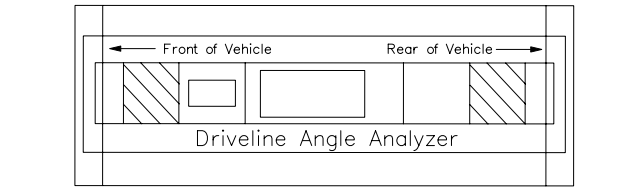
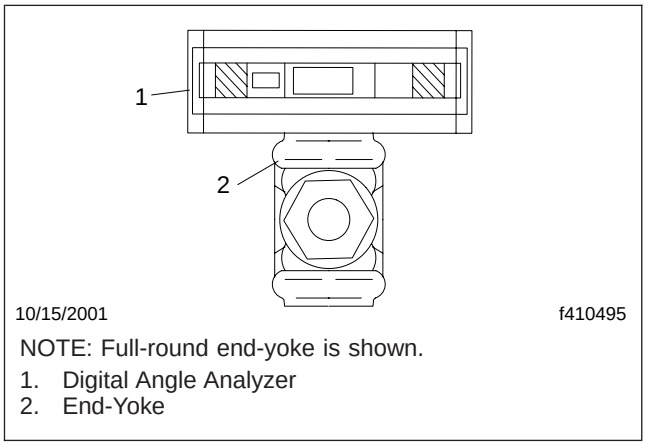


Fig. 1, Digital Angle Analyzer

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 and axle end-yoke angles can be measured at either the top or bottom lug of the end-yoke being checked.
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.

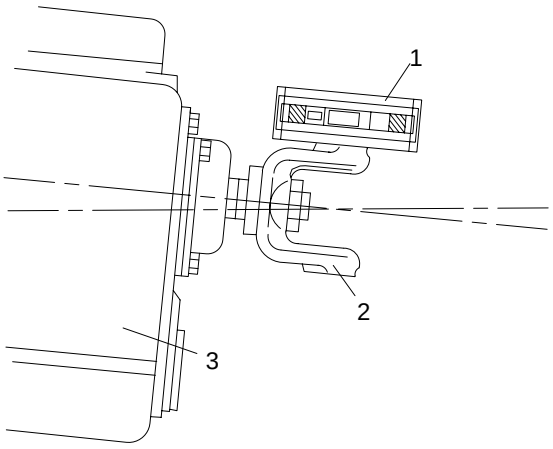
1. Digital Angle Analyzer
2. End-Yoke

Fig. 2, Horizontal Positioning of Yoke Lug Machined Surface

NOTE: To turn the driveshaft, raise one side of the rear axle until the tires are off the ground. Place a safety stand under the axle. With the transmission in neutral, turn the tire to move the driveshaft.

6. Adjust the DAA to read 0 degrees. 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 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.
7. Without changing the position of the end-yoke, turn the DAA until it is parallel to the frame centerline. See **Fig. 3**. 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.

Engine and Pinion Angle Measurement



10/15/2001 f410487

NOTE: Full-round end-yoke is shown.

1. Digital Angle Analyzer
2. End-Yoke
3. Transmission

Fig. 3, Measuring Pinion Angles

Driveline Angle Checking

NOTE: Driveline suppliers have made angle checking software availble. Contact your local driveline representative or check the manufacturer's website for the software.

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 **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 that ride height is correct. See **Group 32**.

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 or 5 degrees ±1/2 degree. For instructions, see **Subject 100**.

   Engines manufactured from January 1, 2007 must be 4 degrees ±1/2 degree.

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. Measure the rear axle pinion angle at the back of the 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.

3. Compare the measured angle with that shown in **Specifications 400**. The measured rear-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.

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.

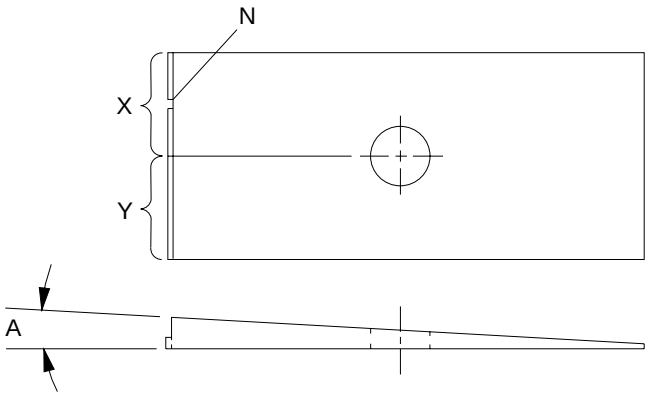
Single-Drive-Axle Suspensions (All): Adjust rear axle pinion angle to 3 or 5 degrees ±1 degree depending on vehicle specification in modules 420 and 431.

Suspension Ride Heights/Planing Angles		
Description	**Ride Height***	**Available Planing Angles**
16k M2 52" Vari-Rate Spring w/ RS 13/15-120 axles	270 mm (unladen)	3 Degrees, or 5 Degrees
16k M2 52" Vari-Rate Spring w/ RS 17-145 axles	285 mm (unladen)	
18k M2 52" Vari-Rate Spring w/ & w/o Helper	300 mm (unladen)	
21k M2 52" Vari-Rate Spring w/ & w/o Helper	310 mm (unladen)	
23k M2 52" Vari-Rate Spring 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)	
19k 52" Flat leaf spring w/radius leaf & w/o helper	275 mm (unladen)	
21k 52" Flat leaf spring w/radius leaf & w/o helper	285 mm (unladen)	
23k 52" Flat leaf spring w/radius leaf & w/o helper	285 mm (unladen)	

* Ride height taken from the bottom bolt of the forward suspension hanger.

Table 1, Suspension Ride Heights/Planing Angles

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 2, Shim Notch Decoding

General Description

Pneumatic-brake-equipped S2 Chassis use the Meritor WABCO E-Version Antilock Braking System (ABS) with a frame-mounted electronic control unit (ECU).

The ABS is an electronic wheel speed monitoring and control system that works with the standard air brakes. It passively monitors vehicle wheel speed at all times, then controls braking force during emergency stops. As a result, the driver has full control of braking until the ECU senses that a wheel is about to skid, when the ABS will ease braking only on the wheels that are threatening to lock. By controlling individual wheel braking, the ABS gives drivers more vehicle control when wheels might otherwise lock up and cause a skid or loss of control.

The ABS reads individual wheel speed with signal-generating sensors activated by tone rings located on the hubs of the monitored road wheels. See **Fig. 1**. The sensors transmit vehicle wheel speed information to the ECU. The control unit follows programmed specifications, and signals the appropriate modulator valves to regulate air pressure in the brake chambers. This prevents wheel lockup and enhances steering control during emergency braking situations. During normal braking conditions, only the standard air brake system is in effect.

NOTE: Tone rings are also referred to as tooth wheels, ABS exciters, ABS rings, and variations of those names. They all refer to toothed or slotted rings turning with the wheel hubs of ABS-equipped vehicles. Stationary ABS sensors count the passing teeth or slots to tell the ECU how fast that wheel is turning.

S2 Chassis have the standard four-channel ABS with four wheel speed sensors and four modulator valves (4S/4M).

If the vehicle is equipped with Automatic Traction Control (ATC), wheel spin is controlled during reduced-traction start and acceleration.

Principles of Operation

The ABS is controlled by the ECU, mounted inside the left frame rail toward the rear of the vehicle. The ECU is a computer that receives, processes, and compares wheel speed information from each wheel sensor. During emergency brake applications or braking on slick surfaces, the control unit regulates the braking force applied to each wheel by sending control signals to the individual wheel modulator valves.

Major components of the ABS are:

- Wheel speed sensors
- An electronic control unit (ECU)
- Modulator valves (solenoid-controlled valves)
- Automatic Traction Control (ATC) valve (optional)
- ABS warning and wheel-spin indicator lamps

CAUTION

Before any electric welding on an ABS-equipped vehicle, disconnect the battery power, ground cables, and the electrical harness connectors at the ABS ECU. Electric currents produced during electric welding can damage various electronic components on the vehicle.

Wheel Speed Sensors

The wheel speed sensor assembly is a signal-generating device. The assembly includes a sensor (a coil wrapped around a magnet to generate an electrical field), a tone ring, and a sensor clip that holds the sensor in position near the tone ring. See **Fig. 1** and **Fig. 2**.

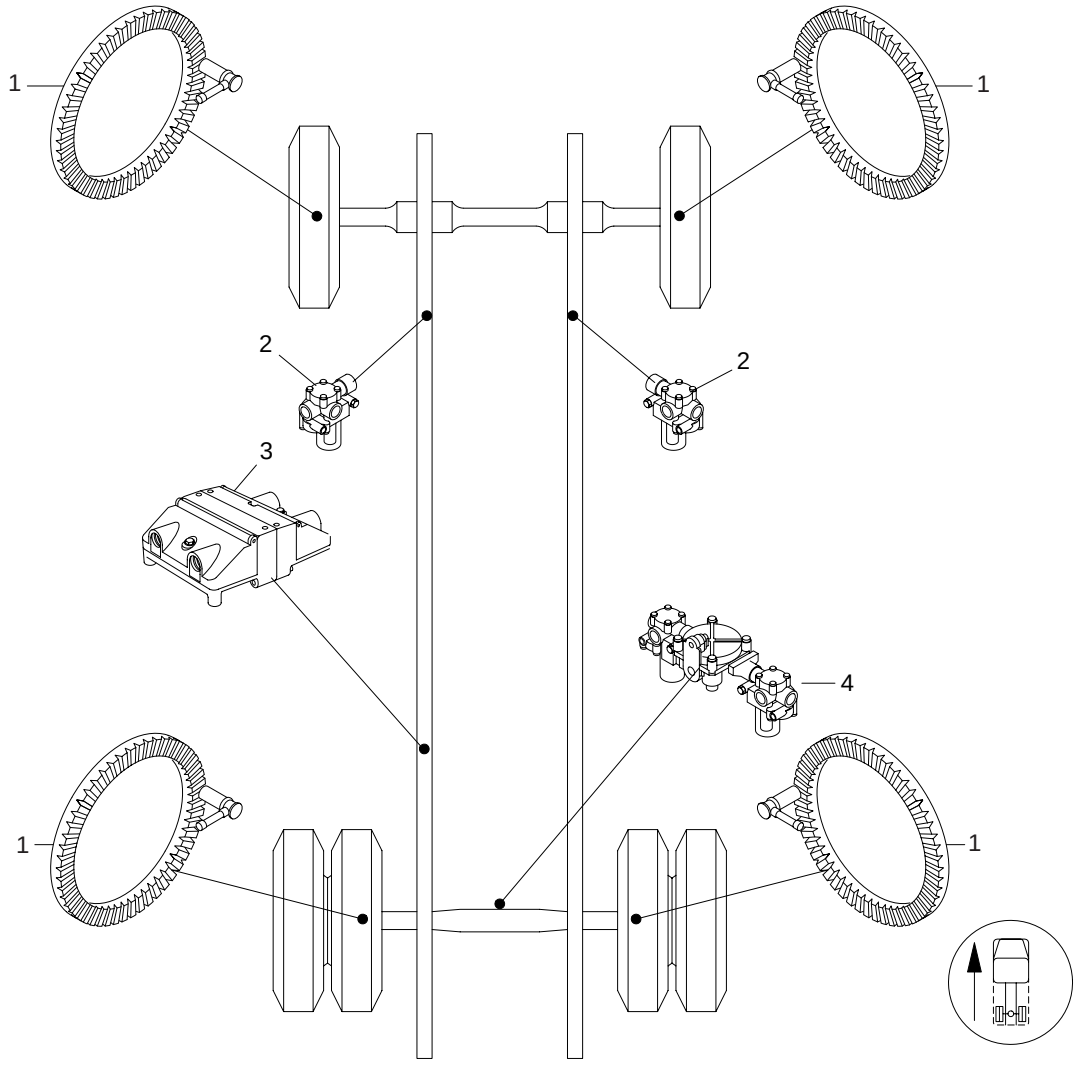
Each ABS-controlled wheel has a stationary wheel speed sensor assembly, mounted very close to, or touching, a tone ring mounted on the hub. When the wheel is rolling, the teeth or slots on the tone ring cause interruptions in the magnetic field created by the sensor. The interruptions create electrical pulses that are sent to the ECU which counts them to determine wheel speed.

Electronic Control Unit (ECU)

The ECU is mounted on the left-hand frame rail. See **Fig. 1** and **Fig. 3**.

The wheel speed sensors tell the ECU how fast each wheel is turning. The ECU compares those speeds to determine whether any wheel is beginning to skid. If the ECU senses that a wheel is beginning to skid, the wheel control circuit of the locking wheel or

General Information



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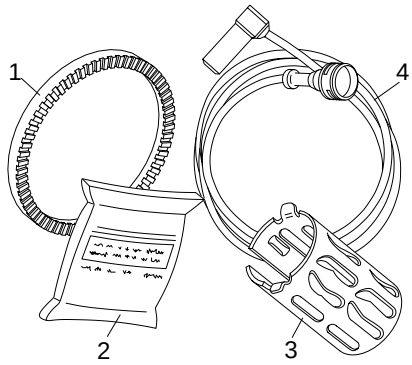
1. Tone Ring and Sensor
2. Front Modulator Valve Assembly
3. Electronic Control Unit (ECU)
4. Rear Modulator Valve Assembly

Fig. 1, ABS Component Location (4-channel, 4S/4M system)

wheels signals their modulator valve to release, hold, or reapply braking pressure.

The ECU also shuts off the engine brake and the exhaust brake, if they are installed, when it senses that a wheel is beginning to skid. It automatically re-activates the engine and exhaust brakes when there is no more danger of wheel skidding. The ABS does this by communicating with the engine ECM through the J1939 datalink.

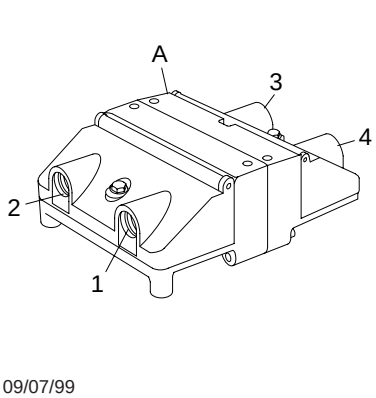
The ECU constantly monitors the wheel sensors, modulator valves, automatic traction control (ATC) valve (if the vehicle is so-equipped) and the electrical circuitry. After the ignition switch is turned on, the ABS warning lamp and the ATC wheel spin indicator



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1. Tone Ring
2. Lubricant
3. Sensor Spring Clip
4. Sensor

Fig. 2, Wheel Speed Sensor Components



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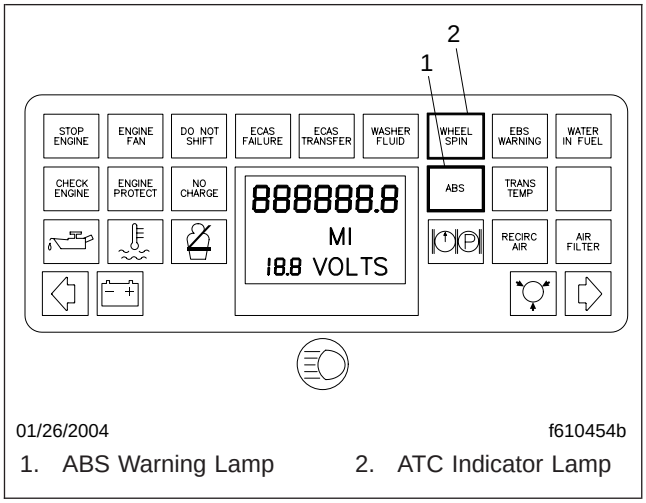
A. Frame-mounted ECU.
B. ECU connector pin locations.

1. X1 Connector (gray)
2. X2 Connector (black)
3. X3 Connector (green)
4. X4 Connector (brown—6S/4M, 6S/6M only)

Fig. 3, ECU Module, and Pin Locations in the Connector

lamp (WHEEL SPIN) on the dash illuminate for about 3 seconds. See **Fig. 4** for a typical instrument cluster.

During the self-test, the modulator valves and the ATC valve cycle on and off, creating clicking noises that may be heard inside the vehicle. These clicking noises are normal and do not indicate an ABS problem. If all of the ABS and ATC components are functioning correctly, the lamps go off after about 3 seconds.



01/26/2004 f610454b

1. ABS Warning Lamp
2. ATC Indicator Lamp

Fig. 4, ABS and ATC lamps (ICU Level 1 [ICU 3] shown)

On vehicles with automatic traction control, the ATC indicator lamp comes on if a drive wheel spins during acceleration. After the self-test is done, the lamp should not illuminate during normal operation.

IMPORTANT: If the ABS warning lamp and the ATC indicator lamp do not work as described above, locate and repair the problem immediately. See **Troubleshooting, 300** for fault diagnosis.

If the safety circuit senses a failure in any part of the ABS system while the vehicle is running, the ABS warning lamp comes on. Then, a fault code is stored in ECU memory. The ABS works on a diagonal (RF/LR and LF/RR). If a fault occurs, ABS is disabled in the diagonal in which the fault occurred. However, normal braking is still functional in both diagonals.

Fault codes can be retrieved using Meritor TOOLBOX software (the recommended software), ServiceLink, or the ICU if it is equipped with a mode/reset switch.

IMPORTANT: Do not open the ECU. Opening the ECU will void the warranty.

Modulator Valves

Modulator valves control the air pressure in each affected brake chamber during an ABS operation. Re-

sponding to the signal received from the ECU, modulator valves prevent wheel lockup by regulating brake pressure. During normal braking applications, the ABS system is inactive, and compressed air flows freely through the modulator valves to the brake chambers.

Each ABS-monitored wheel has its own modulator valve, mounted on the left or right frame rail near the wheel. The rear modulator valve assembly is mounted on a crossmember near the brake chambers. See **Fig. 1**. The rear 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.

The front modulator valves are mounted on the frame rails near the front wheels.

Each modulator valve assembly includes two solenoid control valves (one supply and one exhaust) and two diaphragms. See **Fig. 5**.

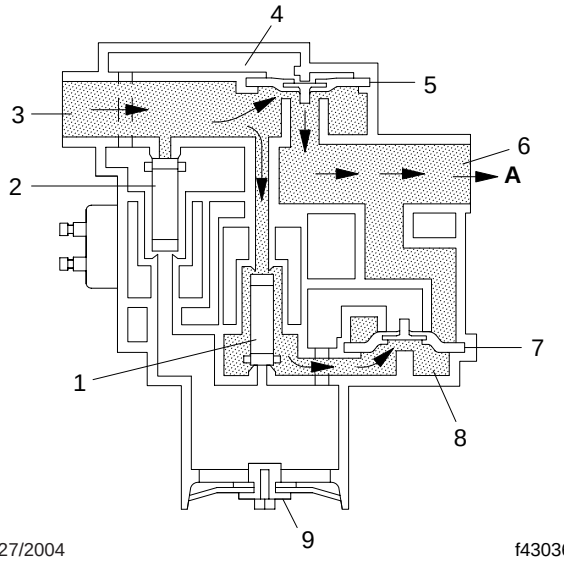
- The supply diaphragm opens and closes an air passage between the supply port and delivery port. It is controlled by the supply solenoid valve.
- The exhaust solenoid valve controls the exhaust diaphragm, which opens and closes an air passage between the exhaust port and the delivery port.

The ECU energizes different combinations of these solenoid valves to perform four functions: normal braking (without ABS control), ABS brake release, ABS brake hold, and normal brake reapplication.

Normal (Without Antilock) Brake Application—Supply

During normal braking, both solenoids in the ABS modulator valve are de-energized and inactive. See **Fig. 5**.

The supply diaphragm control chamber of the inlet valve is open to the atmosphere. Air pressure entering the supply port unseats the supply diaphragm. This opens the passage to the delivery port and allows air pressure to flow through the valve, into the brake chamber. Simultaneously, air pressure flows past the solenoid and puts pressure on the exhaust diaphragm. This pressure combines with spring force to keep the exhaust diaphragm seated and close the path from the delivery port to the exhaust port.



A. Air to Brake Chamber

1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

Fig. 5, Pressure Increase (without Antilock)

The ABS valve maintains this balanced (or pressure increase) position until a wheel starts to lock. Then the ECU activates one or both of the solenoids.

Normal (Without Antilock) Brake Application—Exhaust

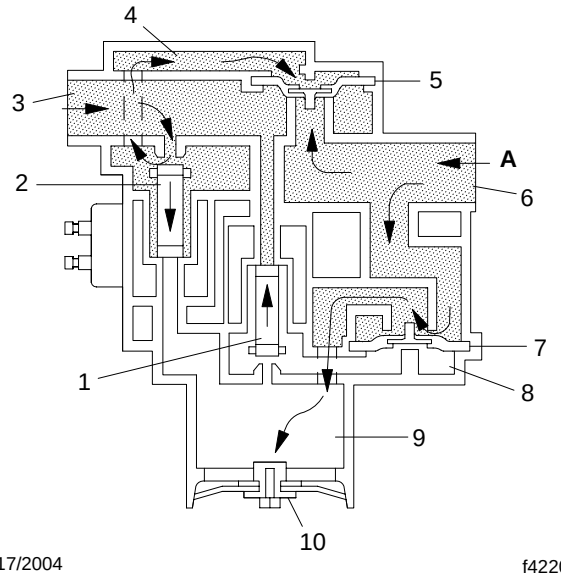
Air pressure at the supply port decreases when the brake pedal valve is released. This reverses the direction of airflow through the valve and exhausts air pressure from the brake chamber. Air can also be released from the ABS valve exhaust port during brake release.

Antilock Brake Control—Exhaust

When it senses a wheel is locking, the ECU energizes and opens both ABS valve solenoids. The energized supply solenoid allows air pressure to enter the supply diaphragm control chamber, where it holds the supply diaphragm in the seated position.

This stops any more air from entering the brake chamber. See **Fig. 6**.

Energizing the exhaust solenoid cuts off the supply of air pressure entering the exhaust diaphragm and exhausts that air to the atmosphere. Then, pressure from the brake chamber enters through the delivery port and unseats the exhaust diaphragm. This opens the passage between the delivery port and the exhaust port, which releases air pressure from the brake chamber.



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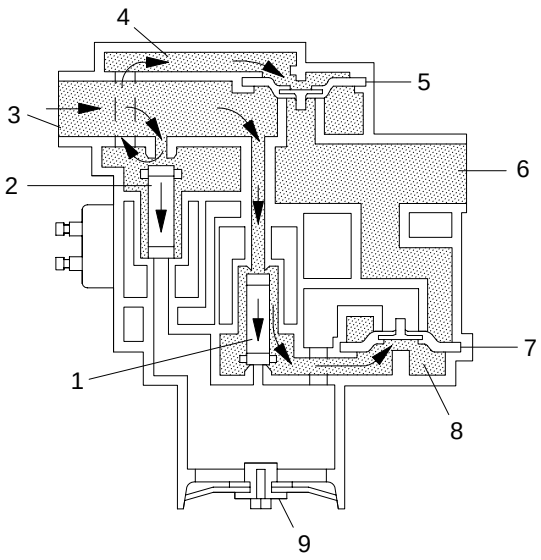
A. Air From Brake Chamber

1. Exhaust Solenoid (open)
2. Supply Solenoid (open)
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Port Diaphragm (unseated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Chamber
10. Exhaust Port

Fig. 6, Pressure Decrease (Antilock)

Antilock Brake Control—Hold

When enough air is released through the exhaust port to prevent the wheel from locking, the exhaust solenoid is de-energized. This seats the exhaust diaphragm and stops any more air leaving the brake chamber. The supply solenoid remains energized to prevent air pressure from passing through the ABS valve. The remaining air pressure in the brake chamber is held and remains constant. See **Fig. 7**.



02/27/2004 f422055

1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (seated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

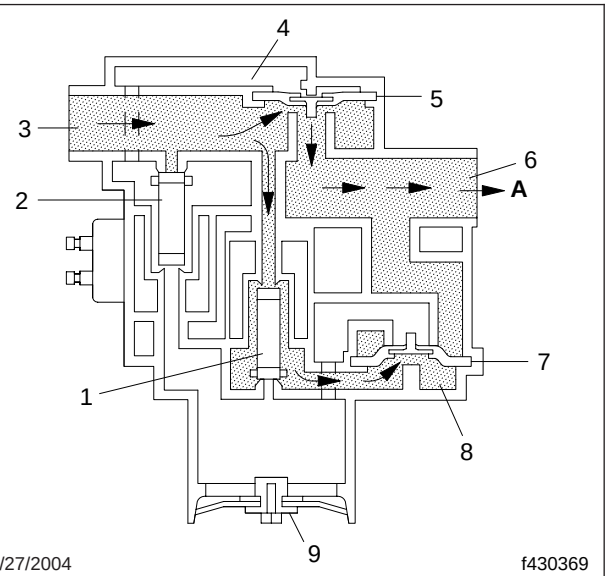
Fig. 7, Pressure Constant

Antilock Brake Control—Reapply

To achieve proper braking, the ECU monitors wheel speed and determines when to reapply brake pressure. When necessary, both ABS valve solenoids are de-energized, returning the system to the normal brake-application supply state. See **Fig. 8**.

The ECU cycles through the different valve states (pressure increase, pressure decrease, and pressure hold) very rapidly in order to control wheel speed. The Meritor WABCO ABS achieves efficient braking by independently controlling individual wheels.

General Information



A. Air To Brake Chamber

1. Exhaust Solenoid
2. Supply Solenoid
3. Supply Port
4. Supply Diaphragm Control Chamber
5. Supply Diaphragm (unseated)
6. Delivery Port
7. Exhaust Diaphragm (seated)
8. Exhaust Diaphragm Control Chamber
9. Exhaust Port

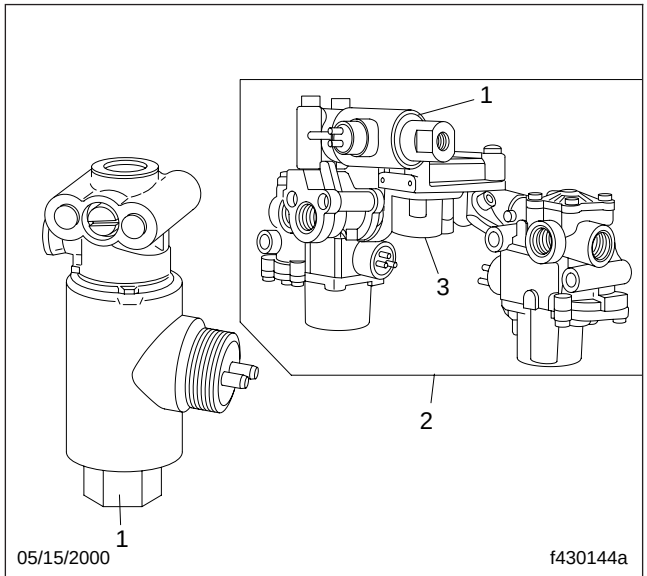
Fig. 8, Pressure Increase (Antilock)

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.

In ATC, the ECU compares the speeds of the drive wheels with the speed of the unpowered steer-axle wheels. 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 that has better traction, through differential braking.

The ATC valve controls only the brake chambers for the drive wheels. It is mounted on the service relay valve in the 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.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. Service Relay Valve

Fig. 9, ATC Valve

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.

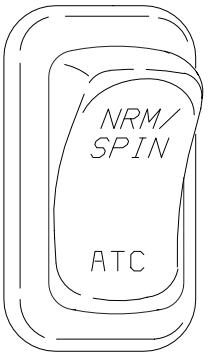
ABS Warning and ATC Indicator Lamps

The ABS warning lamp receives power whenever the ignition switch is turned on. The ground path for this indicator is through the ABS lamp relay, which is controlled by the ABS ECU. 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. 4**.

The warning lamp tells the driver that either the self-test is working, or an ABS system malfunction exists. After a wheel-sensor-related fault has been repaired, if the stored faults are cleared, the ABS warning lamp remains on until the vehicle is driven above a speed of 4 mph (6 km/h).

The ATC indicator lamp also receives power whenever the ignition switch is on. If the drive-axle wheels spin, the ATC indicator lamp turns on. The ABS ECU controls this lamp.

On vehicles equipped with automatic traction control, if the NORM/SPIN switch is activated, the ABS ECU allows more wheel spin than normal and the ATC indicator blinks continuously until the switch is moved back to the ATC default position. See **Fig. 10**.



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NOTE: This is a momentary rocker switch, shown in the ATC default position.

Fig. 10, ATC Switch for Soft Surfaces

If the ATC wheel-spin indicator lamp stays on during normal vehicle operation, it indicates a malfunction in the ATC system.

Tire Size

⚠ WARNING

The size of the tires installed at the factory is programmed into the ECU. Installing different size tires could result in reduced braking, leading to longer stopping distances, and could possibly lead to an accident with personal injury or property damage.

For proper ABS/ATC operation with the standard ECU, the front and rear tire sizes must be within 20 percent of each other. When the tire-size range is exceeded, system performance can be affected and the warning lamp may come on. Do not continue driving with the ABS lamp illuminated.

Call Meritor WABCO at 1-800-535-5560 for a consultation 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

⚠ 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.

1. Chock the tires. This will prevent accidental rolling of the vehicle when air is released from the brake system.
2. Don't disconnect pressurized hoses because they will whip as air escapes from the line. Drain the air system before disconnecting the air hoses.
3. 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.
4. 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.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

Front Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the rear tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the sensor bracket. See **Fig. 1**.

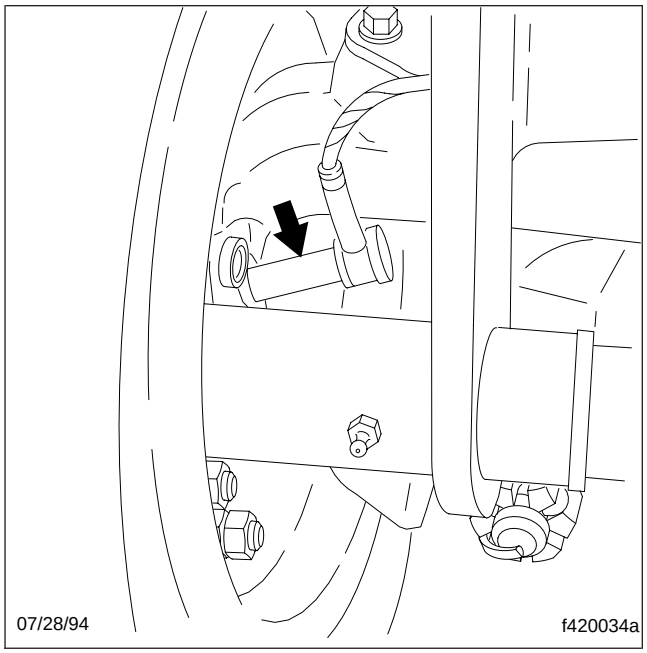


Fig. 1, Removing the Wheel Speed Sensor

3. Remove the sensor cable clip from the top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the sensor spring clip from the sensor bracket.
6. Connect the new sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Coat the sensor spring clip and the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L, or an equivalent.
9. Press the sensor spring clip into the sensor bracket at the brake spider hole until it stops. Make sure the spring clip tabs are on the inboard side of the vehicle.
10. Press the sensor into the sensor spring clip until it is stopped by the tone wheel.
11. Remove the chocks from the rear tires.

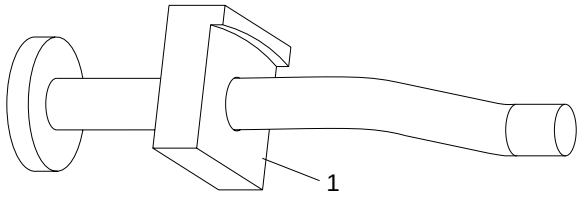
Rear Axle

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the front tires to prevent vehicle movement.
2. Twist and pull the sensor to remove it from the mounting block in the axle housing.
3. Remove the sensor spring clip.
4. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
5. Disconnect the sensor cable from the chassis harness.
6. Connect the new sensor cable to the chassis harness.
7. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
8. Press the sensor spring clip into the mounting block until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L, or an equivalent. Using your hand, push the sensor into the sensor spring clip until it is stopped by the tone wheel.
10. Remove the chocks from the front tires.

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.



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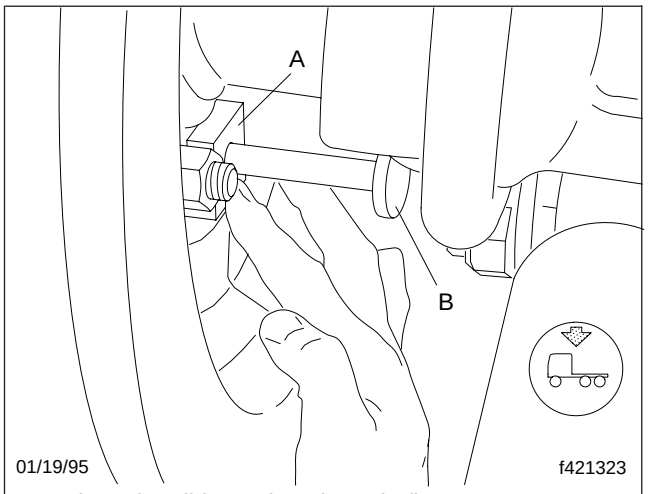
1. Adjustment Tool Slide

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 at 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**.
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.



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A. Place the slide against the axle flange.
B. Tap the handle with your hand.

Fig. 2, Positioning the Tool

7. Remove the chocks from the tires.

Modulator Valve Removal and Installation

Removal

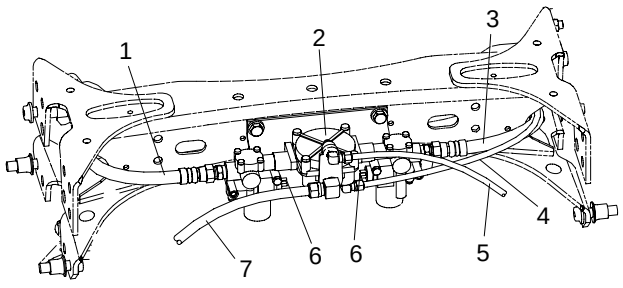
NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Section 54.00** for information on special terminals and connectors, and on ordering tools for them.

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

⚠ WARNING

Release all the compressed air from the air reservoirs before disconnecting any air hose. Disconnecting air hoses from the modulator valves without first releasing the pressure in the air reservoirs can cause the hoses to thrash around dangerously, possibly resulting in personal injury or property damage. Before starting work on the brake system, read Safety Precautions, 100 in this section.

2. Release the pressure from the air reservoirs.
3. Mark the electrical connectors for ease of installation. Disconnect the wiring from the modulator valve or modulator valve assembly. The rear assembly includes two modulator valves and a service relay valve. See **Fig. 1**.



05/15/2000 f430114a

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 modulator 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 so 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

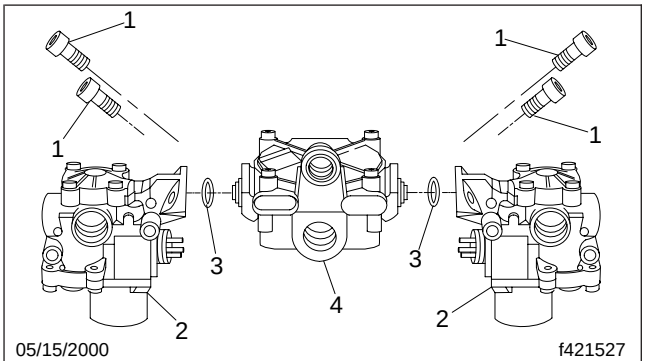
1. Apply the brakes, turn the ignition switch on, and wait for the ABS indicator light to come on.
2. Listen to the modulator valves cycle one by one, then together diagonally as follows:
   - 4-Channel valve cycle: 1, 2, 3, 4; then 1 and 2 together, followed by 3 and 4.
3. If a valve fails to cycle, 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.

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**.

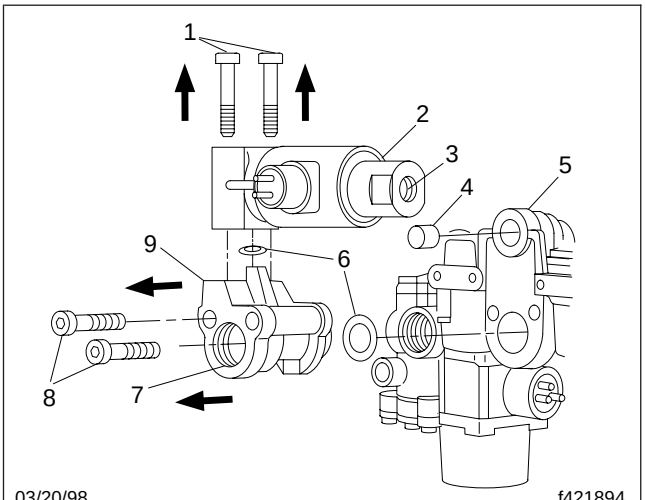


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1. Capscrew, Allen-Head, M8
2. Modulator Valve
3. O-Ring
4. Service Relay Valve

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.
   - 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.



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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

   - 3.3 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 (18 to 20 N·m).
   - 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.

Modulator Valve Disassembly and Assembly

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 (540 to 680 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**.

Tone Ring Installation

NOTE: Tone rings are also referred to as tooth wheels, ABS exciters, ABS rings, and variations of those names. They all refer to toothed or slotted rings on ABS-equipped vehicle wheel hubs, turning with the wheel. Stationary ABS sensors count the passing teeth or slots to tell the ECU how fast that wheel is turning.

IMPORTANT: Some ABS hubs do not have a tone ring installed or machined on the hub. On those hubs, the tone ring must be ordered separately and installed on the hub before installation of the hub onto the axle. Some tone rings are made of special material and require a specific procedure for proper installation. Doing the procedure incorrectly can damage or destroy the tone ring or cause the ABS to work improperly. The procedure below is used for many stamped steel or powdered metal tone rings such as those manufactured by Gunite. ConMet aluminum hub tone rings are installed at room temperature with special drivers. Check the tone ring and hub manufacturer's literature or website for specific procedures.

⚠ WARNING

If the teeth of a cast-in tone ring are damaged, that hub must be replaced immediately. If a removeable tone ring is badly corroded, bent, or damaged, it must be replaced immediately. The ABS may not work correctly with damaged tone rings. This could lead to decreased vehicle control, increased braking distances, and an accident with personal injury or property damage.

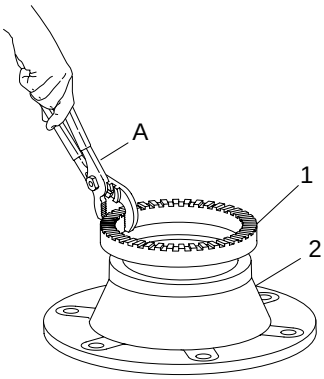
The following procedure is typical for Gunite hubs and similar ones.

1. Submerge the tone ring in boiling water or place it in an oven at 250°F (121°C) for approximately 15 minutes.

⚠ CAUTION

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**.



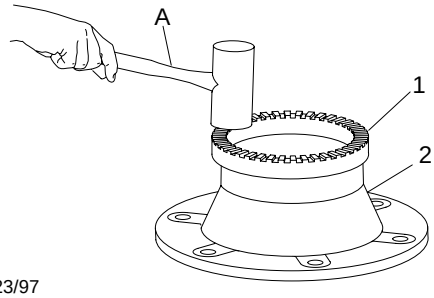
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A. Use pliers to apply the ring.

1. Tone Ring 2. Hub

Fig. 1, Installing the Ring on the Hub

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**.



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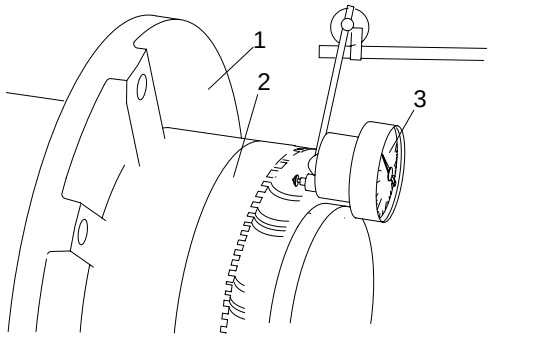
A. Use a rubber mallet.

1. Tone Ring 2. Hub

Fig. 2, Tapping the Tone Ring

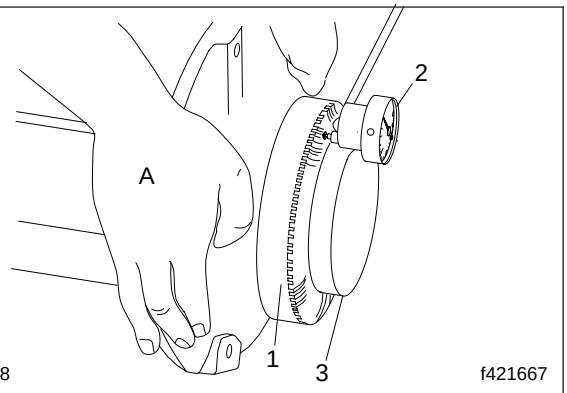
4. Install the hub on the axle. Place a dial indicator with a magnetic base so the dial indicator is against the tone-ring teeth. See **Fig. 3**.
5. Rotate the hub and check the ring for runout. The runout should be less than 0.005 inch (0.13 mm). See **Fig. 4**.

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

6. Install the wheel. For instructions, see **Group 40**.

Dynamometer Testing Vehicles With ATC

⚠ 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 Meritor TOOLBOX software to disable the ATC.
- 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.

General Information

This subject contains information for diagnosing problems in the WABCO E-Version pneumatic ABS system under the following headings:

- Troubleshooting Tables
- Component Specific Tests
- ABS/ATC Circuit Pin Wire Numbers
- Using Meritor TOOLBOX software to reconfigure the ECU

NOTE: Use Meritor TOOLBOX or ServiceLink for the preferred method of J1587 fault code diagnosis. Meritor WABCO also provides technical assistance through its website and the Arvin-Meritor Customer Service Center phone: 1-800-535-5560.

NOTE: For wiring, see module 330 BOM in PartsPro for the correct schematic specific to the vehicle being serviced.

Troubleshooting Tables

Use the following tables to troubleshoot the ABS by MID-SID.

J1587 Fault Code Cross-Reference		
MID-SID	**Description**	**Troubleshooting Table**
	Wheel Sensor	
136-001	Left Front	**Table 2**
136-002	Right Front	**Table 3**
136-003	Left Rear	**Table 4**
136-004	Right Rear	**Table 5**
	Modulator Valve	
136-007	Left Front	**Table 6**
136-008	Right Front	**Table 7**
136-009	Left Rear	**Table 8**
136-010	Right Rear	**Table 9**
136-014	Ground Faults	**Table 10**
136-015		**Table 11**
136-018	ATC Valve (if equipped)	**Table 12**
136-019	Auxiliary Output	**Table 13**
136-231	J1939 Datalink	**Table 14**
136-251	Voltage	**Table 15**
136-253	Configuration Errors	**Table 16**
136-254	Miscellaneous Faults	**Table 17**

Table 1, J1587 Fault Code Cross Reference

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	001	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 7 and 8 of the X2 (black) ECU connector while rotating the LF wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					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.

WABCO E-Version ABS Troubleshooting

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	001	03	Sensor shorted to power	2. Measure the voltage across pin 7 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 8 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor harness, replace the sensor.
					No voltage at any pin.	Repeat the test and check for intermittent short to power in circuits 377LF– and 377LF+. If the problem persists, suspect that the ECU is faulty.
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.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor harness, replace the sensor.
					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+. If the problem persists, suspect that the ECU is faulty.
136	001	05	Open circuit	4. Measure the resistance between pins 7 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+. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	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 circuits 377LF– and 377LF+ in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	001	06	Short circuit			Perform tests 4 and 5.
136	001	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure the correct tone ring is installed (100-tooth is the normal application). Repair as needed.
136	001	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.

Left Front Wheel Sensor Troubleshooting (SID 001)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	001	09	Wire mismatch	6. Check for mixed sensor connections. While using Meritor TOOLBOX software, spin each wheel individually. Confirm that the output is from the correct sensor.		Correct wiring connections, as needed.
136	001	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, 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.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
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.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 2, Left Front Wheel Sensor Troubleshooting (SID 001)

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pin 5 and 6 of the X2 (black) ECU connector while rotating the RF wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	002	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.
136	002	03	Sensor shorted to power	2. Measure the voltage across pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 6 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					No voltage at any pin.	Repeat the test and check for intermittent short to power in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.

WABCO E-Version ABS Troubleshooting

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	04	Short to ground	3. Measure the resistance between pin 5 of the X2 (black) connector and a good chassis ground. Repeat the test between pin 6 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.
136	002	05	Open circuit	4. Measure the resistance between pin 5 and 6 of the X2 (black) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377RF+ and 377RF–. If the problem persists, suspect that the ECU is faulty.
					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) 377RF+ and 377RF– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	002	06	Short circuit			Perform tests 4 and 5.
136	002	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	002	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	002	09	Wire mismatch	6. Check for mixed sensor connection. Using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.

Right Front Wheel Sensor Troubleshooting (SID 002)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	002	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, 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.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	002	11	Erratic signal			Perform test 7.
136	002	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 3, Right Front Wheel Sensor Troubleshooting (SID 002)

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	003	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 1 and 2 of the X3 (green) ECU connector while rotating the LR wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	003	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.
136	003	03	Sensor shorted to power	2. Measure the voltage across pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If problem is in the sensor cable, replace the sensor.
					No voltage at any pin.	If the problem persists, suspect that the ECU is faulty.
136	003	04	Short to ground	3. Measure the resistance between pin 1 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 2 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If the short is in the sensor cable, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377LR+ and 377LR–. If the problem persists, suspect that the ECU is faulty.

WABCO E-Version ABS Troubleshooting

Left Rear Wheel Sensor Troubleshooting (SID 003)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	003	05	Open circuit	4. Measure the resistance between pins 1 and 2 of the X3 (green) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377LR+ and 377LR–. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	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) 377LR+ and 377LR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	003	06	Short circuit			Perform tests 4 and 5.
136	003	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	003	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	003	09	Wire mismatch	6. Check for mixed sensor connection. While using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.
136	003	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, 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.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	003	11	Erratic signal			Perform test 7.
136	003	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 4, Left Rear Wheel Sensor Troubleshooting (SID 003)

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	01	Incorrect sensor air gap	1. Adjust the sensor. Check the AC voltage across pins 3 and 4 of the X3 (green) ECU connector while rotating the RR wheel 30 rpm.	Voltage is 0.2 VAC or greater.	Sensor adjustment solved the problem.
					Voltage is less than 0.2 VAC.	Check for excessive wheel bearing end play and hub runout. Repair as needed.
136	004	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.
136	004	03	Sensor shorted to power	2. Measure the voltage across pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Measurable voltage at any pin.	If the short is in the vehicle harness, repair the wiring. If the problem is in the sensor harness, replace the sensor.
					No voltage at any pin.	If the problem persists, suspect that the ECU is faulty.
136	004	04	Short to ground	3. Measure the resistance between pin 3 of the X3 (green) connector and a good chassis ground. Repeat the test between pin 4 and ground.	Resistance between either pin and ground is less than 100,000 ohms.	If the short is in the vehicle harness, repair the wiring. If the problem is in the sensor harness, replace the sensor.
					Resistance between either pin and ground is greater than 100,000 ohms.	Repeat the test for intermittent short to ground in circuits 377RR+ and 377RR–. If the problem persists, suspect that the ECU is faulty.
136	004	05	Open circuit	4. Measure the resistance between pins 3 and 4 of the X3 (green) connector.	Resistance is 900–2000 ohms.	Repeat the test and check for intermittent open or short in circuits 377RR+ and 377RR–. If the problem persists, suspect that the ECU is faulty.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	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) 377RR+ and 377RR– in chassis harness.
					Resistance is greater than 2000 ohms OR less than 900 ohms.	Replace the sensor.
136	004	06	Short circuit			Perform tests 4 and 5.

WABCO E-Version ABS Troubleshooting

Right Rear Wheel Sensor Troubleshooting (SID 004)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	004	07	Damaged tone ring			Inspect tone ring for damage and missing teeth. Make sure correct tone ring is installed (100-tooth is normal application). Repair as needed.
136	004	08	Excessive wheel slip			Check sensor adjustment. This fault usually occurs when there is excessive tire spin for more than 16 seconds.
136	004	09	Wire mismatch	6. Check for mixed sensor connections. While using Meritor TOOLBOX software, spin each wheel individually. Check that output is from the correct sensor.		Correct wiring connections, as needed.
136	004	10	Intermittent signal	7. Adjust the sensor. Using the wheel sensor output screen in Meritor TOOLBOX software, 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.
					Signal output incorrect.	Check for intermittent wheel sensor circuit connections. (Brake chatter can cause this problem.) Repair as needed.
136	004	11	Erratic signal			Perform test 7.
136	004	12	Frequency too high	8. Check sensor wiring and connectors for intermittent contact.	Wiring OK.	If the problem persists, suspect that the ECU is faulty.
					Wiring incorrect.	Repair wheel sensor circuit, as needed.

Table 5, Right Rear Wheel Sensor Troubleshooting (SID 004)

Left Front Modulator Valve Troubleshooting (SID 007)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	007	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 2, 10, and 11 of the X2 (black) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378LFI, 378LFO, and 378LF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378LFI, 378LFO, or 378LF–.

Left Front Modulator Valve Troubleshooting (SID 007)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	007	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LFI, 378LFO, or 378LF– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	007	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LFI and 378LFO for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 6, Left Front Modulator Valve Troubleshooting (SID 007)

Right Front Modulator Valve Troubleshooting (SID 008)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	008	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pins 3, 4, and 9 of the X2 (black) connector, and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378RFO, 378RFI, and 378RF– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378RFO, 378RFI, or 378RF–.
136	008	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RFO, 378RFI, or 378RF– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	008	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RFO and 378RFI for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 7, Right Front Modulator Valve Troubleshooting (SID 008)

WABCO E-Version ABS Troubleshooting

Left Rear Modulator Valve Troubleshooting (SID 009)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	009	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pin 10, 11, and 12 of the X3 (green) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378LRI, 378LRO, and 378LR– for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378LRI, 378LRO, or 378LR–.
136	009	05	Open circuit Inlet or outlet circuit open.	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LRI, 378LRO, and 378LR– for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.
136	009	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378LRI and 378LRO for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 8, Left Rear Modulator Valve Troubleshooting (SID 009)

Right Rear Modulator Valve Troubleshooting (SID 010)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	010	03	Short to power *Inlet or outlet circuit shorted to battery supply or another modulator valve wire.*	1. Measure the voltage between pin 7, 8, and 9 of the X3 (green) connector and a good chassis ground.	No voltage at any pin.	Repeat test. Check circuits 378RRO, 378RR–, and 378RRI for intermittent short to power. Check above circuits for shorts to other modulator valve wires. Repair as necessary. If the problem persists, suspect that the ECU is at fault.
					Measurable voltage at any pin.	Repair short to power in circuit 378RRO, 378RR–, or 378RRI.
136	010	05	Open circuit *Inlet or outlet circuit open.*	2. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RRO, 378RR–, and 378RRI for poor or open connections. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Right Rear Modulator Valve Troubleshooting (SID 010)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	010	06	Short to ground *Inlet or outlet circuit shorted to ground.*	3. Measure the modulator valve inlet and outlet circuit resistance. Disconnect the connector from the valve and perform the modulator valve resistance test.	Resistance in both circuits is within 4 to 9 ohms.	Check harness wiring circuits 378RRO and 378RRI for short to ground. Repair as necessary.
					Resistance in both circuits is not within 4 to 9 ohms.	Replace the modulator valve.

Table 9, Right Rear Modulator Valve Troubleshooting (SID 010)

Ground Faults Troubleshooting (SID 014)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	014	04	Low voltage or open circuit	1. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pins 1 and 12.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts.	Check vehicle batteries and charging system. Check ABS ECU power and ground circuits for open or high resistance. Repair as necessary.
136	014	05	Central ground open or high resistance	2. Disconnect the X1 (gray) connector at the ABS ECU. Check the ground circuit (pin 11) for high resistance or open circuit.	Ground is okay.	Verify the fault. Check the ground circuits intermittent open circuit. Repair as necessary.
					Ground is open or has high resistance.	Repair ground circuit as necessary.
136	014	07	Internal relay does not open			If the fault repeats, replace the ABS ECU.

Table 10, Ground Faults Troubleshooting (SID 014)

Ground Faults Troubleshooting (SID 015)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	015	03	ATC valve circuit shorted to power.	1. Disconnect the X3 (green) connector, check for voltage between pin 6 and ground.	Voltage at pin 6.	Circuit 378T– is shorted to power. Locate fault and repair as necessary.
					No voltage at pin 6.	Verify fault. Check for intermittent fault in circuit 378T–, repair as necessary.

WABCO E-Version ABS Troubleshooting

Ground Faults Troubleshooting (SID 015)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	015	04	Low voltage or open circuit	2. Disconnect the X1 (gray) connector at the ABS ECU. With the ignition ON, measure the voltage between pin 2 and a good ground.	Voltage is 9.5 to 14 volts.	System voltage is acceptable. Check for intermittent low voltage. Check the batteries and charging system. Voltage may have been temporarily too low. Repair as necessary.
					Voltage is less than 9.5 volts.	Repair voltage supply to ECU.
136	015	05	ATC valve - High Impedance			Replace the ABS ECU if the fault persists.
136	015	06	ATC valve circuit shorted to ground	Disconnect the X3 (green) connector, check resistance between pin 6 and a good ground.	Resistance is less than 10,000 ohms.	Circuit 378T– is shorted to ground. Repair as necessary.
					Resistance is greater than 10,000 ohms.	Verify fault. Check for intermittent fault in circuit 378T–. Repair as necessary.
136	015	07	Internal relay fault			If the fault repeats, replace the ABS ECU.

Table 11, Ground Faults Troubleshooting (SID 015)

ATC Valve Troubleshooting (SID 018)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	018	03	Short to power.	1. Disconnect the X3 (green) connector from the ABS ECU. Disconnect the ATC valve connector. Measure the voltage between pin 5 of the X3 (green) connector and a good chassis ground.	Voltage	Circuit 378T+ is shorted to power. Repair as necessary.
					No voltage.	Check circuit 378T+ for intermittent short to power. Repair as necessary. If the fault persists, suspect that the ECU is at fault.
136	018	05	Open circuit	2. Disconnect the ATC valve connector. Measure the continuity across the two pins of the ATC valve. NOTE: If the vehicle does not have an ATC valve, reconfigure the ECU.	Resistance is 7 to 14 ohms.	Perform test 3.
					Resistance is not 7 to 14 ohms.	Replace ATC valve.
				3. Reconnect the ATC valve connector. Measure the resistance across pins 5 and 6 of the X3 (green) connector.	Resistance is 7 to 14 ohms.	Verify fault. Check for intermittent open circuit in 378T+ and 378T–. Repair as necessary.
					Resistance is not 7 to 14 ohms.	Repair circuit 378T+ or 378T–.

ATC Valve Troubleshooting (SID 018)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	018	06	Short to ground.	4. Disconnect the X3 (green) connector. Check continuity between pin 5 and a good ground.	Continuity.	Circuit 378T+ is shorted to ground. Repair as necessary.
					No continuity.	Verify fault. Check circuit 378T+ for intermittent short to ground. Repair as necessary.

Table 12, ATC Valve Troubleshooting (SID 018)

Auxiliary Output Troubleshooting (Not fitted, but possible to encounter error code) (SID 019)				
MID	**SID**	**FMI**	**Problem**	**Action**
136	019	03	Short to power	This fault should not appear. Re-configure the ECU. If fault continues to appear, check the wiring in the X2 (black) ABS ECU connector. Pins 1 and 12 should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor WABCO.
136	019	05	Open circuit	Verify fault. Contact Meritor WABCO if fault persists.
136	019	06	Short to ground	This fault should not appear. Reconfigure the ECU. If fault continues to appear, check the wiring in the X2 (black) ABS ECU connector. Pins 1 and 12 should be unused. Make sure there are no connections to these pins. If incorrect wiring is found, correct it and reconfigure the ECU. If this does not correct the problem, contact Meritor WABCO.

Table 13, Auxiliary Output Troubleshooting (SID 019)

J1939 Datalink Troubleshooting (SID 231)					
MID	**SID**	**FMI**	**Problem**	**Test**	**Action**
136	231	02	J1939 speed plausibility error. NOTE: This fault indicates a discrepancy between vehicle speed reported on J1939 and ABS sensed vehicle speed.		Check the speedometer calibration. Check for the tire size mismatch. The vehicle speed reported on the J1939 datalink does not agree with the wheel sensor speeds.
136	231	05	J1939 open/short		Repair J1939 datalink as necessary.
136	231	06	J1939 open/short Code 136s231 05 may be active as well.		Repair J1939 datalink as necessary.

WABCO E-Version ABS Troubleshooting

J1939 Datalink Troubleshooting (SID 231)					
MID	**SID**	**FMI**	**Problem**	**Test**	**Action**
136	231	07	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check the engine retarder, ECU, and wires.	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	08	J1939 time out NOTE: Fault occurs if engine retarder sends message incorrectly.	Check engine ECU and wires. Check J1939 datalink.	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	09	J1939 time out NOTE: Fault occurs if engine or transmission sends message incorrectly.	Check engine and transmission ECUs and wires. Check J1939 datalink.	Check J1939 datalink, engine ECU, transmission ECU, and wiring. Repair as necessary.
136	231	10	J1939 time out NOTE: Fault occurs if the exhaust retarder sends a message incorrectly.	Check the engine ECU and wires. Check the J1939 datalink.	Check J1939 datalink and engine ECU. Repair as necessary.
136	231	12	J1939 internal error		Verify fault. Clear code from the ECU memory. If fault persists, replace the ABS ECU.

Table 14, J1939 Datalink Troubleshooting (SID 231)

Voltage Troubleshooting (SID 251)						
MID	**SID**	**FMI**	**Problem**	**Test**	**Test Result**	**Action**
136	251	03	Overvoltage Voltage to ECU was too high for more than 5 seconds.	Set the engine at governed speed. Using Meritor TOOLBOX software, measure the diagonal voltages.	Voltage is 9.5 to 14 volts	Check for intermittent sources of high voltage. Check condition of charging system and batteries. Verify fault.
					Voltage is greater than 14 volts.	Check charging system. Repair as necessary.

Table 15, Voltage Troubleshooting (SID 251)

Configuration Errors Troubleshooting (SID 253)				
MID	**SID**	**FMI**	**Problem**	**Action**
136	253	01	ATC configuration error. NOTE: ATC valve is detected without engine datalink (J1939).	Check J1939 for proper wiring. Check engine ECU for communication. Repair as necessary, then reconfigure ECU.
136	253	02	ABS configuration/wheel parameter incorrect.	Reconfigure ECU. If the fault repeats, then the wrong ECU is installed. Replace with the correct ECU.
136	253	12	Check sum error.	Check parameter setting. Check if diagnostic device was disconnected during active diagnosis.

Table 16, Configuration Errors Troubleshooting (SID 253)

Miscellaneous Faults Troubleshooting (SID 254)				
MID	**SID**	**FMI**	**Problem**	**Action**
136	254	05	ABS/ATC ECU, no loads.	No modulator valve connected. Fault may have resulted from end-of-line test at factory.
136	254	08	Excessive wheel slip.	Check wheel speed sensor air gaps. One wheel was much faster than the other. May have been caused by testing vehicle on a dynamometer.
136	254	09	Modulator valve actuated too long.	Modulator valve was activated too long (more than 75% of 5 minutes). After a delay, function will return to normal.
136	254	12	Internal error.	If the fault persists, replace the ABS ECU.
136	254	13	Accelerometer out of range.	If the fault persists, replace the ABS ECU.
136	254	14	ECU Mounting.	Check ECU mounting. Replace the ECU if the fault persists.
			Extreme banked road (measured acceleration not plausible).	No correction required. This fault is for reporting only.
			Accelerometer linearity (measured acceleration not plausible).	

Table 17, Miscellaneous Faults Troubleshooting (SID 254)

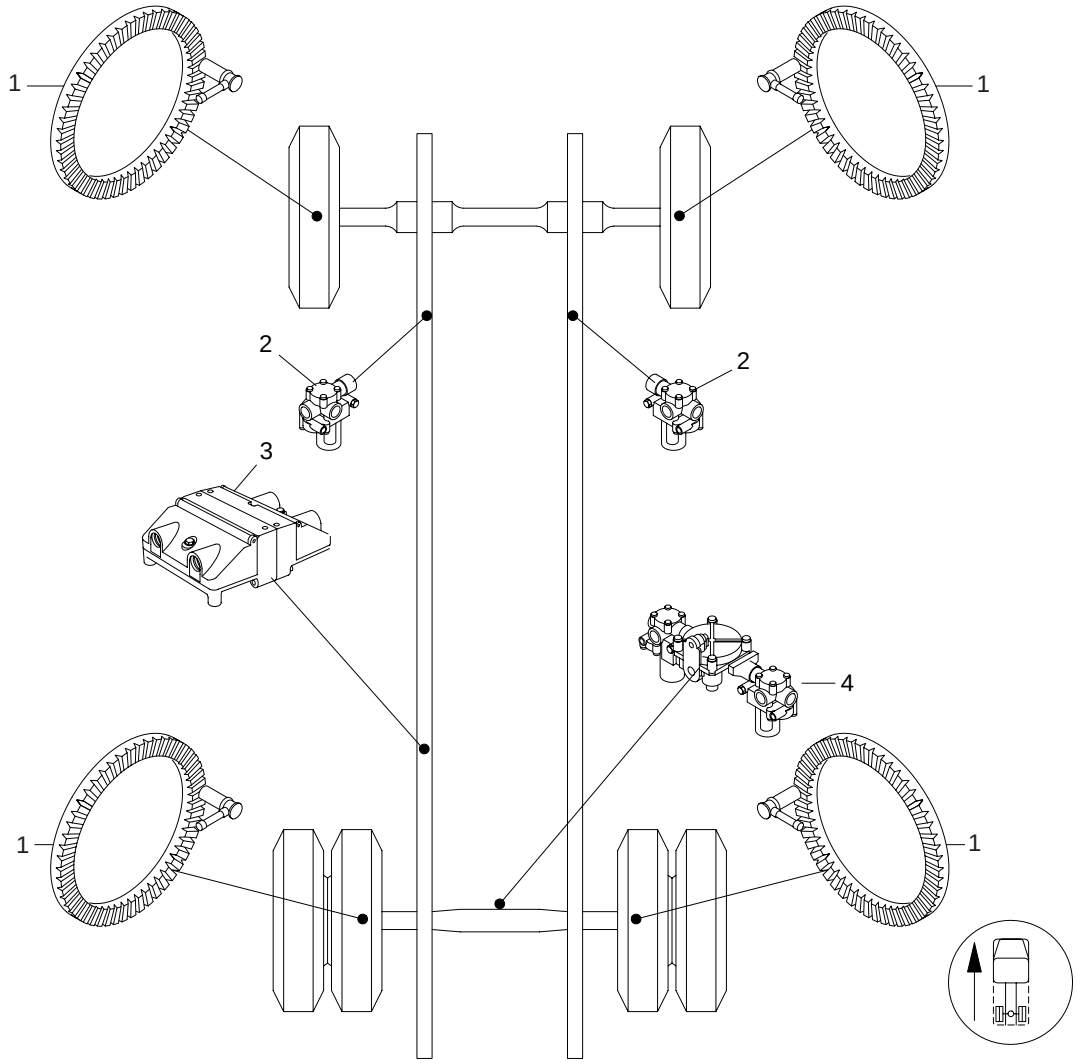
Wheel Speed Sensor Tests

Wheel Speed Sensor and Circuit Resistance

To check the resistance in a wheel speed sensor and its circuit, refer to **Fig. 1** and 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 from the ECU the connector that contains the circuit for the sensor being tested. See **Table 18** for detailed pinout information.
3. Connect ohmmeter probes to the connector terminals and measure the resistance.
   - If the resistance is 900 to 2000 ohms, the sensor and its 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."
4. Connect the sensor connector to the ECU.

WABCO E-Version ABS Troubleshooting



01/21/2004 f430361

1. Tone Rings and Wheel Sensors
2. Front Modulator Valves
3. ABS ECU (Inside Frame Rail)
4. Rear Modulator Valve Assembly

Fig. 1, S2 Chassis ABS Main Component Locations

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 sensor cable from the chassis harness.
3. Connect ohmmeter probes to the pins on the sensor and measure the resistance.
   - If the resistance reading is 900 to 2000 ohms but the resistance noted in the previous test, "Wheel Speed Sensor and Circuit

Resistance" was not, repair or replace the chassis harness wiring.

- If the resistance is less than 900 ohms or greater 2000 ohms, clean the terminals and check the resistance again. If the resistance reading is still not correct, replace the sensor.

4. Connect the sensor cable to the chassis harness and remove the chocks from the tires.

WABCO E-Version Circuit Pin and Wire Numbers

Connector	Pin Number	Wire Number	Circuit Description
X1 Gray	1	376A	ECU Battery Supply (+12 volt)
	2	376C	ECU Ignition Supply (+12 volt)
	3	376T	Wheel Spin Light and ATC Switch
	4	1587+	J1587+
	5	—	—
	6	1939–	J1939–
	7	1939+	J1939+
	8	—	Not used
	9	1587–	J1587–
	10	376L1	ABS Light
	11	GND	ECU Ground
	12	GND	ECU Ground
X2 Black	1	—	Not used
	2	378LFI	Left Front Modulator Valve, In
	3	378RFO	Right Front Modulator Valve, Out
	4	378RFI	Right Front Modulator Valve, In
	5	377RF+	Right Front Sensor, High
	6	377RF–	Right Front Sensor, Low
	7	377LF–	Left Front Sensor, Low
	8	377LF+	Left Front Sensor, High
	9	378RF–	Right Front Modulator Valve, Ground
	10	378LFO	Left Front Modulator Valve, Out
	11	378LF–	Left Front Modulator Valve, Ground
	12	—	Not used

WABCO E-Version ABS Troubleshooting

WABCO E-Version Circuit Pin and Wire Numbers			
Connector	**Pin Number**	**Wire Number**	**Circuit Description**
X3 Green	1	377LR–	Left Rear Sensor, Low
	2	377LR+	Left Rear Sensor, High
	3	377RR+	Right Rear Sensor, High
	4	377RR–	Right Rear Sensor, Low
	5	378T+	ATC Valve, High
	6	378T–	ATC Valve, Low
	7	378RRO	Right Rear Modulator Valve, Out
	8	378RR–	Right Rear Modulator Valve, Ground
	9	378RRI	Right Rear Modulator Valve, In
	10	378LRO	Left Rear Modulator Valve, Out
	11	378LR–	Left Rear Modulator Valve, Ground
	12	378LRI	Left Rear Modulator Valve, In

Table 18, WABCO E-Version Circuit Pin and Wire Numbers

Wheel Speed Sensor Voltage

NOTE: Meritor TOOLBOX software can be used for this test to compare speed signal output of all sensors. Low or erratic output indicates a problem.

Check the voltage output of a wheel speed sensor, as follows.

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 to be tested, so the wheels can rotate.
3. Disconnect from the ECU the connector for the sensor being tested. See **Table 18** for detailed pinout information.
4. Set a digital multimeter to the AC voltmeter mode. Connect the probes to the 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, go to the next step.
    - If the voltage reading is less than 0.2 volt AC, push the sensor into its holder until the sensor touches the tone ring. Repeat the voltage test. If the voltage 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. Remove the chocks from the tires.

Modulator Valve Tests

Modulator Valve Function Check

NOTE: Valves can be tested using the Meritor WABCO TOOLBOX software or the following procedure.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Turn the ignition on.
3. When the ABS warning light comes on, listen for the modulator valves to cycle one by one. The 4-Channel valve cycle is: 1, 2, 3, 4. See **Fig. 2**.
4. If the valves do not all cycle correctly, turn the ignition off and check the connectors for tightness. Repeat the self-test.

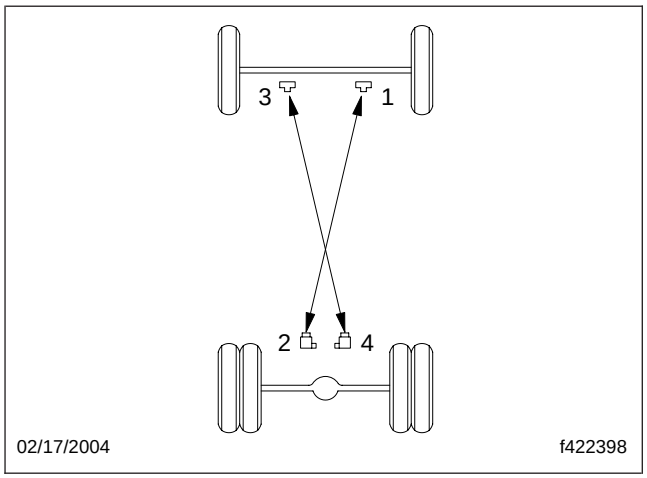


Fig. 2, Modulator Valve Function Test Sequence

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 Circuit Resistance."

Modulator Valve and Circuit Resistance

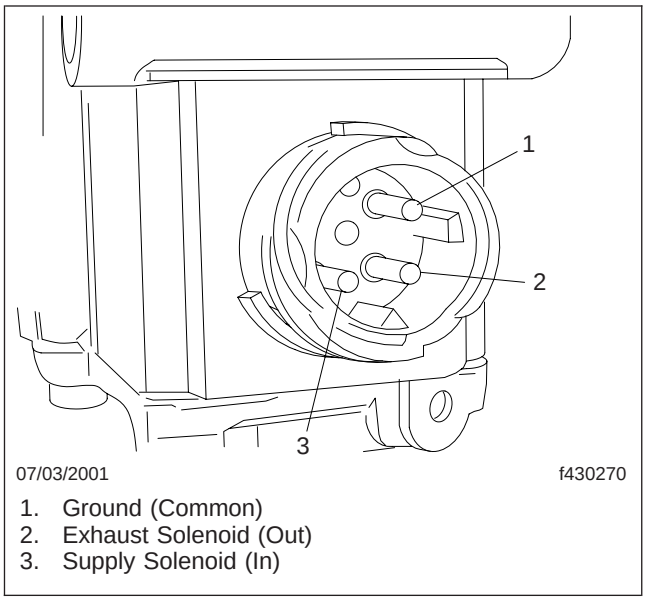
To check the resistance in a modulator valve and its circuit, perform the following test.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect (from the ECU) the connector that contains the circuit for the modulator valve being tested. See **Table 18** for detailed pinout information.
3. Connect ohmmeter probes to the connector pins for the modulator valve "In" and "Ground" terminals. Measure the resistance. Move the probes to the pins for the "Out" and "Ground" terminals and measure the resistance.
4. The resistance in both cases must be 4 to 9 ohms.
    - If the resistance in both cases is 4 to 9 ohms, the modulator valve and its circuit are good. Install the connector on the ECU and remove the chocks from the tires.
    - If the resistance in either is less than 4 ohms or greater than 9 ohms, go to the next test, "Modulator Valve Resistance."

Modulator Valve Resistance

To check the resistance in a modulator valve, perform the following test.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the modulator valve being tested.
3. Connect ohmmeter probes to the modulator valve "In" and "Ground" terminals. See **Fig. 3**. Measure the resistance. Move the probes to the "Out" and "Ground" terminals and measure the resistance.



1. Ground (Common)
2. Exhaust Solenoid (Out)
3. Supply Solenoid (In)

Fig. 3, Modulator Valve Terminals

4. The resistance in both cases must be 4 to 9 ohms.
    - If the resistance in both cases is 4 to 9 ohms but the resistance noted in the previous test, "Modulator Valve and Circuit Resistance" was not, repair or replace the chassis harness.
    - If the resistance is less than 4 ohms or greater than 9 ohms, clean the terminals on the modulator valve and check the re-

sistance again. If the resistance still is not correct, replace the valve.

5. Install the connectors and remove the chocks from the tires.

ATC Valve Tests

ATC Valve and Circuit Resistance

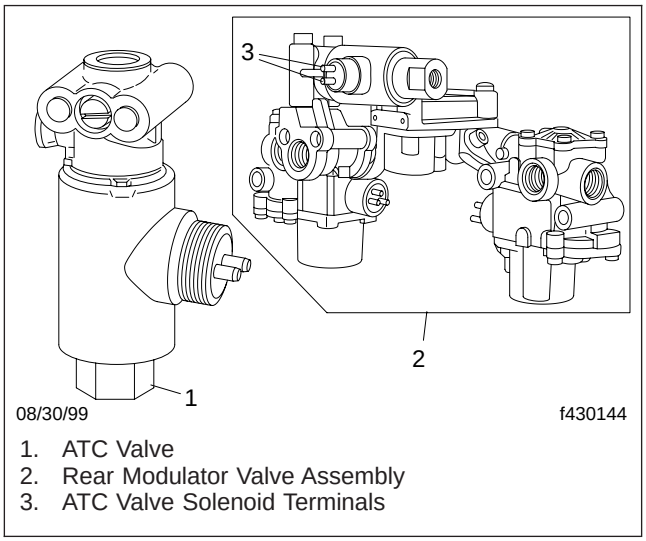
To check the resistance in the ATC valve and its circuit, perform the following test.

1. Park the vehicle on a level surface, set the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect connector X3 (green) from the ABS ECU.
3. Connect ohmmeter probes to the X3 (green) connector pins 5 and 6 and read the resistance.
4. The resistance of the ATC valve and its circuit must be 7 to 14 ohms.
    - If the resistance is 7 to 14 ohms, the ATC valve and its circuit are good. Install the connector on the ECU and remove the chocks from the tires.
    - If the resistance is less than 7 ohms or greater than 14 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 connector from the ATC valve. See **Fig. 4**.
3. Connect ohmmeter probes to the ATC valve terminals and read the resistance.
4. The resistance of the ATC valve must be 7 to 14 ohms.
    - If the resistance is 7 to 14 ohms, but the resistance noted in the previous test, "ATC Valve and Circuit Resistance" was not, repair or replace the wiring.



1. ATC Valve
2. Rear Modulator Valve Assembly
3. ATC Valve Solenoid Terminals

Fig. 4, ATC Valve (Inset, Mounted Between Rear Modulator Valves)

    - If the resistance is less than 7 ohms or greater than 14 ohms, clean the terminals on the ATC valve and check the resistance again. If the resistance is still not correct, replace the valve.
5. Install the connector and remove the chocks from the tires.

Using Meritor TOOLBOX Software to Reconfigure the E-Version ECU

Reconfiguration Procedure

E-version ECUs memorize the following components if they are connected at power-up:

- ATC valve
- Datalink SAE J1939

Once these components have been memorized, the ECU will look for them at each power-up. If it does not find a memorized component, the ECU records a fault. This can occur if an ECU is moved from one vehicle to another and one or more of the memorized components are not available on the new vehicle. For example, if an ATC valve is memorized but is not present at the next power-up, the ECU records a fault. If this occurs, use TOOLBOX software to reconfigure the ECU.

NOTE: For complete instructions for using Meritor TOOLBOX software, refer to the ArvinMeritor "TOOLBOX User's Manual, TP-99102."

To reconfigure the ECU with TOOLBOX software, use the "Reset Memorized" command: Select "Reset Memorized" from the "Component Tests" pull-down menu to tell the ECU to reset the memorized or "learned" components.

Clearing Faults Using Meritor TOOLBOX Software

Fault Clearing Procedure

Use the "Clear Faults" button, in the Meritor TOOLBOX software fault display screen, to clear faults.

NOTE: The ABS lamp will remain on, even after faults have been cleared, until the vehicle is driven over 4 mph.

For additional information on using Meritor TOOLBOX software for clearing faults or for an alternative reconfiguration procedure, see "Meritor Maintenance Manual MM-0112." It can be downloaded from the ArvinMeritor website, or call Meritor at 1-800-535-5560 to purchase a copy.

General Information

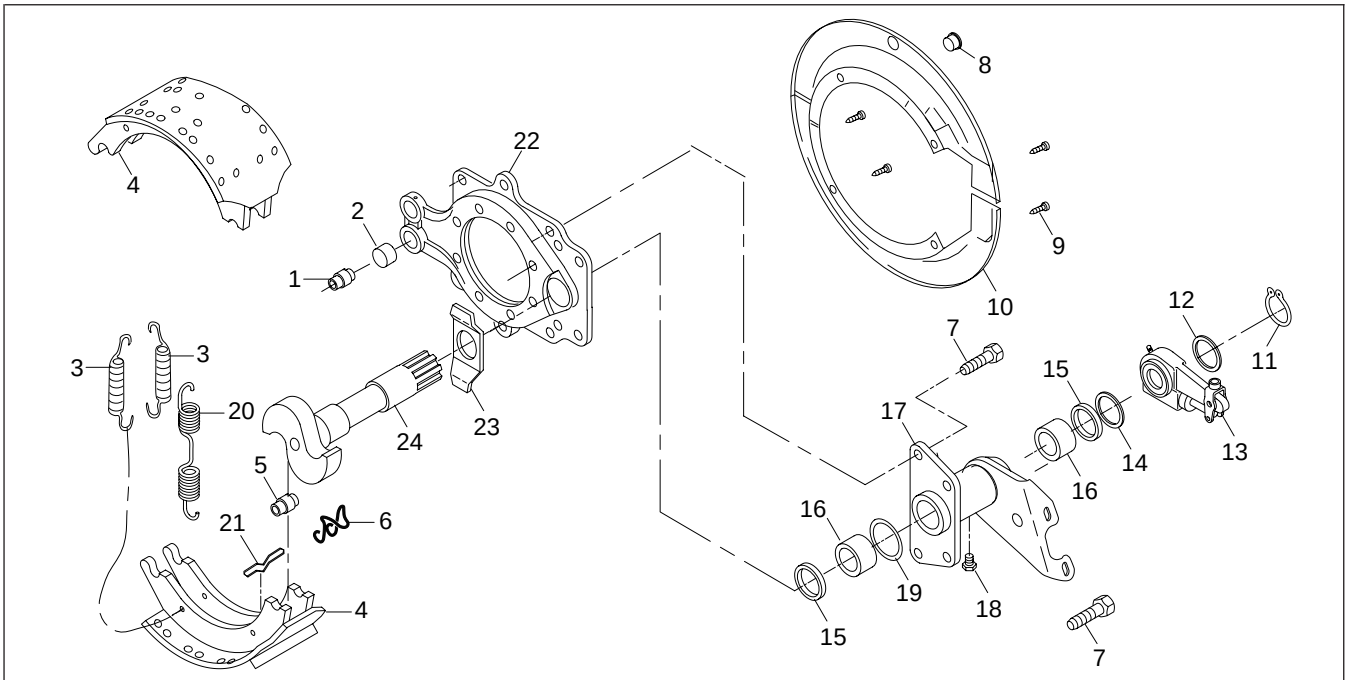
Meritor Cam-Master® Q Plus brakes are air-actuated, cam-operated, foundation brakes. The main components in each brake assembly (wheel end) include the following:

- 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 braking 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 controlled (moved) by either the outward braking 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.



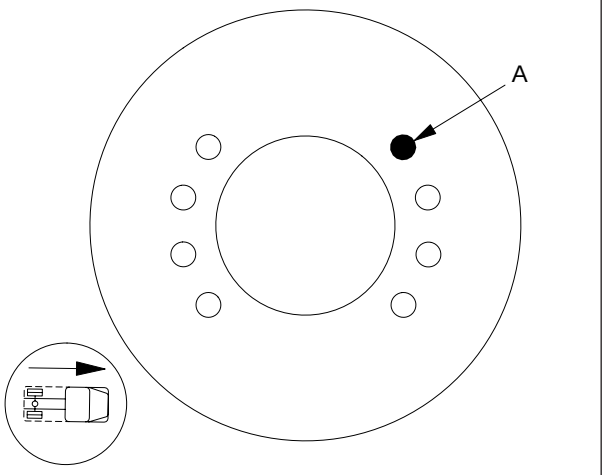
12/11/97 f421684

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 Information

Meritor steer axles have seven 0.656-inch-diameter holes for attaching the spider to the axle flange. An oversized eighth hole (0.687-inch diameter) in the axle flange is for an antilock brake system (ABS) wheel speed sensor bushing. See **Fig. 2**. The eighth hole is in the 10 or 2 o'clock position, depending on which side of the axle is viewed.



A. Oversized Hole (10 or 2 o'clock position) for ABS bushing.

Fig. 2, Hole for ABS Wheel Speed Sensor Bushing

All 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). MX500 brakes and Meritor automatic slack adjusters do not have grease fittings.

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 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. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (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

Safety Precautions

and filter must be approved by MSHA or NIOSH, and worn during all procedures.

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.

WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

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 0.80 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

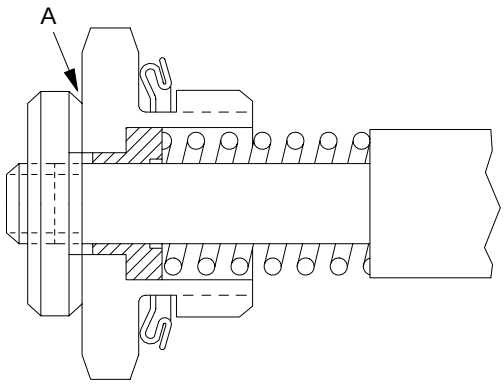
When work is being done on the spring chamber, carefully follow the service instructions of the chamber manufacturer. The sudden release of a compressed spring can cause serious personal injury.

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 the vehicle has a Meritor automatic slack adjuster, disengage the pull-pawl on the side of the adjuster.
   - 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 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, Meritor Slack Adjuster Pull-Pawl

NOTE: On Haldex or Gunite 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

Brake Shoe Removal and Installation

the brake shoes are fully retracted and the drum clears the lining. See **Subject 130** for instructions.

- On Meritor adjustors, turn the square adjusting nut clockwise (as if tightening a right-hand threaded fastener).
- On Haldex or Gunite adjusters, turn the adjusting hexnut counterclockwise. You will hear a ratcheting sound.

6. Remove the wheels. For instructions, see **Group 40**.
7. Remove the brake drums. For instructions, see **Group 33** for front axles or **Group 35** 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**.

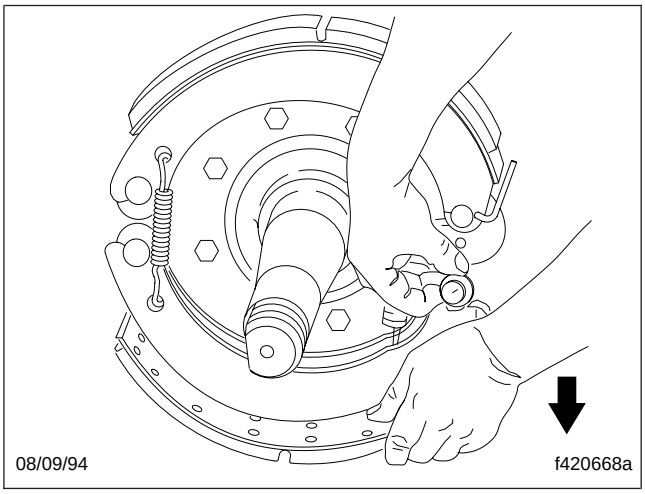


Fig. 2, Cam Roller Removal

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.

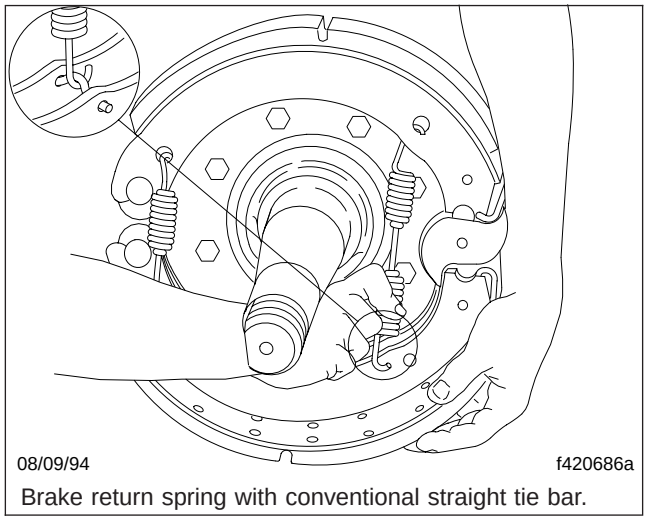


Fig. 3, Return Spring Removal/Installation, Straight Tie Bar

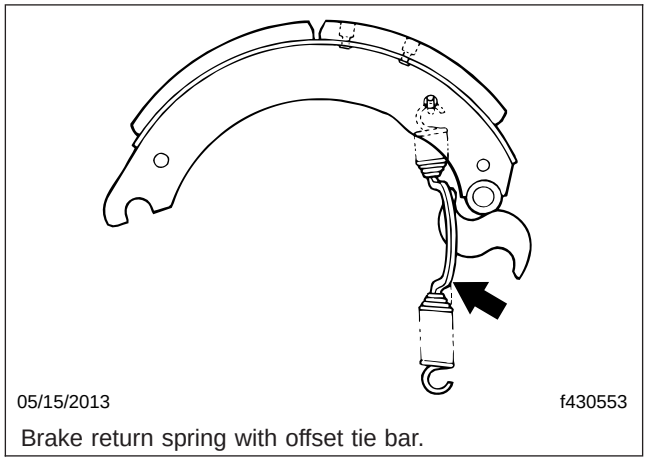


Fig. 4, Return Spring Removal/Installation, Offset Tie Bar

9. Inspect the brake shoes and linings for wear or damage. For instructions, see **Subject 120**.

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.

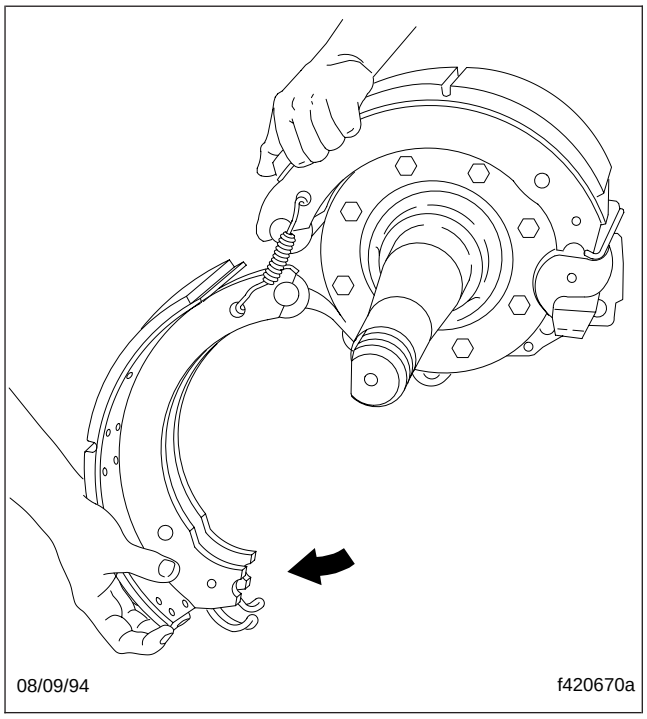


Fig. 5, Brake Shoe Removal

NOTE: Springs, rollers, and anchor pins should be replaced when installing new brake linings.

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**.

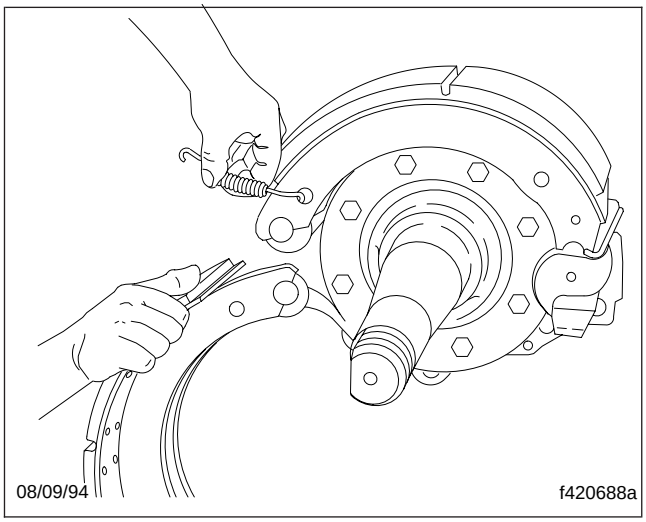


Fig. 6, Retaining Spring Installation

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**.

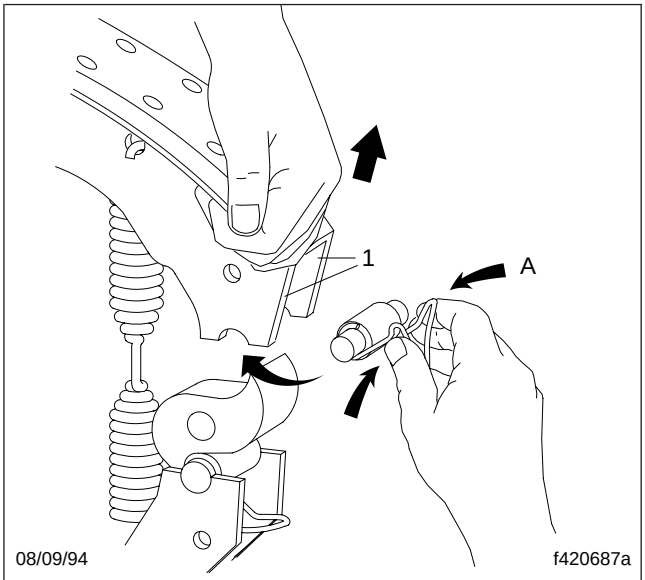
1.4 Pull the lower brake shoe away from the cam to allow enough space to install a new cam roller and retainer clip.

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**.

2. Install the brake drums. For instructions, see **Group 33** for front axles or **Group 35** for rear axles.
3. Install the wheels. For instructions, see **Group 40**.

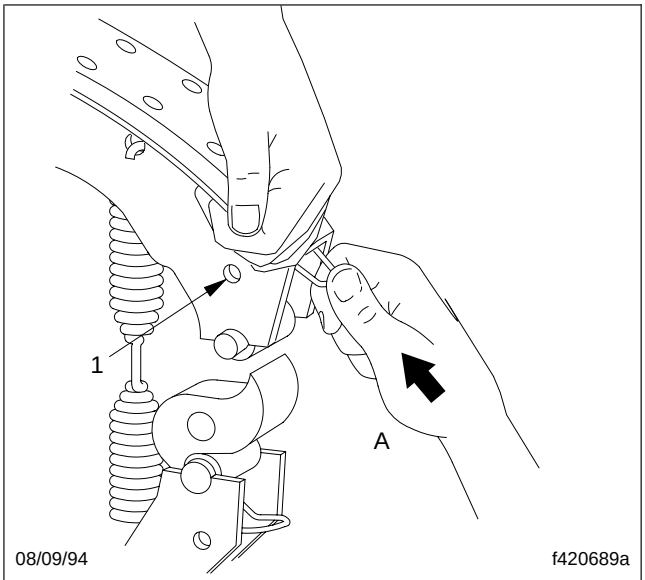
Brake Shoe Removal and Installation



A. Squeeze the ears of the retainer together.

1. Brake Shoe Webs

Fig. 7, Cam Roller and Retainer Clip Installation



A. Push the retainer until the ears lock in the holes.

1. Web Hole

Fig. 8, Securing the Retainer Clip

4. Adjust the brakes at the slack adjusters. For instructions, see **Subject 130**.
5. Remove the safety stands, lower the vehicle, and remove the chocks from the tires.

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. Before returning the vehicle to service, in a safe area, check for proper brake operation, 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 shows a lack of braking effort on those wheels.

WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Inspection

1. Remove the brake shoes, using the instructions in **Subject 110**.
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.

CAUTION

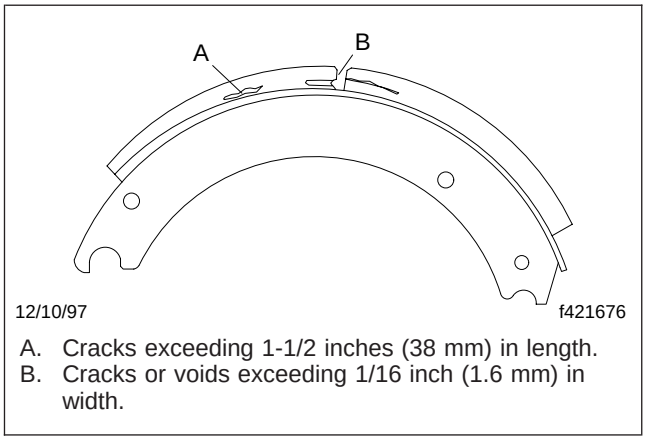
Do not let the brake linings wear to the point that the rivets or bolts touch the drums. Damage to the drums will occur if the linings are allowed to wear to this point.

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 rivets or bolts may contact the brake drums.

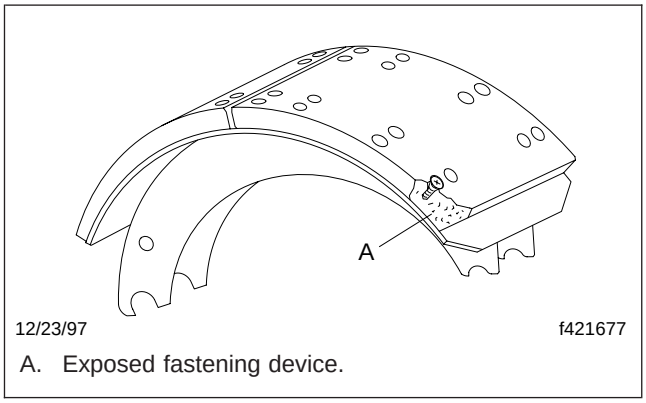
2.3 The lining is considered worn-out and the vehicle should not be driven if:

- 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**.
- Portions of the lining are missing exposing a rivet when viewed from the edge. See **Fig. 2**.
- Cracks extend across the lining face and through the lining edge, or the lining is loose on the shoe. See **Fig. 3**.



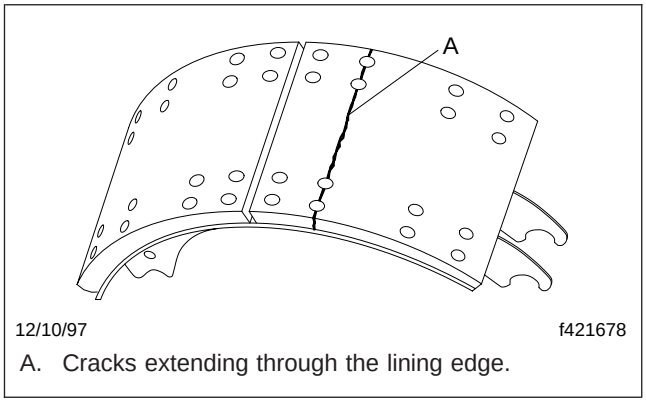
A. Cracks exceeding 1-1/2 inches (38 mm) in length.
B. Cracks or voids exceeding 1/16 inch (1.6 mm) in width.

Fig. 1, Cracks and Voids



A. Exposed fastening device.

Fig. 2, Portions of Brake Lining Missing



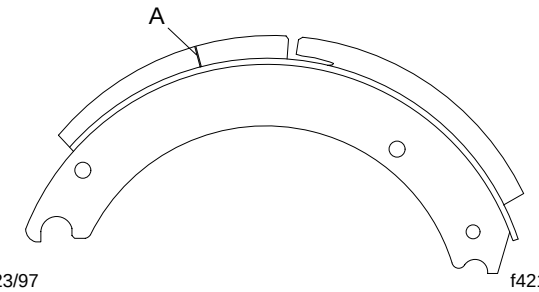
A. Cracks extending through the lining edge.

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:

Brake Shoe and Lining Inspection

- 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**.

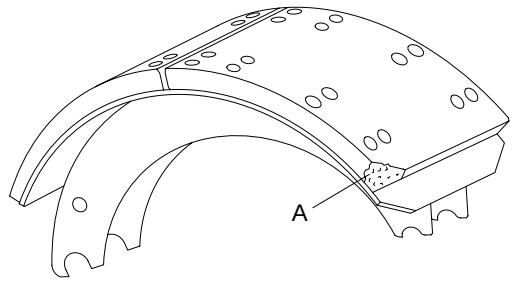


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A. Cracks not exceeding 1-1/2 inches (38 mm) in length or 1/16 inch (1.6 mm) in width.

Fig. 4, Cracks and Voids

- Corner portions of the lining are missing with no fastener exposed. See **Fig. 5**.



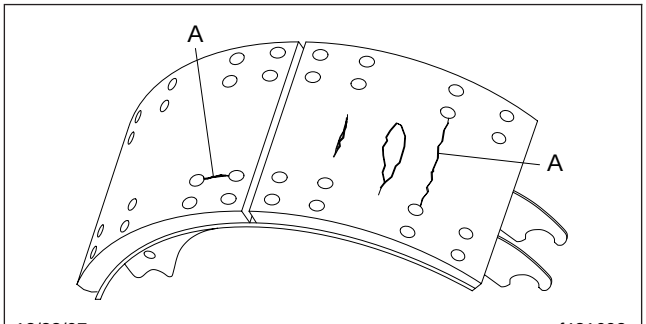
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A. Corner segment is missing but no fastener is exposed.

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.

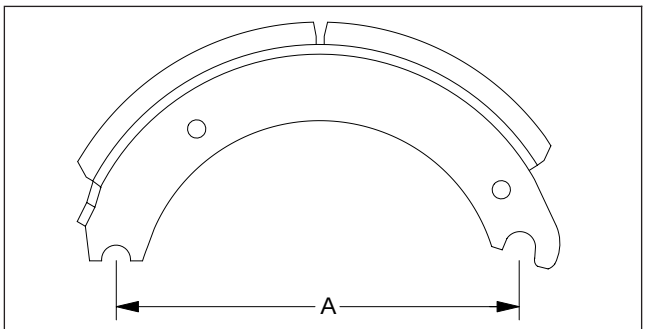


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A. Cracks extending from hole to hole.

Fig. 6, Crack in the Brake Lining

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).
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 shoe if needed. See **Fig. 7**.



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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. For instructions, see **Group 33** or **Group 35** of 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 the appropriate section in this group.

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.
- The applied chamber stroke is measured using an 80 to 90 psi (550 to 620 kPa) brake application to move the slack adjuster.

With the engine off, 100 psi (689 kPa) of air tank pressure will apply the required 80 to 90 psi (550 to 620 kPa) brake application for measuring the applied chamber stroke.

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 (550-620 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

Brake Adjustment

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

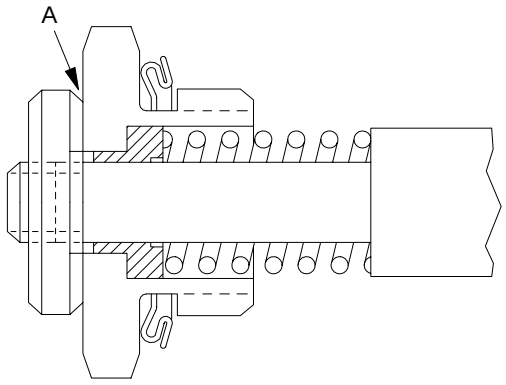
IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

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 pushrod 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 the appropriate section in this group for slack adjuster disassembly and inspection procedures.

⚠ CAUTION

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.



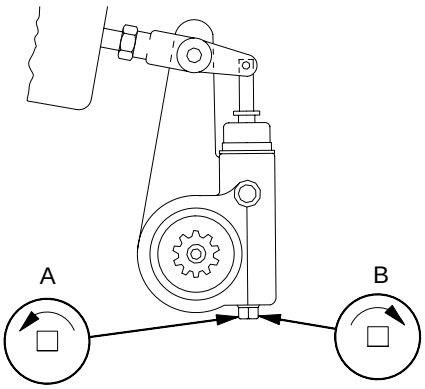
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A. Insert screwdriver here.

Fig. 1, Meritor Slack Adjuster 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), as follows. See **Fig. 2**.



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A. Shorten stroke. B. Lengthen stroke.

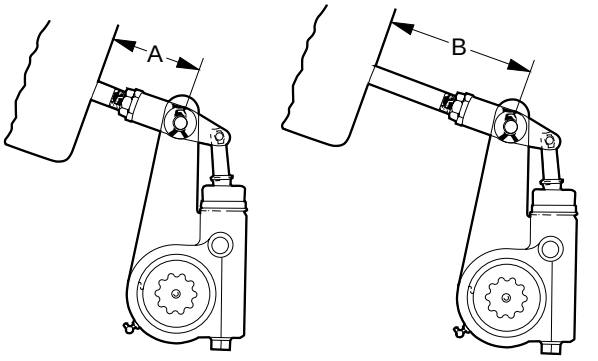
Fig. 2, Turning the Adjusting Nut

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, as follows.

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**.



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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

7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum.

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), as follows.

8.1 Start the engine and build the air pressure to 100 psi (689 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**.

⚠ CAUTION

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

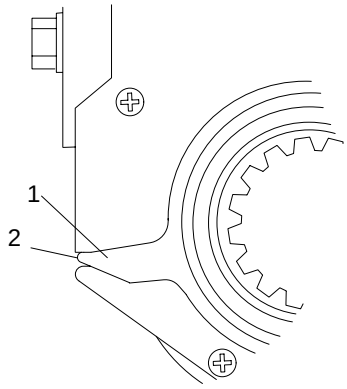
IMPORTANT: Before adjusting the brakes, see the pre-adjustment checks and general adjustment information at the beginning of this subject.

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).

CAUTION

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.

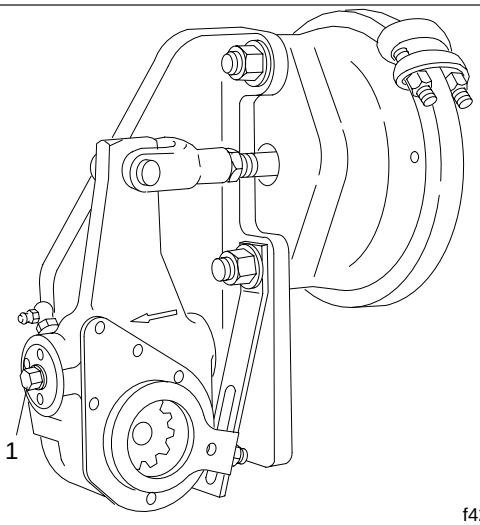


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1. Installation Indicator 2. Indicator Notch

Fig. 4, Installation Indicator

5. Measure how much torque is required to overcome the resistance of the internal clutch (internal clutch slippage), as follows.
   - 5.1 Using a torque wrench with a 7/16-inch socket, turn the adjusting nut counterclockwise. See **Fig. 5**. You will hear a ratcheting sound.



10/17/95 f420699a

1. Adjusting Hexnut

Fig. 5, Adjusting Hexnut

   - 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), as follows.
   - 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, as follows.
   - 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.
   - 7.2 Using a lever, move the slack adjuster until the brake linings contact the brake drum. Then, measure the distance from

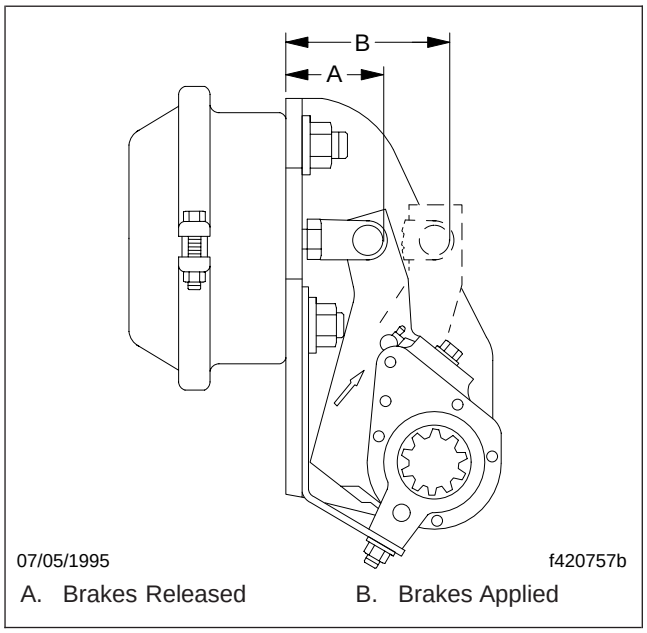


Fig. 6, Measuring the Stroke

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), as follows.

8.1 Start the engine and build the air pressure to 100 psi (689 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**.

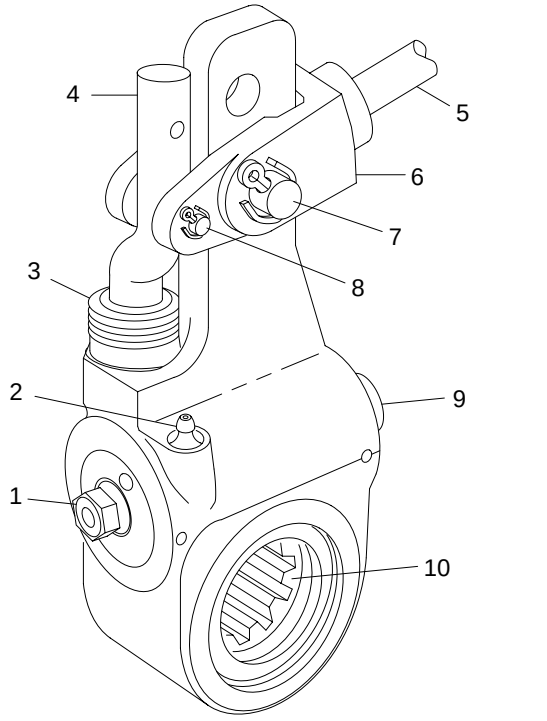
Gunite Automatic Slack Adjuster

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), as follows.

4.1 Using a 7/16-inch torque wrench, turn the adjusting nut counterclockwise. See **Fig. 7**. You will hear a ratcheting sound.

Brake Adjustment



10/27/93 f420653a

1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2"
8. Clevis Pin, 1/4"
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 7, Gunite Slack Adjuster

4.2 If the clutch slips with a torque less than 15 lbf·ft (20 N·m), the slack adjuster must be replaced.

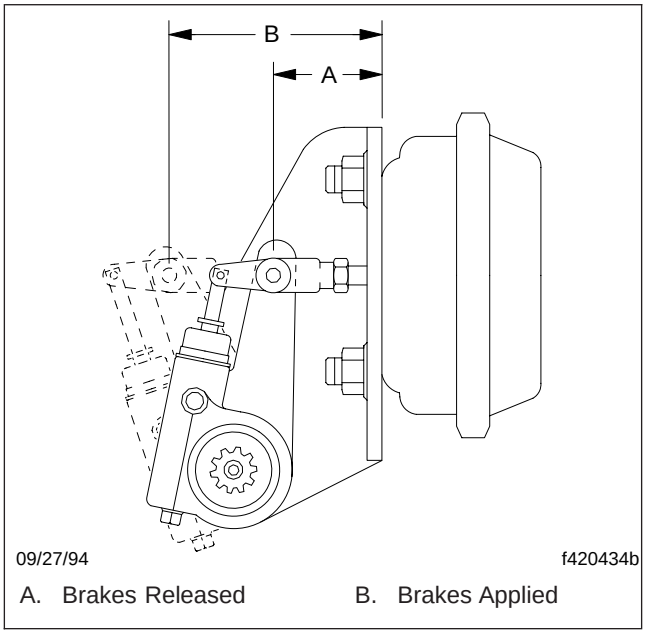
5. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows.

   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, as follows.

   6.1 Measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 8**. Record this measurement as dimension A.



09/27/94 f420434b

A. Brakes Released B. Brakes Applied

Fig. 8, Measuring the Stroke

   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. 8**. 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, measure the free-stroke again and readjust it until it is correct.

7. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

   7.1 Start the engine and build air pressure to 100 psi (689 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. 8**, 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.

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 150**. 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. Check for proper brake operation. For instructions, see **Subject 110**.

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.

WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Replacement

IMPORTANT: Vehicle brake systems require the correct lining material to perform as originally designed. The type of lining material that is specified for the vehicle is based on several technical considerations and Department of Transportation (DOT) braking performance regulations. To ensure fewer relines and greater compatibility with the vehicles brake system, use the same quality of friction lining material that was installed at the factory.

Always reline both wheels of an axle at the same time.

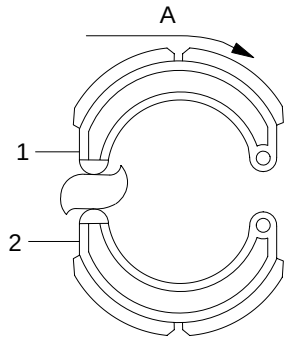
Always install the same linings and drums on both wheels of an axle. It is not necessary that both axles (front and rear) have the same linings and drums.

Combination linings with different friction ratings for the primary and secondary shoes are sometimes used. When combination friction lining sets are used, the lining blocks must be installed in the correct locations on the brake shoes.

NOTE: Always follow the instructions supplied with the replacement combination lining sets for correct installation. The primary linings must be installed on the primary shoe. The first shoe past the cam in the direction of the wheel rotation is the primary shoe.

The primary shoe can be either in the upper or the lower position, depending on the location of the cam. If the cam is behind the axle, then the upper shoe is the primary shoe. See **Fig. 1**. If the cam is in front of the axle, then the lower shoe is the primary shoe. See **Fig. 2**.

1. Remove the brake shoes. See **Subject 110** for instructions.

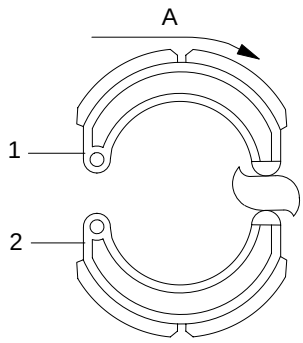


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A. Wheel rotation.

1. Primary Shoe 2. Secondary Shoe

Fig. 1, Camshaft Behind the Axle



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A. Wheel rotation.

1. Secondary Shoe 2. Primary Shoe

Fig. 2, Camshaft Ahead of the Axle

2. Using a dial indicator, 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). For instructions, see **Subject 150**.
   - If the cam-to-bushing radial free play exceeds 0.020 inch (0.5 mm) of movement, replace the bushings.
   - The axial end play should be 0.005 to 0.030 inch (0.13 to 0.80 mm). If it exceeds 0.030 inch (0.80 mm) of movement, remove the snap ring that secures the slack adjuster on the camshaft. Add shims between the slack adjuster and the snap ring.

Brake Shoe Lining Replacement

3. Remove the lining blocks from the brake shoes, as follows.

CAUTION

Drilling out rivets or cutting off rivet heads with a chisel can cause the rivet hole to become out-of-round, which could damage the brake shoe.

3.1 If the lining blocks are riveted, use a suitable riveting mandrel to push out the old rivets.

If the lining blocks are bolted, remove the bolts, lockwashers, and nuts.

3.2 Separate the lining blocks from the brake shoes.

4. Check the brake shoes for rust, expanded rivet or bolt holes, broken welds, and incorrect alignment. Replace the shoes if any of these conditions exist.

5. If necessary, clean each brake shoe with solvent and wire brush the shoe table. Then, paint the brake shoe with rust-inhibitive paint.

6. Install the lining blocks on the brake shoes, as follows.

IMPORTANT: Use rivets that have the correct material, shank diameter, length, head size, and shape. Use tubular rivets that are 1/4-inch diameter by 9/16-inch long, SAE no. 10, made of plated steel or brass.

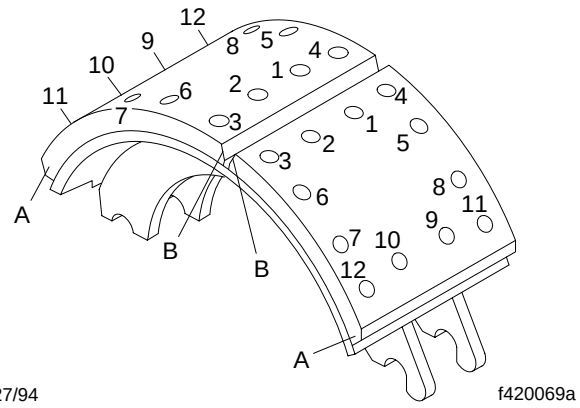
6.1 If the lining blocks are riveted, align the brake shoe rivet holes with the corresponding lining block holes. Using a C-clamp, clamp the lining block to the brake shoe.

Insert the correct size rivets in all the holes. Hold the rivets in place temporarily with masking tape.

Fasten the rivets (from the lining block to the brake shoe) in the sequence shown in **Fig. 3**.

6.2 If the lining blocks are bolted, align the brake shoe bolt holes with the corresponding lining block holes. Using a C-clamp, clamp the lining block to the brake shoe.

Insert the correct size bolts and new lockwashers into all the holes and threads.



NOTE: The numbers represent the fastening sequence.
A. Toe B. Heel

Fig. 3, Rivet and Bolt Fastening Sequence

Loosely install all the nuts, then tighten them in the sequence shown in **Fig. 3**.

- Tighten 3/8-inch brass bolts 18 to 23 lbf·ft (24 to 31 N·m).
- Tighten 1/4-inch brass bolts 80 to 100 lbf·in (900 to 1120 N·cm).

7. Check the lining installation by trying to insert a 0.010-inch (0.25-mm) feeler gauge along the edges between the linings and the shoe table. See **Fig. 4**.

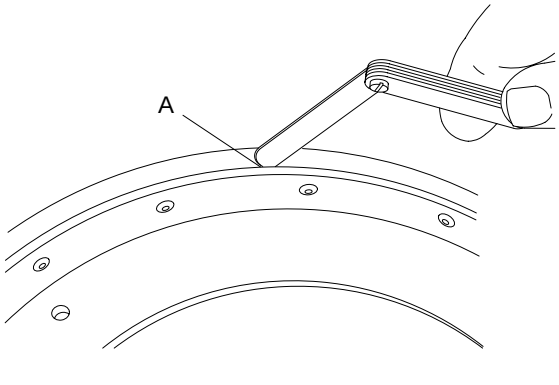
It should not be possible to insert the feeler gauge anywhere along the edge, except beyond the last row of rivets at each end. A larger clearance of up to 0.025 inch (0.64 mm) can exist at the ends. See **Fig. 5**.

8. Circle-grind the brake lining to get the correct lining-to-drum contact, as follows.

8.1 With the cam in the full-release position, grind the new brake linings 0.070 inch (1.8 mm) less than the drum diameter.

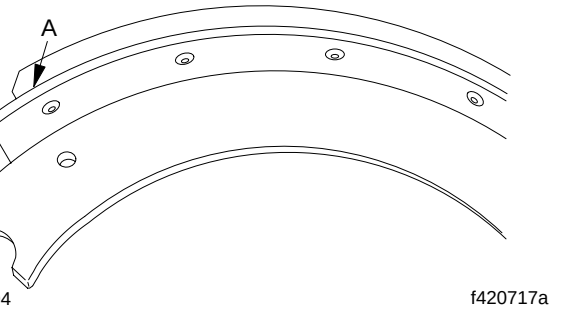
8.2 Adjust the cam and grind the lining until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.

9. Install the brake shoes, see **Subject 110** for instructions.



A. The clearance between the brake lining and shoe table must be less than 0.010 inch (0.25 mm).

Fig. 4, Checking Clearance Along Edge



A. The clearance between the shoe table and the ends of the brake lining can be up to 0.025 inch (0.64 mm).

Fig. 5, Checking Clearance at Ends

Brake Components Disassembly, Inspection, Cleaning, and Assembly

Disassembly and Inspection

⚠ WARNING

Before starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

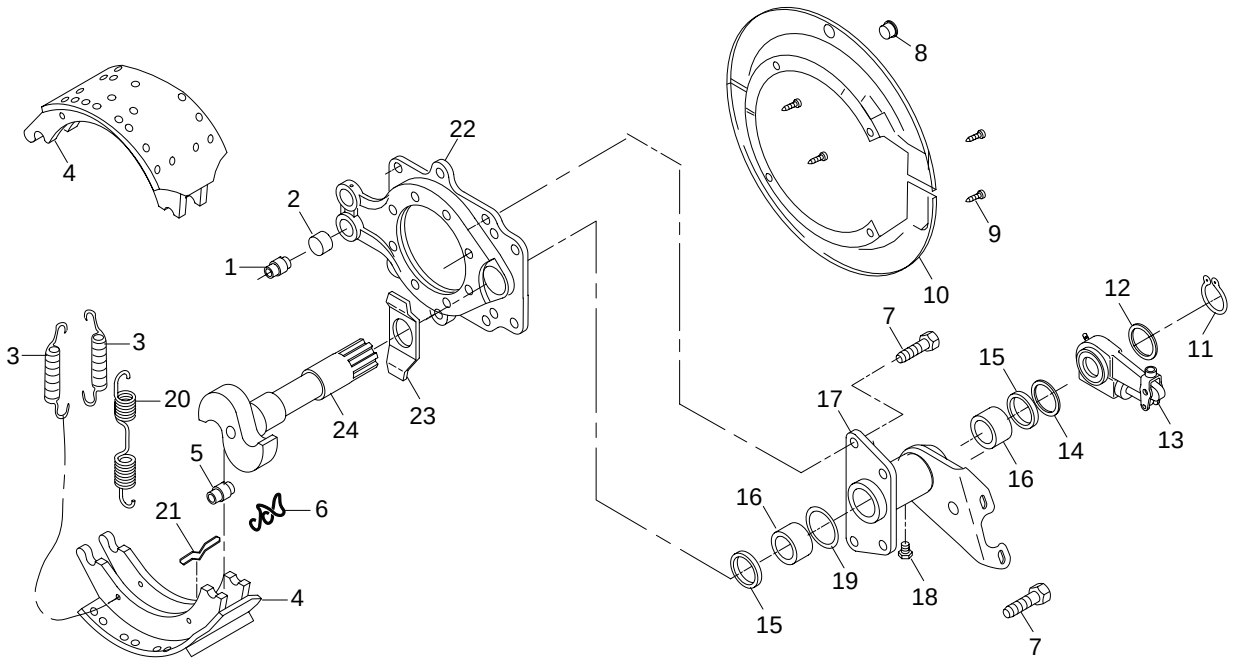
Three Q Plus brake assemblies are shown in the following figures:

- **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, as follows. 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

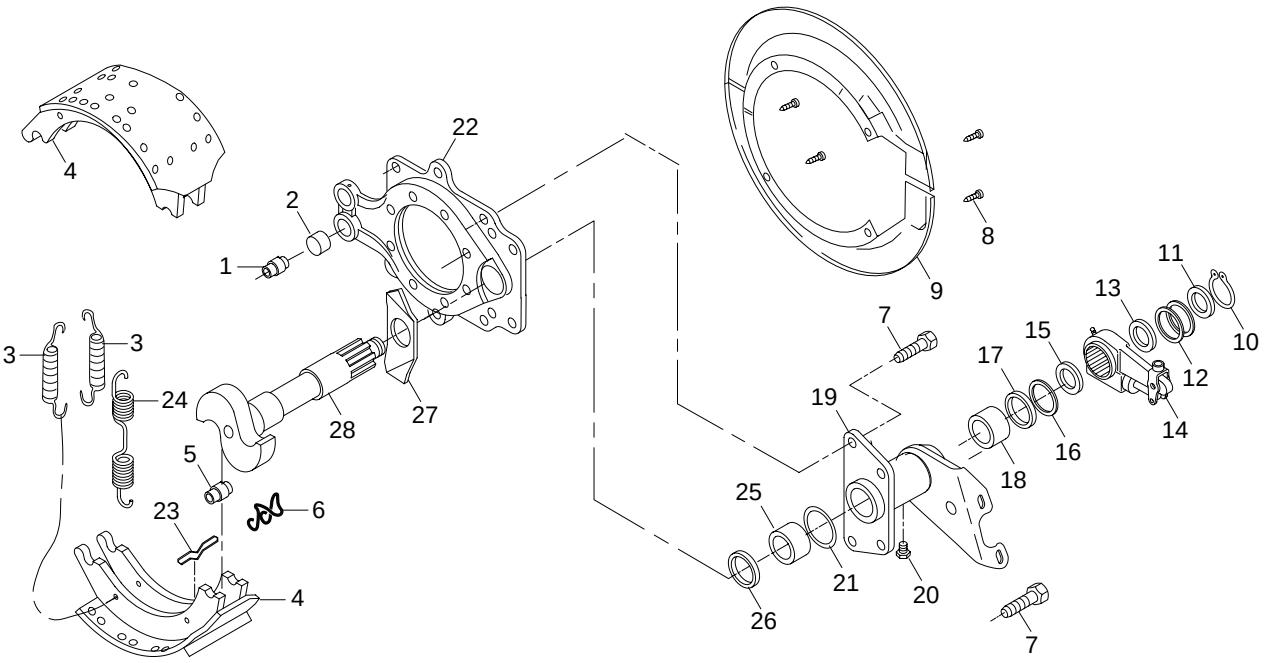


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1. Anchor Pin
2. Anchor Pin Bushing
3. Retaining Spring
4. Brake Shoe and Lining Assembly
5. Cam Roller
6. Roller Retainer
7. Capscrew, Chamber Bracket
8. Plug
9. Capscrew, Dust Shield
10. Dust Shield
11. Camshaft Snap Ring
12. Washer (spacer)
13. 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)

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" i.d.
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" i.d.
26. Orange Camshaft Seal
27. Camhead Thrustwasher
28. S-Head Camshaft

Fig. 2, Q Plus MX500 Brake (with cast spider)

glazed, grooved, or out-of-round can be repaired. For detailed instructions, see **Group 33** or **Group 35**.

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, as follows. For detailed instructions, see the appropriate section in this group.

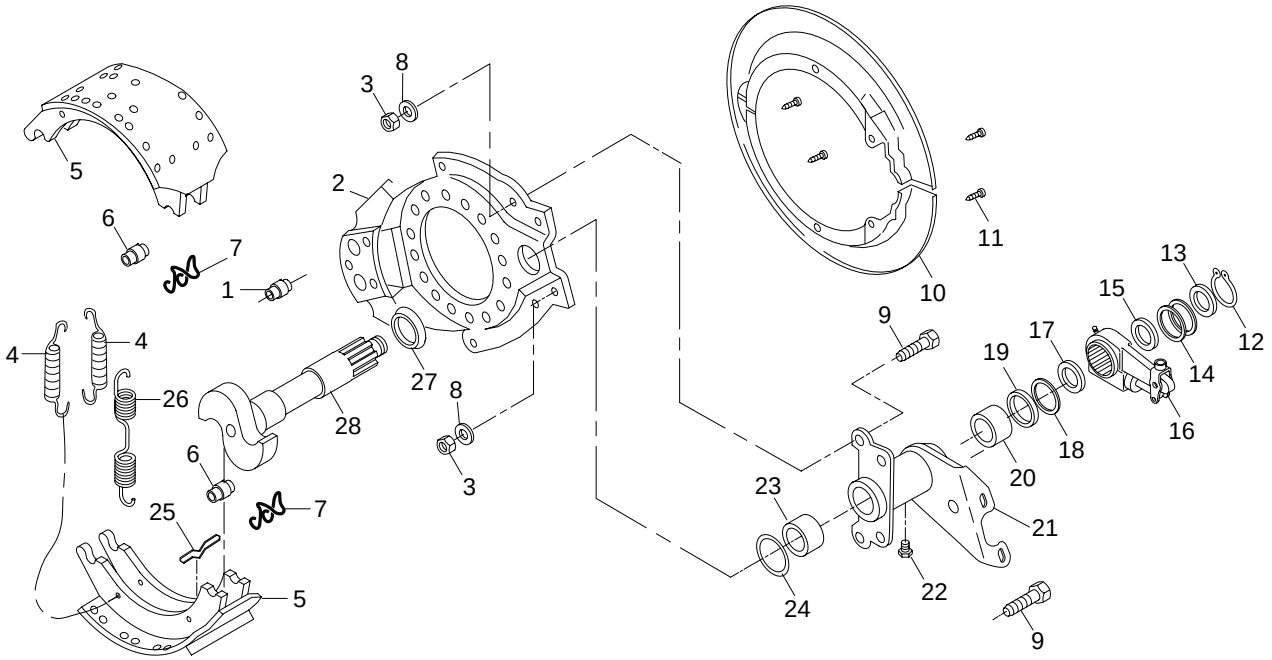
3.1 Remove the cotter pin from the clevis pin; remove the clevis pin. See **Fig. 5**.

CAUTION

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,

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" i.d.
21. Camshaft-and-Chamber Bracket
22. Pipe Plug
23. Camshaft Bushing, 1-5/8" i.d.
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)

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.

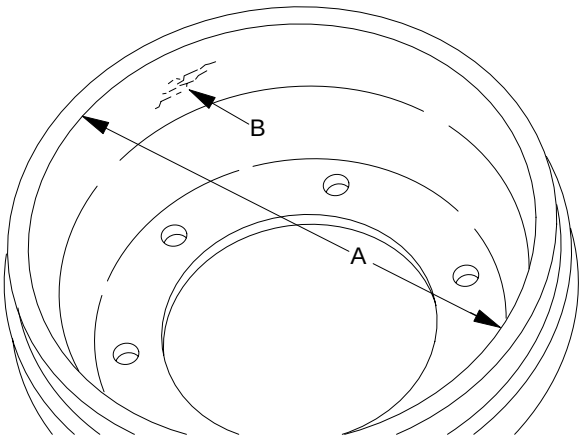
4. Check the camshaft radial free play, as follows. See **Fig. 7**.

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, as follows.

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

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. For instructions, see the appropriate section in this group.

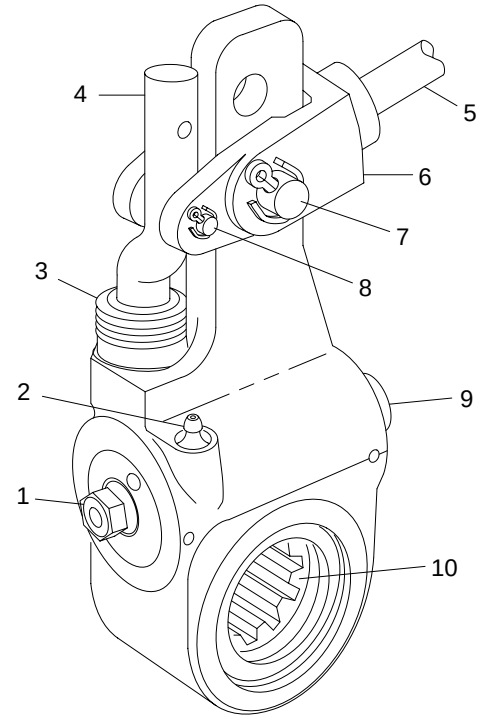
5.2 Remove the slack adjuster from the camshaft.

6. Inspect the slack adjuster for damage or binding, as follows.

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).



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NOTE: Gunite automatic slack adjuster shown.

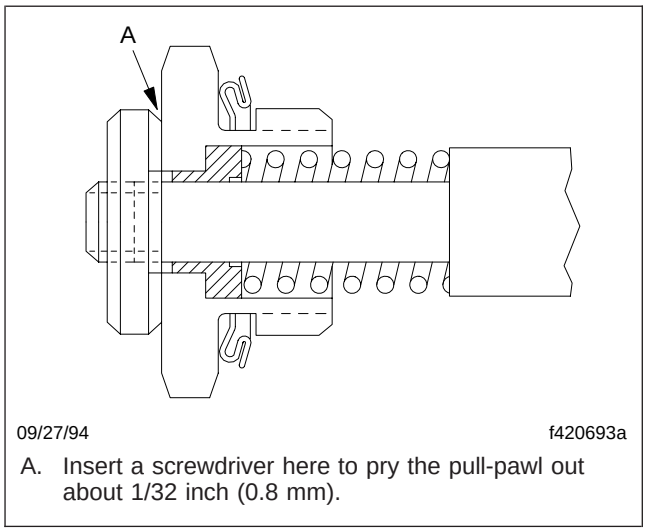
1. Adjusting Hexnut
2. Grease Fitting
3. Boot
4. Link
5. Brake Chamber Pushrod
6. Clevis
7. Clevis Pin, 1/2"
8. Clevis Pin, 1/4"
9. Grease Relief Opening
10. Slack Adjuster Spline

Fig. 5, Disconnecting the Slack Adjuster from the Clevis

If there is binding, or if more than 25 lbf·in (280 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.



A. Insert a screwdriver here to pry the pull-pawl out about 1/32 inch (0.8 mm).

Fig. 6, Disengaging the Pull-Pawl on Meritor Automatic Slack Adjusters

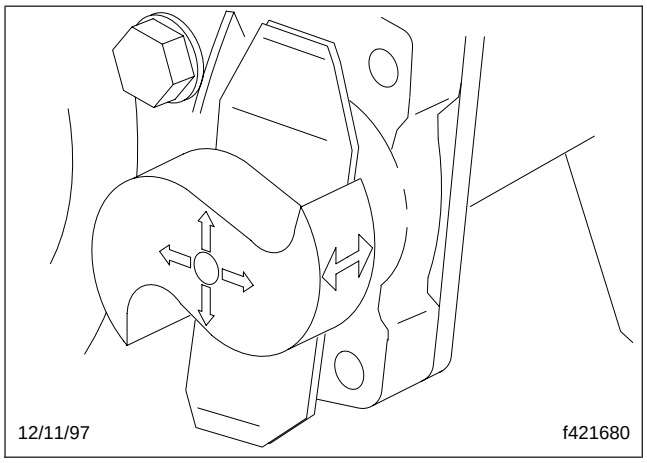


Fig. 7, Checking Free Play

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.

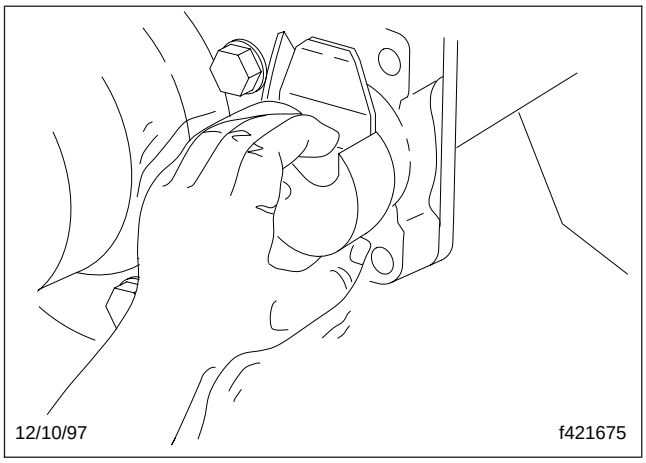


Fig. 8, Removing the Camshaft

⚠ 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.
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.

Brake Components Disassembly, Inspection, Cleaning, and Assembly

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, as follows: 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.
    - 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 starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

CAUTION

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:

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.

CAUTION

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.

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, as follows.
    - 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.

      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 starting the procedure below, read the safety precaution information in Safety Precautions 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

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**.

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, as follows.

   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**.

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	176 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 116
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
5/8–18 Bolt with Plain Hexnut	—	150 to 190	203 to 258

Table 1, Dust Shield, Spider, and Bracket Torque Specifications

Brake Components Disassembly, Inspection, Cleaning, and Assembly

Chamber Type (Size)	Brake Chamber Torque Specifications: lbf·ft (N·m)		
	Midland	MGM	Anchorlok
16	35 to 50 (48 to 68)	35 to 40 (48 to 54)	Not Available
20, 24, 30, 36	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
Spring Chamber	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)

Table 2, Brake Chamber Torque Specifications

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, as follows. See **Fig. 12**.

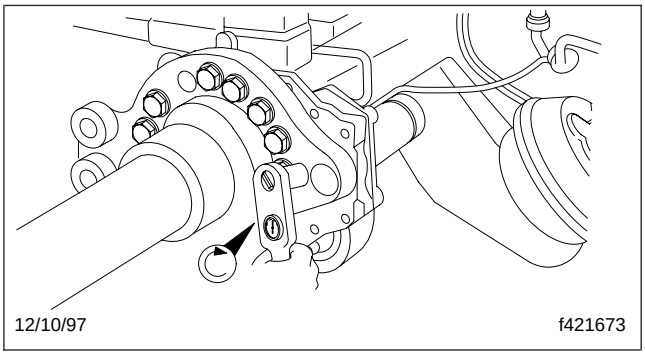


Fig. 9, Tightening the Brake Spider Fasteners

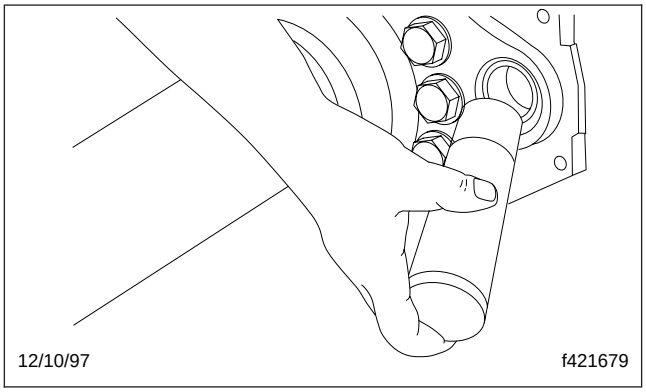
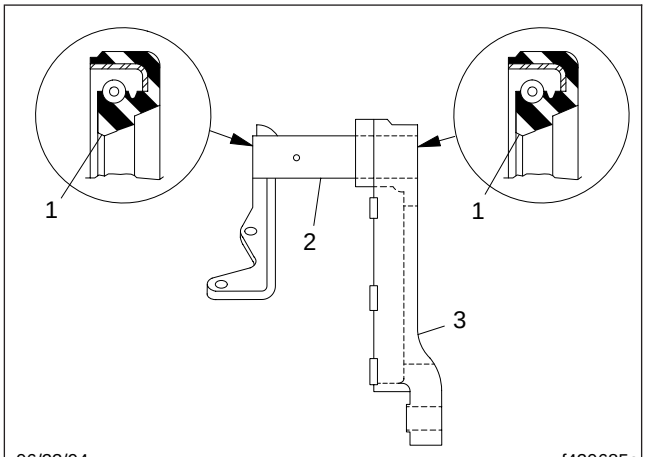


Fig. 10, Installing the Seals and Bushings



NOTE: The seal faces the slack adjuster.

1. Seal Lip
2. Camshaft-and-Chamber Bracket
3. Brake Spider

Fig. 11, Positioning the Seals

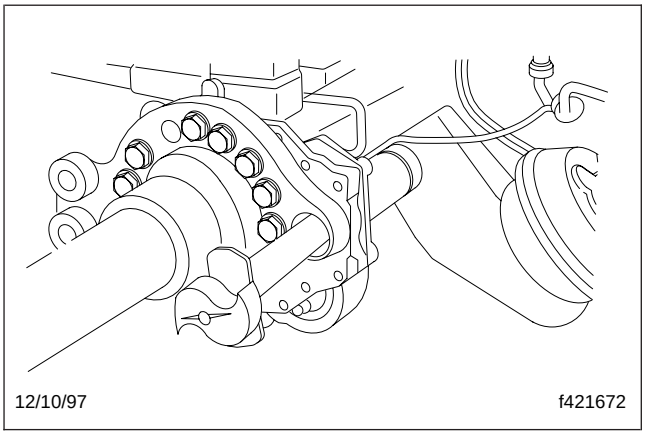


Fig. 12, Installing the Camshaft

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 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 the appropriate section in this group.

⚠ 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 increased, 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, as follows.

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, as follows.

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.

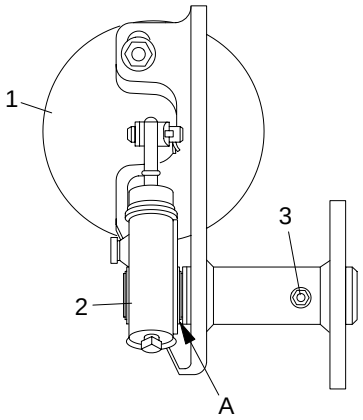
9.4 Using Meritor-approved NLGI grade 2 synthetic polyurea grease (EVO-LUBE TEK-615), lubricate the brake assembly through the grease fitting in the bracket until new grease flows from the inboard seal. See **Fig. 13**.

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.

Brake Components Disassembly, Inspection, Cleaning, and Assembly

10. Install the brake shoes. For instructions, see **Subject 110**.

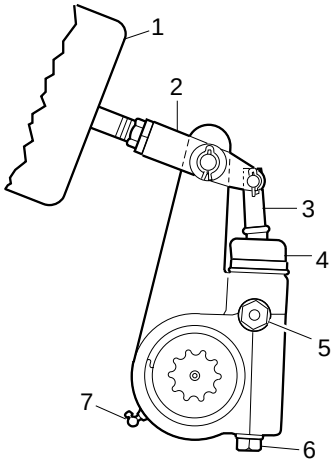


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A. Grease Exit

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 be at 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**
Incorrect brake linings are installed	Install the correct Meritor approved brake linings.
Wrong slack adjuster is installed.	Replace the slack adjuster with the correct one.
Clevis is not installed correctly.	Check the slack adjuster installation. For instructions, see the appropriate slack adjuster section in this group.
Jam nut at the clevis is loose.	Tighten the jam nut to specifications.
Spring brake is not fully retracting.	Repair or replace the spring brake.
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 Size	**Grade**	**lbf·ft**	**N·m**
Brake Shoe Lining Nuts			
1/4 inch	5	80 to 20 lbf·in	900 to 1120 N·cm
3/8 inch	5	18 to 23	24 to 31
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	176 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 116
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
5/8–18 Bolt With Plain Hexnut	—	150 to 190	203 to 258

Table 1, Q Plus Brake Torque Specifications

Chamber Type (Size)	**Brake Chamber Torque Specifications: lbf·ft (N·m)**		
	Midland	**MGM**	**Anchorlok**
16	35 to 50 (48 to 68)	35 to 40 (48 to 54)	Not Available
20, 24, 30, 36	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)
Spring Chamber	70 to 100 (95 to 136)	100 to 115 (136 to 156)	With hexnut, 110 to 115 (149 to 203) With locknut, 85 to 95 (115 to 129)

Table 2, Brake Chamber Torque Specifications

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)

Specifications

Meritor Grease Specification			
Specification Number	**NLGI Grade**	**Grease Type**	**Outside Temperature: °F (°C)**
O-637	1 and 2	Calcium Base	See Manufacturer's Specification
O-641	—	Antiseize	See Manufacturer's Specification
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 Adjusters**
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.

IMPORTANT: On MGM TR series chambers, the parking/emergency brake section is factory sealed (no clamp ring) and is a *non-serviceable* unit.

General Information

MGM TR series tandem cam brake chambers consist of a service brake section and a parking/emergency spring brake section. See **Fig. 1**. The service brake section is the smaller section near the clevis assembly.

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 pushrod assembly, a parking (spring) brake diaphragm, a piston, a power spring, and a detachable release bolt.

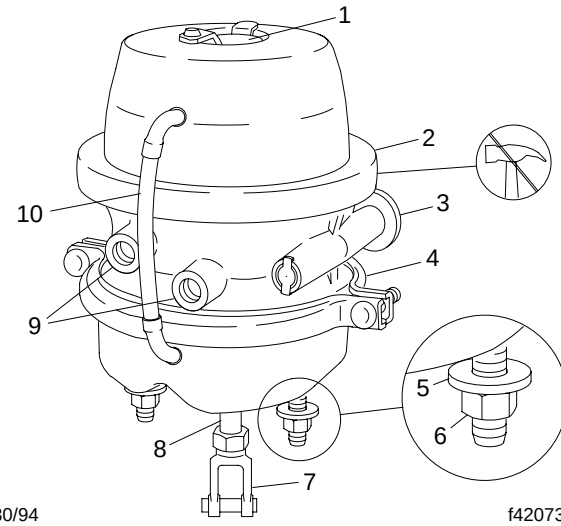
All MGM brake chambers are mounted to the frame using prevailing torque locknuts and hardened flatwashers.

MGM TR series chambers may be equipped with an external breather tube that protects the parking brake chamber from contaminants. These chambers are called Model TR-T chambers. See **Fig. 1**.

Periodic maintenance of the brake chambers is required. Also, whenever the service brake chamber is disassembled (*do not attempt to disassemble the parking brake chamber*), the parts should be inspected for damage.

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.



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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. Air Inlet Ports
10. External Breather Tube

Fig. 1, Model TR-T (TR Series) Brake Chamber

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 dia-

General Information

phragm toward the flange case. The resulting motion on the pushrod forces the service brake diaphragm and piston rod outward, applying the brakes.

General Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface, shut down the engine, and set the parking brake. 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. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (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.

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,

Safety Precautions

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.

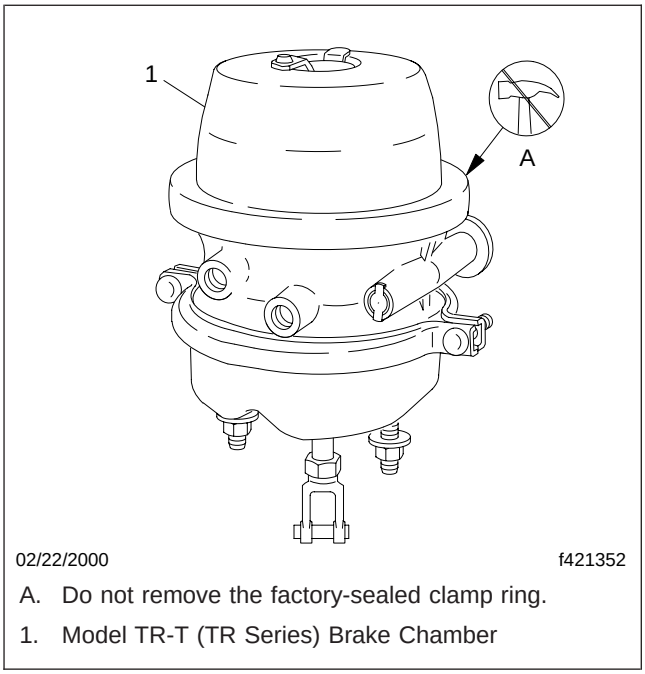
Work areas should be cleaned by industrial vacuums with HEPA filters or by wet wiping. Compressed air or dry sweeping should never be used for cleaning. Asbestos-containing waste, such as dirty rags, should be sealed, labeled, and disposed of as required by EPA and OSHA regulations. Respirators should 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.

Power Spring Manual Compression and Reset

⚠ 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. Model TR-T (TR Series) Brake Chamber

Fig. 1, Brake Chamber

Manual Compression (Parking Brake Release)

1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Remove the end cover cap from the center hole in the head of the chamber. See **Fig. 2**.

⚠ 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.

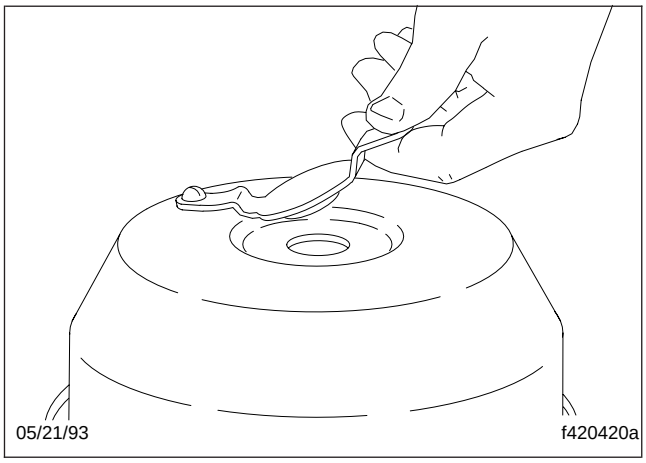


Fig. 2, Removing the End Cover Cap

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 MGM service manual.

3. Using a hand wrench (*do not 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. Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set the parking brake in the "release" position).
5. Insert the release bolt into the center hole in the chamber head. See **Fig. 4**. Insert the bolt until it bottoms out in the hole in the piston inside the chamber.

IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged the pis-

Power Spring Manual Compression and Reset

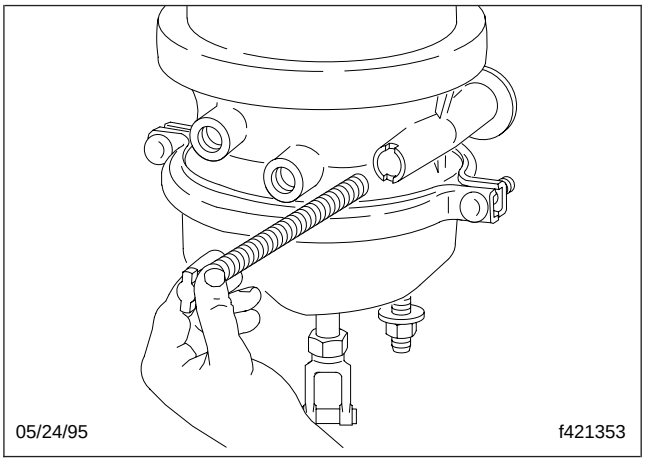


Fig. 3, Removing the Release Bolt

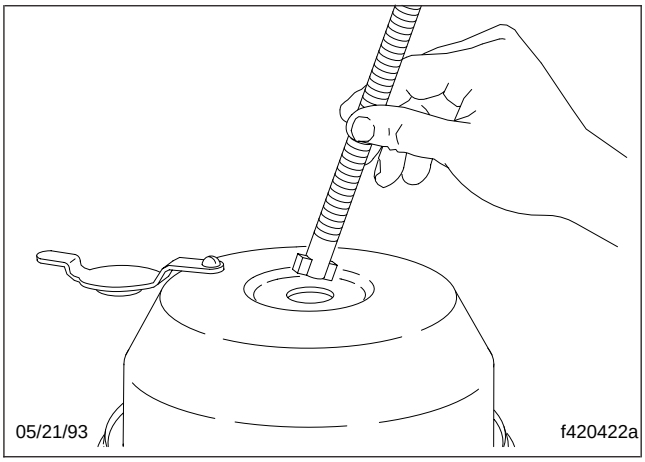


Fig. 4, Inserting the Release Bolt

ton correctly, repeat this step. Repeat it until you are absolutely sure.

6. 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 does not lock into the piston in less than a 1/2-inch (13-mm) outward movement, repeat these steps until you are sure it does lock.

7. 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**.

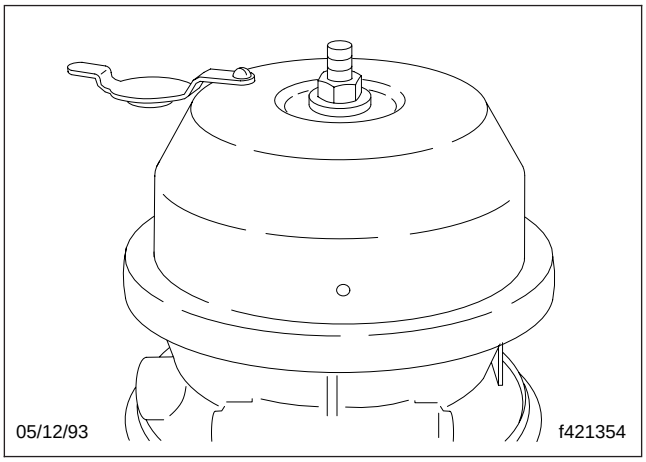
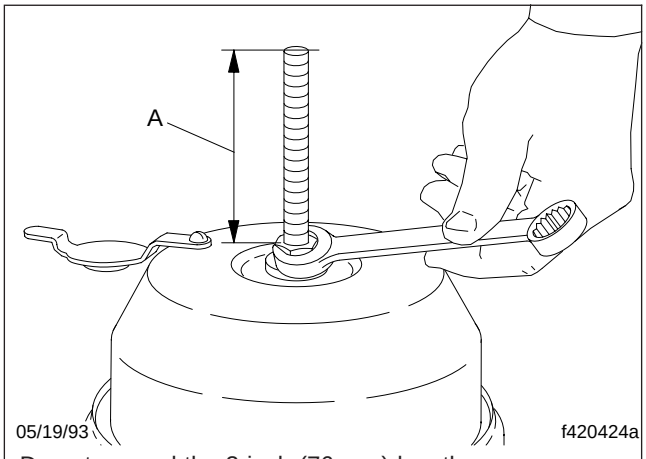


Fig. 5, Flatwasher and Release Nut Installed

⚠ CAUTION

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.

8. Using a hand wrench (*do not use an impact wrench*), turn the release nut clockwise until the bolt extends 3 inches (76 mm) above the nut. See **Fig. 6**.



Do not exceed the 3-inch (76-mm) length.
A. Measure this distance.

Fig. 6, Turning the Release Nut

IMPORTANT: Do not exceed the 3-inch (76-mm) length.

9. 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).

⚠ CAUTION

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. With air applied to the parking brake section (the parking brake control valve is in the "release" position), 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 (*do not use an impact wrench*), install the release bolt, flatwasher, and release nut in the storage pocket. MGM 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**.

⚠ CAUTION

If the external breather tube or 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 external breather tube or end cover cap in place voids the MGM warranty.

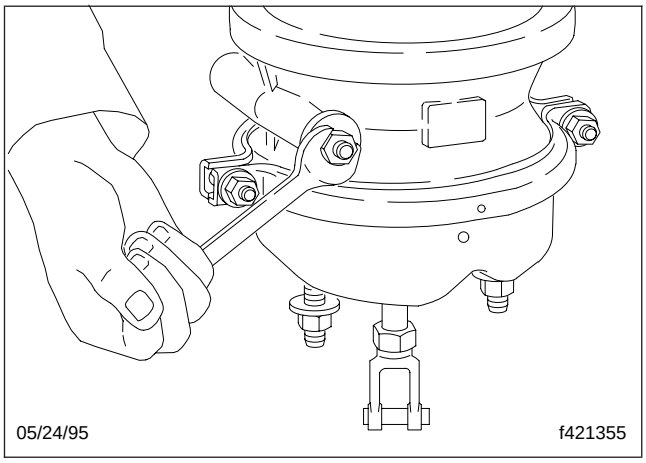


Fig. 7, Tightening the Release Nut

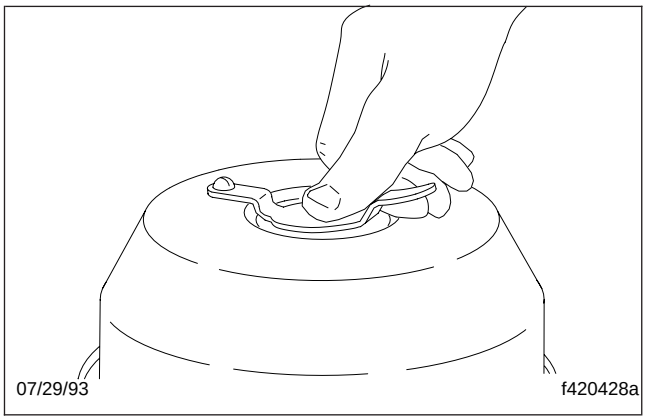


Fig. 8, Snapping the End Cover Cap in Place

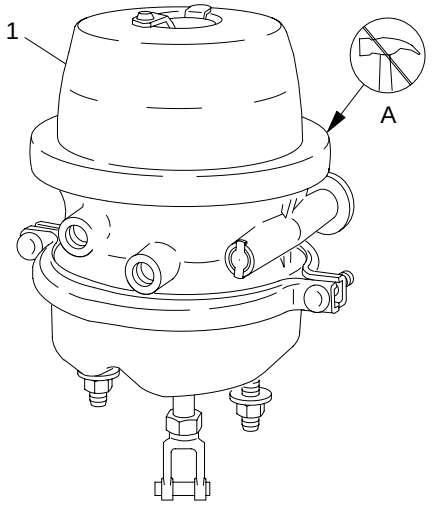
NOTE: Check the plastic end cover cap periodically. If it is damaged or missing, replace it with a new one at once.

7. Remove the chocks from the tires.

Service Brake Diaphragm Removal and Installation

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.



02/22/2000 f421352

A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

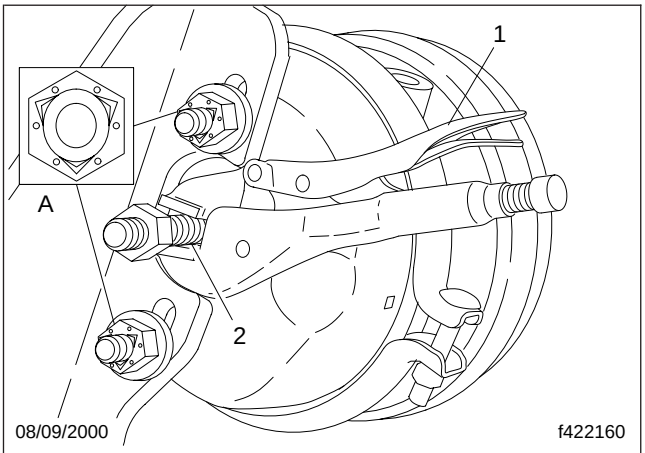
Fig. 1, Brake Chamber

Removal

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**.



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A. Prevailing Torque Locknut

1. Locking-Jaw Pliers
2. Piston Rod

Fig. 2, Locking the Piston Rod in Place

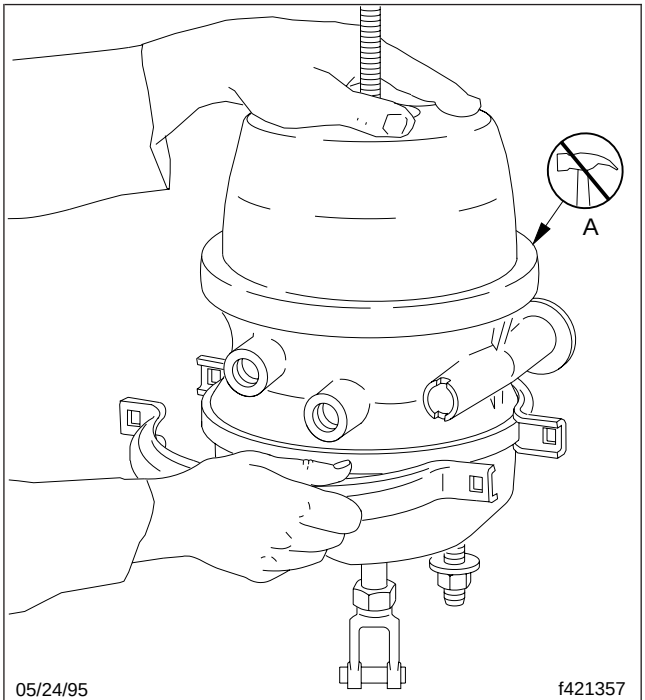
WARNING

Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. 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 100**.
3. Mark the air lines for later reference. Carefully disconnect them from the brake chamber.

   On chambers equipped with an external breather tube, disconnect the tube and elbow from the service brake chamber.
4. Using a hand wrench *(do not use an impact wrench),* remove the clamp nuts on the service clamp ring *(do not disassemble the parking brake section).*
5. While holding the parking brake section securely in place, remove the service clamp ring. Remove the parking brake section from the service brake non-pressure chamber. See **Fig. 3**.
6. Remove the service brake diaphragm from the bottom of the parking brake section.

Service Brake Diaphragm Removal and Installation



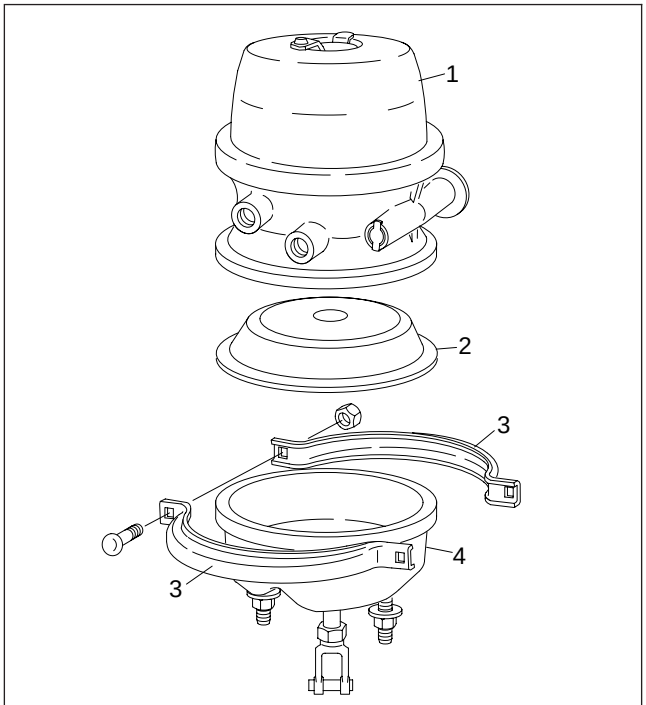
A. Do not remove the factory-sealed clamp ring.

Fig. 3, Removing the Service Clamp Ring

Installation

IMPORTANT: At this time, take the opportunity to inspect the parking/emergency brake section, and replace it if it shows signs of damage, corrosion, or rust.

1. Inspect all parts in the service (non-pressure) chamber. Replace any damaged or worn parts with genuine MGM-engineered replacement parts.
2. Place the new service brake diaphragm in the bottom recess of the parking brake section. See **Fig. 4**.
3. If installing a new parking brake section, be sure it is the same size and make as the old one.
4. Check that the release bolt is fully extended outward. For instructions, see **Subject 100**.
5. 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.



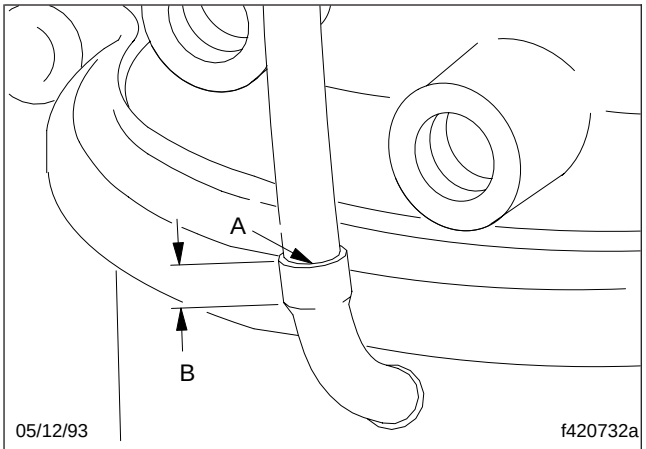
1. Parking/Emergency Brake Section
2. Service Brake Diaphragm
3. Service Brake Clamp Ring
4. Service Brake (Non-Pressure) Chamber

Fig. 4, Brake Chamber Parts

6. With the service brake clamp ring in place, install the clamp bolts and nuts.
7. Using a hand wrench *(do not use an impact wrench),* alternately tighten each clamp nut in increments of 60 to 120 lbf·in (680 to 1360 N·cm) while constantly rechecking the alignment of mating parts.

   If realignment is needed, loosen the nuts again, and repeat this step.
8. 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).
9. Make sure the air hose fittings are free of grease, dirt, and other debris. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

10. 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).
11. 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.
12. 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*). MGM recommends 25 to 30 lbf·ft (34 to 41 N·m) torque on the clamp hexnuts.
13. On chambers equipped with an external breather tube, make sure that the open end of the tube is free of grease, dirt, and other debris. Apply a high-quality rubber cement to the tube and insert it into the elbow at least a 1/2 inch (13 mm). See **Fig. 5**. Insert the tube into the service brake chamber.



A. Apply adhesive here.
B. Check for 1/2 inch (13 mm) minimum engagement.

Fig. 5, Installing the External Breather Tube

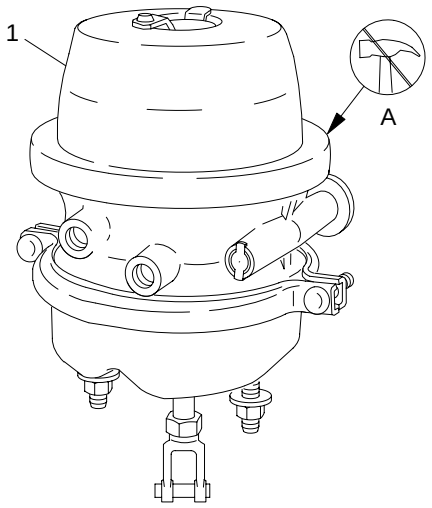
14. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the end cover cap in place. For instructions, see **Subject 100**.
15. Adjust the brakes at the slack adjuster.

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, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, see **Section 42.11** "Automatic Slack Adjusters, Meritor".

Replacement

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.



02/22/2000 f421352

A. Do not remove the factory-sealed clamp ring.

1. Model TR-T (TR Series) Brake Chamber

Fig. 1, Brake Chamber

IMPORTANT: The parking/emergency brake section can be replaced as a unit. For instructions, see **Subject 110**.

Combination Service and Parking Brake Chamber Removal and Installation

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.

Removal

WARNING

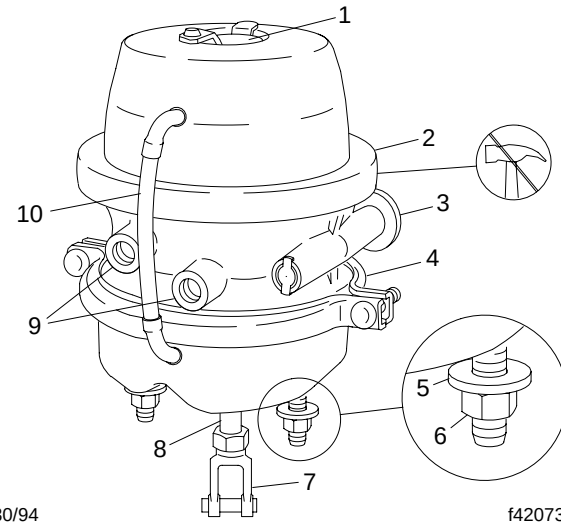
Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in Subject 100. When the power spring is caged, the vehicle may be without brakes, allowing it to roll out of control, possibly resulting in personal injury or property damage.

1. Manually release the parking brake (cage the power spring). For instructions, see **Subject 100**.
2. Mark the air lines for later reference. Carefully disconnect the air lines from the brake chambers.
3. Remove the cotter pin(s) from the clevis pins. Remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster. See **Fig. 1**.

NOTE: Meritor automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

4. Ensure the parking brake has been released manually (the power spring has been caged). For instructions, see **Subject 100**. Also, ensure the service brake piston is fully retracted (in the brakes "OFF" position). Record both of the following dimensions in either inches or millimeters, measuring outward from the base of the service brake chamber. See **Fig. 2**.
    - X dimension: to end of threaded piston rod.

IMPORTANT: When installing the new assembly, its service piston rod must be cut to exactly duplicate this "rod-plus-clevis" length *after* the clevis assemby is installed on the piston rod. See **Fig. 3**.



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. Air Inlet Ports
10. External Breather Tube

Fig. 1, Model TR-T (TR Series) Brake Chamber

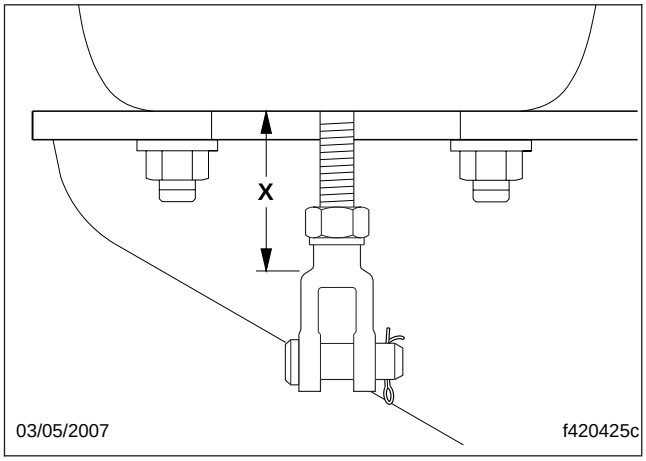


Fig. 2, Measuring X

If new chambers are to be attached to automatic slack adjusters, the X dimension is the

Combination Service and Parking Brake Chamber Removal and Installation

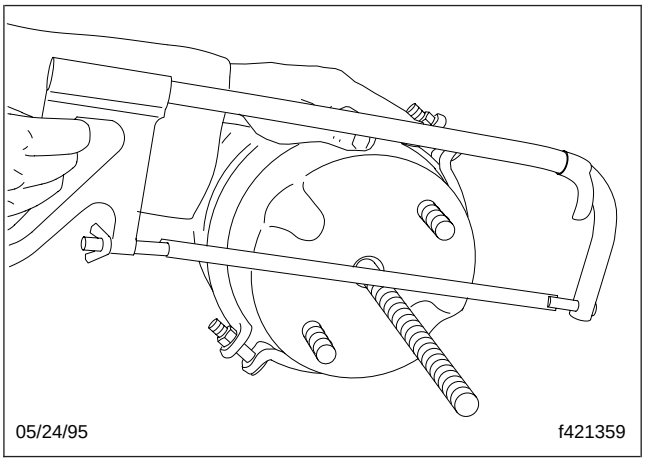


Fig. 3, Cutting the Service Piston Rod

most critical measurement. When installing 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. 3**.

5. From each mounting stud, remove any installed nuts and washers. Cautiously remove the brake chamber from the mounting bracket.

Installation

1. If installing a new brake chamber unit, perform the following steps. See **Fig. 1**.
   - 1.1 Make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 100** and perform 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 (*do not 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.

   On chambers equipped with an external breather tube, make sure that the tube is installed in the side of the chamber that faces away from the road surface. An improperly installed breather tube voids the MGM warranty.
4. Check mating and alignment with the vehicle air lines, as follows.
   - 4.1 Using a hand wrench (*do not 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 (680 to 1360 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. For instructions, see the appropriate slack adjuster section in this manual.
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. Apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*do not 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 25 lbf·ft (34 N·m).

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*). MGM 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, then snap the end cover cap in place. For instructions, see **Subject 100**.
10. Adjust the brakes at the slack adjuster. For instructions, see the appropriate slack adjuster section in this manual.

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, see the appropriate slack adjuster section in this manual.

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	25 (34)

Table 1, Torque Values

General Information

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**.

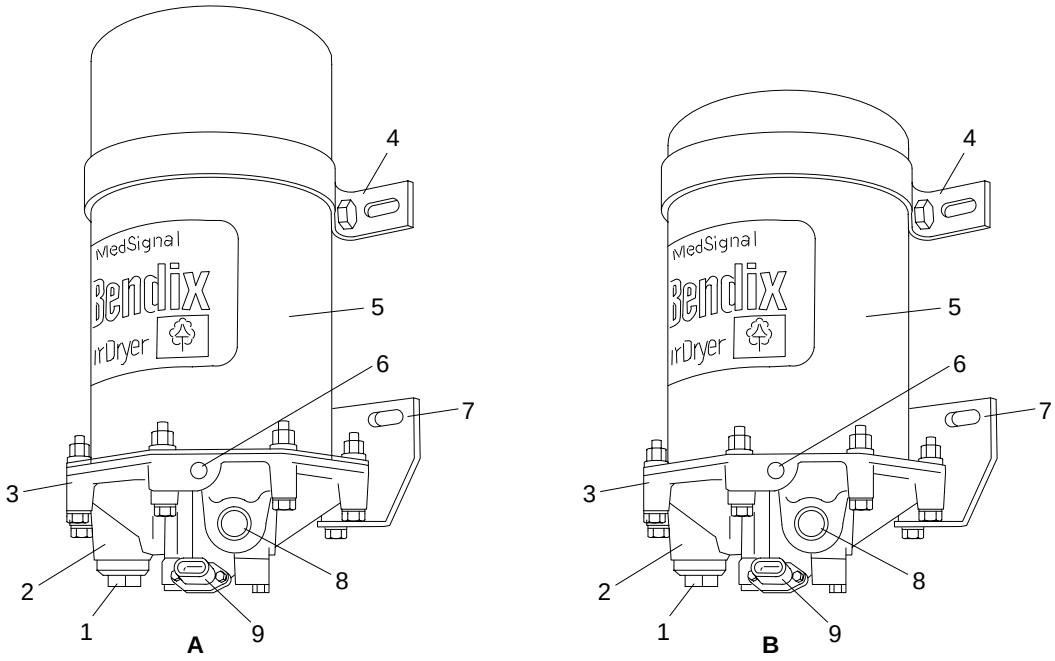
The AD-9 air dryer consists of the desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight bolts and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connections, and the purge valve housing assembly. The removable purge valve housing assembly features a purge valve mechanism and a turbocharger cutoff that are designed to prevent loss of engine turbo boost pressure during the purge cycle of the air dryer.

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-9 has three female pipe thread air connections; each is identified as follows in **Table 1**.

Port I.D.	Function/Connection
4-CON	Control Port (purge valve control and turbo cutoff)
11-SUP	Supply Port (air in)
2-DEL	Delivery Port (air out)

Table 1, Air Dryer Port Identification



11/08/2001 f430289

A. Extended Purge Air Dryer

B. Standard Air Dryer

1. Delivery Port
2. Check Valve Assembly
3. End Cover
4. Upper Bracket
5. Outer Shell
6. Control Port
7. Lower Bracket
8. Supply Port
9. Wiring Harness

Fig. 1, Bendix AD-9 Air Dryer

General Information

The standard air dryer uses a metal seat turbo cutoff valve. See **Fig. 2**. 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 turbo air leakage can occur in the unloaded mode.

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

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 direction of flow changes several times, reducing the temperature, causes contaminants to condense and drop to the bottom or sump of the air dryer end cover. See **Fig. 3**.

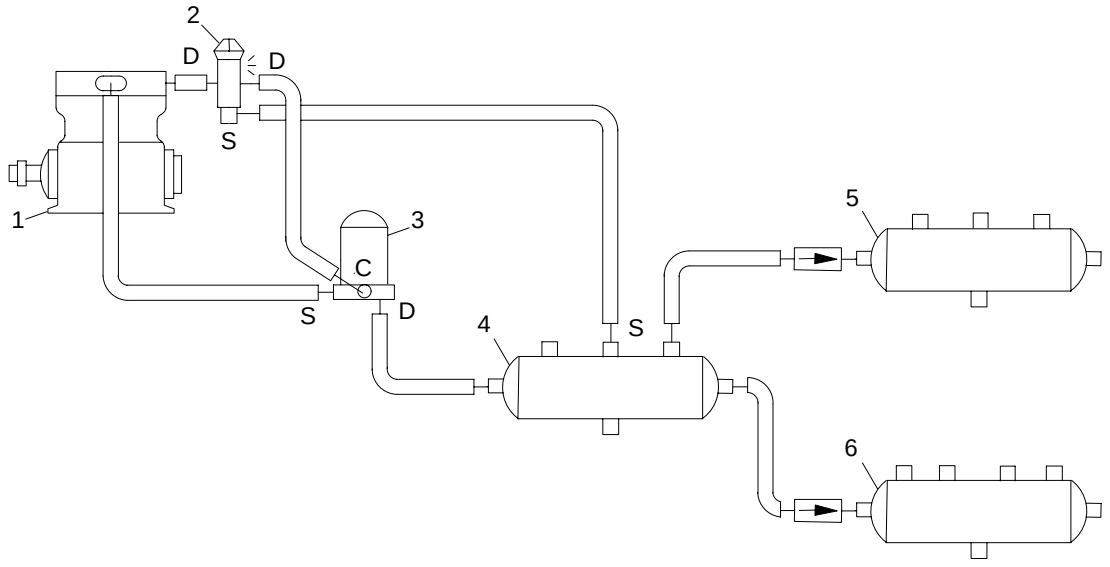
After exiting the end cover, air flows into the desiccant cartridge. Once in the cartridge, air first flows through an oil separator, which removes water, oil, oil vapor, and solid contaminants.

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.

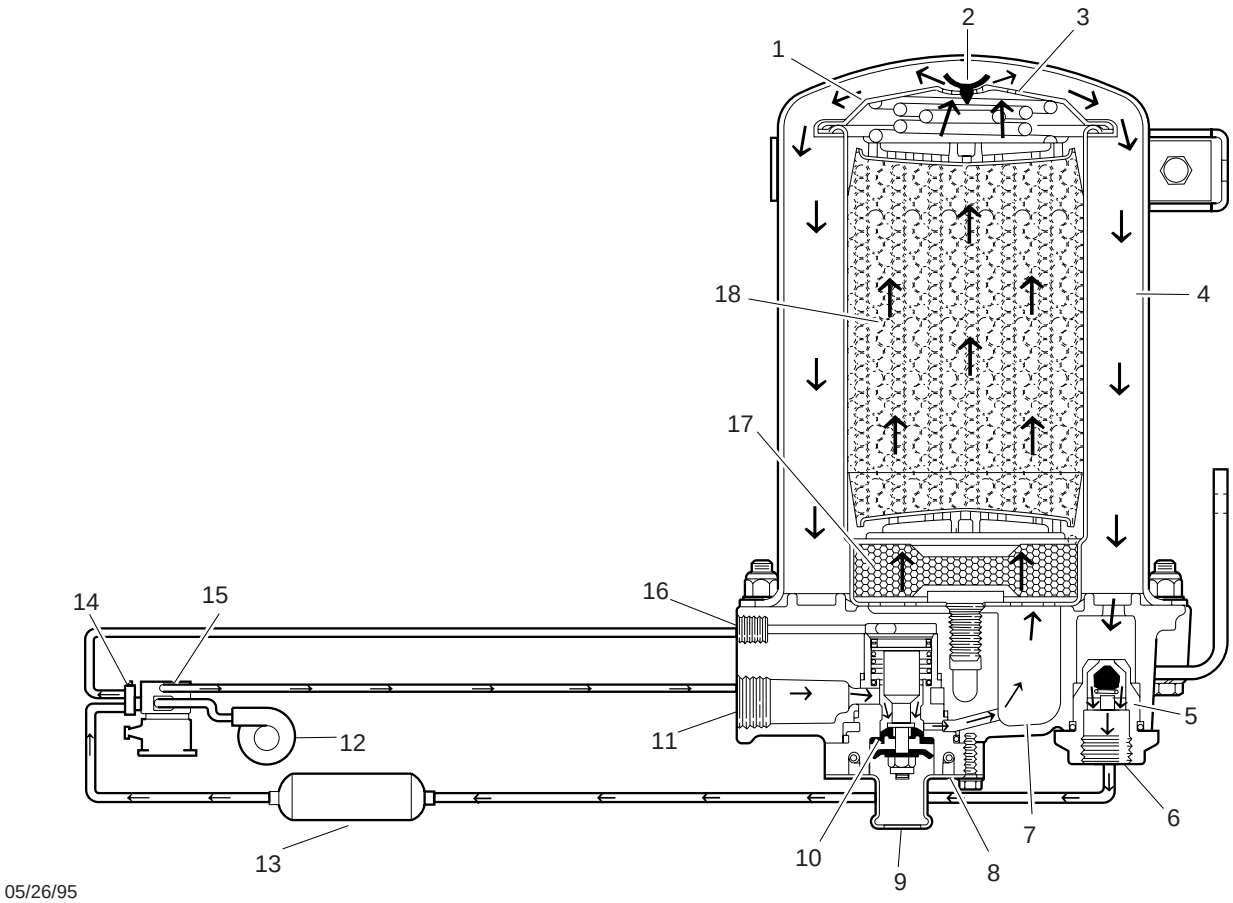
Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.



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



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

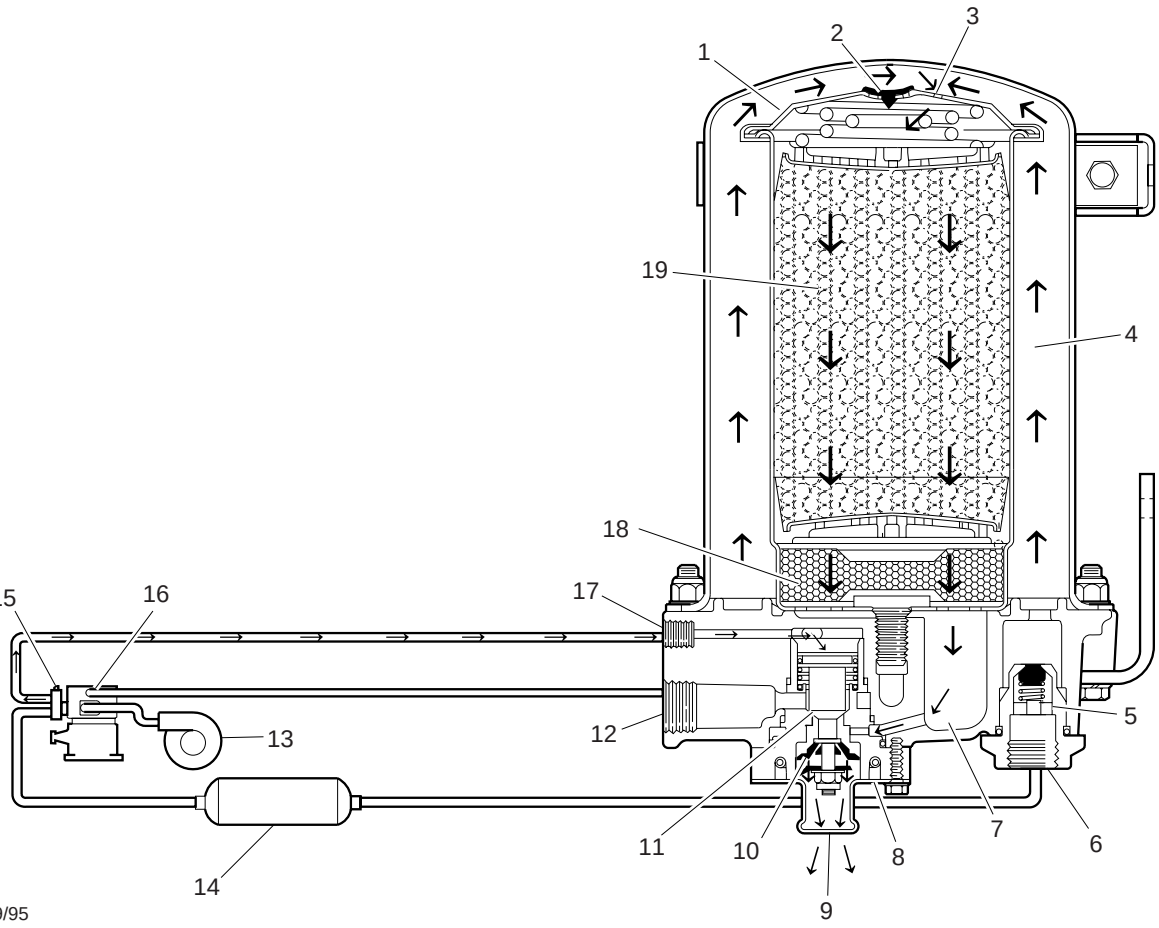
Fig. 3, AD-9 Charge Cycle

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. See **Fig. 4**. 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, and 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.

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. 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. 4, AD-9 Purge Cycle

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 desiccant 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.

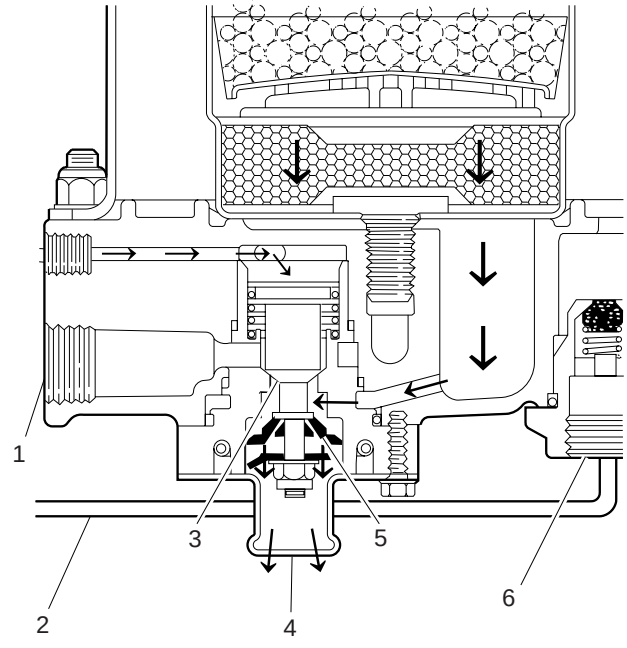
The end cover single check valve assembly prevents compressed air in the brake system from returning to the air dryer during the purge cycle. After the 30 second purge cycle is complete, the air dryer is ready for the next charge cycle to begin.

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 *S2 Chassis Maintenance Manual* for intervals and procedures.

Turbocharger Cutoff Feature

Primarily, the turbo 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 turbo 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. See **Fig. 5**.



1. Supply Port
2. Delivery Line
3. Turbocharger Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 5, AD-9 Turbo Cutoff

At the beginning of the purge cycle, the downward travel of the purge piston is stopped when the turbo cutoff valve (tapered portion of the purge piston) contacts its mating metal seat in the purge valve housing. With the turbo cutoff valve seated (closed position), air in the discharge line and AD-9 supply port is restricted from entering the air dryer. While the turbo cutoff *effectively* prevents 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:

1. 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 push rods and slack adjusters, which may apply as air pressure drops.
2. 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.
3. 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.
4. 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.
5. 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.
6. Replace devices with stripped threads or damaged parts. Repairs requiring machining should not be attempted.

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. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain all reservoirs to zero pressure.

CAUTION

Compressor discharge line may still contain residual pressure.

3. Identify and disconnect the three air lines from the end cover. 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 housing assembly.
5. Loosen the hexbolt that secures the upper mounting 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 tow holes of the end cover. These bolts are longer than the other six bolts.
7. Remove the air dryer from its mounting brackets.

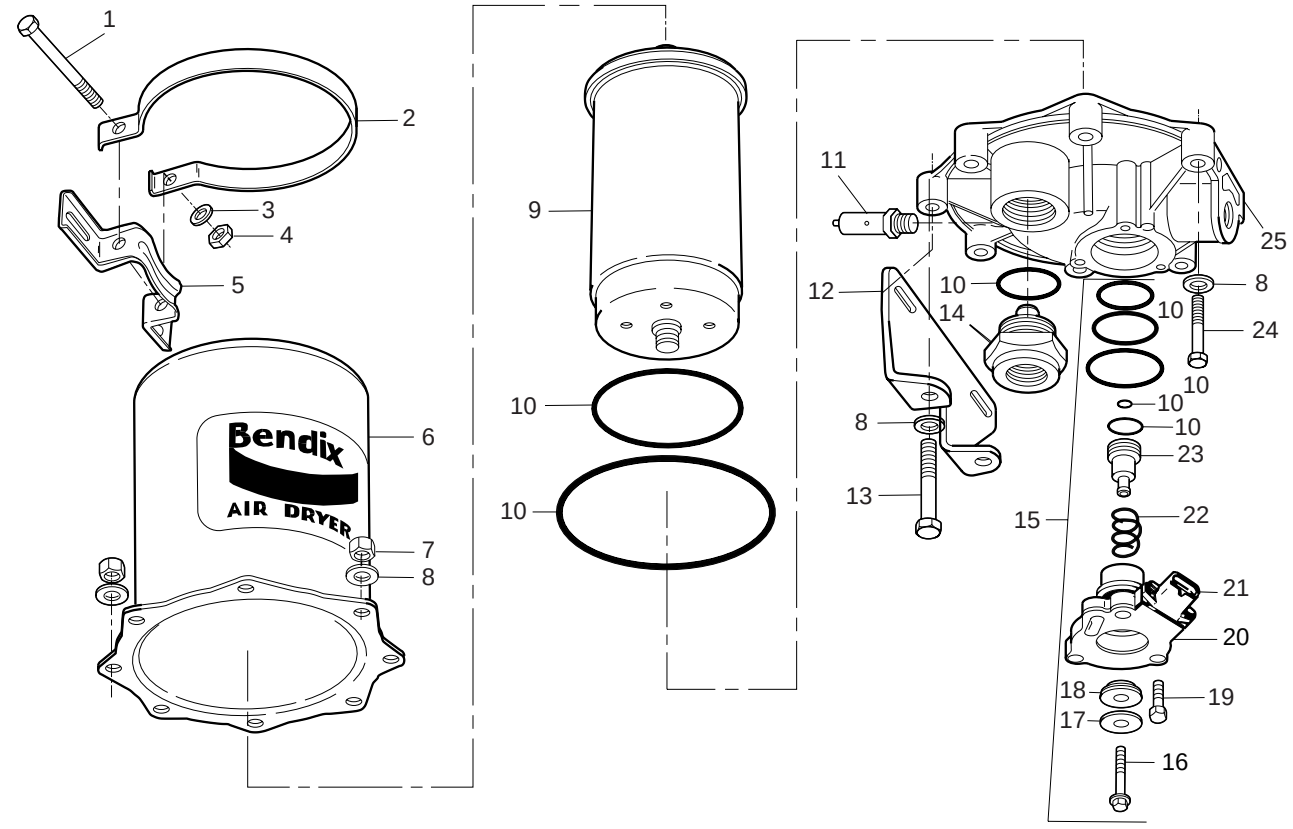
Installation

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

1. Position the air dryer into the upper mounting bracket and strap. 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. See Fig. 1.
2. Using the remaining two 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 bolt and nut on the upper mounting bracket strap 80 to 120 lbf·in (900 to 1360 N·cm).
4. Connect the three air lines to the correct ports on the end cover as identified in "Removal".
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 *S2 Chassis Maintenance Manual.*

Air Dryer Removal and Installation



08/09/95 f421383

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 Bolt (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
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 Bolt
25. End Cover

Fig. 1, Bendix AD-9 Air Dryer

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

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

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

⚠ CAUTION

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, as follows. See Fig. 1.
3. Remove the purge valve housing assembly, as follows. See Fig. 1.
   - 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.

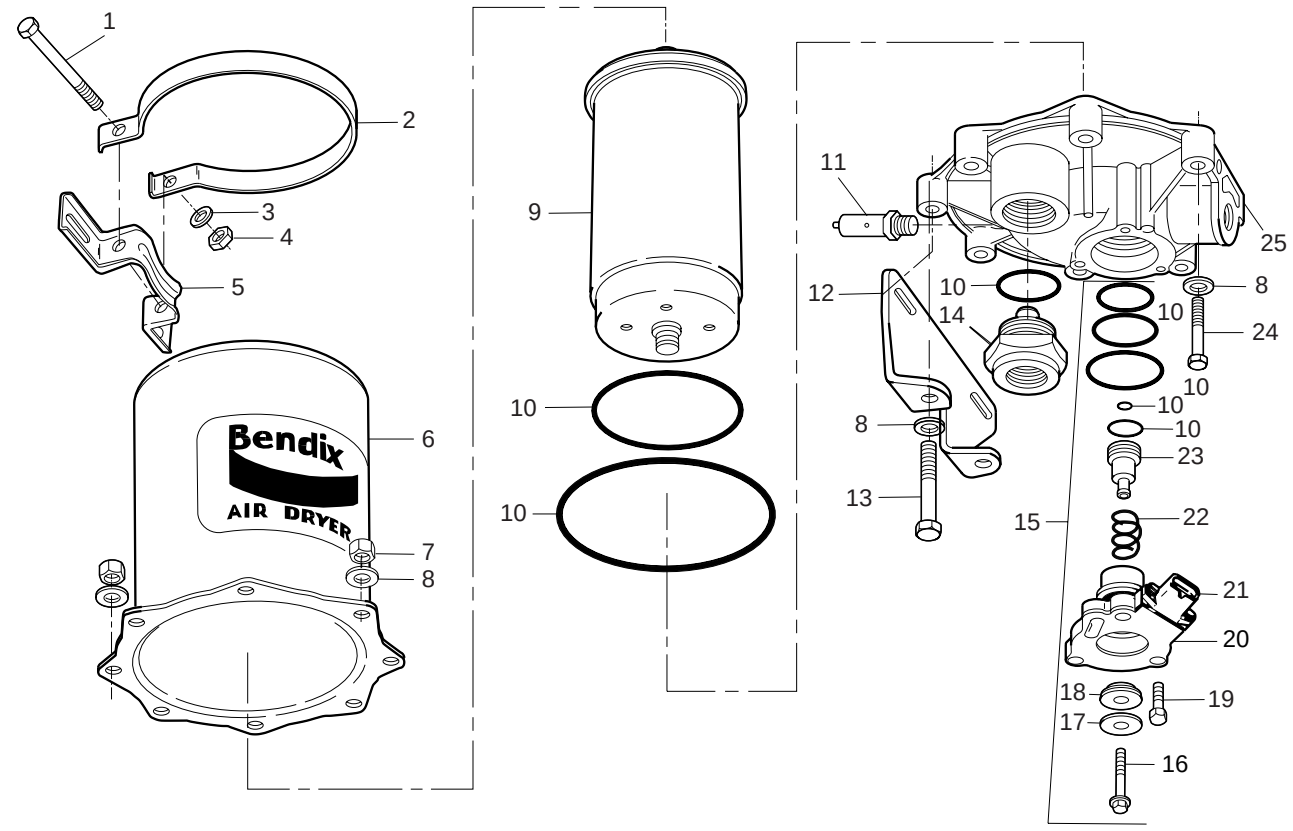
   NOTE: These O-rings may lodge in and have to be removed from the end cover bores.
4. Remove the heater and thermostat assembly, as follows. See Fig. 1.
   - 4.1 Remove and discard the two screws that attach the heater and thermostat assembly to the purge valve housing.
   - 4.2 Gently rotate the electrical 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. See Fig. 1.
   - 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 bolt 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, locknuts, and twelve special washers that secure the end cover to the housing. Separate the end cover and desiccant cartridge from the housing. See Fig. 1.
7. Remove the end-cover-to-outer-housing O-ring. See Fig. 1.
8. Don't remove the safety valve 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 (1360 to 4520 N·cm). Make sure the drain hole (slot) is facing down.
9. Place a strap or chain wrench around the desiccant cartridge 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.

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. See Fig. 1.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly



08/09/95 f421383

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 Bolt (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve Bolt
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)

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Cleaning 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.

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

⚠ 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. 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 (115 to 225 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 bolt. Torque the purge valve bolt 60 to 80 lbf·in (680 to 900 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.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

Start all three screws by hand, then torque them 85 to 125 lbf·in (960 to 1400 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 2820 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.
   - 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**.

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 **Subject 130**.

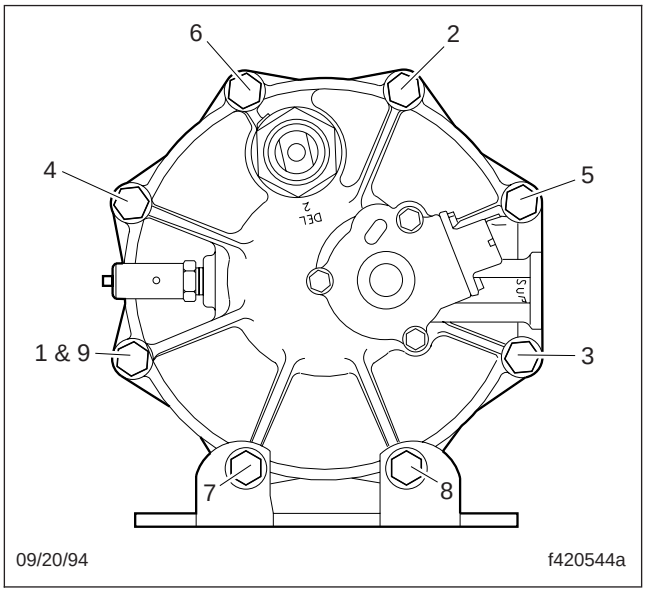


Fig. 2, End Cover to Housing Torque Pattern

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.

Troubleshooting Tables

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."

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
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.
System is leaking excessively.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is 1 psi/min (7 kPa/min) per service reservoir.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
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

The following air brake plumbing diagrams are a typical S2 Chassis configuration.

For detailed plumbing diagrams for a specfic vehicle, see PartsPro®.

Overall Chassis Diagram

Figure 1 is a full view of a typical plumbing diagram for an air brake installation. See **Fig. 2** and **Fig. 3** for detailed views of **Fig. 1**.

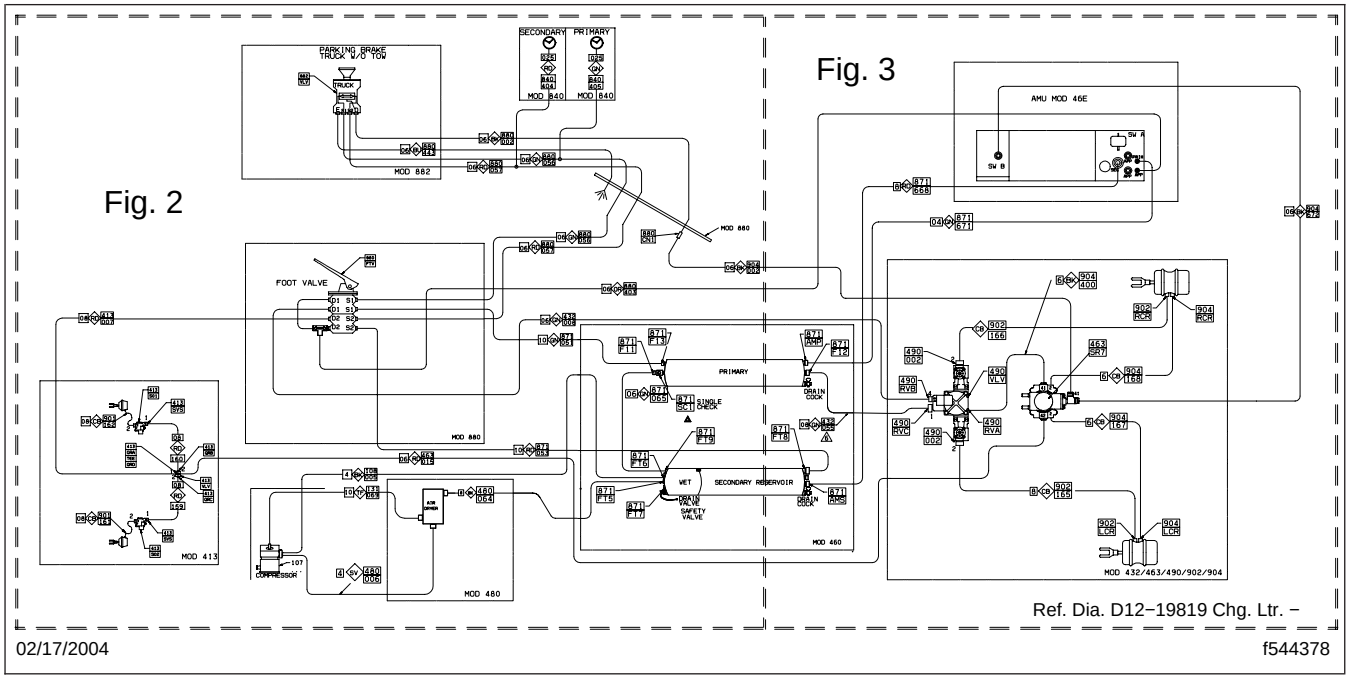


Fig. 1, Air Plumbing (full view)

Chassis Diagrams

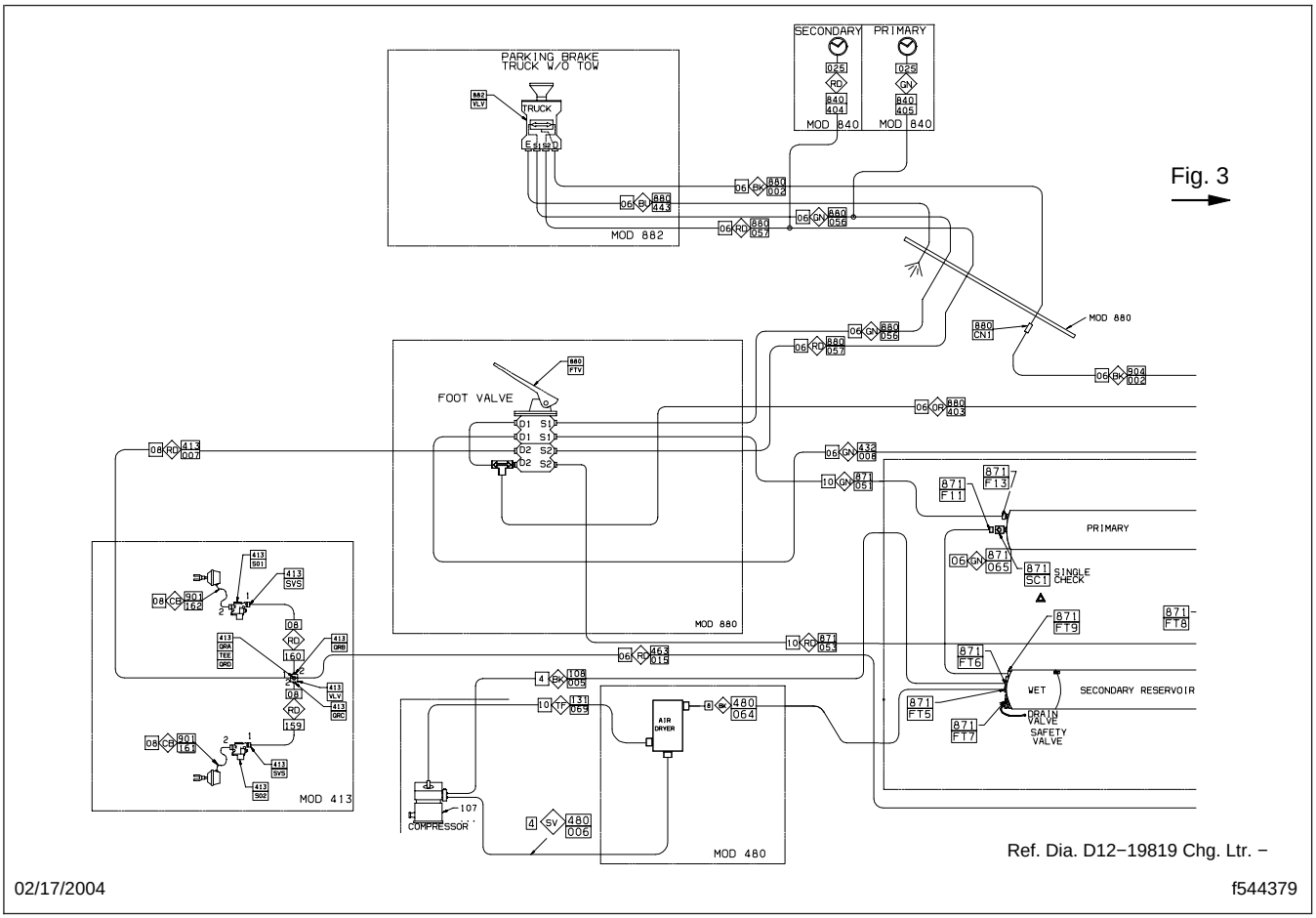


Fig. 2, Air Plumbing (partial view)

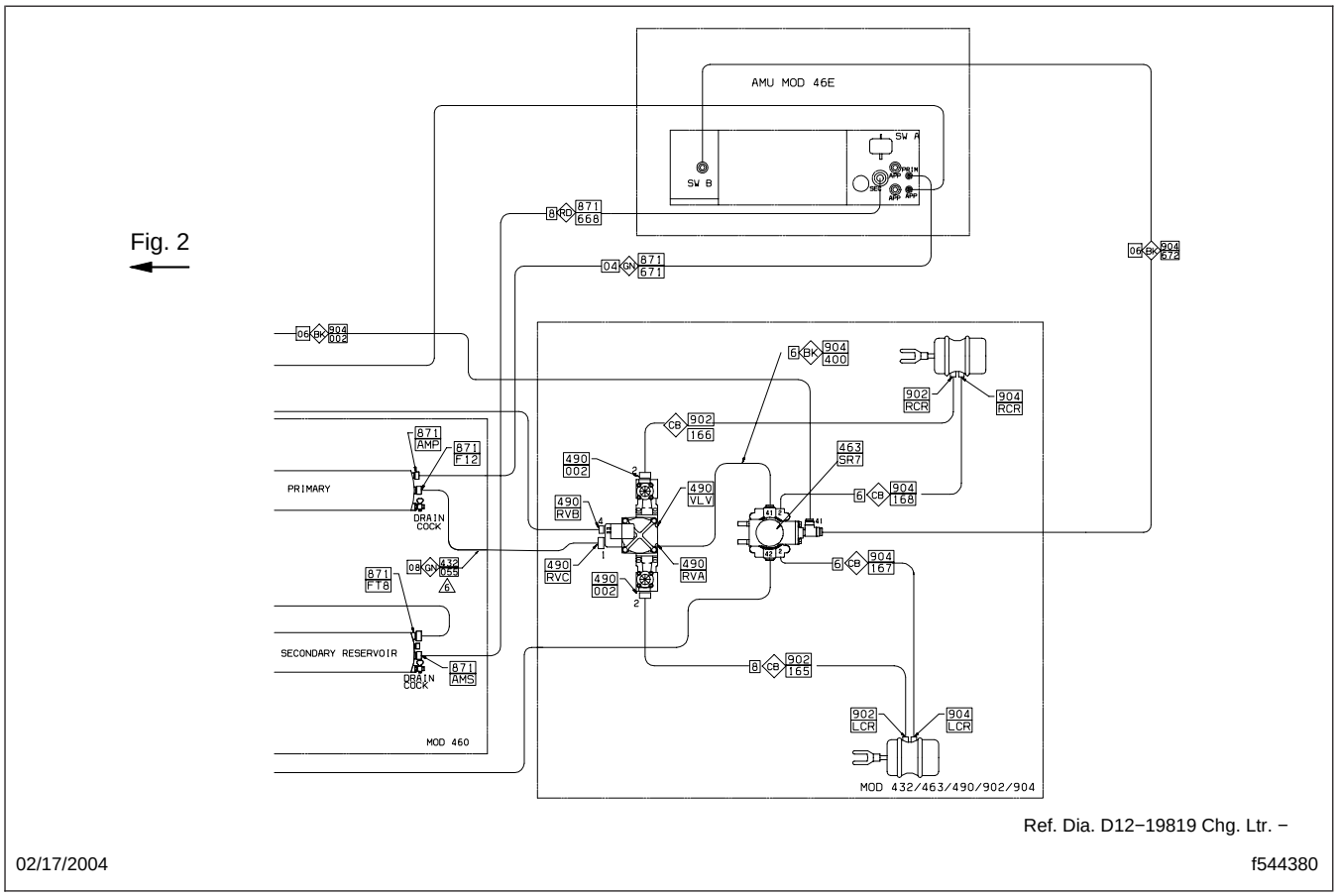


Fig. 3, Air Plumbing (partial view)

General Information

Bosch® hydraulic pin slide disc brakes are two-piston sliding caliper brakes for use at both front and rear wheels. See **Fig. 1**. Each pin slide caliper disc brake wheel installation is comprised of three major components. See **Fig. 2**.

Caliper Assembly

The caliper assembly includes two hydraulic piston bores. The piston bores contain the pistons, piston seals, and piston boots. The caliper assembly attaches to and slides on sealed pins located in an anchor plate. The anchor plate is mounted on the steering knuckle flange on front axles or on the axle flange on rear axles. Two sizes of calipers are used: 66 mm Twin (2 piston) and 73 mm Twin (2 piston). See **Fig. 3**.

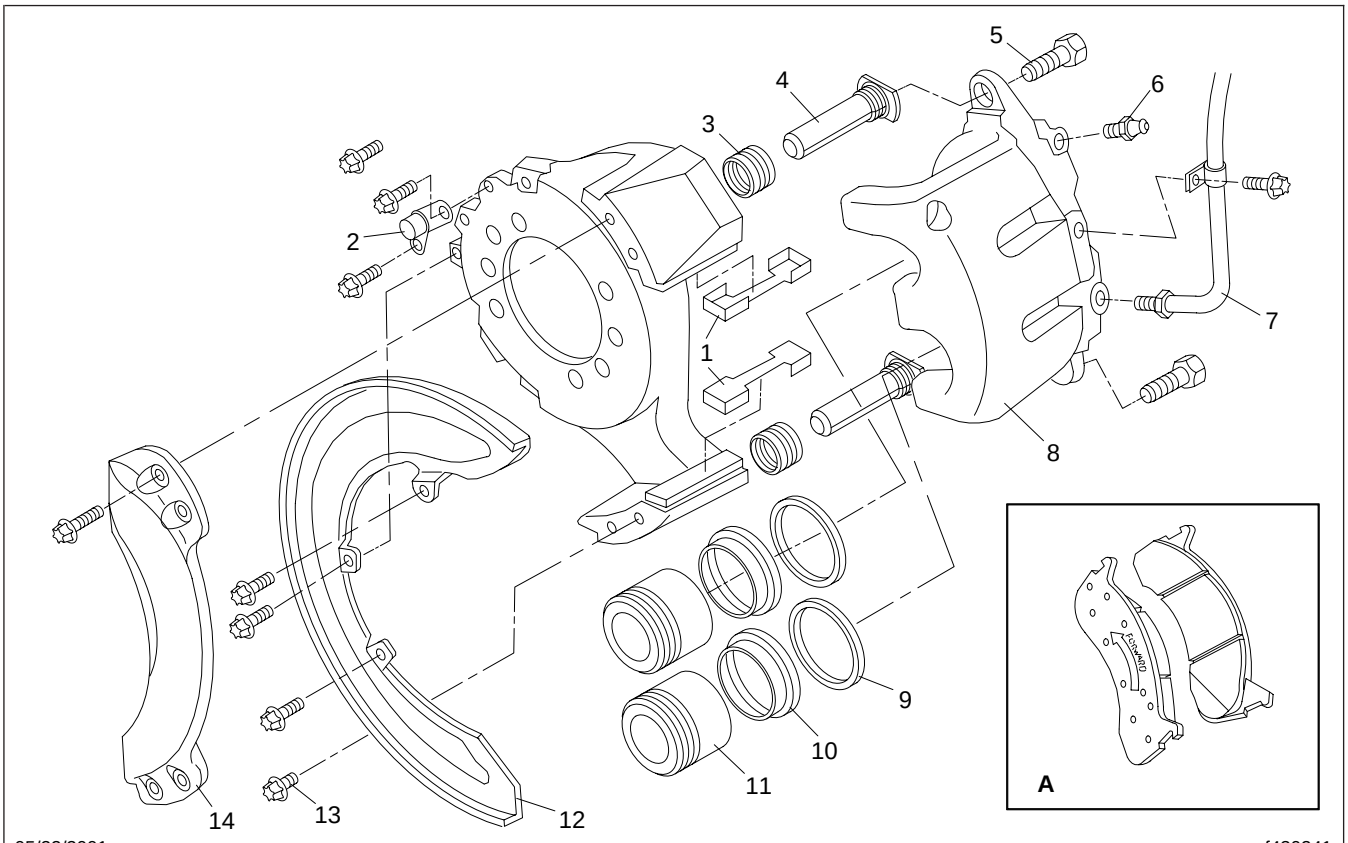
Disc Brake Pads

The inboard and outboard disc brake pads are positioned with both ends mounted on the anchor plate pad abutments. The pads rest on stainless steel slippers covering the anchor plate pad abutments. Inboard and outboard disc brake pads may be chamfered, and if so are marked with an arrow and the word "FORWARD" for proper installation. Brake pads may not be interchangeable inner to outer, so correct location is required during assembly.

Anchor Plate Assembly

The anchor plate includes lubricated floating guide pins sealed by rubber boots and anchor plate pad abutments protected by stainless steel slippers. A tie bar which spans the anchor plate abutment arms is used on 73 mm pin slide disc brake installations only. A splash shield on the back of the rotor helps protect the brake assembly from road contamination. Bosses are provided for mounting an antilock brake system speed sensor. See **Fig. 4**.

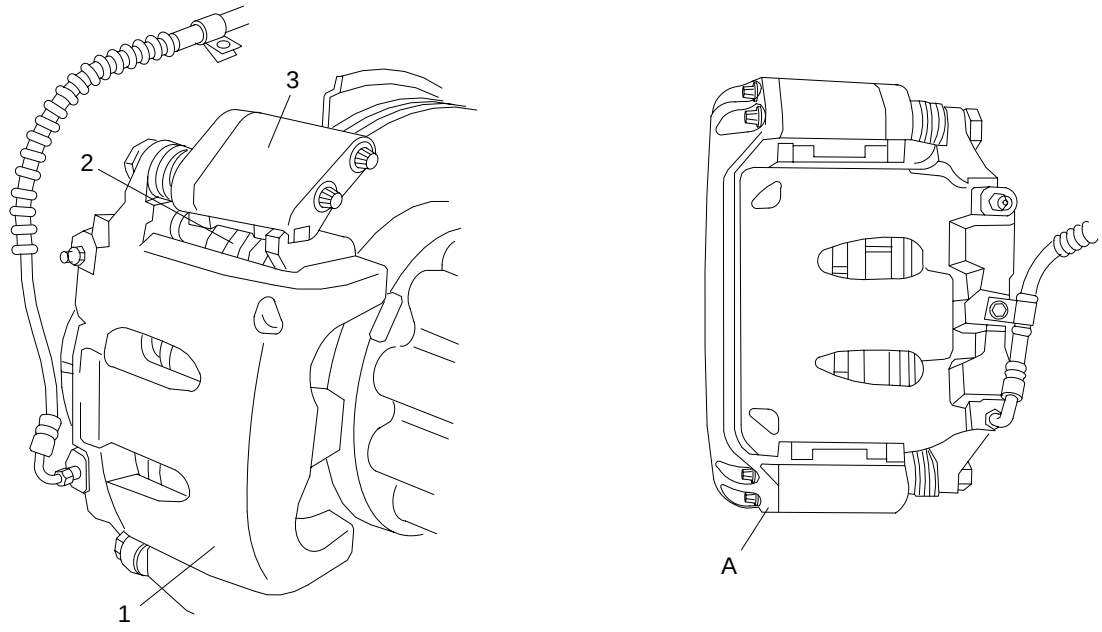
General Information



A. Brake Pads

1. Slipper
2. Antilock Brakes Sensor Bracket
3. Guide Pin Boot
4. Guide Pin
5. Guide Pin Bolt
6. Bleed Screw
7. Brake Line
8. Caliper
9. Caliper Boot Seal
10. Piston Boot
11. Caliper Piston
12. Splash Shield
13. Plug (66 mm only)
14. Tie Bar (73 mm only)

Fig. 1, Pin Slide Brake (exploded view)



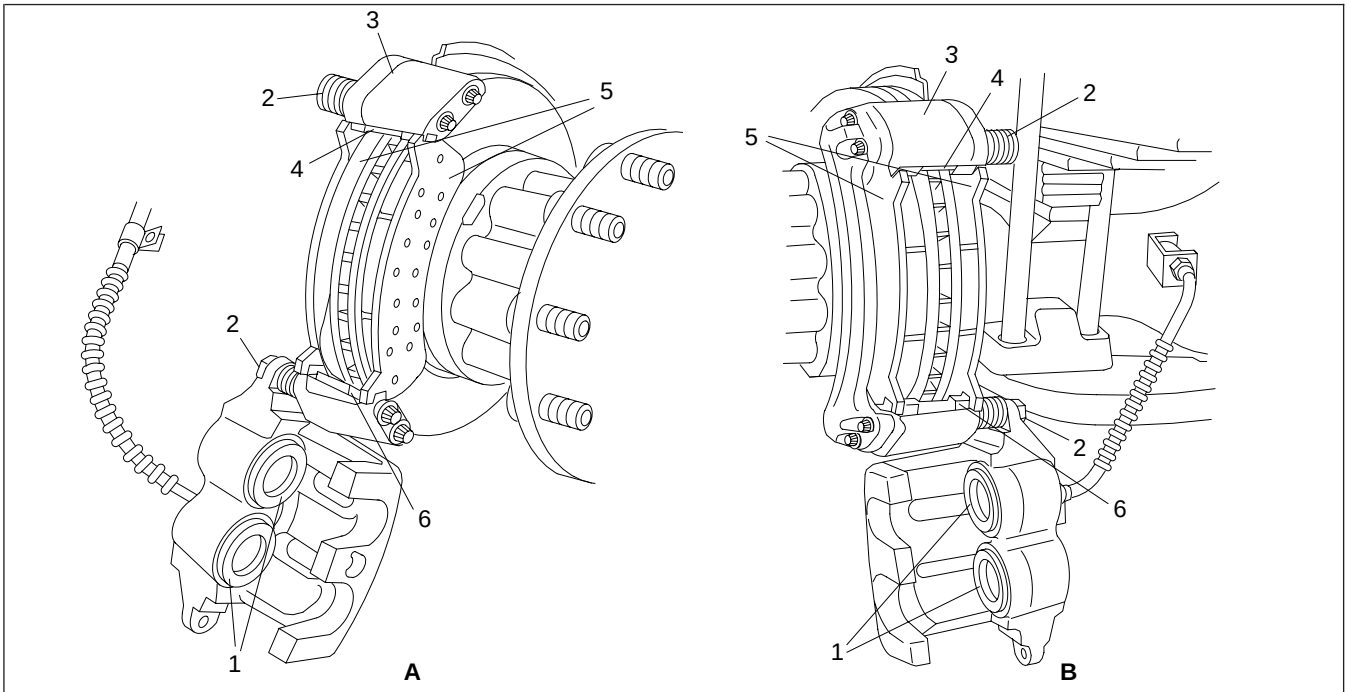
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A. 73 mm slider disc brakes incorporate a tie bar between the anchor plate abutment arms.

1. Caliper Assembly
2. Brake Pads
3. Anchor Plate Assembly

Fig. 2, Bosch Pin Slide Brakes Major Components

General Information

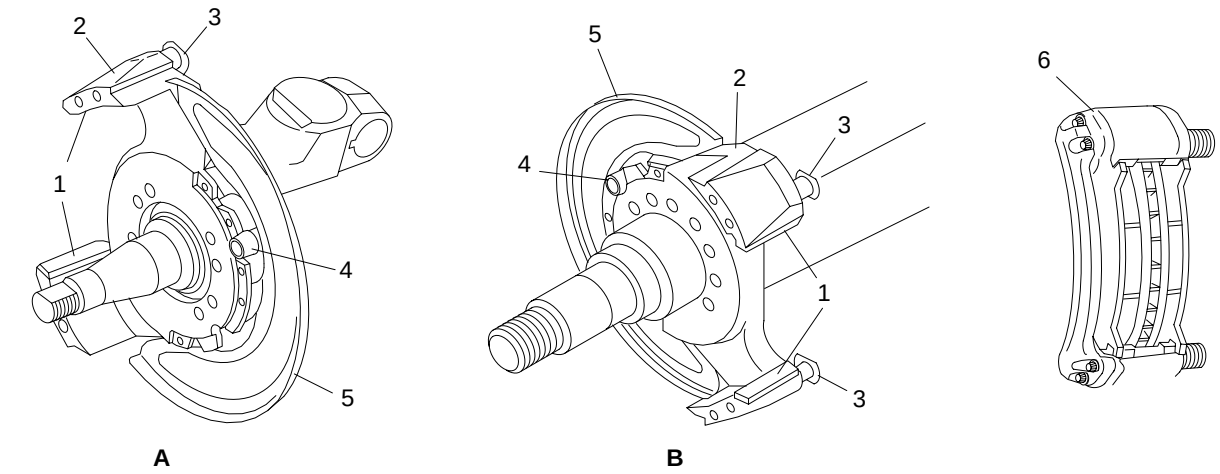


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A. Front (66 mm shown)
1. Hydraulic Pistons with Seals and Boots
2. Sealed Pins
3. Anchor Plate

B. Rear (73 mm shown)
4. Upper Slipper
5. Brake Pads
6. Lower Slipper

Fig. 3, Bosch Pin Slide Brakes System Components



A. Front
B. Rear

1. Pad Abutment
2. Anchor Plate
3. Floating Guide Pin
4. Antilock Braking System Sensor Mounting
5. Splash Shield
6. Tie Bar (73 mm brakes only)

Fig. 4, Anchor Plate and Splash Shield

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.
- Disconnect the batteries.
- 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.

⚠ WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

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. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (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.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air

Safety Precautions

(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 starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

IMPORTANT: It is recommended that all disc brake pads on the vehicle be replaced at the same time. This will maintain balanced braking. If complete replacement is not desirable or necessary, make sure that at a minimum all disc brake pads on one axle (both ends) are replaced at the same time.

Removal

1. Park the vehicle on a level surface. Shut down the engine and apply the parking brake.
2. Open the hood.
3. If removing rear axle wheel pads, remove about half of the fluid from the rear section of the master cylinder reservoir. See **Fig. 1**. If removing front axle wheel pads, remove about half of the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. Inspect all brake pad linings. Lining pads should be replaced when the remaining lining reaches 3/16-inch (5-mm) thickness or less.

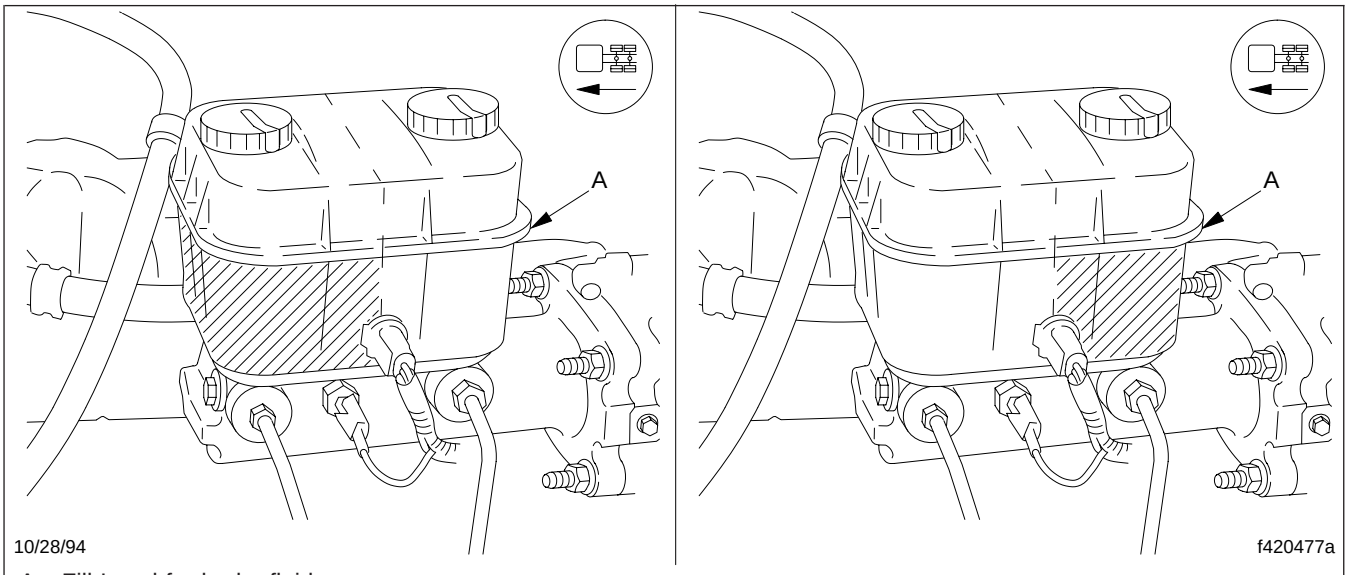
⚠ CAUTION

Care must be taken when positioning the pry bar. Incorrect positioning of the pry bar could result in damage to the caliper.

7. Insert a pry bar in one of the rotor cooling fin slots and pry the caliper outboard, pushing the caliper pistons into the piston bores. See **Fig. 2**.
8. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 2**.

IMPORTANT: When servicing disc brake pads only, remove the upper (top) caliper guide pin bolt. Do not loosen the lower (bottom) guide pin bolt.

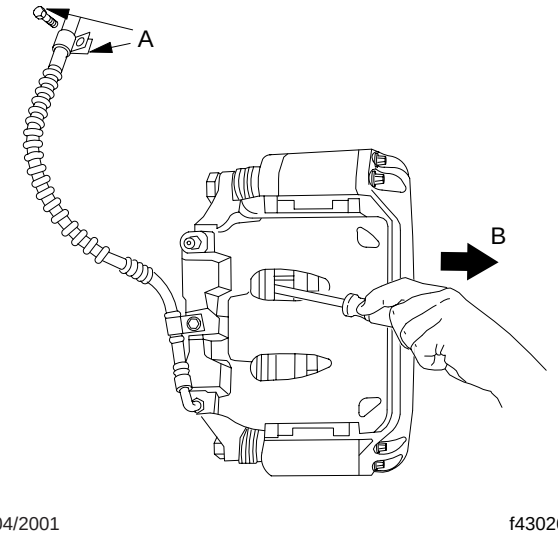
9. Remove only the upper (top) guide pin bolt. See **Fig. 3**.



A. Fill Level for brake fluid.

Fig. 1, Master Cylinder Reservoir

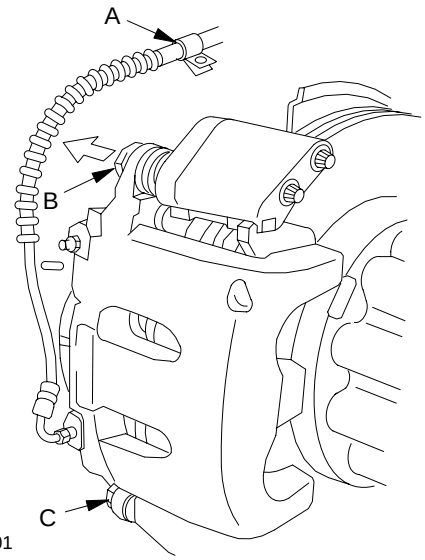
Brake Pad Removal, Inspection, and Installation



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A. Remove this screw and clip on front axles only.
B. Move the caliper outboard to push the pistons in.

Fig. 2, Piston Retraction and Brake Line Clip Removal



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A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin bolt.
C. Do not loosen the lower guide pin bolt.

Fig. 3, Caliper Upper Guide Pin Bolt Removal

CAUTION

Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

10. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower guide pin and bolt. See **Fig. 4**. Do not allow the brake line hose to become pinched or kinked.
11. Remove the inboard and outboard disc brake pads from the anchor plate pad abutment slippers.

IMPORTANT: Do not mark on the pad face.

12. If the original disc brake pads are to be reused, be sure to mark them in some manner so that they are installed in the same location.

Inspection

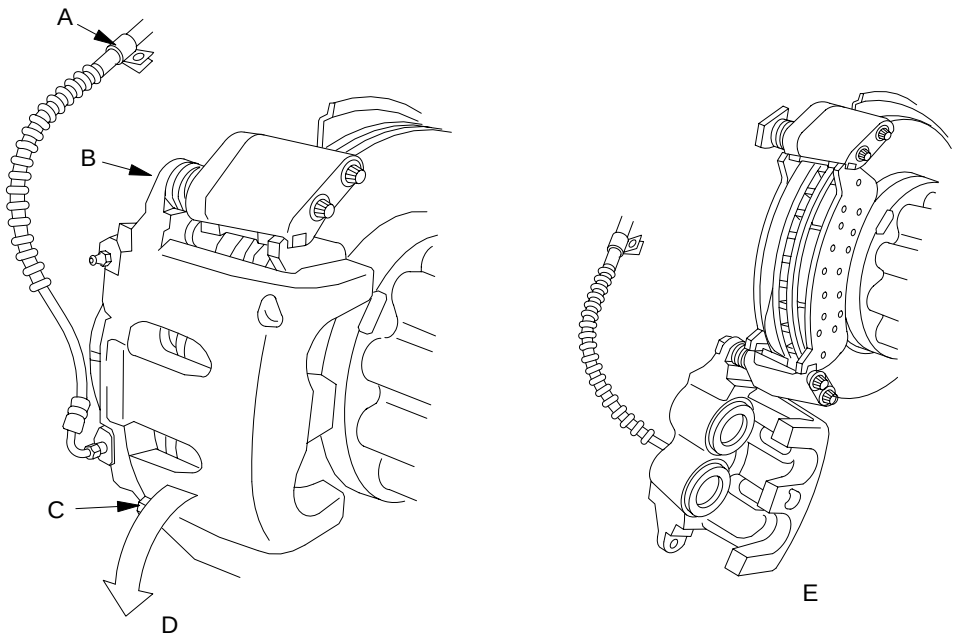
IMPORTANT: Do not damage or dislodge the guide pin boots while cleaning the machined surfaces.

1. Inspect the machined surfaces of the caliper, guide pin mounting face, and anchor plate. If rust or corrosion is present, use a hand-held wire brush to clean the surfaces.
2. Inspect the caliper, piston seals, and pistons for leakage or damage. If leakage or damage is found, repair or replace the piston(s) as required.
3. Inspect the anchor plate for damage to the mating surfaces at the anchor plate pad abutment slippers and guide pin heads. If damage is found, repair or replace as required.
4. Inspect the rotor for scoring, warping, cracks, bluing, heat spots, or other damage. See **Fig. 5**. If any damage is found, repair or replace the rotor. For instructions, see **Subject 140**.

Installation

1. Position a metal plate across both caliper pistons. Use a C-clamp to push both pistons into the caliper to provide clearance for the new disc brake pads. See **Fig. 6**.

Brake Pad Removal, Inspection, and Installation



A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Do not loosen the lower guide pin bolt.
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 4, Opening the Caliper to Access Brake Pads and Pistons

CAUTION

When replacing disc brake pads, use the same lining material on both axles. Mixing lining types can result in unbalanced braking, increased pad wear, or degraded stopping performance.

IMPORTANT: Inboard and outboard brake pads may not be interchangeable. The word "Forward" and a forward rotor rotation direction arrow may appear on each pad backing plate. Orient the pads as indicated by the arrow.

2. Position the inboard and outboard disc brake pads onto the anchor plate pad abutment slippers with the lining facing toward the rotor. See **Fig. 7**.

CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head, to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

3. Carefully rotate the caliper closed about the lower guide pin and bolt. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 8**.

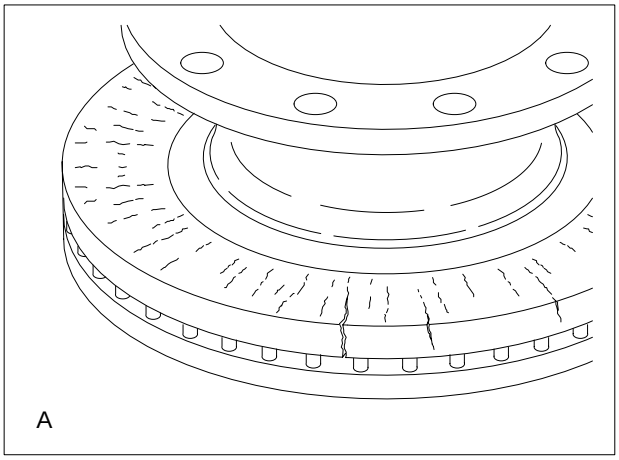
CAUTION

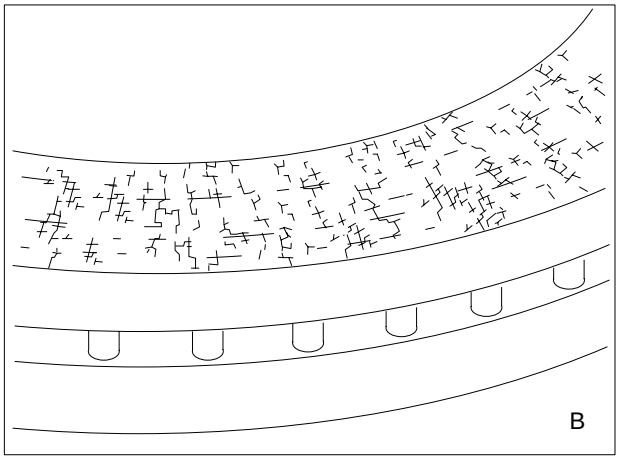
Do not overtighten caliper pin bolts. Increased brake drag may result from incorrect tightening.

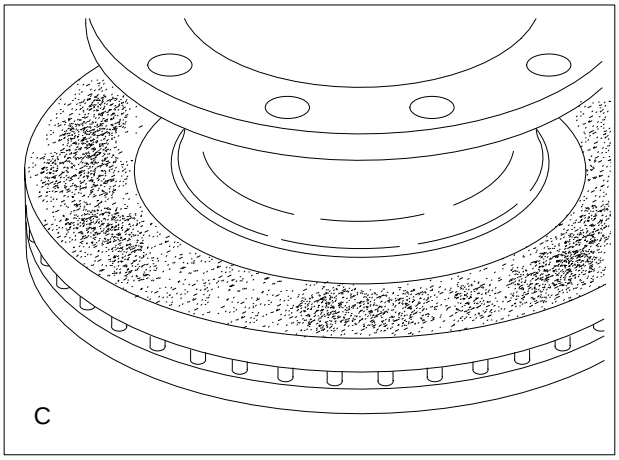
IMPORTANT: If the lower guide pin bolt was loosened, see **Fig. 9** before tightening either the upper or lower guide pin.

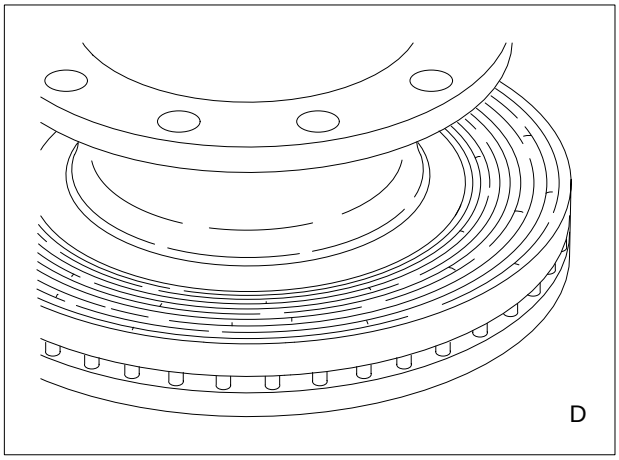
4. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand thread the guide pin bolt, then tighten it 93 to 107 lbf·ft (126 to 145 N·m). See **Fig. 9**.

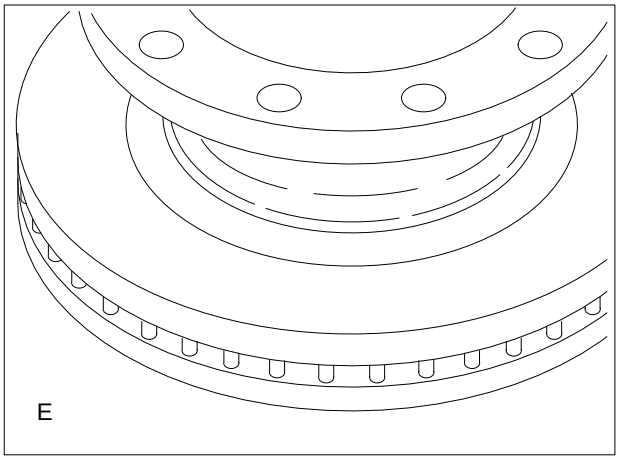
Brake Pad Removal, Inspection, and Installation











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A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 5, Rotor Surface Check

Brake Pad Removal, Inspection, and Installation

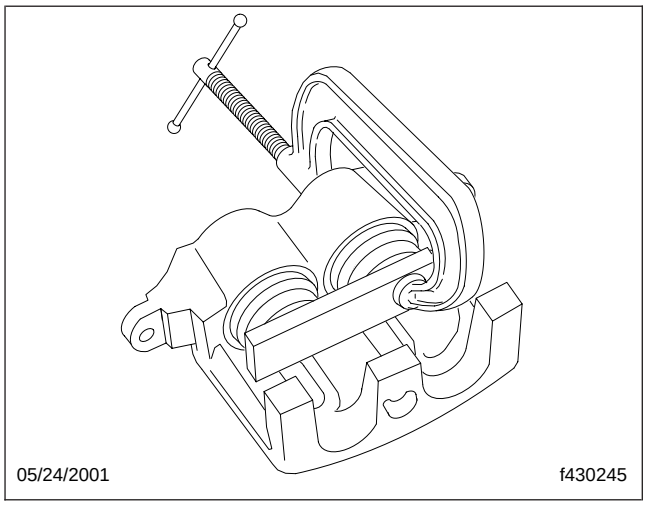


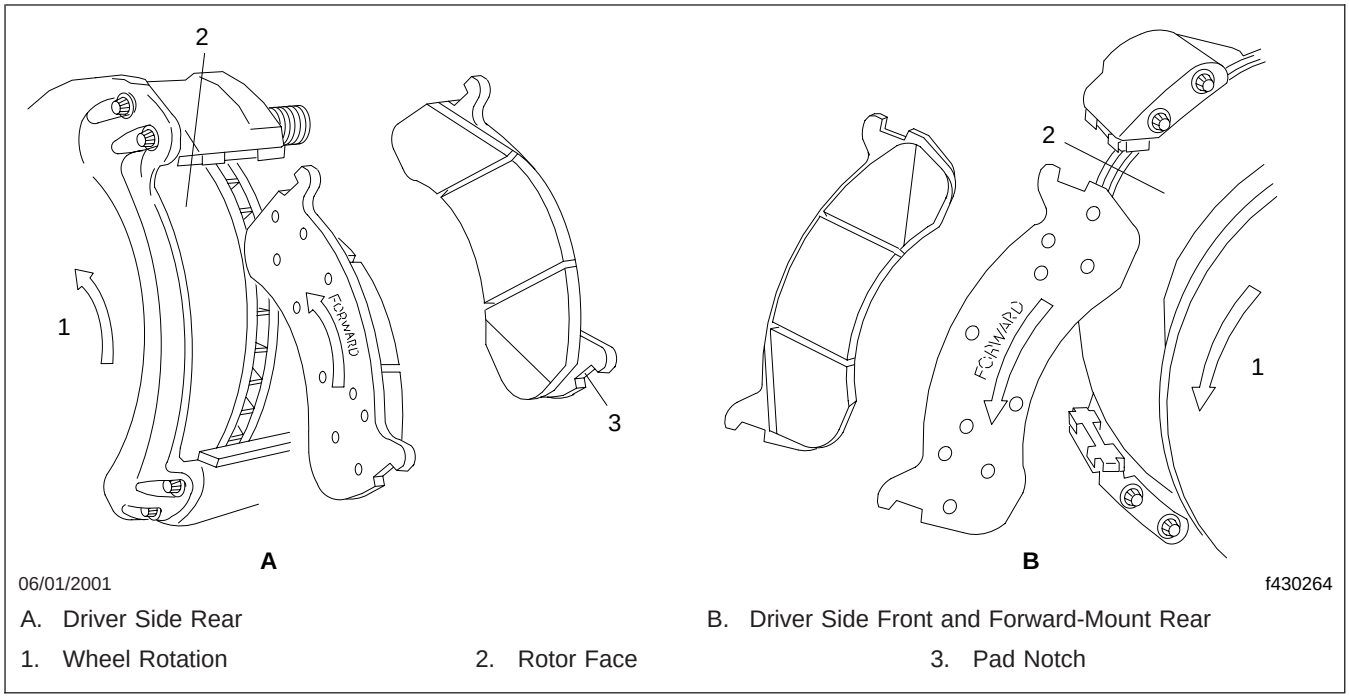
Fig. 6, Retracting Pistons Into the Caliper

are seated and positioned to slide along the pad abutment slippers.

7. Install the tires, remove the jackstands, and lower the vehicle.
8. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
9. Pump the brake pedal until it feels firm. If it does not get firm, check for leaks or air in the brake system. Repair any leaks, if needed, then bleed the system, following the instructions in **Subject 160**.

⚠ WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.

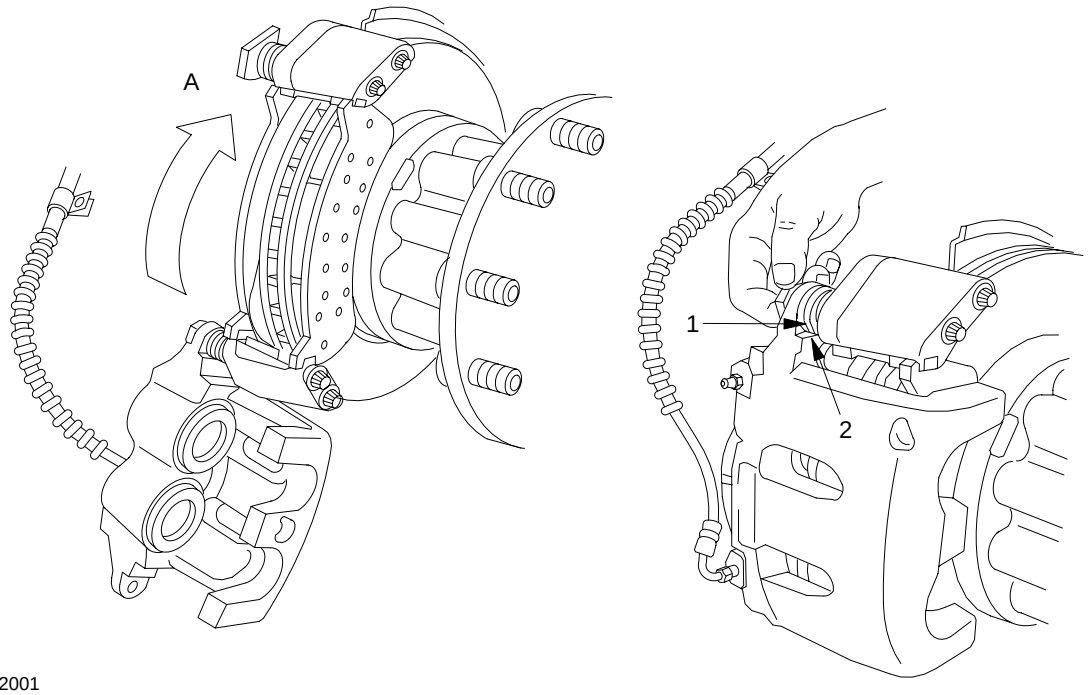


A. Driver Side Rear
B. Driver Side Front and Forward-Mount Rear
1. Wheel Rotation
2. Rotor Face
3. Pad Notch

Fig. 7, Replacing Brake Pads on Front and Rear Brakes

5. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
6. Inspect all components serviced. Make sure the guide pins are torqued according to the specifications in this procedure. Make sure the pads
10. Close the hood and remove the chocks from the tires.
11. Road test the vehicle and seat the brake pads, as follows.

Brake Pad Removal, Inspection, and Installation



A. Swing the caliper up into position.

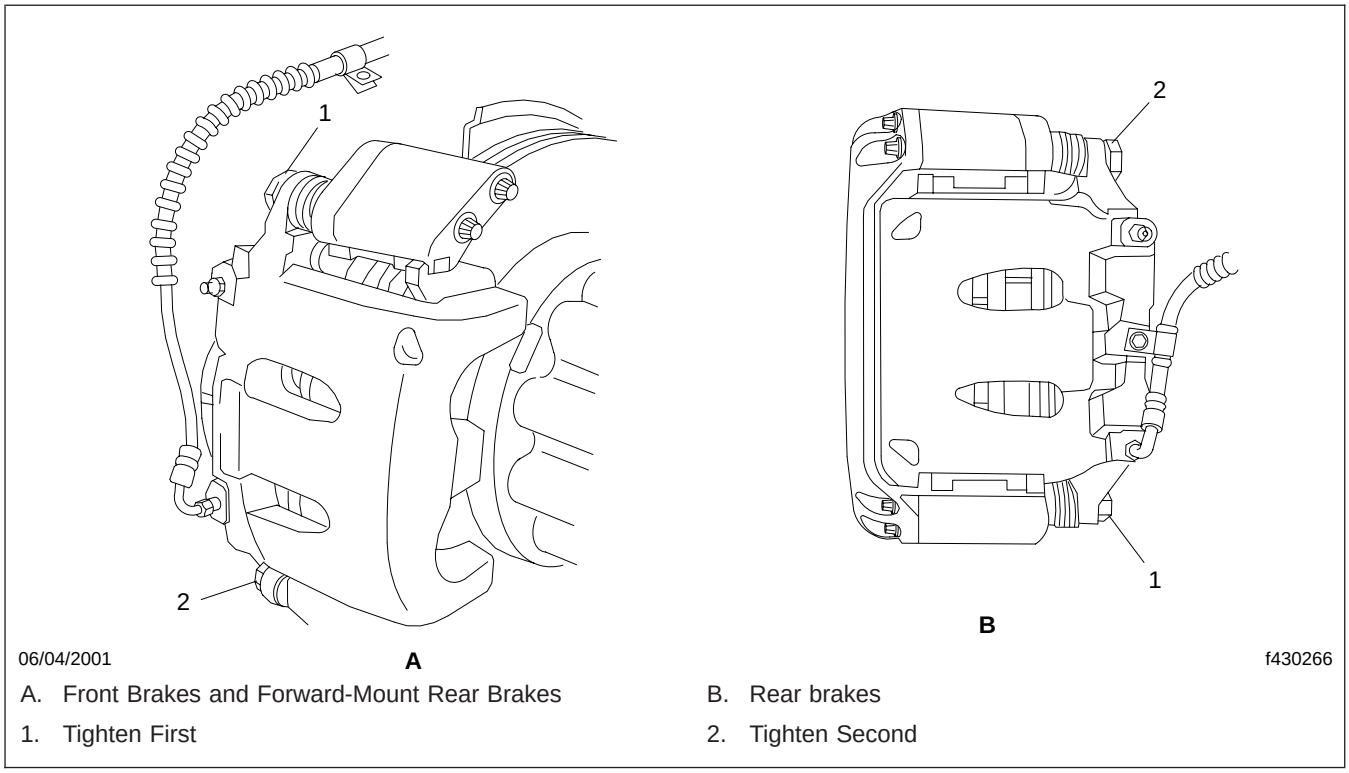
1. Flat on Guide Pin
2. Flat on Caliper

Fig. 8, Closing the Caliper Over Brake Pads and Rotor

11.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

11.2 Repeat this step between 4 or 5 times, allowing a one-minute interval between brake applications.

Brake Pad Removal, Inspection, and Installation



A. Front Brakes and Forward-Mount Rear Brakes
B. Rear brakes
1. Tighten First
2. Tighten Second

Fig. 9, Tightening Sequence for Caliper Mounting Bolts

Brake Caliper Removal and Installation

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine.
2. Open the hood.
3. If removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. See **Fig. 1**. If removing the front wheel caliper(s), remove half the fluid from the front section. Removing the fluid from the reservoir keeps the reservoir from overflowing when retracting pistons into the caliper.
4. Chock the front or rear tires, depending on which axle is being worked on. Jack up the axle and support it with jackstands.
5. Remove the tires.
6. On front axles only, remove the brake line retaining clip from its support mounting. This will allow the brake line hose to hang free. See **Fig. 2**.
7. Remove the upper (top) guide pin bolt. See **Fig. 2**.

⚠ CAUTION

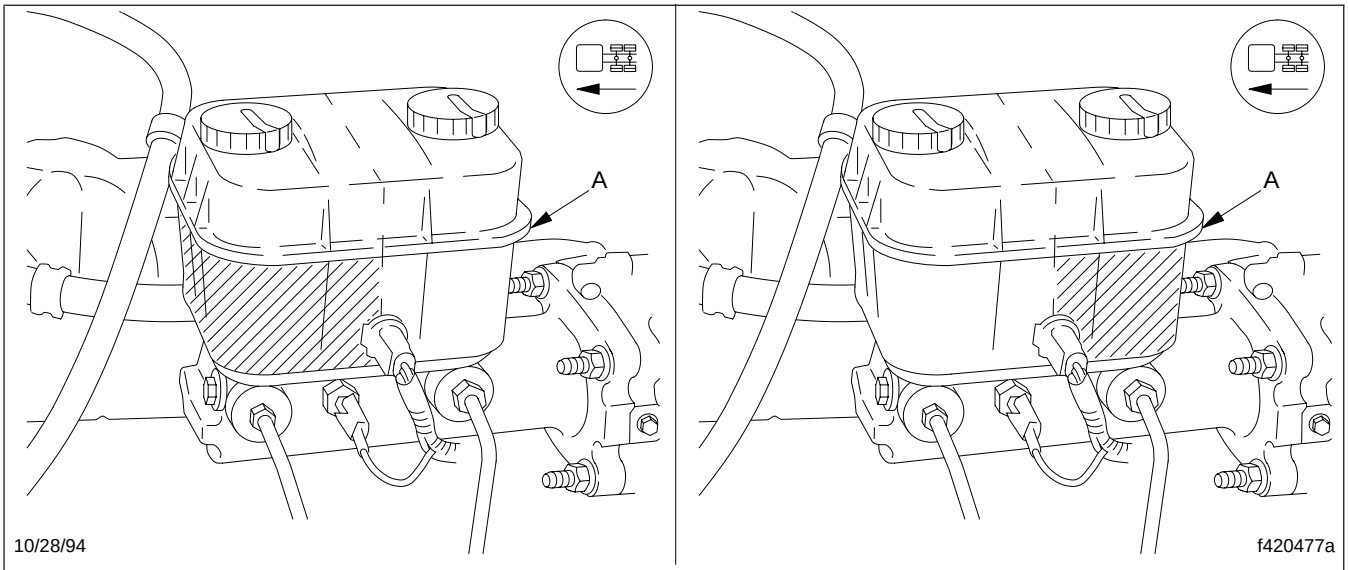
Do not pull on the guide pins. This may dislodge the guide pin boot from the guide pin or anchor plate grooves, which could damage the guide pin boot.

8. Swing the caliper assembly away from the rotor by carefully rotating the caliper on the lower guide pin and bolt. See **Fig. 3**. Do not allow the brake line hose to become pinched or kinked.
9. Disconnect the brake fluid line from the caliper. See **Fig. 4**.
10. Remove the lower guide pin bolt and remove the caliper from the anchor plate.

Installation

⚠ CAUTION

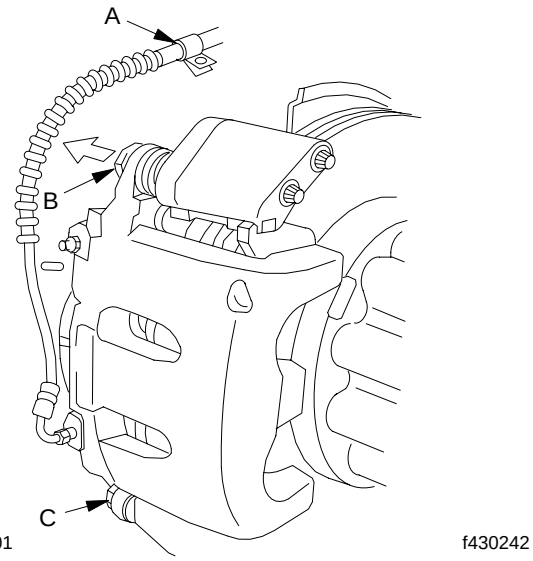
Use isopropyl alcohol to clean the brake seals, boots, and pistons. Do not soak components for an extended period of time.



A. Fill level for brake fluid.

Fig. 1, Master Cylinder Reservoir

Brake Caliper Removal and Installation



A. Make sure this clip is detached from the support bracket.
B. Remove the upper guide pin bolt.
C. Do not loosen the lower guide pin bolt.

Fig. 2, Upper Guide Pin Mounting Bolt Removal

1. Clean contamination, dirt, and debris from the exterior of the caliper, machined faces, and around the caliper piston boots.
2. Inspect the caliper for brake fluid leakage or damage to pistons or piston boots. If there is leakage or damage, the caliper should be repaired or replaced. For repair instructions, see **Subject 130**.
3. Make sure the pistons are fully retracted into the caliper. Piston boots must be fully seated in the piston boot groove and the boot grooves in the caliper face.
4. Position the caliper on the anchor plate with the caliper lower guide pin boss hole aligned with the threaded hole in the lower guide pin head. Hand-thread the guide pin bolt through the caliper and into the anchor plate.

⚠ CAUTION

Use care when positioning the caliper over the disc brake pads, rotor, and upper guide pin head to avoid tearing, cutting, or dislodging the piston boots or guide pin boot.

5. Carefully rotate the caliper closed about the lower guide pin and bolt. Do not allow the brake line hose to become pinched or kinked. Align the flat on the upper guide pin head with the flat on the caliper upper guide pin boss. See **Fig. 5**.

⚠ CAUTION

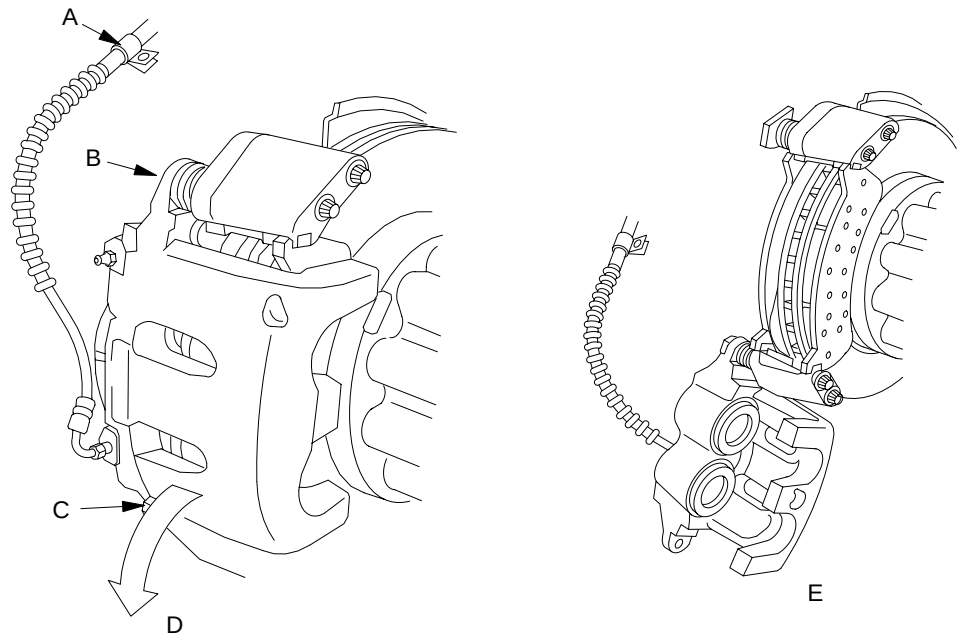
Always tighten caliper guide pin bolts in the proper sequence. Do not overtighten caliper guide pin bolts. Increased brake drag may result from incorrect tightening.

IMPORTANT: See **Fig. 6** and **Fig. 7** before tightening either the upper or lower bolt.

6. Hold the caliper in the closed position with the caliper upper guide pin boss hole aligned with the threaded hole in the upper guide pin head. Hand-thread the upper guide pin bolt. Then tighten the upper and lower guide pin bolts 93 to 107 lbf·ft (126 to 145 N·m) in the order shown in **Fig. 6** and **Fig. 7**.
7. On front axles only, install the previously removed brake line retaining clip. Make sure the brake line hose is not pinched or kinked.
8. If the brake supply hose was disconnected, connect it, as follows.
   - 8.1 Tighten the brake supply hose fitting 15 lbf·ft (20 N·m).
   - 8.2 Bleed the brake supply line to the caliper, following the instructions in **Subject 160**. If you have removed more than one brake caliper, bleed the entire brake system.
9. Install the tires, remove the jackstands, and lower the vehicle.
10. Check the fluid level in the master cylinder reservoir and add the necessary amount of new DOT 3 approved brake fluid.
11. Close and latch the hood.
12. Remove the chocks from the tires.

⚠ WARNING

Do not move the vehicle until the brake pedal feels firm. To do otherwise could result in loss of vehicle control, causing an accident resulting in personal injury or property damage.



A. Make sure this clip is detached from the support bracket.
B. Guide pin bolt has been removed.
C. Lower Guide Pin Bolt
D. Swing the caliper down until it stops.
E. Caliper in the lowered position.

Fig. 3, Swinging the Caliper Down (Open)

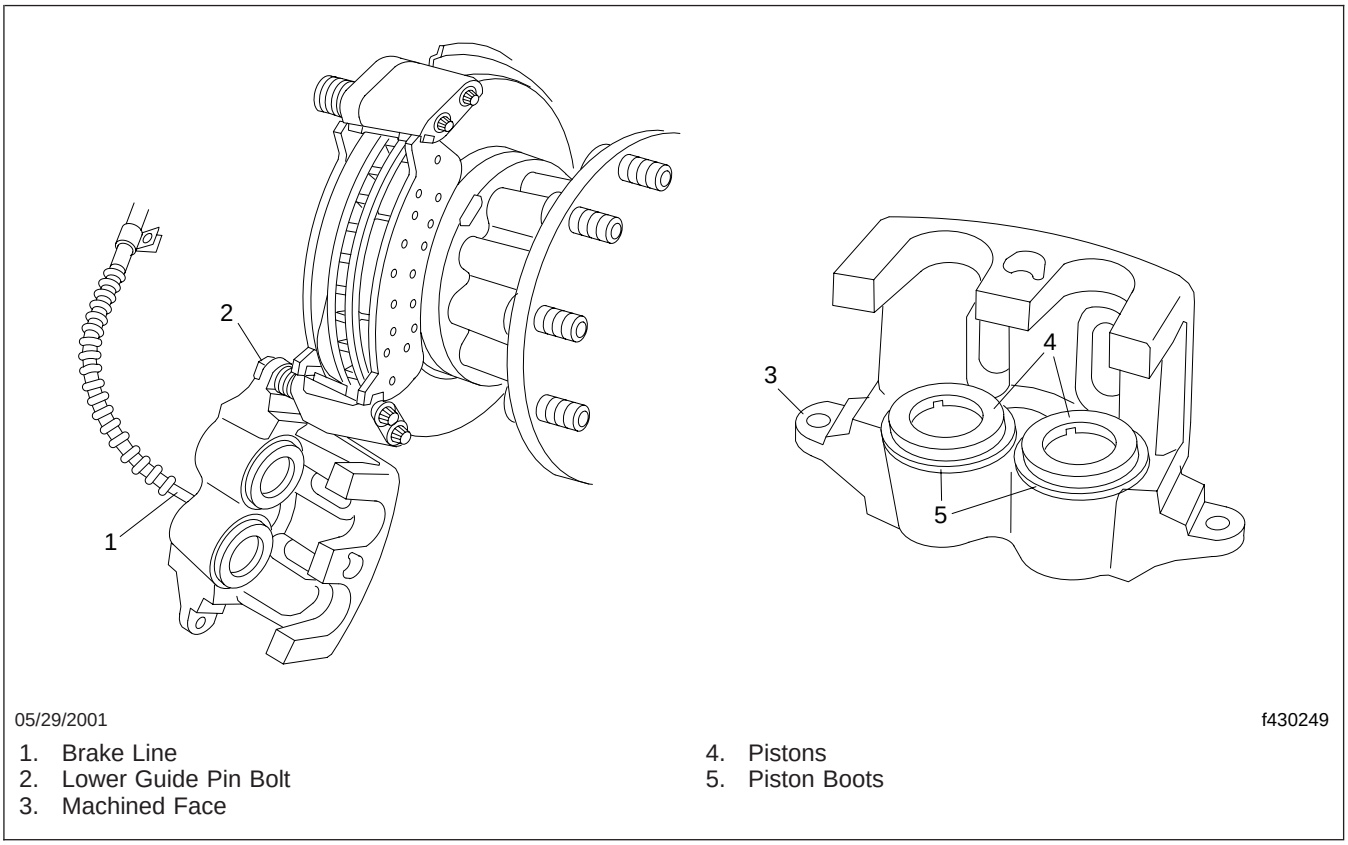
13. Seat the brake pads by pressing firmly on the brake pedal several times.

    If new brake pads were installed, road test the vehicle to seat the brake pads, as follows.

    13.1 Accelerate the vehicle to 30 mph (48 km/h), then brake to a stop, using medium brake pedal pressure. *Do not slam on the brakes.*

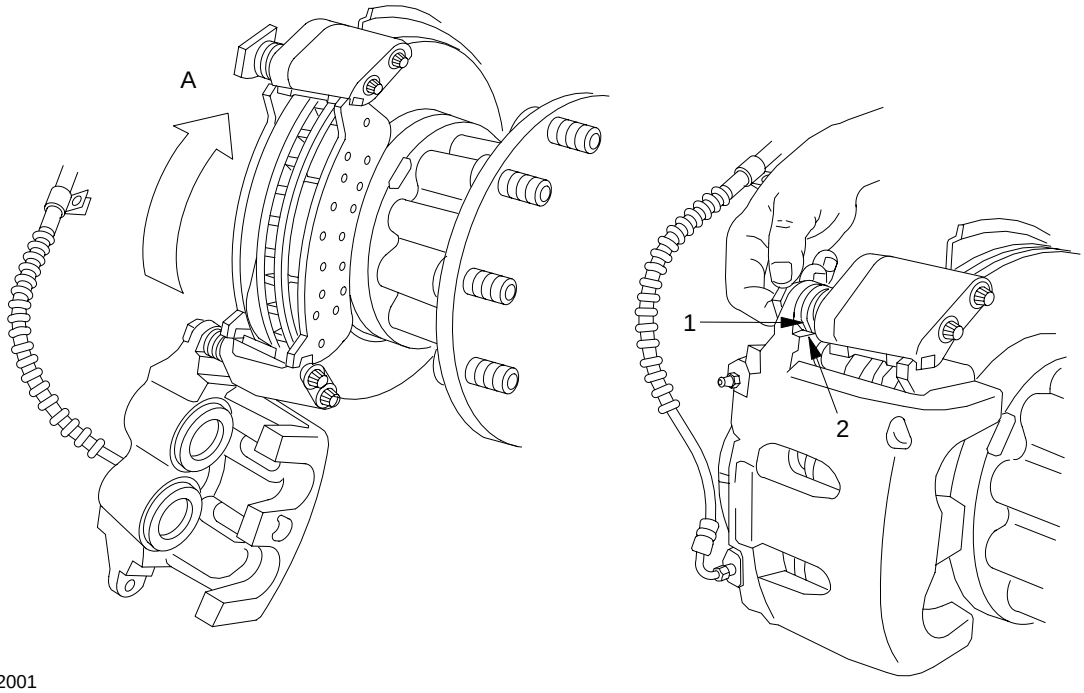
    13.2 Repeat this step four or five times, allowing a one-minute interval between brake applications.

Brake Caliper Removal and Installation



1. Brake Line
2. Lower Guide Pin Bolt
3. Machined Face
4. Pistons
5. Piston Boots

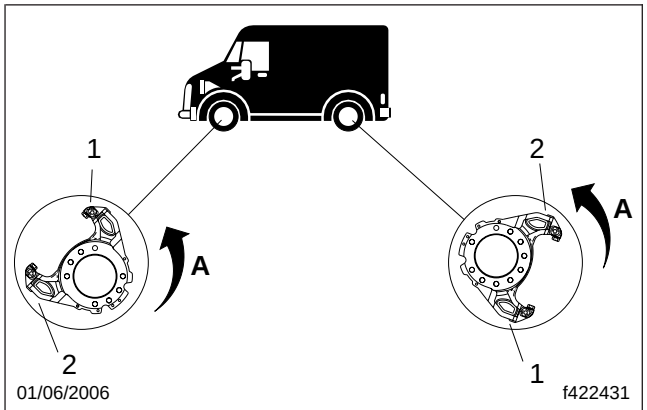
Fig. 4, Removing the Caliper from the Anchor Plate



A. Swing the caliper up into position.

1. Flat on Guide Pin
2. Flat on Caliper

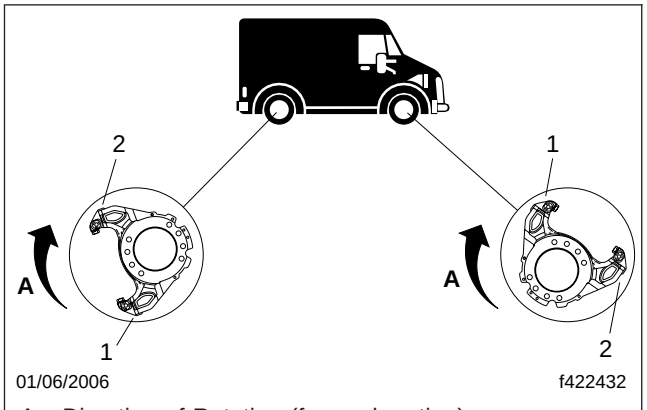
Fig. 5, Closing the Caliper Over the Brake Pads and Rotor



A. Direction of Rotation (forward motion)

1. Tighten First 2. Tighten Second

Fig. 6, Tightening Sequence for Caliper Mounting Bolts, Left Side



A. Direction of Rotation (forward motion)

1. Tighten First 2. Tighten Second

Fig. 7, Tightening Sequence for Caliper Mounting Bolts, Right Side

Brake Rotor Removal and Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Remove the brake caliper from the rotor, following the instructions in **Subject 120**.
3. Remove the hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle. Put the hub on the floor so the rotor is facing up.
4. Remove the brake rotor from the wheel hub. Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 1**. Lift the brake rotor off the hub.

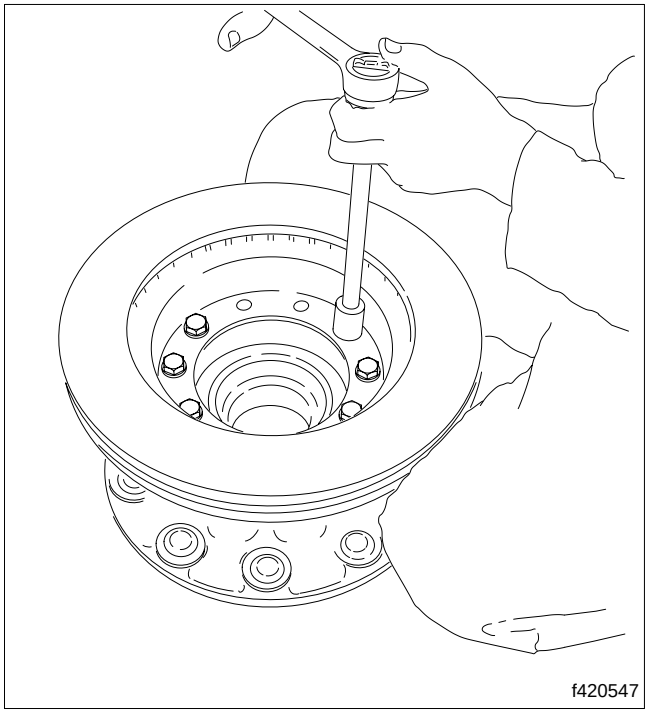
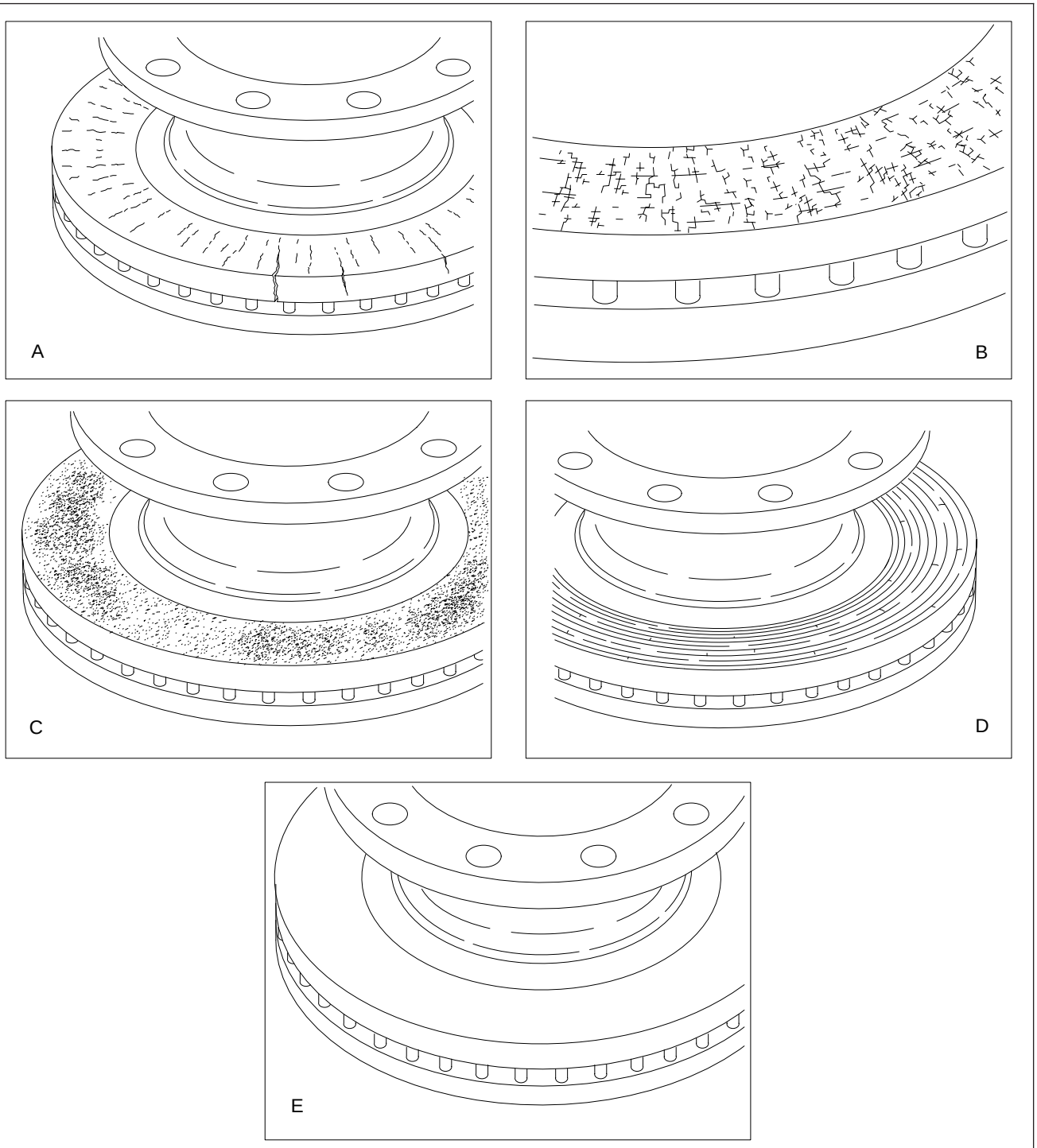


Fig. 1, Rotor-to-Hub Fasteners

Installation

1. Inspect the rotors for scoring, warping, cracks, bluing or heat spots, or other damage. See **Fig. 2**. If signs of damage are found, the rotor should be resurfaced or replaced.
2. Install the rotor on the wheel hub, as follows.
   - 2.1 Position the rotor on the hub as shown in **Fig. 3**. Make sure the holes in the rotor are lined up with those of the hub.
   - 2.2 Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 4**.
3. Install the hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
4. Check rotor runout and parallelism. For instructions, see **Subject 140**.
5. Install the brake caliper on the rotor, following the instructions in **Subject 120**.

Brake Rotor Removal and Installation



A. Cracking
B. Heat Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 2, Rotor Surface Check

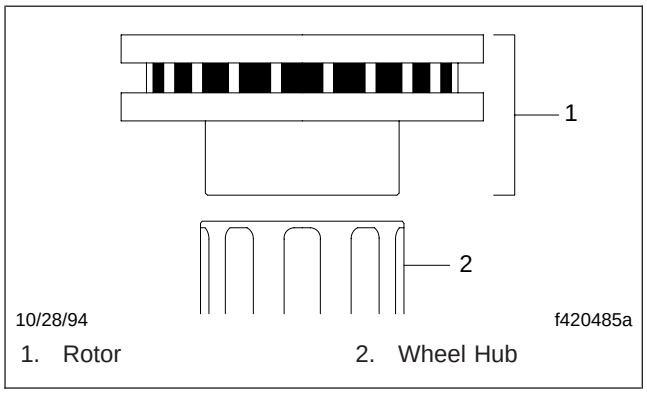


Fig. 3, Rotor-to-Hub Position

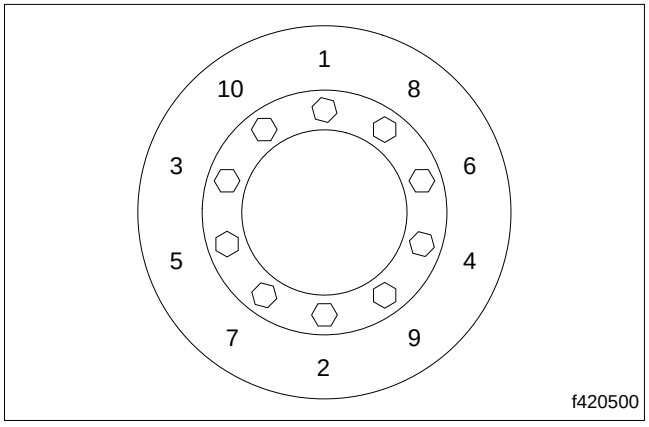
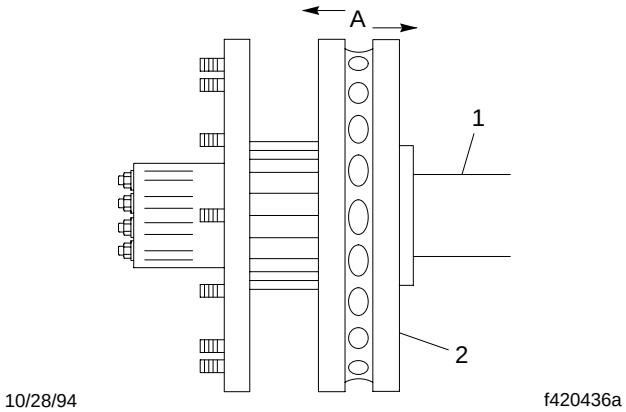


Fig. 4, Tightening Pattern

Runout Check

Brake rotor runout refers to the amount of lateral wobble the rotor has when it is turning, with the wheel bearings correctly adjusted. See **Fig. 1**. Check the rotor runout whenever you replace the brake pads.



A. Runout

1. Axle
2. Rotor

Fig. 1, Brake Rotor Runout

1. If not already done, chock the tires, jack up the axle you are working on and support it with jackstands. Remove the wheels and tires.
2. If working on the rear axle, put the transmission in neutral.
3. Using a dial indicator, measure the amount of runout while spinning the rotor, as shown in **Fig. 2**. Make sure the indicator is centered on the rotor face (between the outer and inner edges).
4. If the runout is more than 0.015 inch (0.38 mm), check that the rotor is securely mounted to the hub. Also check the wheel bearing end-play, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.

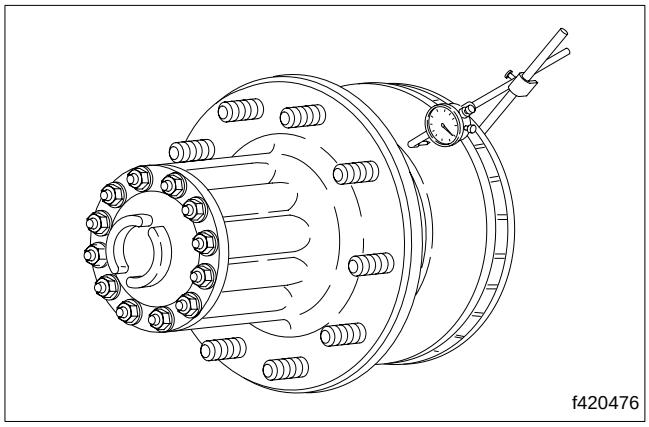
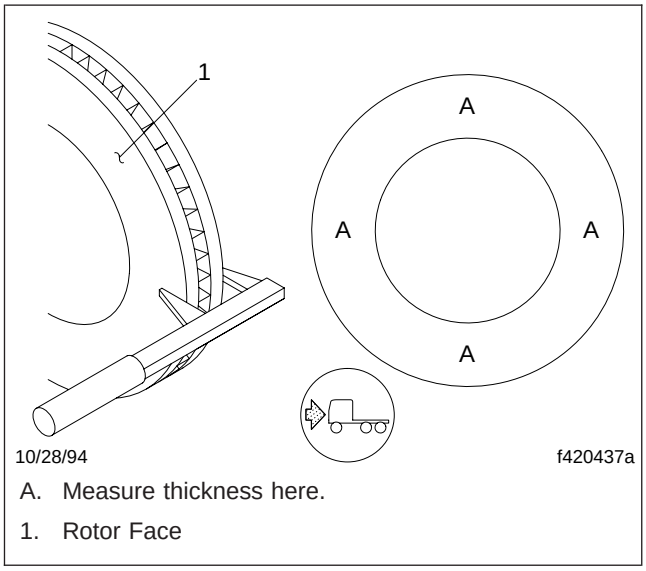


Fig. 2, Measuring Runout

Parallelism Check

Parallelism is the difference in rotor thickness at different points around the rotor. It should be checked whenever the brake pads are replaced.

1. Using a micrometer, measure the thickness of the rotor (between the inboard and outboard faces) at four or more equally spaced points around the rotor. See **Fig. 3**.



A. Measure thickness here.

1. Rotor Face

Fig. 3, Measuring Rotor Thickness

2. If there is a difference of more than 0.005 inch (0.13 mm) between any two measurements, have the rotor resurfaced. If resurfacing will de-

Brake Rotor Runout and Parallelism Check

crease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.

Anchor Plate Disassembly, Cleaning, and Inspection, and Assembly

WARNING

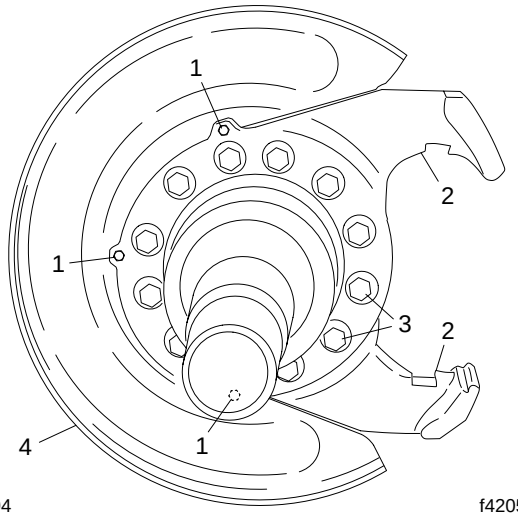
Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Disassembly

1. Park the vehicle on a level surface. Chock the rear or front tires, as required.
2. Jack up the vehicle. Support the axle with jackstands.
3. Remove the tire.
4. Remove the brake caliper from the anchor plate following the instructions in **Subject 120**.
5. Remove the tie bar from the anchor plate on 73 mm brakes, or remove the plugs from the anchor plate on 66 mm brakes.
6. Remove the brake pads from the anchor plate. For instructions, see **Subject 110**.
7. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
8. Remove the anchor plate from the axle, as follows.

   8.1 Remove the three screws that hold the dust shield to the anchor plate; remove the dust shield.

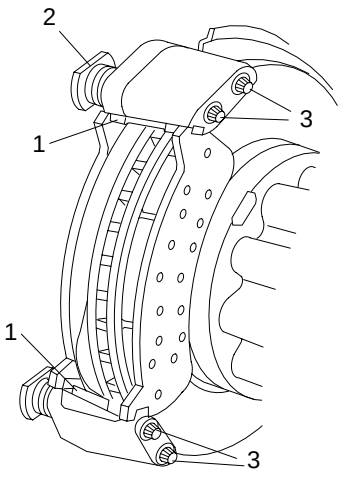
   8.2 Remove the hexbolts, washers, and nuts that attach the anchor plate to the axle. Remove the anchor plate from the axle. See **Fig. 1**.
9. Remove contamination, dirt, and debris from the exterior of the anchor plate.
10. Remove the brake pad abutment slipper, using a blunt- nose drift pin or screwdriver and a light hammer. Avoid marring the anchor plate abutment surfaces. See **Fig. 2**.
11. Remove the guide pins and guide pin boots by pulling out the guide pin with a slight twisting motion.
12. Remove the splash shield and antilock braking system sensor bracket from the anchor plate. See **Fig. 3**.



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1. Dust Shield Screw
2. Anchor Plate
3. Hexbolts
4. Dust Shield

Fig. 1, Axle End (typical)



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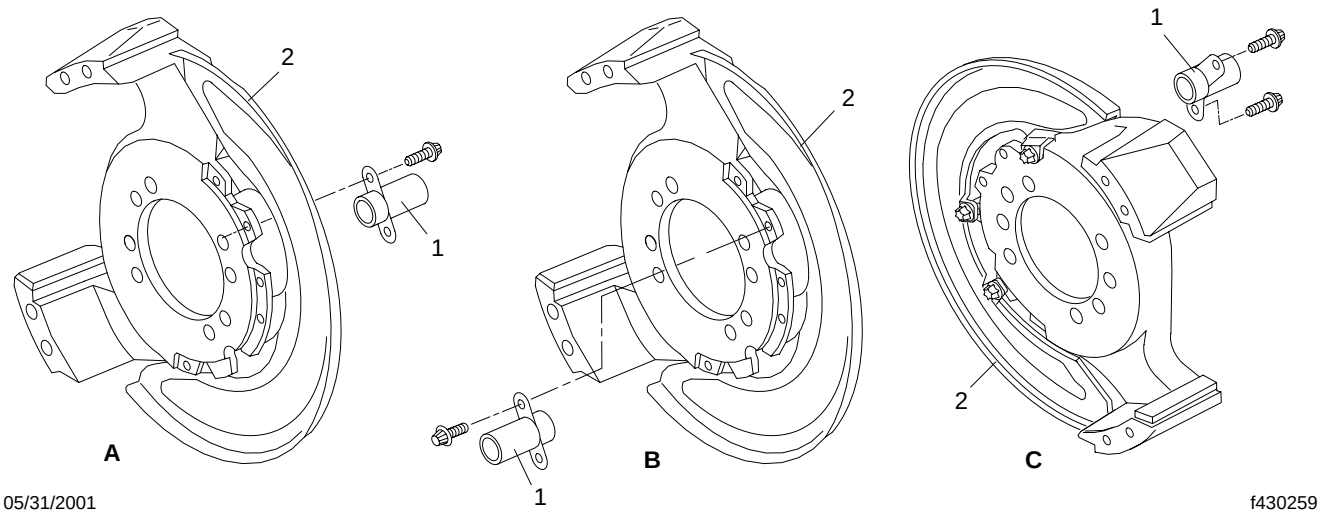
1. Pad Abutment Slipper
2. Guide Pin and Pin Boot
3. Plugs (66 mm brakes only)

Fig. 2, Anchor Plate Components

Cleaning and Inspection

1. Clean the anchor plate, using a brush and solvent. Make sure the anchor plate abutments, anchor plate tie bar mounting surfaces, axle flange

Anchor Plate Disassembly, Cleaning, and Inspection, and Assembly



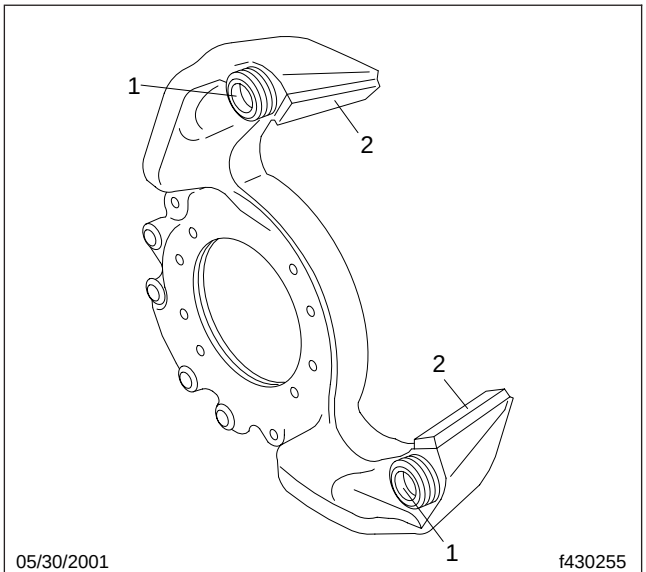
A. Driver Side Front Backing Plate Assembly (66 mm brakes)
B. Driver Side Front Backing Plate Assembly (73 mm brakes)
C. Driver Side Rear Backing Plate Assembly (typical)

1. Sensor Bracket
2. Anchor Plate

Fig. 3, Splash Shield and Sensor Mounting Bracket

mounting surface, and anchor plate boot grooves are clean and free of any rust or corrosion. See **Fig. 4**. Use a hand-held wire brush to clean these surfaces. It is important to clean these areas of the anchor plate. Also make sure the tie bar bolt hole threads are clean and free of foreign matter.

2. Clean the guide pin bores, using a bore brush and solvent. Use compressed air to clean out and dry guide pin bores. Check the guide pin bores for excessive wear. Replace the anchor plate if necessary.
3. Clean the guide pin boots with isopropyl alcohol. Do not use solvent to clean the boots. Inspect each guide pin boot for cracks, tears, holes, and flexibility. If damage is found, the boot must be replaced. See **Fig. 5**.
4. Clean the guide pins with isopropyl alcohol. Make sure the guide pins, and the threads in the guide pins, are free of foreign matter and corrosion. Use compressed air to clean out and dry guide pins and bolt threads in the guide pins. Check the guide pins for wear. Replace them if excessive wear is detected.



1. Guide Pin Bore and Boot Groove
2. Pad Abutment Slipper Mounting

Fig. 4, Anchor Plate Machined Surfaces

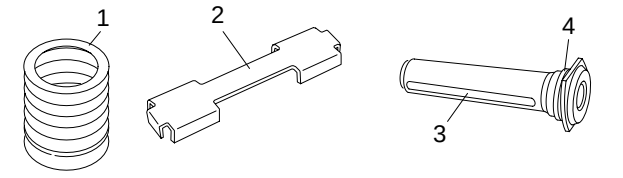
Anchor Plate Disassembly, Cleaning, and Inspection, and Assembly

5. Inspect the pad abutment slippers for damage or wear, and clean them with solvent. Replace them if damaged, or if excessive wear is detected.
6. Inspect the anchor plate for worn or damaged slippers, and damaged or dislodged guide pin boots. If signs of wear or damage are found, the anchor plate should be repaired or replaced.

Assembly

NOTE: All brake parts must be clean and completely dry of cleaning fluids before assembly.

1. Uniformly apply Aeroshell Grade 5 grease to the entire guide pin bore and on the guide pin shaft. Use 1/8 ounce (3 grams) of grease to thoroughly lube each guide pin and guide pin bore set. See **Fig. 6**.



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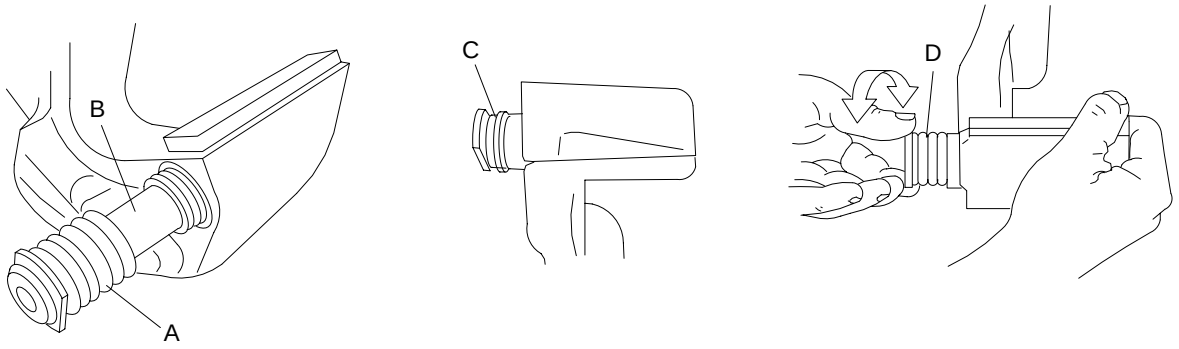
1. Guide Pin Boot
2. Pad Abutment Slipper
3. Guide Pin
4. Boot Groove

Fig. 5, Loose Anchor Plate Components

2. Apply a thin coat of Aeroshell Grade 5 grease to the inside opening at each end of the boot.
3. Slide the guide pin into the guide pin boot.
4. Insert the guide pin with the boot into the anchor plate guide pin bore until the boot is completely compressed.
5. Rotate the guide pin 1/4 to 1/2 turn back and forth in order to seat the guide pin boot.
6. Inspect the guide pin boot to make sure the boot is fully seated all around the guide pin and the anchor plate retaining grooves.
7. Install an anchor plate pad abutment slipper onto each anchor plate abutment. See **Fig. 7**. Use a soft brass or other light hammer to be sure the slipper is seated on the abutment. Avoid marring anchor plate abutment slipper surfaces.
8. Install the splash shield and antilock braking system sensor bracket on the anchor plate.

   When installing the splash shield and sensor bracket on the anchor plate for 66 mm front and all rear brakes, the splash shield and sensor bracket are mounted on the inboard side of the anchor plate and the five bolts are installed from the inboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

   For 73 mm front brakes, the splash shield and sensor bracket are mounted on the outboard side of the anchor plate and the five bolts are



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A. Lube the inside of the boot at both ends.
B. Apply Aeroshell Grade 5 grease to the bore and the pin.
C. Boot and pin in place.
D. Twist to seat in the groove.

Fig. 6, Installing Guide Pins and Boots

Anchor Plate Disassembly, Cleaning, and Inspection, and Assembly

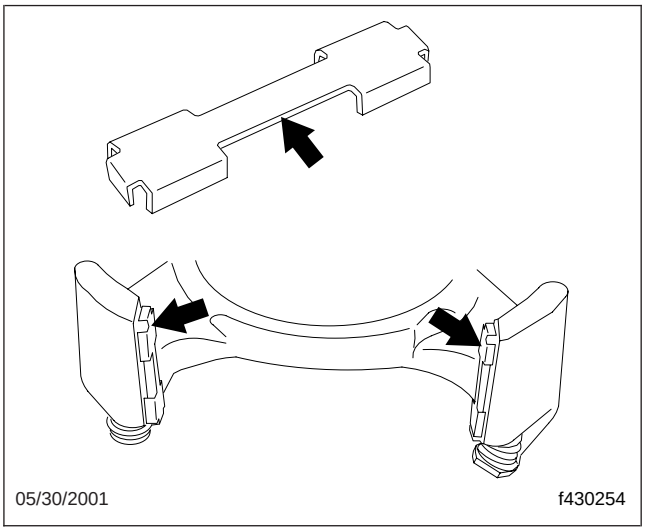
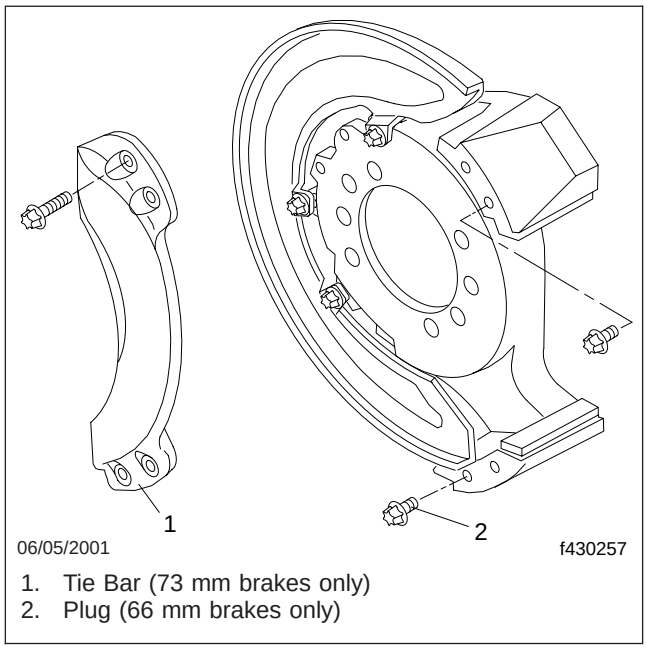


Fig. 7, Pad Abutment Slipper

installed from the outboard side. Tighten the bolts 12 to 16 lbf·ft (17 to 21 N·m).

9. Remove all traces of dirt, grease, and oil from the knuckle and axle brake flange.
10. Install the anchor plate on the axle, as follows.
    - 10.1 Position the anchor plate against the outboard side of the axle flange, making sure the holes in both are lined up.
    - 10.2 From the outboard side of the anchor plate, install the hexbolts and washers. Install the nuts and remaining washers. See **Fig. 1**. Using a star pattern, tighten the hexnuts as follows:
      - Rear Axle; 97 to 123 lbf·ft (132 to 167 N·m)
      - Front Axle Type FC; 70 to 89 lbf·ft (95 to 121 N·m)
      - Front Axle Type FD/FF; 134 to 172 lbf·ft (182 to 233 N·m)
11. Install the dust shield on the anchor plate. See **Fig. 1**.
12. Install the wheel hub and rotor assembly on the axle, following the instructions in **Group 33** for the front axle or **Group 35** for the rear axle.
13. On 66 mm brakes, install the four bolt plugs into the anchor plate face. Tighten the plugs 16 to 27 lbf·ft (22 to 37 N·m). See **Fig. 8**.

On 73 mm brakes, install the anchor plate tie bar using the four tie bar bolts to the anchor plate face. Tighten the bolts 40 to 50 lbf·ft (54 to 68 N·m).



1. Tie Bar (73 mm brakes only)
2. Plug (66 mm brakes only)

Fig. 8, Plugs and Tie Bar

14. Install the brake caliper on the anchor plate, following the instructions in **Subject 120**.
15. Install the brake pads in the anchor plate. For instructions, see **Subject 110**.
16. Install the tire.
17. Remove the jackstands. Lower the vehicle.
18. Remove the chocks.

Bleeding

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions 100. Failure to do so could result in serious and permanent health damage.

Whenever any hydraulic system fitting is loosened or disconnected, the entire system must be bled to remove any air that may have entered it.

⚠ CAUTION

Power steering fluid and brake fluid are incompatible. Never mix these two fluids or serious damage to both hydraulic systems will result. Use only brake fluid for the master cylinder and brake lines. Use only power steering fluid for the power booster.

Always use new, clean brake fluid that meets DOT 3 specifications when bleeding the master cylinder and service brake system. Never reuse brake fluid and do not use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Do not let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Do not let it get on brake pads or rotors.

Pressure Bleeding

NOTE: Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit, consisting of a tank, pressure pump and valve, gauge, tubing, and adapter. These are available from a number of manufacturers and include instructions for use. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Using the manufacturer's instructions, connect the brake master cylinder reservoir, as follows.

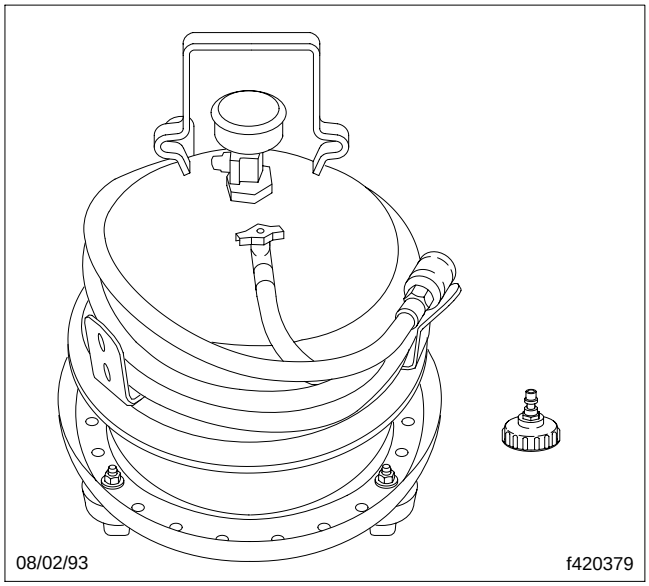


Fig. 1, Pressure Bleeder Kit

3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

3.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.

4. Bleed the hydraulic connections at the rear wheel calipers starting on the right side, as follows.

4.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

5. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir. Connect it to the front compartment of the reservoir.
6. Bleed the front wheel brake calipers starting at the right side, as follows.

System Bleeding

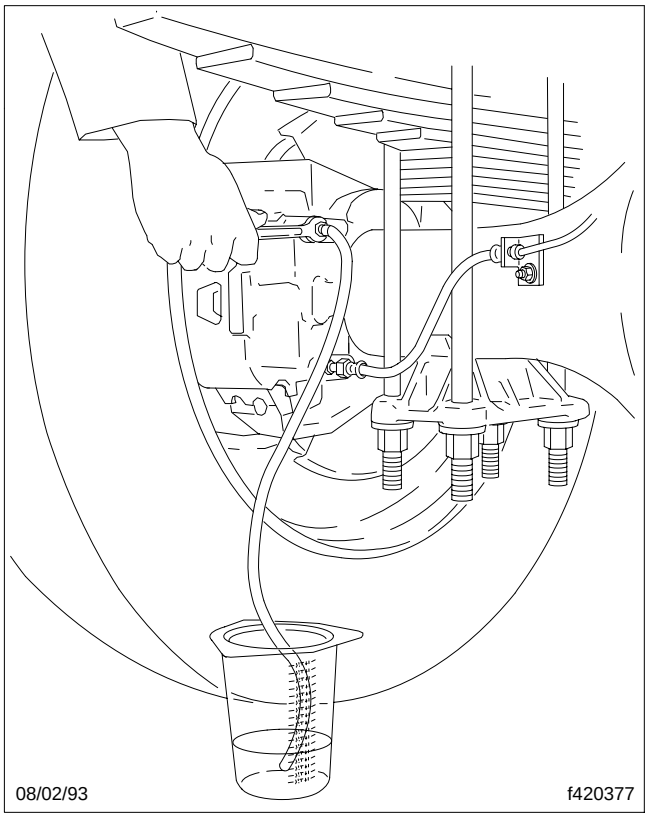


Fig. 2, Bleeding the Hydraulic Connection

6.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

6.2 Loosen the bleeder fitting about 3/4 turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Tighten the fitting firmly.

6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
8. Check the operation of the brakes by depressing the brake pedal several times, until if feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting, 300** and find the problem.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

Manual Bleeding

NOTE: If you do not have pressure bleeding equipment, you can use the manual bleeding procedure.

⚠ WARNING

Read over the information in Subject 100 before starting the procedure below. Failure to do so may result in either serious injury to yourself, or damage to the brake system, resulting in an accident causing serious personal injury or property damage.

IMPORTANT: Do not let the brake master cylinder run dry during manual bleeding operations. Keep the master cylinder reservoir filled with new, DOT 3 approved brake fluid. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Bleed the master cylinder, as follows.

3.1 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the rear outlet port on the master cylinder. See **Fig. 3**. Loosen the fitting about one turn.

3.2 Have someone push the brake pedal down slowly by hand to the floor. Brake fluid, and any air in the master cylinder, will squirt from the fitting.

3.3 *With the brake pedal held down*, tighten the rear hydraulic line fitting firmly.

IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

3.4 Release the brake pedal.

3.5 Loosen the fitting again, and repeat steps for bleeding as required until no air es-

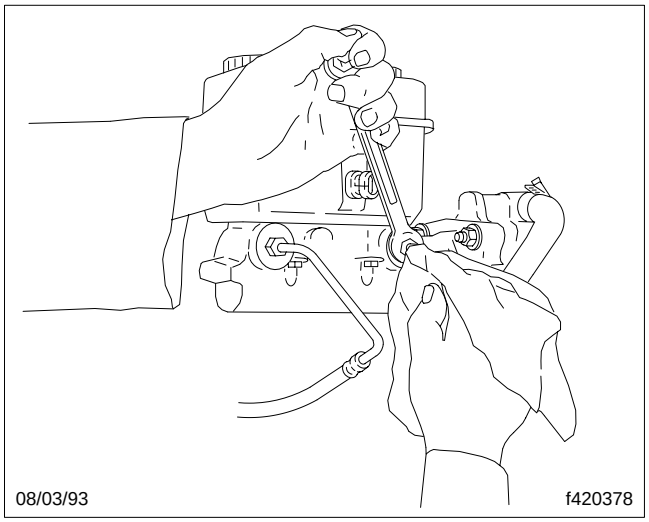


Fig. 3, Rear Outlet Port

capes from the fitting, and the brake pedal feels firm.

3.6 Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.

3.7 Using a wrench (and a rag to absorb leaking brake fluid), loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

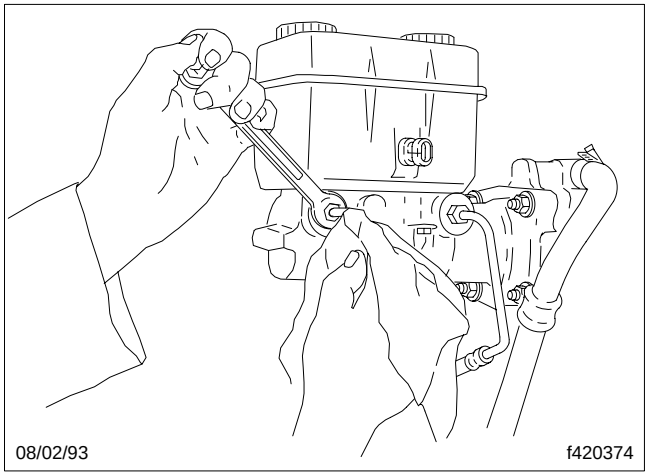


Fig. 4, Front Outlet Port

3.8 Repeat steps as required for the front outlet port.

3.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

4. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper, as follows.

4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig. 2**.

4.2 Loosen the bleeder fitting about 3/4 turn.

4.3 Have someone slowly push the brake pedal to the floor. *With the brake pedal depressed*, tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it is released before you tighten the fitting, more air will get into the system.

4.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat the steps as required until the fluid in the tube is completely free of air bubbles.

4.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

4.6 Repeat the steps for bleeding the connections for the left rear caliper, the right front caliper and the left front caliper.

5. Close and latch the hood.

6. Remove the chocks from the rear tires.

Troubleshooting Tables

IMPORTANT: See **Section 42.14** for detailed hydraulic brake system troubleshooting procedures.

Problem—Noise and Chatter

Problem—Noise and Chatter	
Possible Cause	**Remedy**
Bent, damaged, or incorrect pads.	Replace with the correct pads in axle sets.
Worn out lining plates (plates rubbing rotor).	Resurface or replace the rotor. Replace the pads in axle set.
Rotor polished or linings glazed.	Remove the polish or glaze.
Foreign material embedded in linings.	Replace the pads in axle sets.
Excessive rotor thickness variations or runout.	Resurface or replace the rotor. See **Subject 140**.

Problem—Brakes Grab

Problem—Brakes Grab	
Possible Cause	**Remedy**
Incorrect pads or pads loose on plate.	Replace with the correct pads in axle sets.
Grease or brake fluid on linings.	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper at anchor plate pins.	Tighten to specifications.
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.

Problem—Vehicle Pulls to One Side

Problem—Vehicle Pulls to One Side	
Possible Cause	**Remedy**
Incorrect pads or loose lining on plates.	Replace with the correct pads in axle sets.
Grease or brake fluid on linings.	Repair the grease seal or caliper. Replace the pads in axle sets.
Loose caliper or anchor plate.	Tighten to specifications.
Caliper piston sticking.	Repair or replace the piston or replace the caliper.
Caliper guide pins sticking.	Repair or replace the guide pins and boots. Clean the pin bores and lubricate.
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.

Problem—Pulsating Brake Pedal

Problem—Pulsating Brake Pedal	
Possible Cause	**Remedy**
Worn or damaged front wheel bearings.	Replace the wheel bearings.
Excessive variation in rotor thickness.	Resurface or replace the rotor. See **Subject 140**.

Troubleshooting

Problem—Springy or Spongy Pedal

Problem—Springy or Spongy Pedal	
Possible Cause	**Remedy**
Excessive rotor runout.	Check the bearing adjustment. See **Subject 140**.
Poor quality brake fluid (low boiling point).	Drain and clean the system. Refill with the approved brake fluid.
Weak brake hoses that expand under pressure.	Replace the hoses.
Air in hydraulic system.	Bleed the system. For instructions, see **Subject 160**.

Problem—All Brakes Drag (or Both Brakes on Same Axle)

Problem—All Brakes Drag (or Both Brakes on Same Axle)	
Possible Cause	**Remedy**
Binding brake pedal.	Free-up and lubricate the pedal.
Soft or swollen rubber parts caused by incorrect or contaminated brake fluid.	Replace rubber parts. Flush the system and refill with approved brake fluid. For instructions, see **Subject 160**.
Trapped pressure in brake lines caused by master cylinder and/or booster not fully releasing.	Repair or replace the master cylinder and/or booster as necessary.

Problem—One Brake Drags

Problem—One Brake Drags	
Possible Cause	**Remedy**
Loose or worn front wheel bearings.	Adjust to specifications or replace.
Defective brake hose or hydraulic tube (preventing return of fluid).	Replace the hose or tube.
Sticking caliper piston.	Repair or replace the caliper.
Swollen caliper piston seal.	Replace the seal. Drain and flush the system. Refill with the approved brake fluid.
Sticking caliper guide pin(s).	Repair or replace the pin(s). Lubricate the pins and boots.

Problem—Low Pedal

Problem—Low Pedal	
Possible Cause	**Remedy**
Leak in hydraulic brake system.	Check the master cylinder, calipers, hoses, and tubes. Replace as necessary.
Air in hydraulic brake system.	Bleed the system. For instructions, see **Subject 160**.
Poor quality brake fluid (low boiling point).	Drain the system. Flush and refill with approved brake fluid.
Weak brake hoses that expand under pressure.	Replace the defective hoses.
Pad and piston knockback caused by loose wheel bearings.	Adjust or tighten parts or replace faulty parts as necessary.

Specifications

Kent-Moore Tools	
Kent-Moore Part Number	**Tool**
ZTSE4417	Seating Tool for 66 mm Caliper Pistons
ZTSE4418	Seating Tool for 73 mm Caliper Pistons

Table 1, Kent-Moore Tools

Fastener Torques			
Description	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Caliper Pin Mounting Bolts	M12 x 1.25	—	93–107 (126–145)
Brake Supply Hose Fitting	—	—	15 (20)
Tie Bar-to-Anchor Plate Mounting Bolt (73 mm only)	M10 x 1.5	—	40–50 (54–68)
Tie Bar-to-Anchor Plate Hole Plug (66 mm only)	M10 x 1.5	—	16–27 (22–37)
Splash Shield, ABS Sensor Mounting Bracket, and Brake Line Clip Screw	5/16–18	—	12–16 (17–22)
Anchor Plate Mounting Hexnuts	—	—	Rear Axle: 97–123 (132–167) Front Axle Type FC: 70–89 (95–121) Front Axle Type FD/FF: 134–172 (182–233)
Caliper Bleed Screw	7/16–24	—	8–15 (10–20)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)

Table 2, Fastener Torques

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluids**
DOT 3	Wagner-Premium Plus Super HD
	Delco Supreme II
	Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

Approved Brake System Grease	
Component	**Recommended Grease**
Anchor Plate Guide Pins, Guide Pin Boots, Guide Pin Bores	Aeroshell Grade 5 (ES-1246)
Caliper Piston Bores	Dow Corning DC-4

Table 4, Approved Brake System Grease

Rotor Specifications	
Outside Diameter	15.0 inch (381 mm)
Thickness, New	1.435 inch (36.45 mm)
Thickness, Discard	1.320 inch (33.53 mm)
Surface Finish	40–120 micro inch 40–100 micro inch (preferred)

Table 5, Rotor Specifications

General Information

Air reservoirs serve two main purposes.

1. They store compressed air used to apply the brakes and operate other air-powered devices, such as chassis suspensions, engine fan controls, and seats.
2. 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 with air brakes (and optionally, some vehicles with hydraulic brakes) is equipped with three air reservoirs, or reservoir compartments. Each reservoir or compartment is identified as one of three types: supply, primary, and secondary.

The supply reservoir (or wet tank) receives compressed air directly from the compressor. It collects most of the water and oil condensate from the air, and feeds air to the other reservoirs. At the outlet port of the supply reservoir (the port leading to the primary reservoir) is a safety valve that protects the air system against excessive air pressure build up.

The primary reservoir is the air source for the brakes on the rear axle. At the inlet port of the primary reservoir is an inline check valve. The check valve allows air flow in one direction only, and prevents air flow in the reverse direction in case there is a drop in upstream air pressure.

The secondary reservoir is the air source for the front axle brakes. It is equipped with an internal check valve.

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.

Some vehicles are equipped with a three-chamber air tank. In the three-chamber air tank, there are two internal single check valves located in the supply air chamber (wet tank). The valves are installed in elbows welded into the belled partitions between the chambers. One valve controls air movement from the supply air chamber to the secondary air chamber. The other valve controls air movement from the supply air chamber to the primary air chamber. To see the check valves, remove a fitting from the top of the supply chamber and look through the port. The check valves are not serviceable. If they are not functioning correctly, replace them.

All air reservoirs are equipped with drain valves to eject the water and oil emulsion from the tanks.

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions.

- The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- To eliminate the possibility of component failure, used reservoirs must not be used as replacements.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured, in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Tests

Be sure the air system is fully charged. Using a soap solution or leak detector, check for leaks on the outside surfaces of the reservoirs and drain valves. No leakage is permitted.

If leaks exist at the drain valve, note if they occur at the joint of the valve and coupler or through the valve body. See **Subject 120**.

If leaks occur on the surfaces of the air reservoir, replace the tank; see **Subject 130**.

Internal Check Valves Test, Three-Chamber Air Reservoir

The three-chamber air reservoir has two internal check valves located in the supply chamber of the reservoir. To test the check valves for proper operation, perform the following test.

NOTE: Depending on vehicle configuration, this procedure may require two people.

1. Start the engine and fully pressurize the brake system. Shut down the engine.
2. Discharge the air from the supply chamber of the reservoir.
3. Watch the dash air-pressure gauges for the primary and secondary air systems. If either system loses pressure along with the supply chamber, the check valve is bad. Replace it. See **Subject 140**.

Replacement and Leak Elimination

WARNING

Before working on or around air brake systems and components, see Safety Precautions, 100.

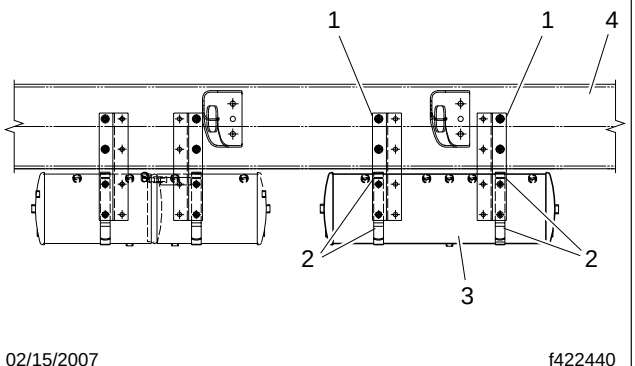
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Using two wrenches (hold the coupler in place with one of them), unscrew the drain valve from the coupler. Clean off the threads inside the coupler on the reservoir, removing all sludge and sealant build-up.

   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 1-1/2 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.
6. Remove the chocks from the tires.

Replacement

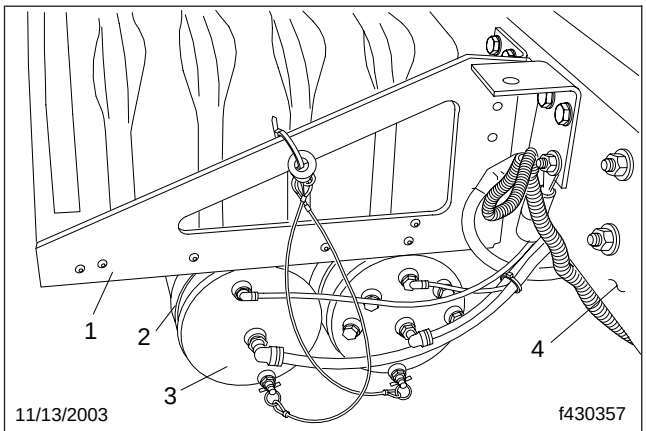
1. Apply the parking brakes, and chock the tires.
2. Drain the air system. For instructions, refer to the *S2 Chassis Operator's Manual*.
3. Mark all reservoir air lines, couplers, and valves for later assembly; disconnect the components. Cap the exposed ports tightly to keep out contaminants. If access is limited, remove the components after removing the reservoir from its mount.
4. Remove the reservoir strap fasteners. Remove the reservoir.
5. 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 20 to 25 lbf·ft (27 to 34 N·m). See **Fig. 1** for an outer frame rail mounting and **Fig. 2** for under battery box mounting.
6. As marked earlier, connect all air lines, couplers, and valves to the new reservoir, removing the caps as each component is installed. Tighten the connections as instructed elsewhere in this group.
7. Remove the chocks.



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1. Mounting Bracket
2. Strap Fasteners
3. Air Reservoir
4. Outer Left-Hand Frame Rail

Fig. 1, Air Reservoir, Outer Left-Hand Frame Rail Mounting



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1. Battery Box Mounting Bracket
2. Strap Fasteners
3. Air Reservoir
4. Left-Hand Frame Rail

Fig. 2, Air Reservoir, Under Battery Box Mounting

Internal Check Valve Replacement, Three-Chamber Air Reservoir

WARNING

Before working on or around air brake systems and components, see Safety Precautions, 100.

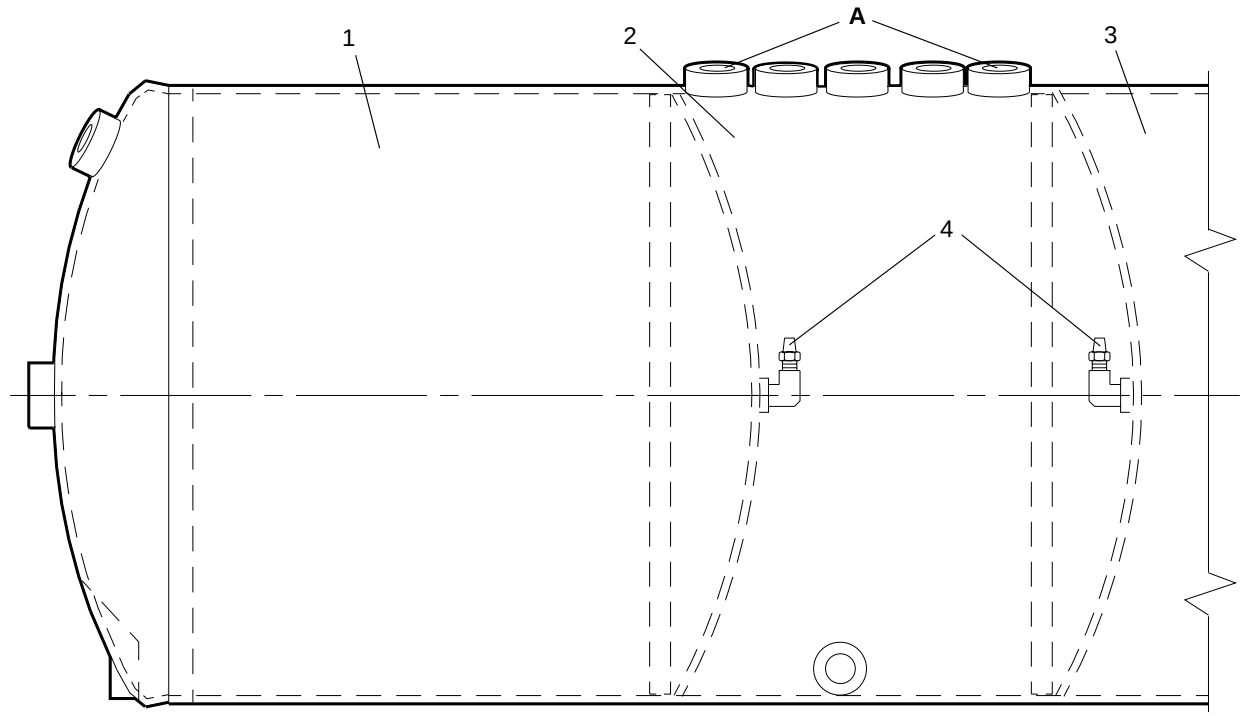
Before changing the internal check valve(s), test the system to determine which valve is bad. See **Subject 110** for the procedure.

1. Park the vehicle on a level surface, shut down the engine, and chock the tires.
2. Drain the brake air system completely.
3. Remove the appropriate fittings from the top of the supply-air chamber to access the valve(s) to be replaced. See **Fig. 1**.

NOTE: Use appropriate measures to ensure that the socket is securely attached to the extension, and that the valve is secured in the socket, so that they do not drop into the reservoir during this procedure.

4. Using a six-point, 1/2-inch, deep socket on a 10-inch extension, unscrew the valve from the fitting in the bell of the chamber partition and remove it from the reservoir.
5. Install the new valve in the fitting in the bell of the chamber partition. Tighten to 27 lbf·ft (40 N·m).
6. Install the air reservoir fittings that were removed.
7. Pressurize the air system and check for leaks around any fittings that were removed, then perform the "Internal Check Valves Test, Three-Chamber Air Reservoir" to determine that the problem has been fixed. See **Subject 110**.
8. Before returning the vehicle to service, test the brakes for proper operation.

Internal Check Valve Replacement



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A. Access valves through these fittings.

1. Secondary Air Chamber
2. Supply Air Chamber
3. Primary Air Chamber
4. Check Valves (2)

Fig. 1, Internal Check Valves, Three-Chamber Air Reservoir

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- In order to eliminate the possibility of component failure, used reservoirs must not be used as replacements
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Replacement

CAUTION

Before working on or around air brake systems and components, review Safety Precautions 100.

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.

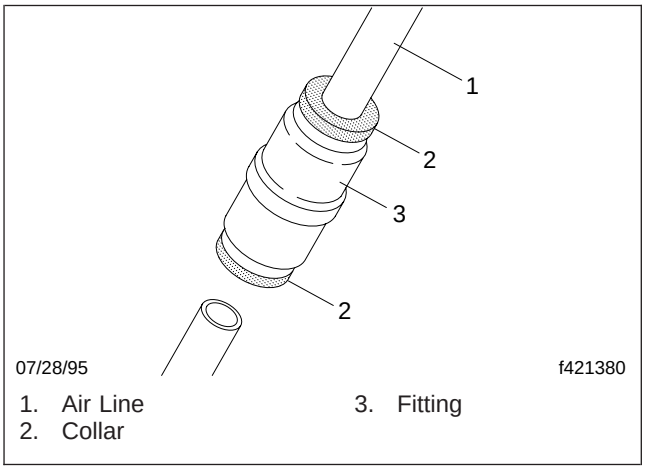
Nylon Air Lines

NOTE: When installing a nylon air line, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

Push-to-Connect (Quick-Disconnect) Fittings

NOTE: If damaged, quick-disconnect fittings must be replaced as an assembly.

1. Push in on the fitting collar to release the air line.
2. Pull the air line out of the fitting. See **Fig. 1**.
3. Push the air line all the way into the fitting.
4. Pull on the air line to make sure the line is installed in the fitting properly.
5. Check that the air line is seated in the fitting.

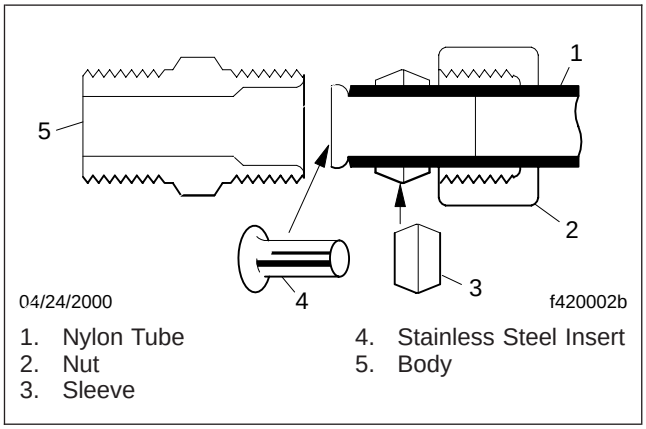


1. Air Line
2. Collar
3. Fitting

Fig. 1, Nylon Air Line and Quick-Disconnect Fitting

Compression Fittings

1. Push the stainless steel insert in, (to free sticking fittings, grip the stainless steel insert with pliers and rotate it slightly). For brass fittings, loosen the fitting nut. See **Fig. 2**.



1. Nylon Tube
2. Nut
3. Sleeve
4. Stainless Steel Insert
5. Body

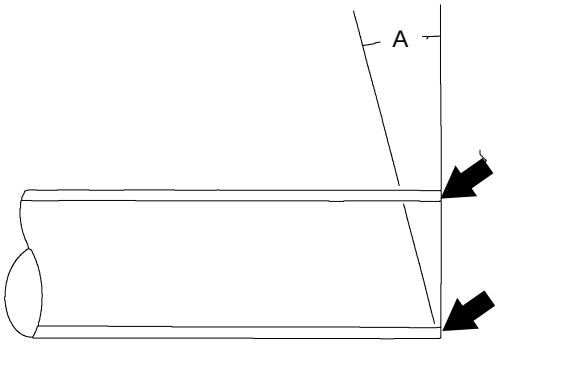
Fig. 2, Nylon Air Line and Compression Fitting

2. Pull the air line out.
3. Use pliers to remove the stainless steel insert from the fitting.
4. Clean all of the fitting components.
5. Place the new stainless steel insert into the fitting body. Use thumb pressure to press it into position.
6. Check the tube end for a square cut-off that does not exceed a 15-degree angle. Check that the tube is not distorted or damaged. See **Fig. 3**.

   If the angle exceeds the specification, recut the air line.

   Use a sharp blade to prevent collapsing the tube or leaving burrs that can damage the O-ring.
7. 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.
8. Install a new sleeve in the nut. Start the threads of the nut on the fitting body.
9. Insert the squared end of the air line tubing in the fitting until it bottoms in the body of the fitting. See **Fig. 4**.
10. Tighten the nut until one thread remains visible.

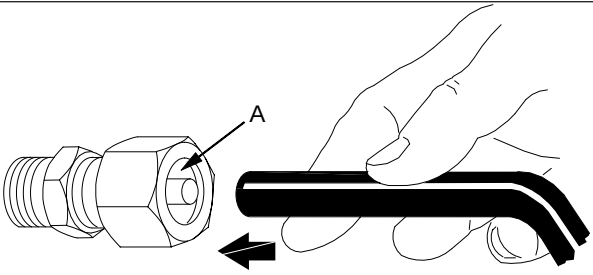
Air Line Replacement



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A. 15 Degrees Maximum

Fig. 3, Check Tube End Angle



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A. Tube end must bottom before tightening the nut.

Fig. 4, Installing Nylon Air Line into Compression Fitting

11. Pull back on the air line to make sure the tube is fully seated.
12. Pressurize the air system. Check the air system for leaks.

Wire Braid Air Lines

NOTE: When installing a wire braid hose, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

1. 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.
2. Install the hose and finger-tighten the nut.
3. Using two wrenches to prevent twisting of the hose, tighten the nut until it seats solidly. Tighten the nut one-sixth turn more.

Replacement

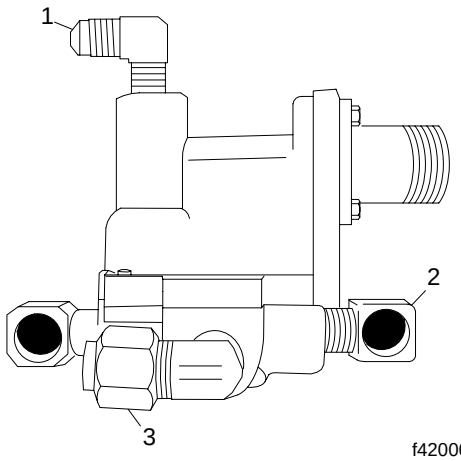
CAUTION

Before working on or around air brake systems and components, review Safety Precautions 100.

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.

Brass and Steel Pipe Fittings

Make sure the fittings are free of grease, dirt, and old sealant. See **Fig. 1**. Apply liquid thread sealant (white) to the threads, and finger-tighten securely.



1. Wire Braid Hose Fitting
2. Pipe Fitting
3. Nylon Tube Fitting

Fig. 1, Screw-On Fittings

For fittings that must be positioned, tighten one additional turn from finger-tight using a wrench. Tighten the fitting until it is correctly positioned.

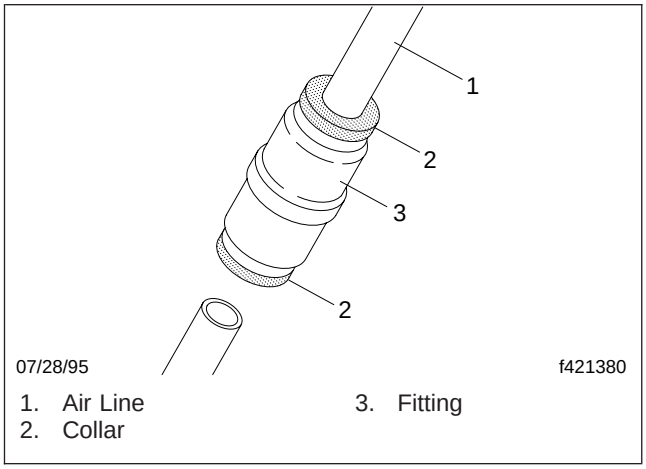
NOTE: Always apply the sealant to the external thread, so that any excess will be scraped off externally rather than internally to the joint.

For fittings that do not require positioning, tighten 1-1/2 additional turns from finger-tight.

Quick-Disconnect Fittings

NOTE: If damaged, quick-disconnect fittings must be replaced as an assembly.

1. Push in on the fitting collar to release the air line.
2. Pull the air line out of the fitting. See **Fig. 2**.



1. Air Line
2. Collar
3. Fitting

Fig. 2, Nylon Air Line and Quick-Disconnect Fitting

3. Push the air line all the way into the fitting.
4. Pull on the air line to make sure the line is installed in the fitting properly.
5. Check that the air line is seated in the fitting.

Specifications

213 Wire Braid Hose			
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)

* 213 hose is identified by two green stripes 180 degrees apart, part numbers, and size; for example, part numbers 213-4, 213-5, and so on.

Table 1, 213 Wire Braid Hose

273 Fabric Braid Hose			
Number*	Inside Diameter: inch	Outside Diameter: inch	Minimum Bend Radius: inch (mm)
4	1/4	5/8	1-1/2 (38)
6	3/8	3/4	1-3/4 (44)
8	1/2	7/8	2 (51)
10	5/8	1-1/16	2-1/2 (64)

* 273 hose is identified by part number and size.

Table 2, 273 Fabric Braid Hose

Nylon Tube Bend Radius			
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	0.441	5/8	2.50 (64)
12	0.566	3/4	3.00 (76)

Table 3, Nylon Tube Bend Radius

Additional Turns from Hand-Tight (Nylon Tube Compression Fitting Nut)	
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 4, Additional Turns from Hand-Tight (Nylon Tube Compression Fitting Nut)

General Information

The major parts of the hydraulic disk brake system are:

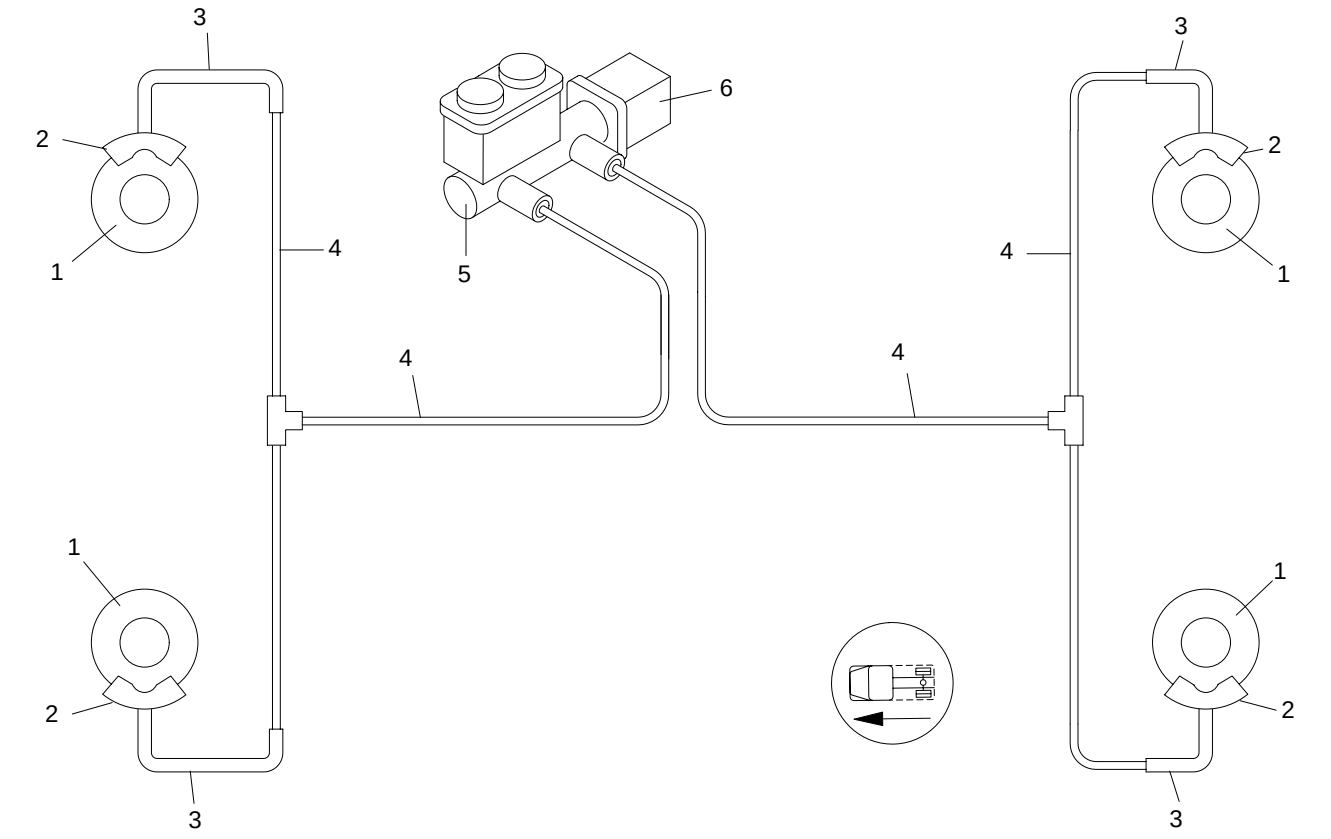
- power brake booster
- master cylinder
- rigid steel hydraulic lines
- flexible rubber hydraulic lines
- brake caliper assembly at each rotor

See **Fig. 1**.

NOTE: This document deals only with the hydraulic brake system. For antilock brake system (ABS) problems, see **Section 42.14**. Illustrations in this section do not show ABS components.

The hydraulic brake components include two completely separate hydraulic systems that use different and incompatible hydraulic fluids, lines, and seals. **The components of each *must* be kept separate from the other.** See **Fig. 2**, which shows the separate systems.

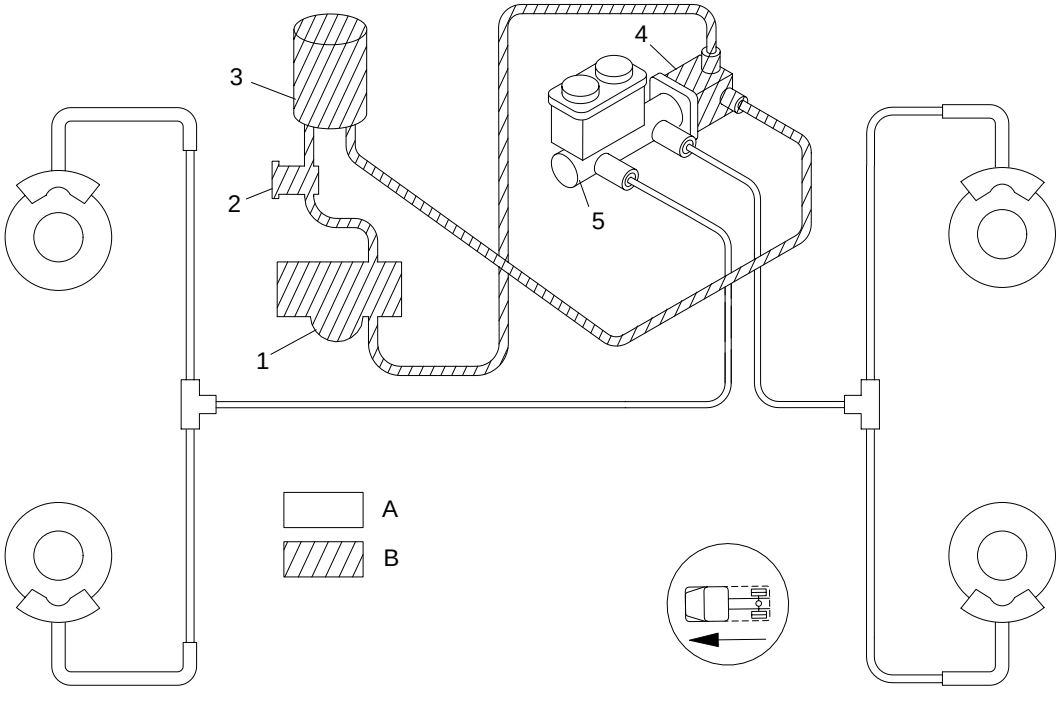
The power brake booster multiplies brake pedal effort to increase power to the brake master cylinder. The power increase comes from pressurized automatic transmission fluid (ATF) supplied by the power steer-



1. Rotor
2. Caliper and Pad Assembly
3. Flexible Brake Line
4. Rigid Brake Line
5. Master Cylinder
6. Power Brake Booster

Fig. 1, Brake System Major Parts

General Information



04/29/2003 f420369b

A. Service Brake System (DOT 3 Brake Fluid)
B. Power Brake Booster and Power Steering System (ATF)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Power Brake Booster
5. Brake Master Cylinder

Fig. 2, Brake System Booster

ing pump. **Note that the power steering system contains ATF, not "power steering fluid."**

⚠ CAUTION

Do not put ATF in the brake master cylinder.

Do not put DOT 3 brake fluid in the power brake booster.

Contaminating either hydraulic system with the wrong fluid causes serious damage.

Power Brake Booster

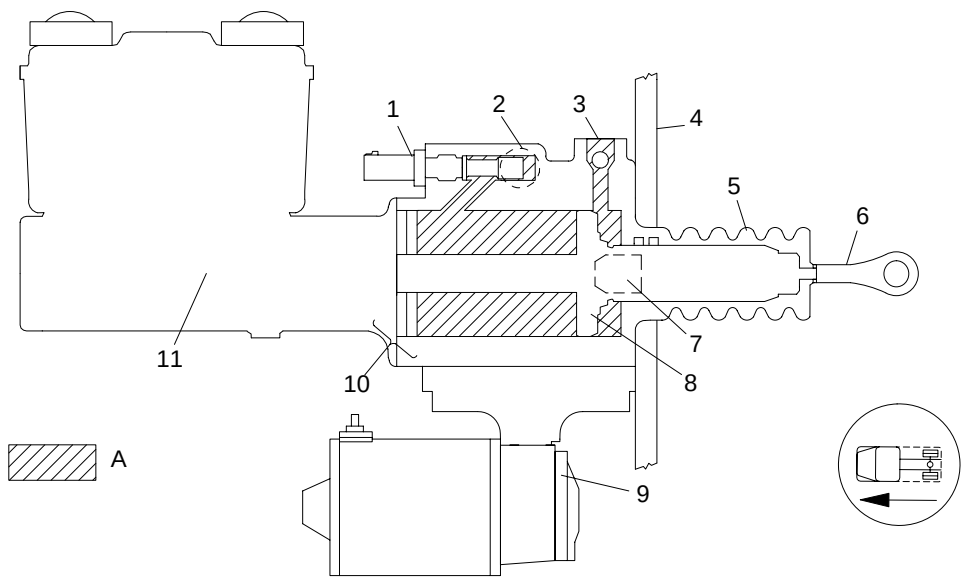
The major parts of the Hydro-Max® II power brake booster mounted on the frontwall are:

- reaction piston
- end-cap assembly
- electric backup pump

The brake master cylinder bolts to the front of the power brake booster.

The brake pedal rod connects the brake pedal to the power piston assembly in the power brake booster. See **Fig. 3**. The reaction piston is inside the power piston. The forward end of the power piston fits through the booster end-cap assembly and rests against the brake master cylinder. The end-cap assembly seals the ATF inside the power brake booster.

The power steering pump sends pressurized ATF to the power brake booster supply port. ATF returns to the power steering reservoir from the power brake booster return port. If the supply of pressurized ATF from the power steering pump to the power brake booster fails, a flow switch starts the electric backup pump to keep the power brakes working.



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NOTE: Not all parts are shown.

A. Automatic Transmission Fluid (ATF)

1. Flow Switch
2. Return Port (to steering reservoir)
3. Supply Port (from steering gear)
4. Firewall
5. Rubber Boot
6. Brake Pedal Rod
7. Reaction Piston
8. Power Piston Assembly
9. Electric Backup Pump
10. End-Cap
11. Master Cylinder (DOT 3 brake fluid only)

Fig. 3, Power Brake Booster

Master Cylinder

The brake master cylinder bolts to the power brake booster and functions as a dual supply system. The primary subsystem supplies pressurized DOT 3 brake fluid to the rear brakes, the secondary subsystem supplies it to the front brakes. See **Fig. 4**. For safety, each subsystem is independent so a problem with one will not affect the other.

The master cylinder is mounted on the front of the power brake booster. For locations and names of the major master cylinder components, see **Fig. 5**.

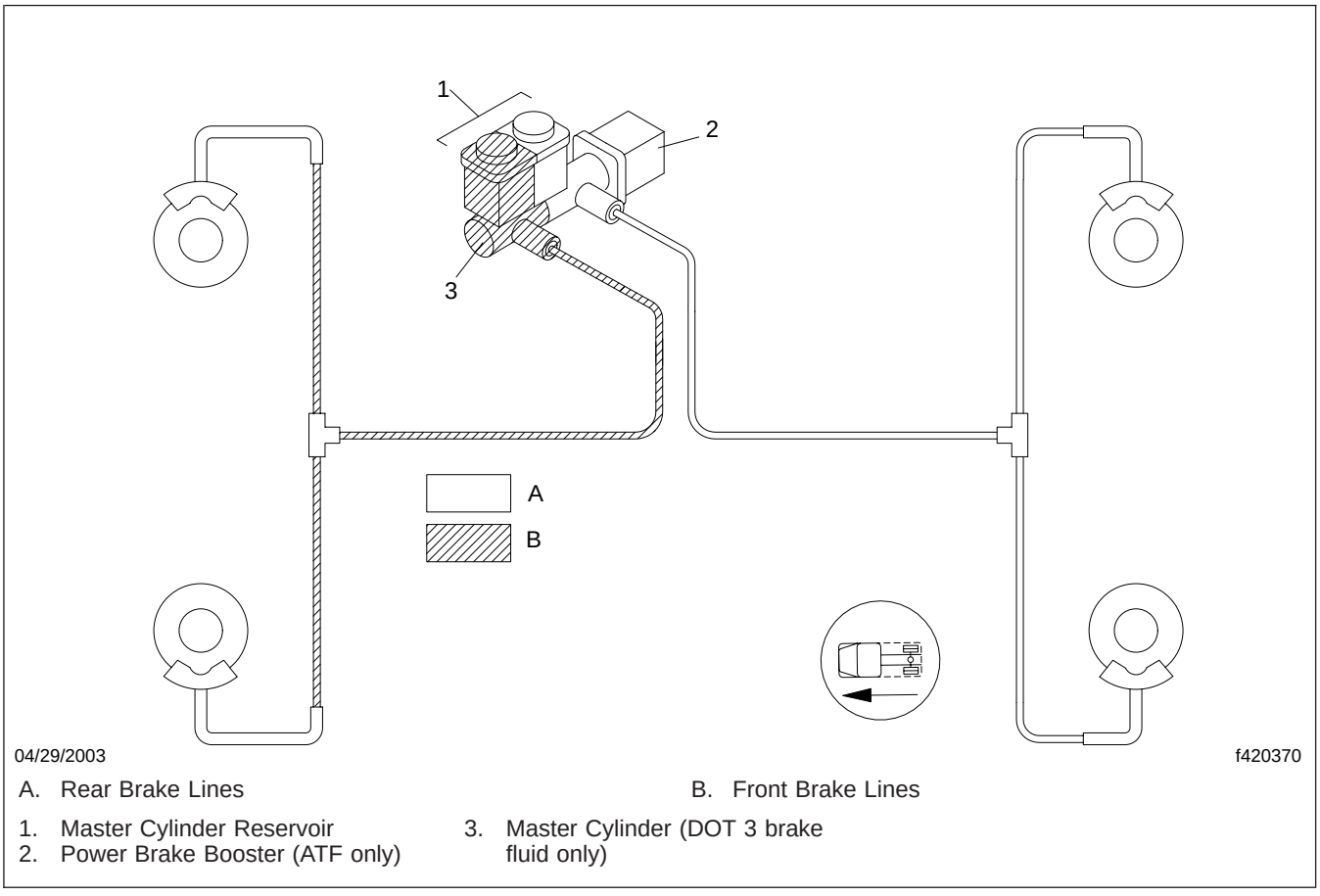
The pressure chambers connect to the front and rear brake caliper assemblies through hydraulic lines and hoses. There is a compensating valve at the bottom of each reservoir section that opens to connect the reservoir to its chamber in the master cylinder. When it is open, the compensation valve allows DOT 3 brake fluid in the reservoir to enter the brake lines to the calipers, to take up for lining wear. When it is closed, the compensation valve allows pressure to build in its subsystem. A pressure differential valve operates a pressure differential switch (not shown), which sets off a dash warning light and buzzer if one of the subsystems does not build pressure.

Non-ABS Brake Monitor Module

The brake monitor module, located behind the instrumentation control unit (ICU) on the driver side of the dash, monitors electrical signals from various sensors (but not ABS) in the service brake system and power brake booster system. If it detects a problem, the module lights the warning light and sounds the buzzer in the dashboard.

The monitor module has nine input terminals and three output terminals, with one ground terminal. See

General Information



A. Rear Brake Lines
B. Front Brake Lines

1. Master Cylinder Reservoir
2. Power Brake Booster (ATF only)
3. Master Cylinder (DOT 3 brake fluid only)

Fig. 4, Dual Supply System

Fig. 6. The output terminals connect to the brake system pressure and warning lights. The input terminals connect to sensors in the brake system that detect improper operation.

See **Table 1** for identification of the output and input terminals on the back of the module, and the circuits to which they are connected.

The monitor module, which operates on 9 to 16 volts DC, actively monitors the hydraulic brake system under any of the following conditions:

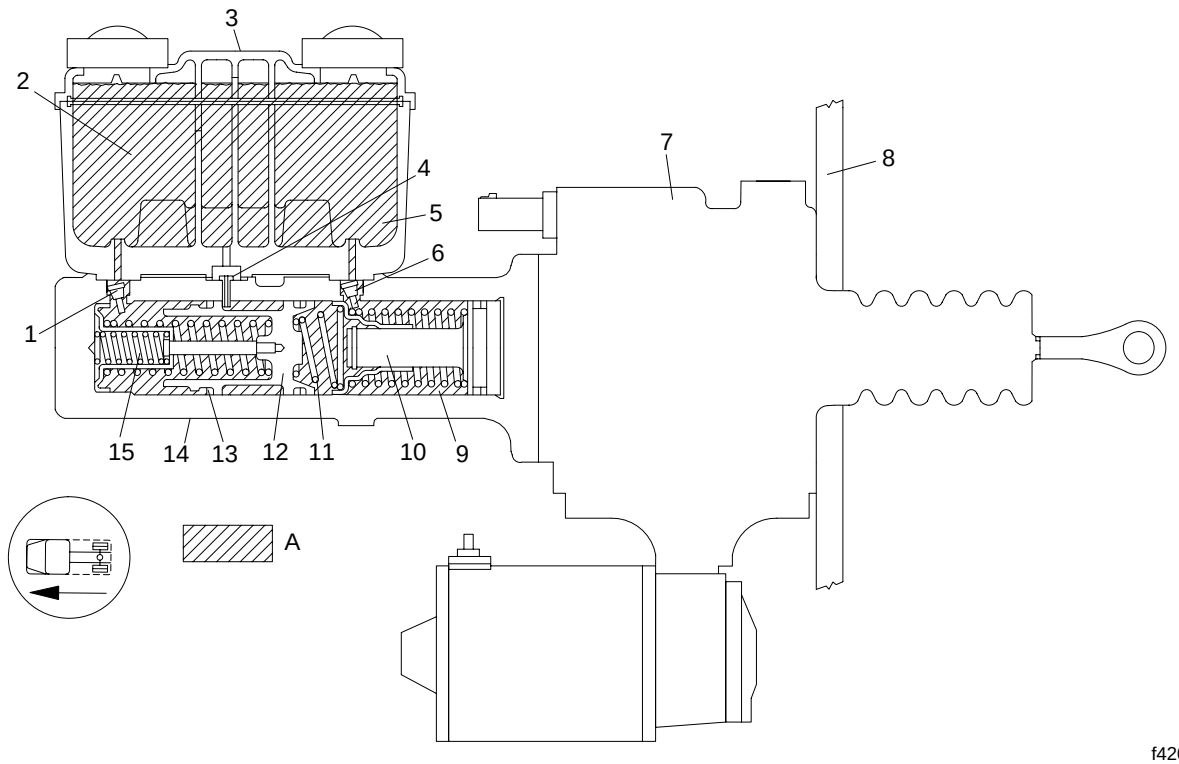
- when the ignition is on;
- when the brake pedal input terminal has power;
- if the ignition is off, but the driver's door is open and the parking brake is not applied.

When the ignition is turned on, the monitor module runs a self-test which lasts from 1 to 3 seconds. The warning light and buzzer come on, then go off if the system is working properly. The module then begins monitoring the hydraulic brake system. If it detects a problem, it turns on the brake warning light and buzzer.

NOTE: The buzzer is controlled by the instrumentation control unit (ICU).

Any of the following things can activate the brake pressure "R" light at output terminal 3.

- Reduced or lost flow of ATF to the power brake booster closes the flow switch on the power brake booster.
- Different pressures between the front and rear brake subsystems close the pressure differential switch.



NOTE: Not all parts are shown.

A. DOT 3 Brake Fluid

1. Secondary Compensating Valve (open)
2. Secondary Reservoir Section
3. DOT 3 Brake Fluid Reservoir
4. Piston Stop
5. Primary Reservoir Section
6. Primary Compensating Valve (open)
7. Power Brake Booster Assembly
8. Frontwall
9. Primary Pressure Chamber
10. Primary Piston/Actuator Assembly
11. Primary Piston Return Spring
12. Secondary Piston/Actuator Assembly
13. Secondary Pressure Chamber
14. Housing
15. Secondary Piston Return Spring

Fig. 5, Master Cylinder

- A drop in master cylinder fluid level closes the switch on the reservoir.
- Too much electrical resistance in the backup pump motor. This is often caused by a bad ground.
- No power to the backup pump at startup.

See **Table 2** for information about what activates the input terminals.

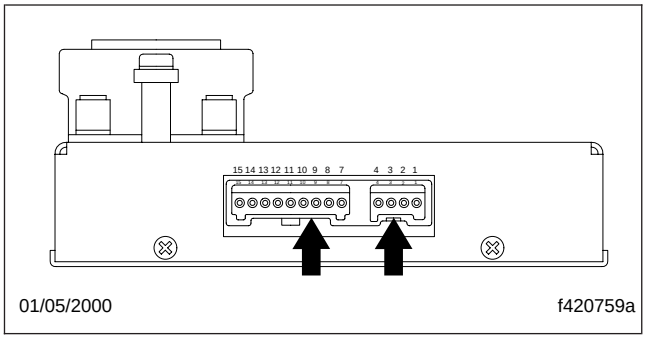


Fig. 6, Monitor Module Terminals

General Information

Monitor Module Terminal Identification		
Terminal Number	**Function**	**Circuit Number**
1	Not Used	—
2	Not Used	—
3	Light "R" (Brake System Pressure) Output	388H
4	Ground	GND
7	Ignition Input	81C
8	Not Used	—
9	Relay	388F

Monitor Module Terminal Identification		
Terminal Number	**Function**	**Circuit Number**
10	Not Used	—
11	Pressure Differential Switch Input	388A
12	Brake Pedal Input	388L
13	Backup Pump Motor	388C
14	Fluid Level Input	388B
15	Flow Switch Input	388G

Table 1, Monitor Module Terminal Identification

Input/Output Terminal Activation			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
7	Ignition Input	81C	The ignition is on.
8	Not Used	—	—
9	Relay Output	388F	The ignition is on or brake pedal is depressed.
10	Not Used	—	—
11	Pressure Differential Switch Input	388A	Pressure difference between front and rear systems becomes more than 483 kPa (70 psi).
12	Brake Pedal Input	388L	Brake pedal depressed.
13	Pump Motor Input	388C	Electrical resistance of backup pump motor too high.
14	Fluid Level Input	388B	Fluid level of master cylinder below 25 percent capacity.
15	Flow Switch Input	388G	No hydraulic flow through power brake booster.

Table 2, Input/Output Terminal Activation

Applying the Brakes

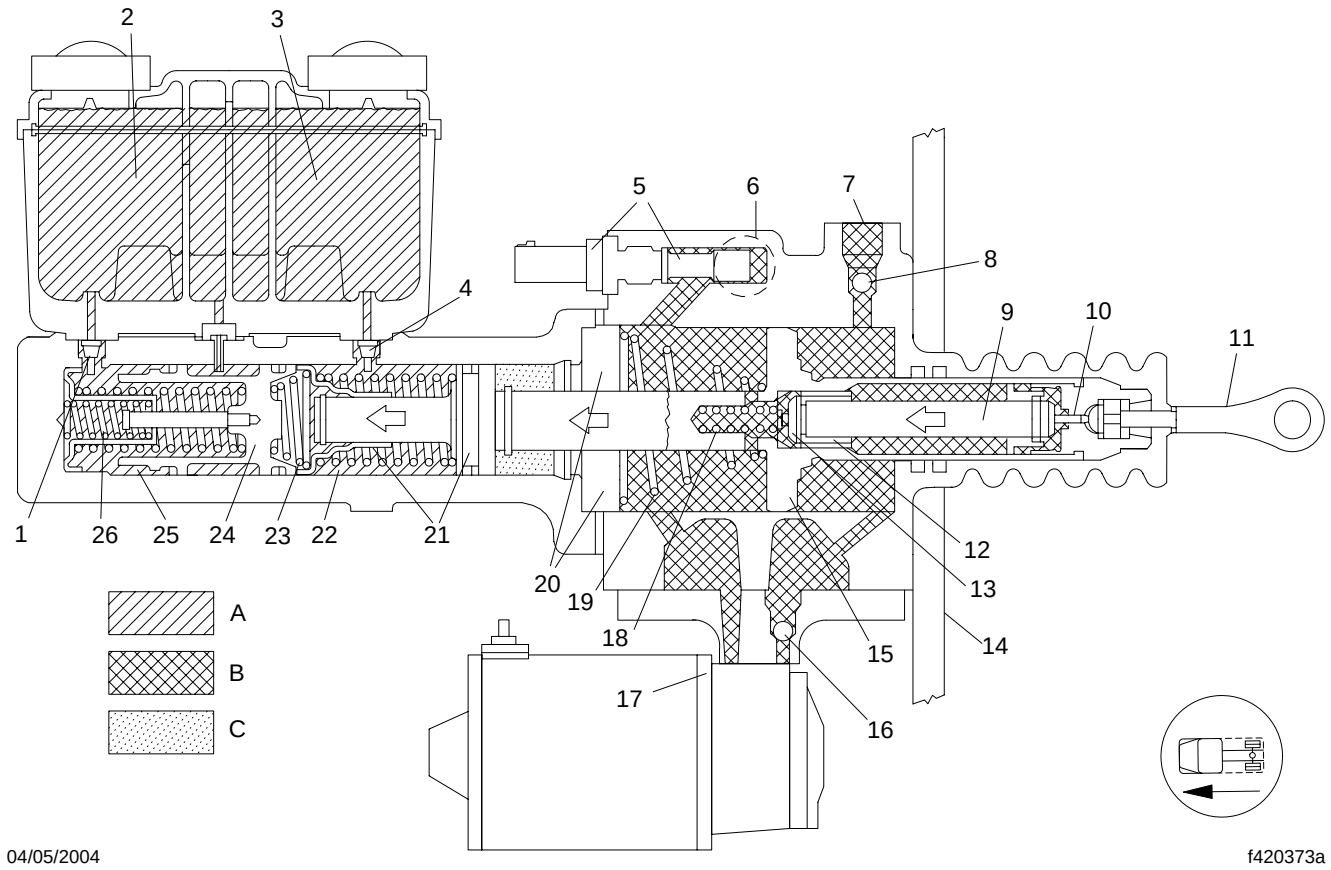
Pushing the brake pedal moves the brake pedal rod against the actuator pin in the power brake booster, moving the reaction piston forward inside the power piston. See **Fig. 7**. This moves the throttle valve, restricting the flow of ATF through the power piston, which increases pressure. The increased ATF pressure pushes the power piston forward through the end-cap assembly and into the master cylinder.

As the primary piston/actuator assembly is pushed forward in the master cylinder, the primary compensating valve closes. This shuts the outlet at the primary reservoir section and raises hydraulic pressure in the primary pressure chamber.

The primary piston/actuator assembly motion also moves the secondary piston/actuator assembly. This closes the secondary compensating valve, pressurizing the secondary pressure chamber.

Both primary and secondary pressure chambers have outlets into individual brake lines leading to the brake calipers. The brake lines transmit the pressure through the brake fluid to the calipers, moving the dual piston pads against the rotors. Friction of the pads squeezing the rotors slows the wheel.

If the power brake booster loses pressure from the power steering pump, the flow switch turns on the backup pump. This closes the main supply check valve and opens the backup pump check valve. The electric backup pump then takes over pressurizing the ATF in the power brake booster, providing



NOTE: Not all parts are shown.

A. DOT 3 Brake Fluid B. ATF C. Air Space

1. Secondary Compensating Valve (closed)
2. Secondary Reservoir Section
3. Primary Reservoir Section
4. Primary Compensating Valve (closed)
5. Flow Switch Assembly
6. Return Port
7. Supply Port
8. Supply Check Valve (shown open)
9. Pressure Regulator Assembly
10. Actuator Pin
11. Brake Pedal Rod
12. Reaction Piston
13. Throttle Valve
14. Frontwall
15. Power Piston
16. Backup Pump Check Valve (shown closed)
17. Electric Backup Pump
18. Throttle Valve Return Spring
19. Piston Return Spring
20. End-Cap
21. Primary Piston/Actuator Assembly
22. Primary Pressure Chamber
23. Primary Piston Return Spring
24. Secondary Piston/Actuator Assembly
25. Secondary Pressure Chamber
26. Secondary Piston Return Spring

Fig. 7, Power Brake Booster and Master Cylinder

enough pressure for the master cylinder to operate the brakes.

Releasing the Brakes

When the brake pedal is released, a return spring in the booster opens the throttle valve, reducing ATF

General Information

pressure in the power brake booster. See **Fig. 7**. The reduced power brake booster pressure allows the master cylinder and piston return springs to move the booster power piston back toward the frontwall side of the power brake booster housing.

In the master cylinder, the return springs push back the primary and secondary pistons, opening their compensating valves. This lowers hydraulic pressure in the master cylinder and the brake lines, allowing the caliper pistons and brake pads to back away from the brake rotors. With the brake pads no longer squeezing the rotors, the brakes let off and the rotors and wheel hubs can turn freely again.

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.
- Disconnect the batteries.
- 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.

⚠ WARNING

Hydraulic brake fluid is hazardous, and can cause blindness if it gets in your eyes. Always wear safety glasses when handling brake fluid or bleeding brake components. Brake fluid may also be a skin irritant. If you get it on your skin, wash it off as soon as possible.

Special care must be taken when disposing of used brake fluid. Put the fluid in a sealed plastic container and label it "Used Brake Fluid." Then dispose of it in an approved manner. Check with local and state regulations as to the correct disposal procedure.

IMPORTANT: During service procedures, keep grease and other foreign material away from caliper assemblies, disc brake pads, brake rotors and external surfaces of the hub. Handle parts carefully to avoid damage to the caliper, rotor, disc brake pads or brake lines.

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. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (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.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency particulate air

Safety Precautions

(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.

Bleeding

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

WARNING

The hydraulic brake and power steering systems must be bled whenever any fitting has been loosened or disconnected. Failure to bleed the system, or bleeding it improperly, allows air to remain in it. That decreases the vehicle braking ability and can result in an accident, property damage, and personal injury.

Properly dispose of used hydraulic brake fluid. Used hydraulic brake fluid is almost always contaminated. Reusing it can cause brake system damage, loss of braking, property damage and serious personal injury.

Automatic transmission fluid (ATF) and brake fluid must not be mixed. Brake fluid may be used only in the master cylinder and brake lines. Use only ATF for the power brake booster. Mixing these two fluids will seriously damage the hydraulic system. ATF will damage the rubber parts of the ABS modulator, master cylinder, and brake calipers, and can cause damage, loss of braking, and serious personal injury.

Always use new DOT 3 brake fluid when bleeding the master cylinder and service brake system. Never reuse brake fluid, and do not use brake fluid containers for any other purpose. DOT 3 brake fluid exposed to the air absorbs water from it, so keep brake fluid containers tightly closed to keep new brake fluid clean and dry. Keeping the master cylinder reservoir properly filled to the bottom of the narrow filler neck helps reduce moisture absorption from the air.

IMPORTANT: Do not let DOT 3 brake fluid touch any painted surfaces. Brake fluid removes paint and may also damage other non-metallic surfaces. Do not let fluid get on brake pads or rotors.

Pressure Bleeding

Pressure bleeding is the preferred method for bleeding the service brake system. It requires the use of a special pressure bleeder kit consisting of a tank, pressure pump and valve, gauge, tubing, and adapter. These are available from a number of manufacturers and include instructions for use. See Fig. 1.

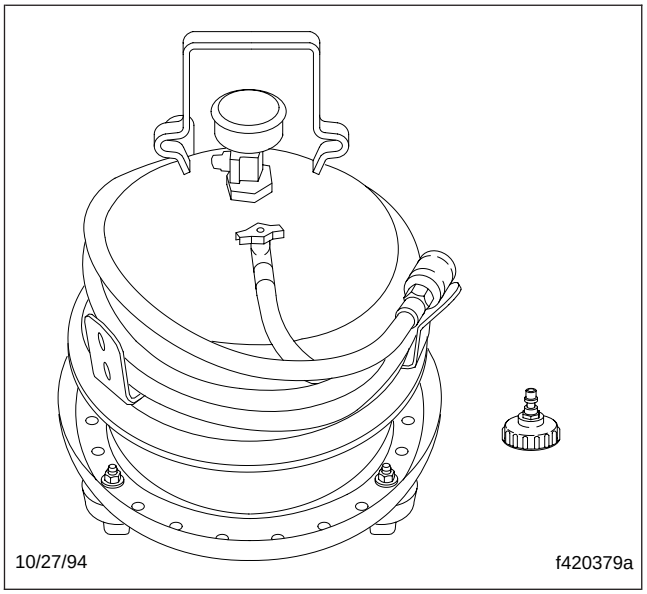


Fig. 1, Pressure Bleeder Kit

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the tires.
2. Open the hood.
3. Connect the pressure bleeder to the brake master cylinder reservoir following the manufacturer's instructions.

WARNING

Do not exceed 35 psi (241 kPa) at the master cylinder inlet. Exceeding this pressure could rupture the master cylinder assembly, spraying brake fluid around the area. This can result in vehicle paint damage and may cause other damage or personal injury.

3.1 Fill the pressure bleeder with new DOT 3 approved brake fluid. Pressurize it according to the manufacturer's instructions.

Hydraulic System Bleeding

3.2 Using the supplied adapter, connect the pressure bleeder to either one of the fill ports on the master cylinder reservoir.

4. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.

4.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tubing fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

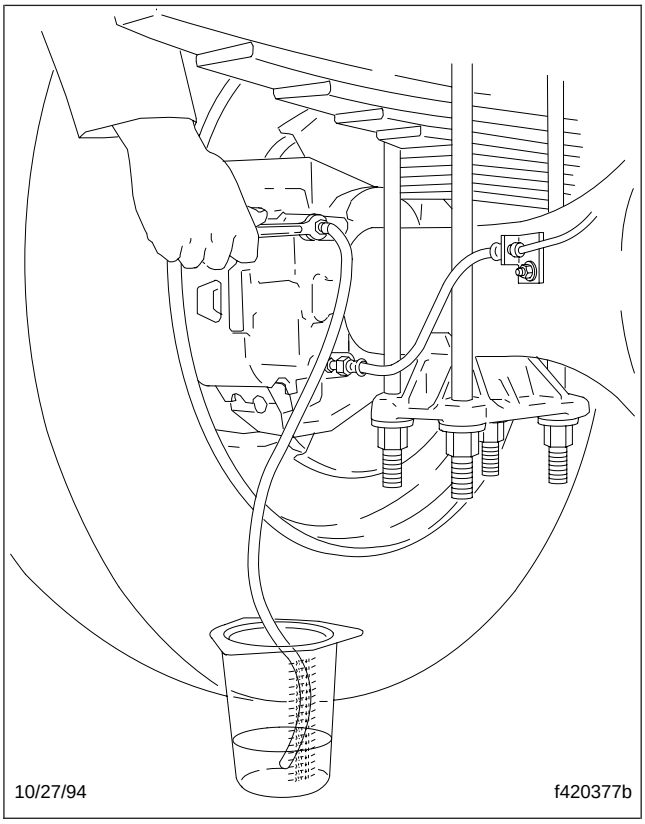


Fig. 2, Bleeding the Connections at the Rear Wheel Calipers First.

4.2 Loosen the bleeder fitting about 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Firmly tighten the fitting.

4.3 Move to the left rear caliper and repeat steps for bleeding the caliper.

5. Check the level frequently and add DOT 3 brake fluid to the master cylinder reservoir as it is needed. Be careful not to let it run low and suck air into the system as you bleed the brakes at the wheels.

6. Bleed the front wheel brake calipers, right side first.

6.1 Put a wrench on the bleeder fitting at the caliper, then attach a length of clear tubing to the bleeder fitting. Make sure the tube fits snugly. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

6.2 Loosen the bleeder fitting about 3/4-turn and let the brake fluid flow out of the fitting until it is free of air bubbles. Firmly tighten the fitting.

6.3 Move to the left front wheel caliper and repeat steps for bleeding the caliper.

7. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.

8. Check the operation of the brakes by pumping the brake pedal several times until it feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

9. Close and latch the hood.

10. Remove the chocks from the rear tires.

11. Repeat step 8. Check for operation of the brakes.

Manual Bleeding

If you do not have pressure bleeding equipment, you can use this manual bleeding procedure.

IMPORTANT: Do not let the brake master cylinder fluid level get too low during manual bleeding operations. Keep the master cylinder reservoir filled with new DOT 3 approved brake fluid. Allowing the brake fluid reservoir to empty will force air into the system, the opposite of what needs to be done.

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

2. Open the hood.

3. Be sure the ignition is turned off. The ignition must remain off for the entire bleed procedure.

4. Bleed the master cylinder, as follows.

   NOTE: It will not usually be necessary to bleed the master cylinder unless the brake fluid reservoir has run dry or master cylinder components have been replaced.

   4.1 Holding a rag underneath the master cylinder to absorb leaking brake fluid, loosen, about one turn, the rear outlet port fitting. See **Fig. 3**.

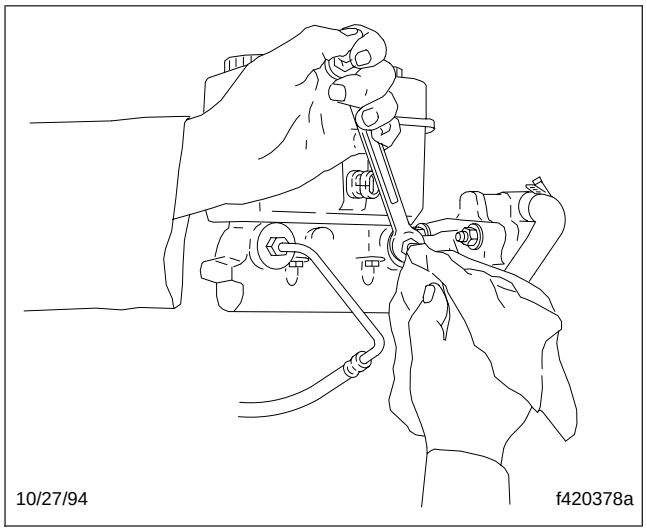


Fig. 3, Loosening the Fitting at the Rear Outlet Port

   4.2 Have someone push the brake pedal down slowly to the floor and *hold it there*. Brake fluid and any air in the master cylinder will squirt from the fitting into your shop rag.

   4.3 *With the brake pedal held down*, firmly tighten the rear hydraulic line fitting.

   IMPORTANT: Do not release the brake pedal until the fitting is tightened, or more air will get into the system.

   4.4 Release the brake pedal.

   4.5 Loosen the fitting again and bleed the line until no air escapes from the fitting and the brake pedal feels firm.

   4.6 Check the fluid level in the master cylinder reservoir. Add new DOT 3 approved brake fluid as needed to raise the level to the bottoms of the narrow filler necks.

   4.7 Using a wrench and holding a rag under it to absorb leaking brake fluid, loosen the fitting at the front outlet port on the master cylinder. See **Fig. 4**. Loosen the fitting about one turn.

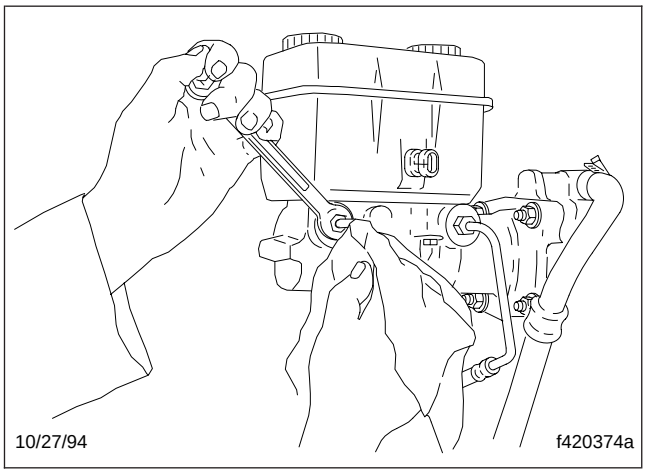


Fig. 4, Loosening the Fitting at the Front Outlet Port

   4.8 Repeat steps as required for the front outlet port.

   4.9 Check the brake fluid level in the master cylinder reservoir. Add new DOT 3 heavy-duty brake fluid as needed.

5. Bleed the brake lines at the wheel calipers, as follows, starting at the right rear wheel caliper.

   5.1 Put a wrench on the bleeder fitting at the caliper. Attach a length of snug-fitting clear tubing to the bleeder fitting. Submerge the other end of the tubing in a container of clean brake fluid. See **Fig. 2**.

   5.2 Loosen the bleeder fitting about 3/4-turn.

   5.3 Have an assistant slowly push the brake pedal to the floor and hold it down. *Hold the brake pedal down* as you tighten the bleeder fitting.

   IMPORTANT: Do not let off the brake pedal until the caliper fitting is tightened. Releasing the pedal before the fitting is tightened will suck air back into the system.

   5.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat bleeding as required until

Hydraulic System Bleeding

the fluid in the tube is completely free of air bubbles.

5.5 Check the brake fluid level in the reservoir. Add new DOT 3 heavy-duty brake fluid as needed.

5.6 Repeat the steps for bleeding the left rear caliper, the right front caliper, and the left front caliper. When finished, fill the reservoir to the bottoms of the narrow filler necks.

6. Close and latch the hood.
7. Connect the batteries.

⚠ WARNING

Do not move the vehicle until you are sure the brakes are working properly.

8. Check the operation of the brakes by pumping the brake pedal several times until it feels firm. The brake pedal should not go all the way down to the floor. If it does, see **Troubleshooting 300**.

   Remove the chocks from the tires.

Power Brake Booster Bleeding

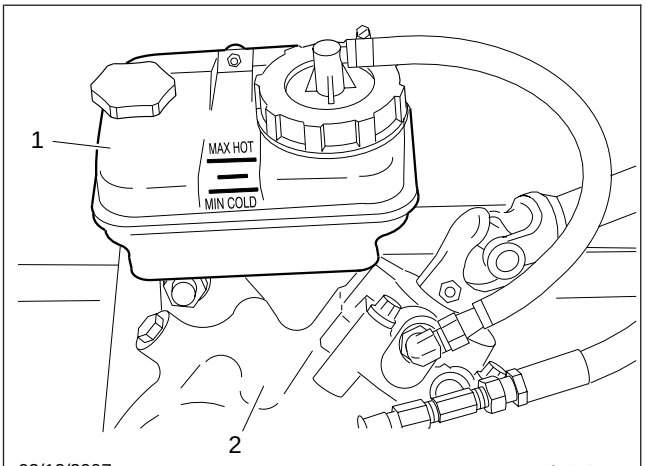
WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

WARNING

The power brake booster uses automatic transmission fluid (ATF), not "brake fluid." Use only clean, approved ATF for the procedure below. Do not use DOT 3 brake fluid. Putting DOT 3 brake fluid in the power brake booster system seriously damages the seals and O-rings in the power brake booster, the power steering pump and the power steering gear. This could result in a loss of power steering and/or braking, which could possibly cause an accident resulting in property damage or serious personal injury.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Check the level of fluid in the power steering reservoir. See **Fig. 1**. Fill it with approved ATF as needed. See **Specifications 400** for approved ATF.
4. Place the transmission in neutral and crank the starter several times, but do not start the engine.
5. Check the ATF level in the power steering reservoir. Fill, if needed.
6. Crank the starter and check the fluid level again.
7. Check the operation of the brakes, as follows.
   - 7.1 With the key off, push the brake pedal. The dash warning light and buzzer should come on and the backup pump should come on.
   - 7.2 Turn the key to the ON position, but do not start the engine. The dash warning light and buzzer should come on, and the backup pump should start to run.
   - 7.3 Start the engine. Depress the brake pedal. The dash warning light, buzzer and backup pump should stay off. If they come on, see **Troubleshooting 300** and find the problem.
   - 7.4 Shut down the engine. Check the ATF level in the power steering reservoir. Fill it as needed.
8. Close and latch the hood.
9. Remove the chocks from the rear tires.



1. Power Steering Reservoir
2. Steering Gear

Fig. 1, ATF Level Check

Replacing Hydraulic Lines

⚠ WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

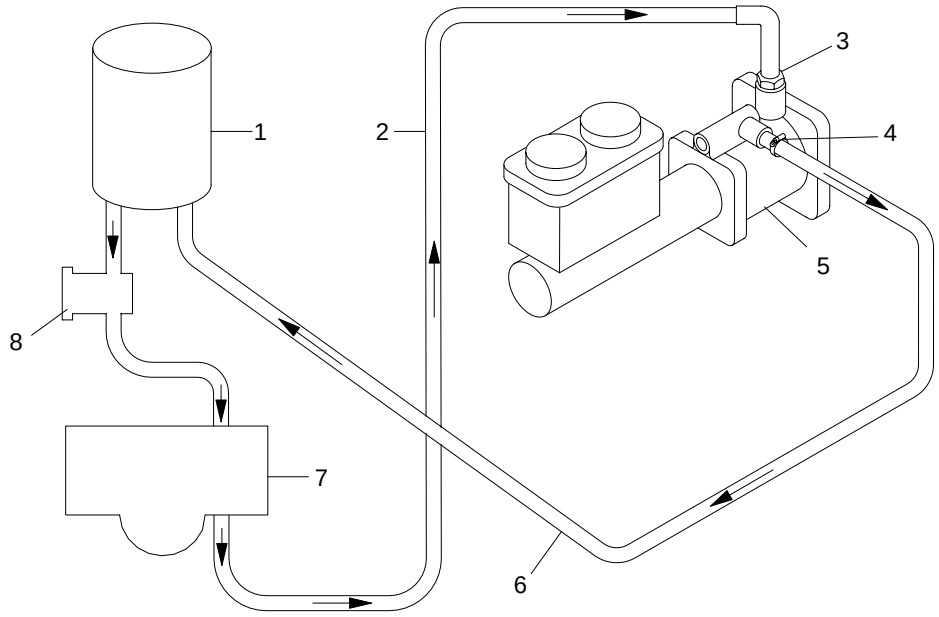
Power Brake Booster System

Pressurized ATF reaches the power brake booster through its connection with the power steering gear. From the power brake booster, the ATF returns into the power steering reservoir. See **Fig. 1**.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Replace all power steering hoses that are leaking or show signs of cracking, softening, or bulging. If a hose is damaged, replace the entire hose; do not attempt to repair it.
   - 3.1 Remove all hose clamps and tie straps used for routing the hose.
   - 3.2 Using a shop towel over the fittings to catch dripping ATF, disconnect both ends of the hose being replaced.
   - 3.3 Install the new hose.

     If replacing the power brake booster supply hose, tighten the supply port connection to 21 ±5 lbf·ft (28 ±6 N·m), and the outlet connection on the power steering gear 41 lbf·ft (56 N·m).

     If replacing the power brake booster return hose, tighten the hose clamps firmly at the



04/23/2003 f420463a

1. Power Steering Reservoir
2. Hydraulic Supply Line
3. Steel Fitting with O-Ring Seal
4. Hose Clamp
5. Power Brake Booster
6. Hydraulic Return Line
7. Power Steering Gear
8. Power Steering Pump

Fig. 1, Power Brake Booster System

Replacing Hydraulic Lines

booster return fitting and the power steering reservoir.

3.4 Install the hose clamps and replace any tie straps removed earlier.

Check the routing of the hose. Make sure it is away from heat sources and moving parts such as the steering and driveline. Make sure there are no kinks or sharp bends in the hose, and that it can not be rubbed or pinched by other parts as they move.

4. Bleed the power brake booster system following the instructions in **Subject 120**.
5. Close and latch the hood.
6. Remove the chocks from the tires.

Service Brake System

The service brake system has two types of hydraulic brake lines: rigid steel tubing, and flexible rubber hose.

The steel brake lines are 1/4-inch o.d. double-walled tubing, and run from the master cylinder to points on the chassis near each wheel. The rubber brake hoses are 1/8-inch i.d. low-expansion rubber; they connect the end of each rigid line to the caliper assembly at each wheel.

IMPORTANT: Replace lines or hoses only with lines or hoses approved for use in high-pressure brake fluid applications.

Do not attempt to repair brake lines or hoses. Faulty lines or hoses must be replaced.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Locate the leak in the brake line. Determine the length and configuration (if a steel line) of the section involved.
4. If necessary, remove any brackets holding the brake line to the frame or axle so that you can remove the damaged section.
5. Put a container under the connection on one end of the leaking brake line. Disconnect the line. Plug both ends of the connection.

   Repeat at the connection on the other end of the leaking brake line, and remove it from the vehicle.
6. Remove the plugs installed earlier. Install the new section of brake line and tighten the connections.
7. Install any brackets that were removed.
8. Bleed the brake system following the procedure in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

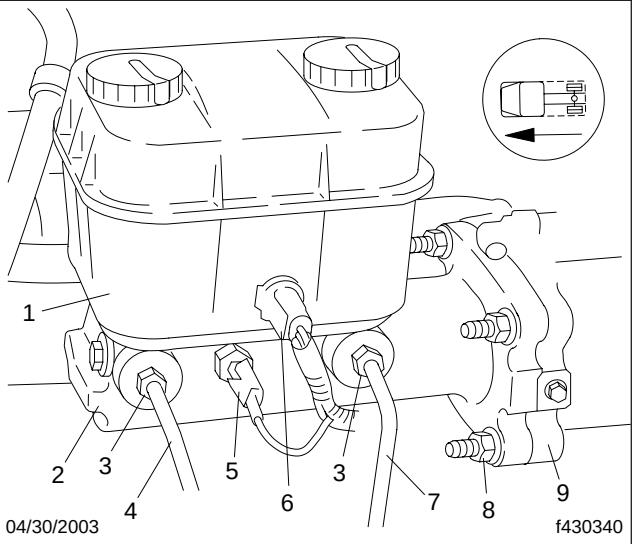
Master Cylinder Removal and Installation

Removal

WARNING

Before starting the procedure below, read the information in Safety Precautions 100. Exposure to brake fluid could cause serious, permanent eye and health damage. Be careful not to get it in your eyes or expose yourself to it unnecessarily.

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the wires from the pressure differential switch on the master cylinder body and the fluid level sensor on the reservoir. See **Fig. 1**.



1. Reservoir
2. Master Cylinder Housing
3. Brake Line Tube Nuts
4. Secondary Subsystem Brake Line
5. Pressure Differential Switch
6. Fluid Level Sensor
7. Primary Subsystem Brake Line
8. Flanged Hexnut
9. Power Brake Booster Mounting Flange

Fig. 1, Master Cylinder Assembly

CAUTION

Do not let the brake fluid get on any painted surface; it can damage the paint. Wrap a rag around the fitting you are working on, or put a container underneath it to catch any fluid leaking as it is disconnected.

4. Disconnect the brake lines from the outlet ports of the master cylinder. See **Fig. 2**. Plug the brake lines to prevent contamination and leakage.
5. Remove the four flanged hexnuts that attach the master cylinder to the power brake booster unit. See **Fig. 3**.

   Remove the master cylinder from the vehicle. See **Fig. 4**. Keep it upright with a rag wrapped around it so you do not drip any brake fluid.

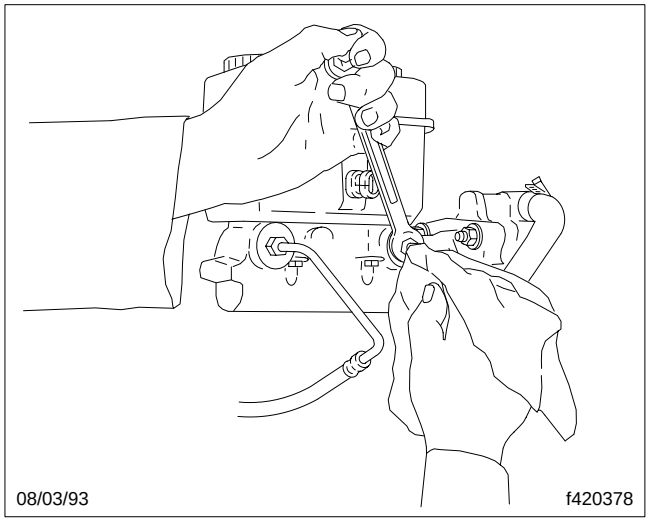


Fig. 2, Removing the Brake Lines

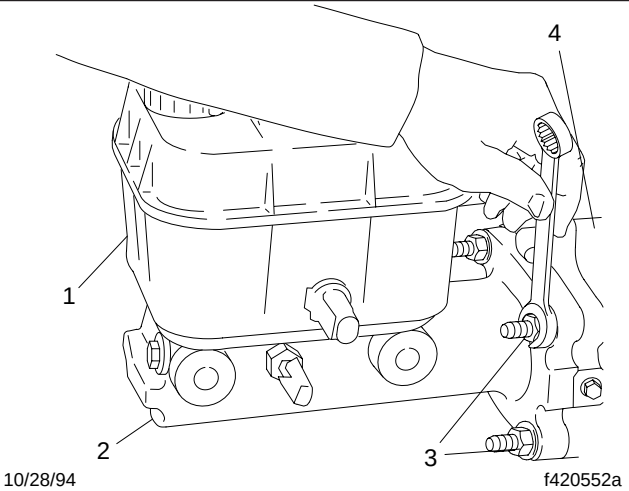
6. Remove the caps from the master cylinder reservoir, then carefully turn it over and dump the brake fluid into a container. Dispose of used brake fluid in a responsible and approved manner.

Installation

1. Bench bleed the master cylinder, as follows.

   1.1 Put the master cylinder and reservoir assembly in a vise.

Master Cylinder Removal and Installation



1. Reservoir
2. Master Cylinder
3. Flanged Hexnut
4. Power Brake Booster

Fig. 3, Removing the Hexnuts

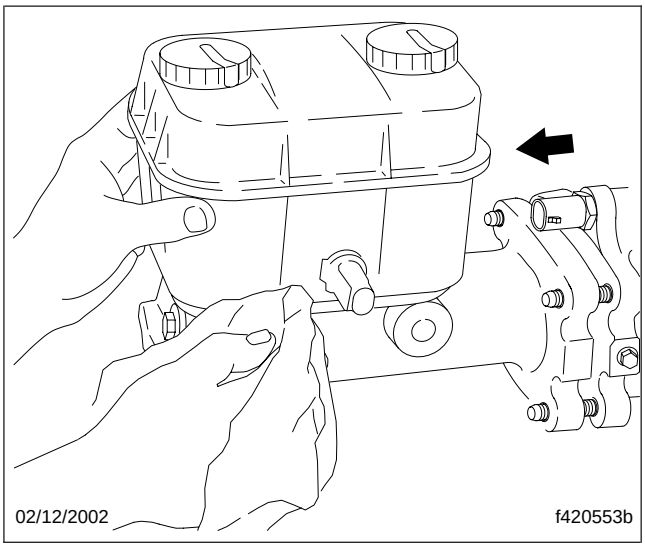


Fig. 4, Removing the Master Cylinder

1.2 Install the plastic adapter and clear tubing on the master cylinder outlet ports, as shown in **Fig. 5**.

1.3 Put the other end of each tube up into the reservoir, as shown in **Fig. 5**.

1.4 Fill the reservoir about half-full with new DOT 3 heavy-duty brake fluid.

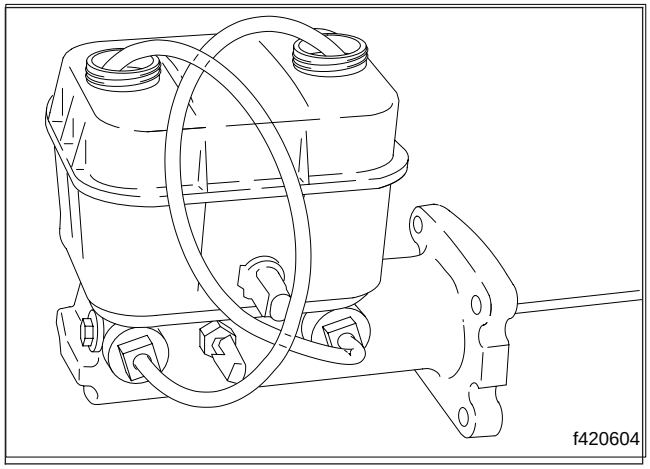
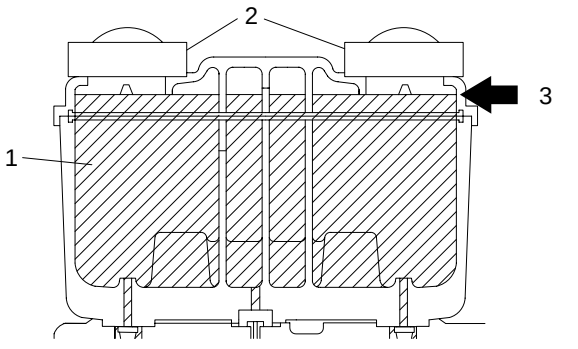


Fig. 5, Outlet Ports With Master Cylinder Bleeder Tubes

1.5 Use a metal rod with a rounded end to push and release the primary piston several times. This purges air bubbles trapped in the master cylinder while returning fluid to the master cylinder while returning fluid to the master cylinder reservoir.

The brake bleeder plastic adapters adn tubing may be left in place to keep the fluid from dripping. Remove them when the master cylinder

2. Slip the master cylinder onto its studs on the front of the power brake booster. Install the four flanged nuts on the studs of the power brake booster and tighten to 27 lbf·ft (37 N·m).
3. Remove the plastic bleeder tubes if they were left on after bench bleeding. Connect the secondary circuit line to the front outlet port on the master cylinder, and the primary circuit line to the rear outlet port. Tighten the fittings to a maximum 16 lbf·ft (22 N·m).
4. Connect the wires to the pressure differential switch and the fluid level sensor. See **Fig. 1**.
5. Fill the reservoir to the bottom of the narrow throat formed by the fill opening with new DOT 3 heavy-duty brake fluid. See **Fig. 6**.
6. Bleed the entire brake system following the instructions in **Subject 110**.
7. Close and latch the hood.
8. Remove the chocks from the tires.



1. DOT 3 brake fluid
2. Filler caps
3. Fill to bottom ring of filler neck

Fig. 6, Master Cylinder Fill Level

Hydro-Max® II Power Brake Booster Removal and Installation

Removal

WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Open the hood.
3. Disconnect the batteries at the negative cables.
4. If the brake master cylinder is still mounted on the power booster, remove it following the instructions in **Subject 140**.
5. Below the dash, remove the cotter key, washer, and clevis pin that connect the power booster push rod to the brake pedal. See **Fig. 1**

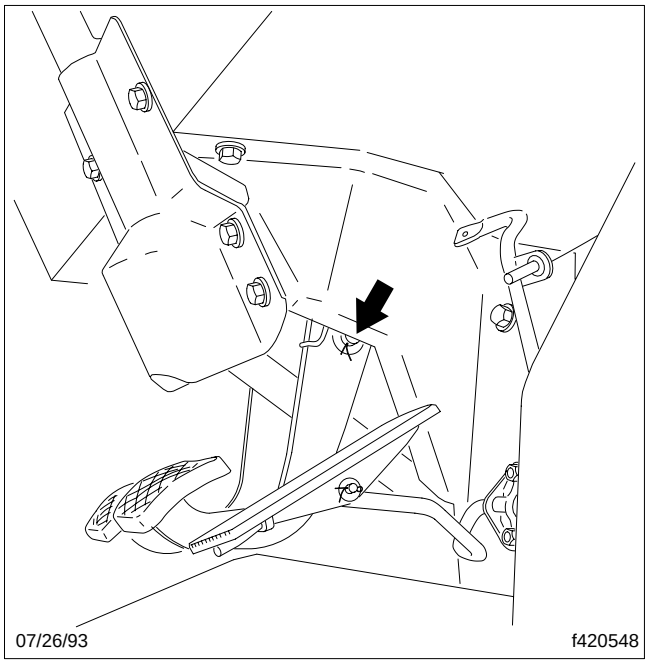
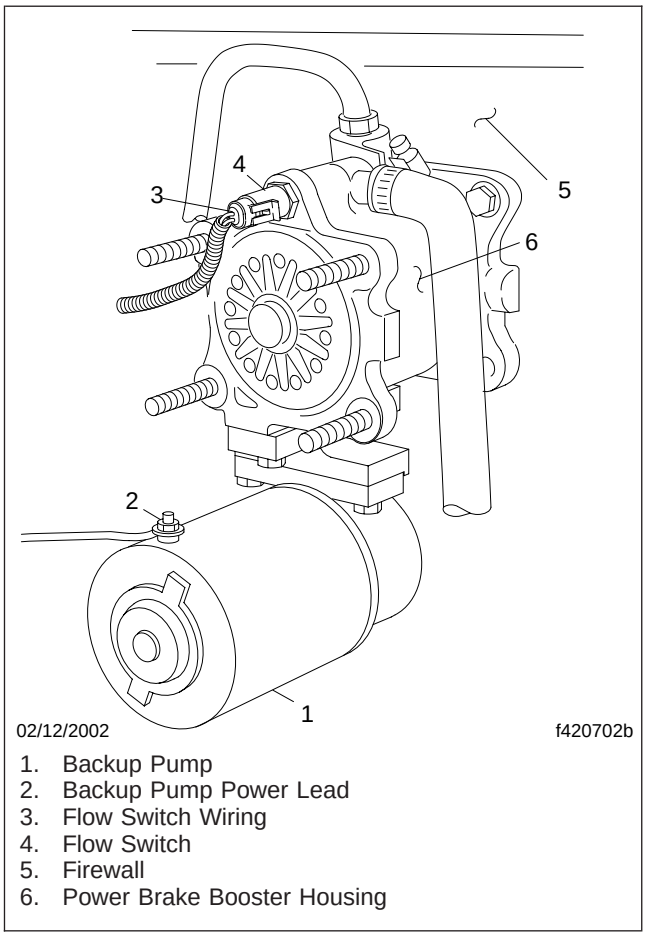


Fig. 1, Brake Pedal

6. Disconnect the wiring from the backup pump assembly. See **Fig. 2**.
7. Disconnect the wiring from the flow switch at the front of the power brake booster. See **Fig. 2**.



1. Backup Pump
2. Backup Pump Power Lead
3. Flow Switch Wiring
4. Flow Switch
5. Firewall
6. Power Brake Booster Housing

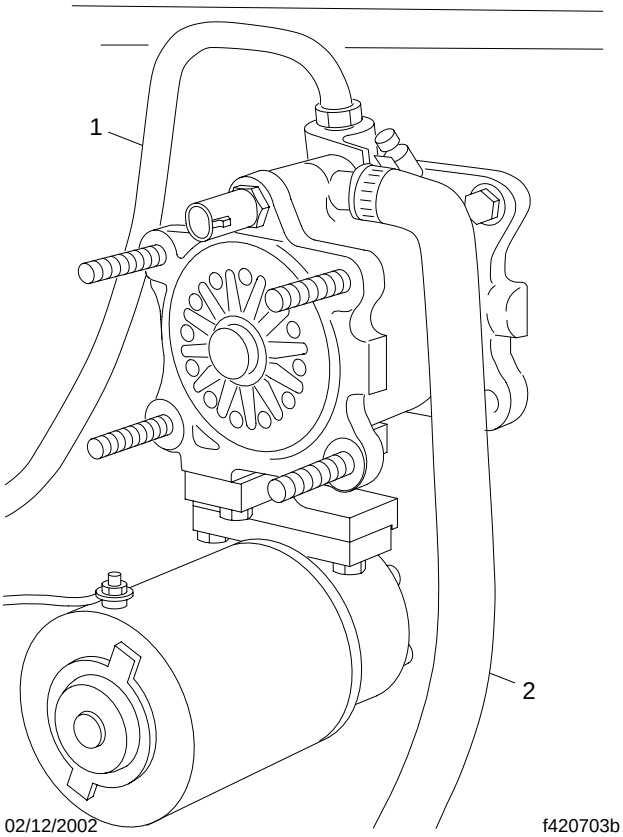
Fig. 2, Backup Pump Assembly (actual appearance may vary)

8. Using a shop towel or a container to catch leaking ATF, disconnect the hydraulic supply and return lines from the power brake booster. See **Fig. 3**. Plug the lines.
9. Remove the four hexbolts and washers that attach the power brake booster to the firewall. See **Fig. 4**. Pull the power brake booster straight out from the firewall. See **Fig. 5**.

Installation

1. Position the power brake booster on the firewall so the brake pedal rod fits through the large hole and into the cab. See **Fig. 5**.
2. Line up the four holes in the power brake booster with those on the firewall. Install the four

Hydro-Max® II Power Brake Booster Removal and Installation



1. Supply Line (steel)
2. Return Line (rubber)

Fig. 3, Power Brake Booster Lines (actual appearance may vary)

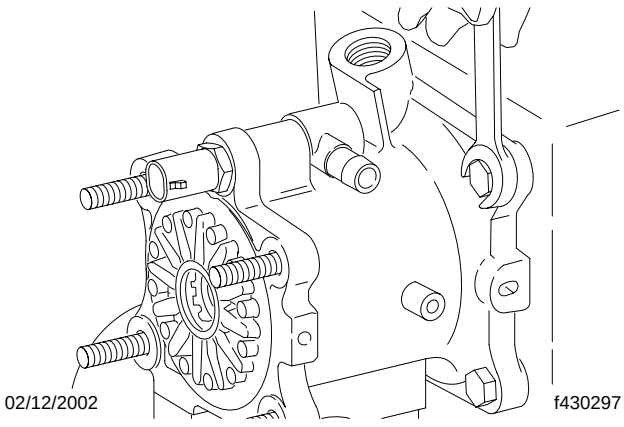


Fig. 4, Power Brake Booster Mounting (actual appearance may vary)

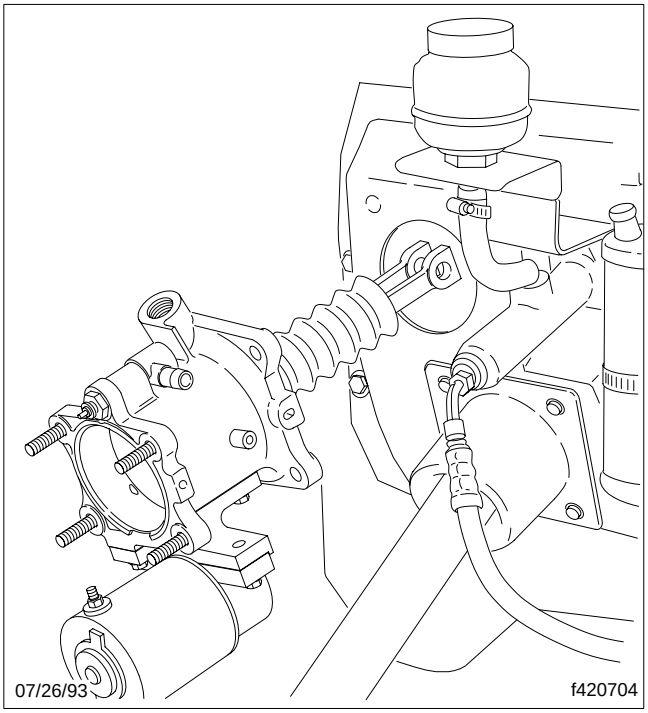
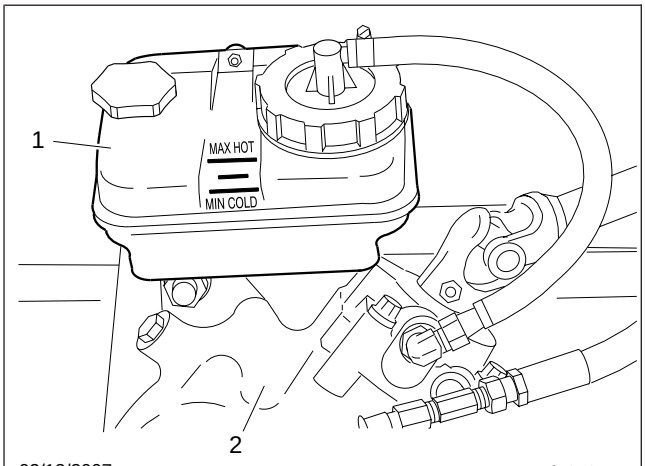


Fig. 5, Power Brake Booster Removal

mounting hexbolts and washers. See **Fig. 4**. Tighten to 27 lbf·ft (37 N·m).

3. Install the master cylinder on the power brake booster, following the instructions in **Subject 140**.
4. Connect the hydraulic supply and return lines. See **Fig. 3**. Tighten the supply line 21 lbf·ft (28 N·m). Tighten the hose clamp on the return line.
5. Connect the wiring to the backup pump assembly and to the flow switch assembly. See **Fig. 2**.
6. Check the ATF level in the power steering reservoir. See **Fig. 6**. Add approved ATF if needed. See **Specifications 400** for the approved ATF.
7. Connect the batteries.
8. Bleed the power brake booster following the instructions in **Subject 110**.
9. Close and latch the hood.
10. Remove the chocks from the rear tires.

Hydro-Max® II Power Brake Booster Removal and Installation



1. Power Steering Reservoir
2. Steering Gear

Fig. 6, Fluid Level Check

Hydraulic Brake Electronic Monitor Module Removal and Installation

NOTE: The monitor module is located on the driver side of the dash behind the instrumentation control unit (ICU3).

Removal

1. Park the vehicle on a level surface and apply the parking brake. Shut down the engine. Chock the rear tires.
2. Disconnect the batteries at the negative terminals.
3. Inside the cab, remove the dash trim panel. See **Fig. 1**.

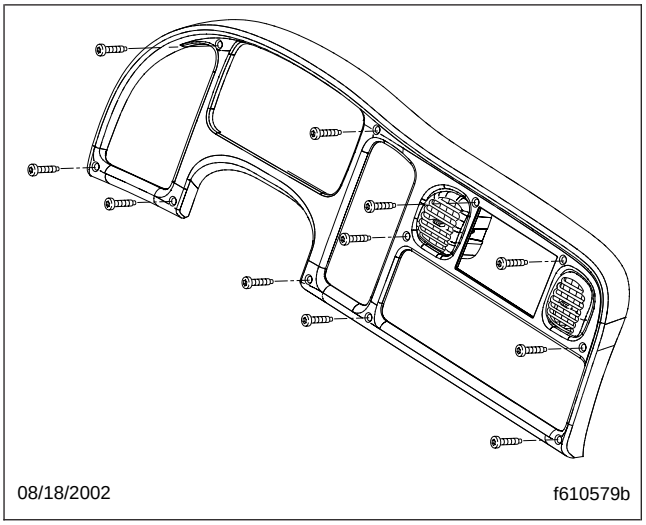


Fig. 1, Dash Trim Panel

4. Locate the monitor module behind the instrumentation control unit (ICU3-M2). Disconnect the 9-pin connector and the 4-pin connector from the module.
5. If necessary, in order to remove the monitor module, remove the ICU3-M2. For instructions, see **Section 54.04, Subject 100**.
6. Remove the monitor module.

Installation

1. Connect the 9-pin and the 4-pin connectors to the monitor module.
2. Install the monitor module on the mounting bracket.
3. If it was removed, install the ICU3-M2. For instructions, see **Section 54.04, Subject 100**.
4. Install the dash trim panel. See **Fig. 1**.
5. Connect the batteries.
6. Remove the chocks from the rear tires.
7. Verify proper operation of the monitor module. See **Subject 120**.

Flow Switch Removal, Inspection, and Installation

NOTE: Refer to **Fig. 1** when performing the following procedures.

The most likely problems requiring service of the flow switch include the following.

- Contamination of the metering piston.
- Damaged contact assembly.
- Leaking at the contact assembly.
- The backup pump runs continuously when the engine is running.
- The backup pump not running when it should be.

Removal

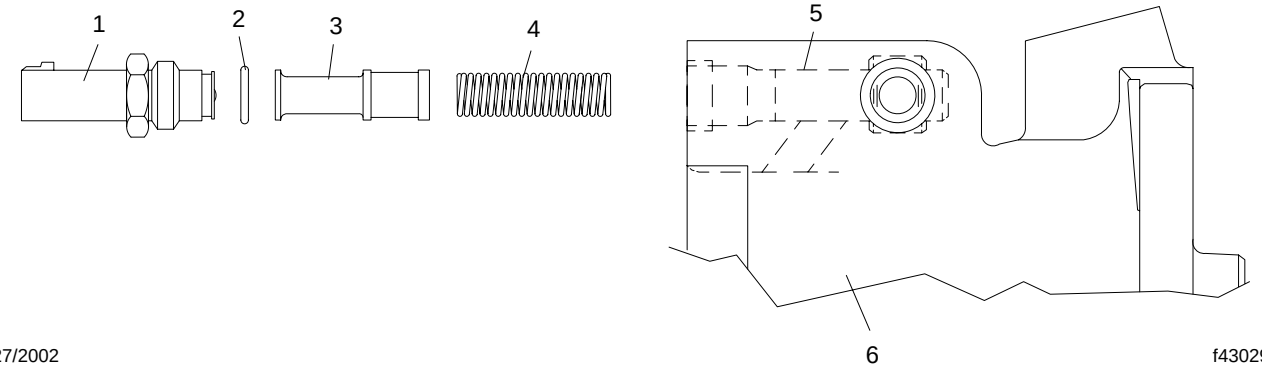
⚠ WARNING

Before working on or around hydraulic brake systems and components, see Safety Precautions 100. Failure to follow those safety precautions may result in personal injury.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Place a container under the booster to catch any automatic transmission fluid (ATF) that may drain out while removing the flow switch contact assembly.
4. Disconnect the wiring harness flow switch connector from the flow switch contact assembly.
5. Remove the contact assembly from the booster. Be prepared to catch the metering piston; it may be pushed out of the booster housing by the spring.
6. If the metering piston did not come out by itself, use a small magnet to extract the metering piston and spring from the bore.

Inspection

1. If the contact assembly is damaged, replace it.
2. If the O-ring seal is damaged, replace it.
3. Inspect the opening into the booster and inspect the flow switch bore. These surfaces must be clean and free of particles, chips, or any other form of contaminant. Remove any contaminant.
4. Inspect the metering piston and spring for cleanliness. Remove any contaminants.



1. Contact Assembly
2. O-Ring
3. Metering Piston
4. Spring
5. Flow Switch Bore
6. Booster

Fig. 1, Flow Switch Assembly (exploded view)

Flow Switch Removal, Inspection, and Installation

Installation

1. If a new contact assembly or O-ring is being used, install the O-ring onto the contact assembly.
2. Install the spring and metering piston into the flow switch bore.
3. Install the contact assembly and O-ring into the booster. Tighten 20 to 40 lbf·in (230 to 450 N·cm).
4. Connect the wiring harness flow switch connector to the flow switch contact assembly.
5. Fill the power steering pump reservoir to the proper level with ATF. Do not reuse old ATF from the booster.
6. Connect the battery ground cable.
7. Confirm proper installation of the switch, as follows.
   - 7.1 Start the engine. With the engine running, the power steering pump circulates ATF through the system. This automatically purges air from the booster.
   - 7.2 While the engine is running, press on the brake pedal several times to make sure the pedal feels normal.
8. Shut the engine off. Press on the brake pedal several times to make sure the pedal feels normal in the backup pump mode.
9. Check for leakage at the flow switch contact assembly.
10. Confirm that the backup pump does not run when the engine is running.
11. Confirm that the backup pump runs when:
    - the engine is off and the ignition key is on, **and,**
    - the ignition key and engine are off but the brake pedal is depressed.
12. Recheck the ATF level in the power steering pump reservoir. If necessary, add ATF.
13. Road test the vehicle to ensure proper steering and braking operation.

General Information

The Bosch driveline parking brake is self-adjusting and should not require adjustment of the cable under normal operating conditions.

NOTE: With time and use, all cables will stretch. The driveline parking brake actuation cable should be checked for proper adjustment whenever the brake is serviced.

There are three methods of actuation for the driveline parking brake. Depending on vehicle configuration, the brake is actuated by one of the following:

- a foot pedal under the dash
- A hand valve located on the dash
- the PB parking brake indicator is selected

the hand valve and the column-mounted shifter control an air-actuated spring chamber, mounted on the frame rail near the parking brake. Follow the appropriate procedure below when adjusting the brake cable after replacing the parking brake, parking brake components, or any of the parking brake actuation components.

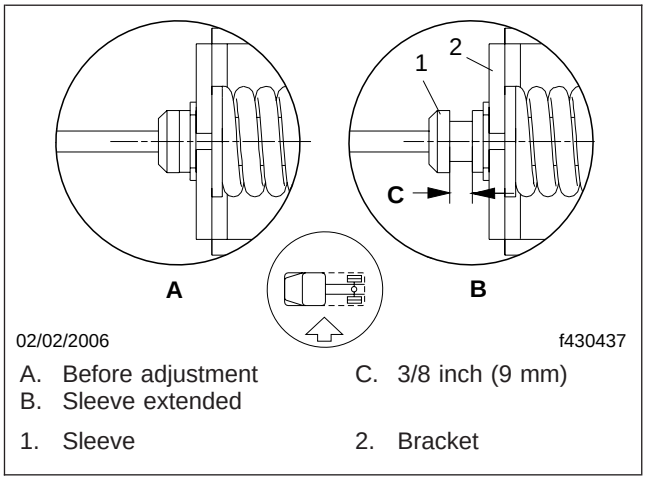
Cable Adjustment, Foot-Pedal-Actuated Parking Brake

⚠ WARNING

Before starting the procedure below, read the information in Safety Precautions 100.

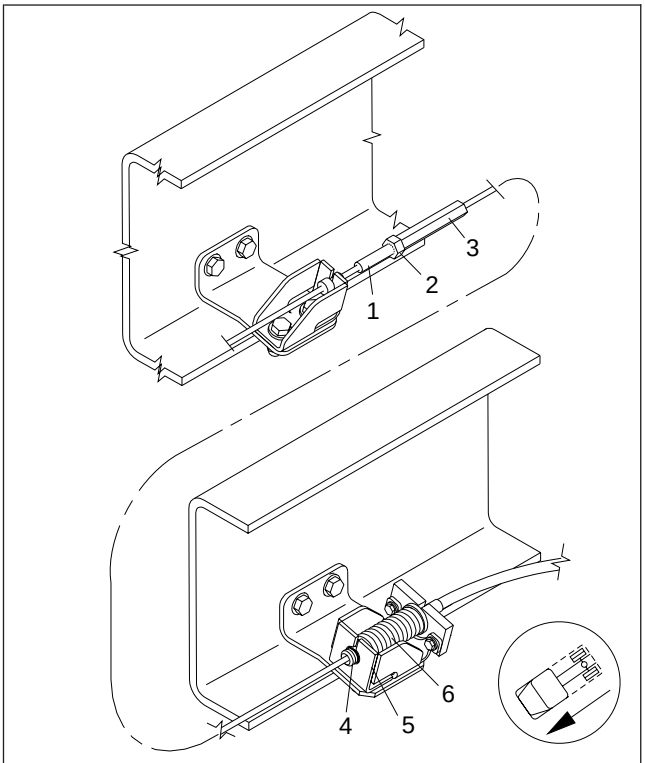
1. Apply the parking-brake pedal until it bottoms out. Measure the sleeve extension at the bracket. See **Fig. 1**. If it is approximately 3/8 inch (9 mm), it is properly adjusted; no further work is needed. If not, release the parking-brake pedal and go to the next step.
2. At the right frame rail, forward of the parking brake, back off the jam nut a few turns, then thread the cable adjuster onto the cable end to the jam nut. See **Fig. 2**.

   Repeat Step 1. Continue tightening the adjuster until the sleeve extends from the bracket approximately 3/8 inch (9 mm).
3. Release and apply the parking brake three times, assuring a solid application.



A. Before adjustment
B. Sleeve extended
C. 3/8 inch (9 mm)
1. Sleeve
2. Bracket

Fig. 1, Cable Sleeve Extended



1. Cable End
2. Jam Nut
3. Adjuster Nut
4. Sleeve
5. Bracket
6. Spring

Fig. 2, Cable Adjustment, Foot-Pedal-Actuated Parking Brake

Parking Brake Cable Adjustment

4. If needed, tighten the adjuster again until the sleeve again extends from the bracket approximately 3/8 inch (9 mm).
5. Tighten the jam nut.
6. Test the brake for proper operation before returning the vehicle to service.

Cable Adjustment, Air-Actuated Parking Brake

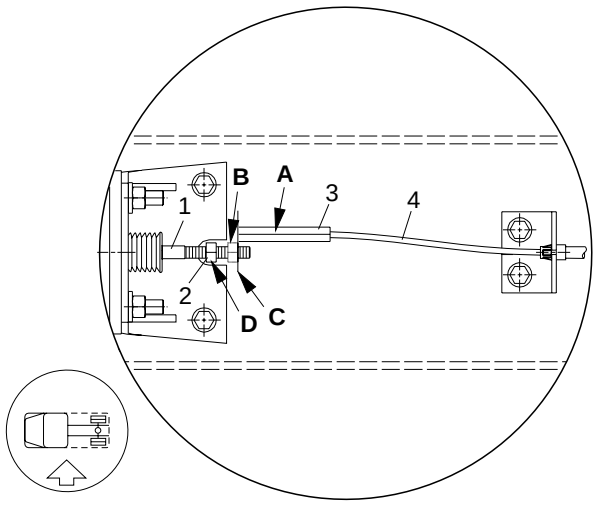
WARNING

Before starting the procedure below, read the information in Safety Precautions 100.

CAUTION

The parking brake chamber is spring-loaded to the applied position and pressurized to the released position. This chamber can not be caged. Keep hands clear while working around the brake chamber. Loss of air pressure will cause the parking brake to apply, and may cause serious personal injury.

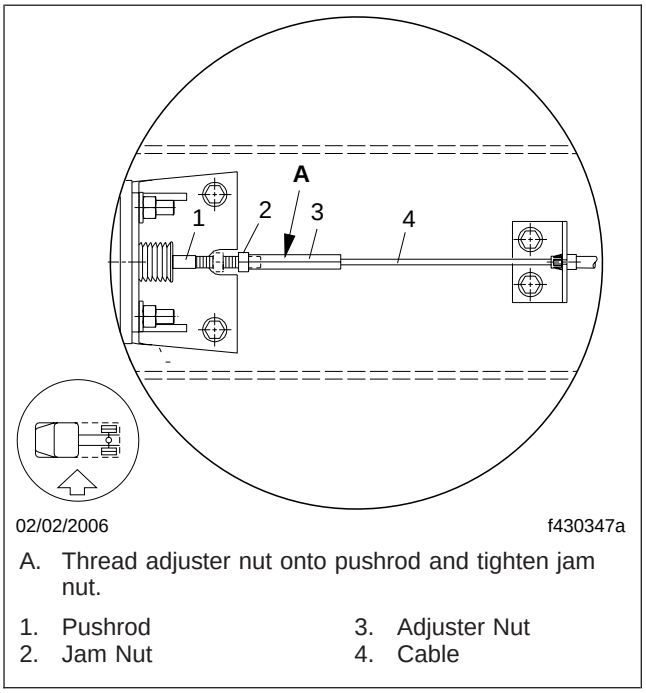
1. Release the parking brake.
2. If the cable is attached to the pushrod, loosen the jam nut and back off the adjuster nut to disconnect it from the pushrod.
3. Pull the adjuster nut forward until the cable slack is removed. See **Fig. 3**.
4. Reposition the jam nut to line up with the end of the adjuster nut.
5. Thread the adjuster nut onto the pushrod and against the jam nut. Tighten the jam nut. See **Fig. 4**.
6. Test the brake for proper operation before returning the vehicle to service.



A. Pull adjuster nut forward until cable slack is removed.
B. Reposition jam nut to align with end of adjuster nut.
C. End of adjuster nut when pulled tight.
D. Jam nut before repositioning

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 3, Cable Adjustment, Air-Actuated Parking Brake



A. Thread adjuster nut onto pushrod and tighten jam nut.

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 4, Air-Actuated Parking Brake Cable Adjustment

Troubleshooting Index

Hydraulic Brake Troubleshooting Index	
Subject	**Figure**
Brake warning lamp and buzzer related to parking brake	**Fig. 1**
Brake warning lamp and buzzer related to service brake	**Fig. 2**
Backup pump runs continuously	**Fig. 3**
Backup pump does not run	**Fig. 5**
Abnormal brake pedal conditions	**Fig. 6**
Brake pedal feels hard	**Fig. 8**
Hydraulic system leakage	**Fig. 9**, **Fig. 10**, **Fig. 12**
Brakes are dragging	**Fig. 13**, **Fig. 14**
Short pad life, uneven pad wear, overheated brakes	**Fig. 13**, **Fig. 14**

Table 1, Hydraulic Brake Troubleshooting Index

Brake Warning Lamp and Buzzer Related to Parking Brake

NOTE: There are two warning lamps generally relating to brakes: the parking/service brake warning lamp and an ABS warning lamp. This section refers only to the parking/service brake warning lamp, not the ABS warning lamp. There is a single buzzer for all brake signals.

The brake warning lamp and buzzer come on together when triggered by one or more of the following:

- the parking brake switch
- the flow switch
- the fluid level indicator switch
- the differential pressure switch
- the electric backup pump

See **Fig. 1** for troubleshooting if the problem seems to be with the parking brake or **Fig. 2** if the service brakes seem to be the problem.

NOTE: Technicians can refer to wiring diagrams in PartsPro, Module 877, in addition to those in Subject 400.

Backup Pump Runs Continuously

Normally, the backup pump will run only if the flow switch has activated its relay.

A properly working relay starts the backup pump only if it is triggered by the flow switch and there is power to the relay coil. A defective relay can stick "on," making the backup pump run even though it is not triggered by the flow switch and there is no power to the relay coil.

See **Fig. 3** for troubleshooting and **Fig. 4** for the electrical components of the master cylinder and power brake booster.

Backup Pump Does Not Run

The backup pump will not run if there is no voltage to the motor or if the motor is damaged—burnt out or jammed, for instance. Some of the possible reasons for the backup pump not running include:

- a dead battery
- a broken relay
- a broken wire between the battery and pump motor
- a break in the circuit between the ignition switch/brake warning lamp switch and the flow switch
- flow switch is not grounded

Troubleshooting

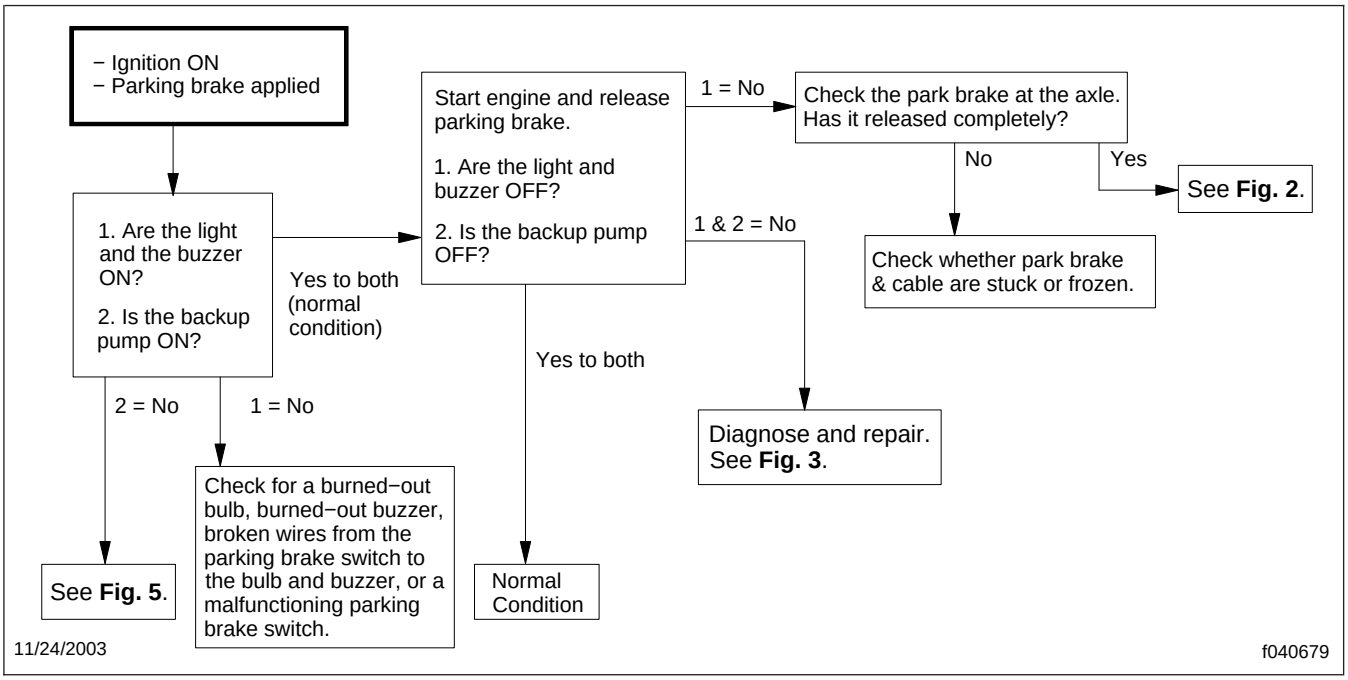


Fig. 1, Flow Chart: Brake Warning Lamp and Buzzer Relating to Parking Brake

See **Fig. 5** for troubleshooting and **Fig. 4** for the electrical components of the master cylinder and power brake booster.

Abnormal Brake Pedal Conditions

Abnormal pedal conditions defined in this section include the following. See **Fig. 6** for flow chart diagnosis.

- Brake pedal dropping 1/2-inch when the engine is started.
- The brake pedal feels spongy, springy or soft.
- The brake pedal continues to fall with steady foot force.
- The brake pedal feels very hard.

Most common reasons for a very hard pedal are—

- Insufficient flow or pressure from the power steering pump;
- ABS is blocking flow of brake fluid to the calipers.

Less likely causes include:

- contaminated power brake booster
- contaminated master cylinder
- binding pedal linkage
- binding power brake booster
- binding master cylinder
- blocked or kinked brake fluid tubes or hoses

With the engine OFF other causes are—

- Backup pump does not run;
- The backup pump does not provide sufficient pressure.

See **Fig. 6** for abnormal brake conditions flow chart.

Figure 7 shows a typical swollen master cylinder reservoir cap seal due to ATF, power steering fluid or motor oil contamination in the master cylinder.

See **Fig. 8** for flow chart regarding very hard brake pedal feel.

Hydraulic System Leakage

If hydraulic fluid leakage is suspected, see **Fig. 9**, **Fig. 10** and **Fig. 11** to diagnose and locate the problem.

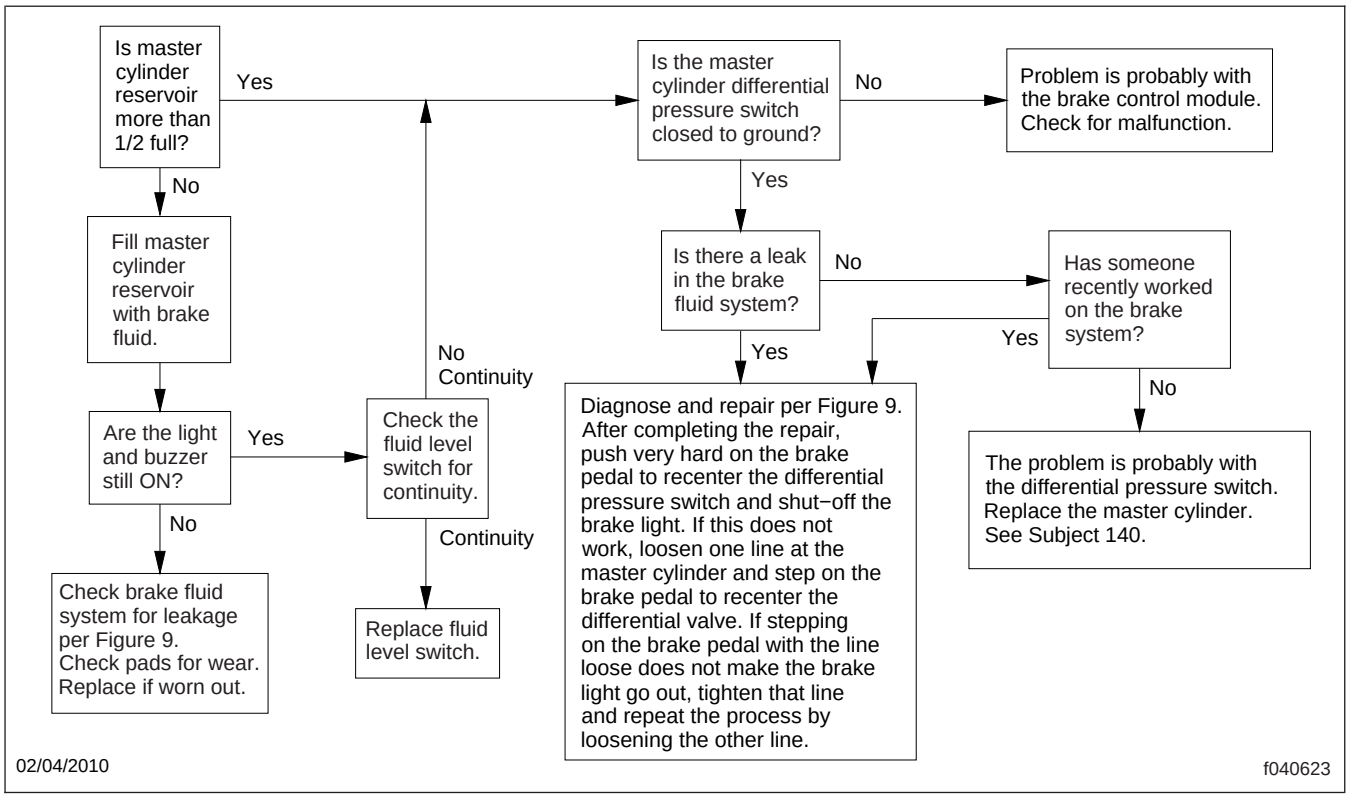


Fig. 2, Flow Chart: Brake Warning Lamp and Buzzer for Service Brake Problems

See **Fig. 12** for the most frequent leak points at the power brake booster.

Brakes are Dragging

The following are possible causes for brake drag:

- The power brake booster does not return to the released position.
- The brake pedal linkage does not return to the released position.
- The master cylinder does not return to the released position.
- The ABS system trapping hydraulic pressure.
- The brake calipers don't release.
- The brake lines or hoses are plugged, kinked, or collapsed.

IMPORTANT: Some tests require doing things in the driver's seat while at the same time watching what happens at the brakes. These tests require two people.

See **Fig. 13** and **Fig. 14** for complete brake-drag diagnostics.

Short Pad Life, Uneven Pad Wear, or Overheated Brakes

NOTE: Because of the great differences in vehicle types, usage, terrain, loads, driving style and many other factors, accurately predicting brake wear is impossible. Severe use, even without other brake system problems, sometimes wears out brakes quickly.

1. Check whether the brake pads are wearing abnormally. For example, check whether the inner and outer pads are wearing unevenly.
2. If the brakes are dragging, smoking, overheating, smelling, pulling, or if there is poor acceleration, see **Fig. 13**.

   If the brake wear is not caused by one of these conditions, the problem is probably caused by vehicle usage or the driver's braking habits. For

Troubleshooting

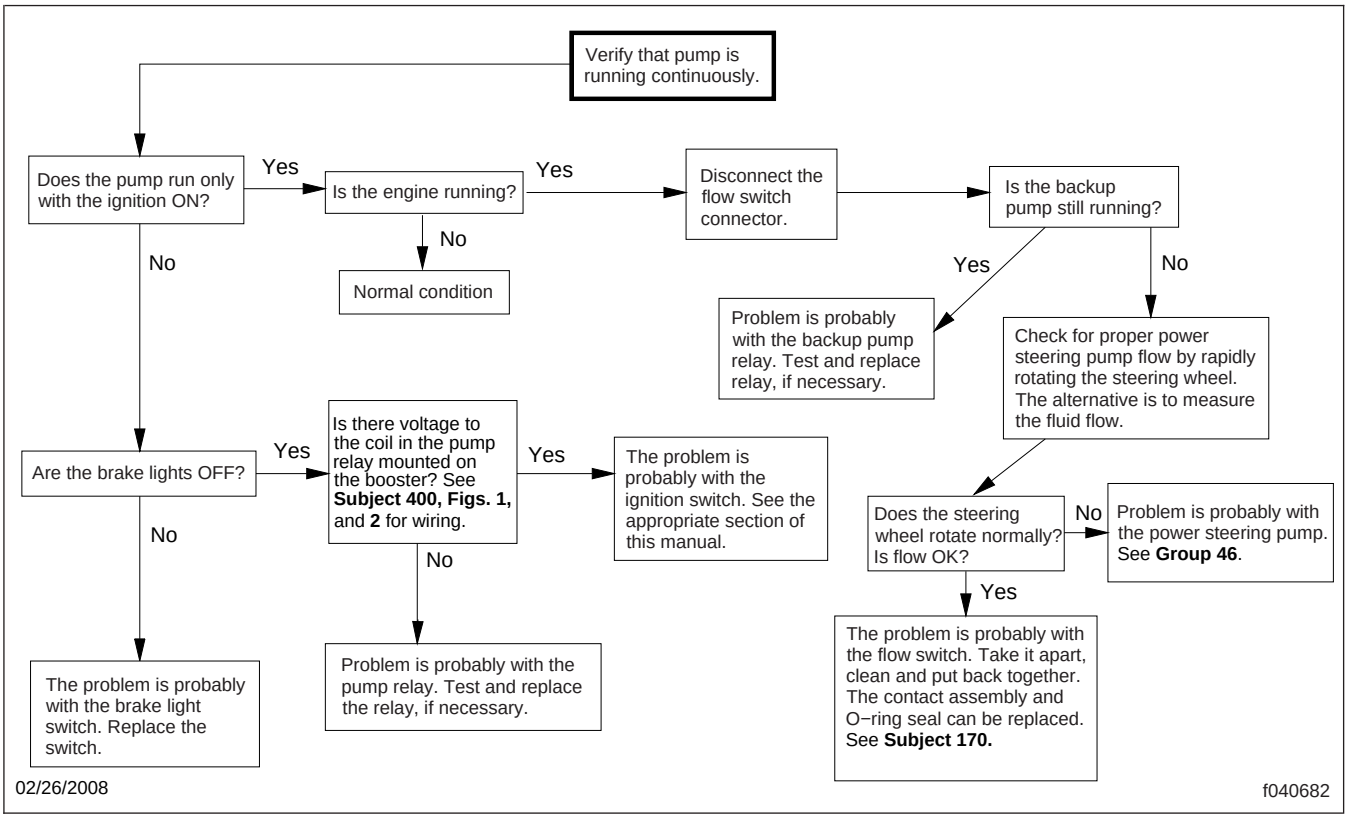
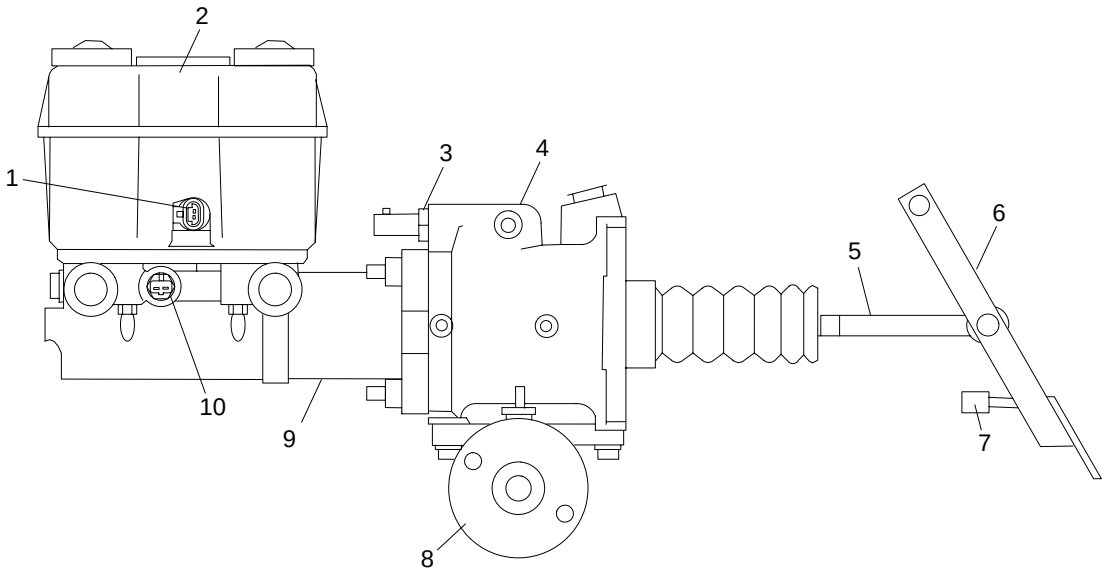


Fig. 3, Flow Chart: Backup Pump Runs Continuously

low temperature or light duty conditions, consult the brake manufacturer for appropriate replacement linings.



1. Fluid Level Indicator Switch
2. Master Cylinder Reservoir
3. Flow Switch
4. Power Booster
5. Brake Pedal Linkage
6. Brake Pedal
7. Brake Warning Lamp Switch
8. Backup Pump
9. Master Cylinder
10. Differential Pressure Switch

Fig. 4, Components of the Master Cylinder and Power Brake Booster

Troubleshooting

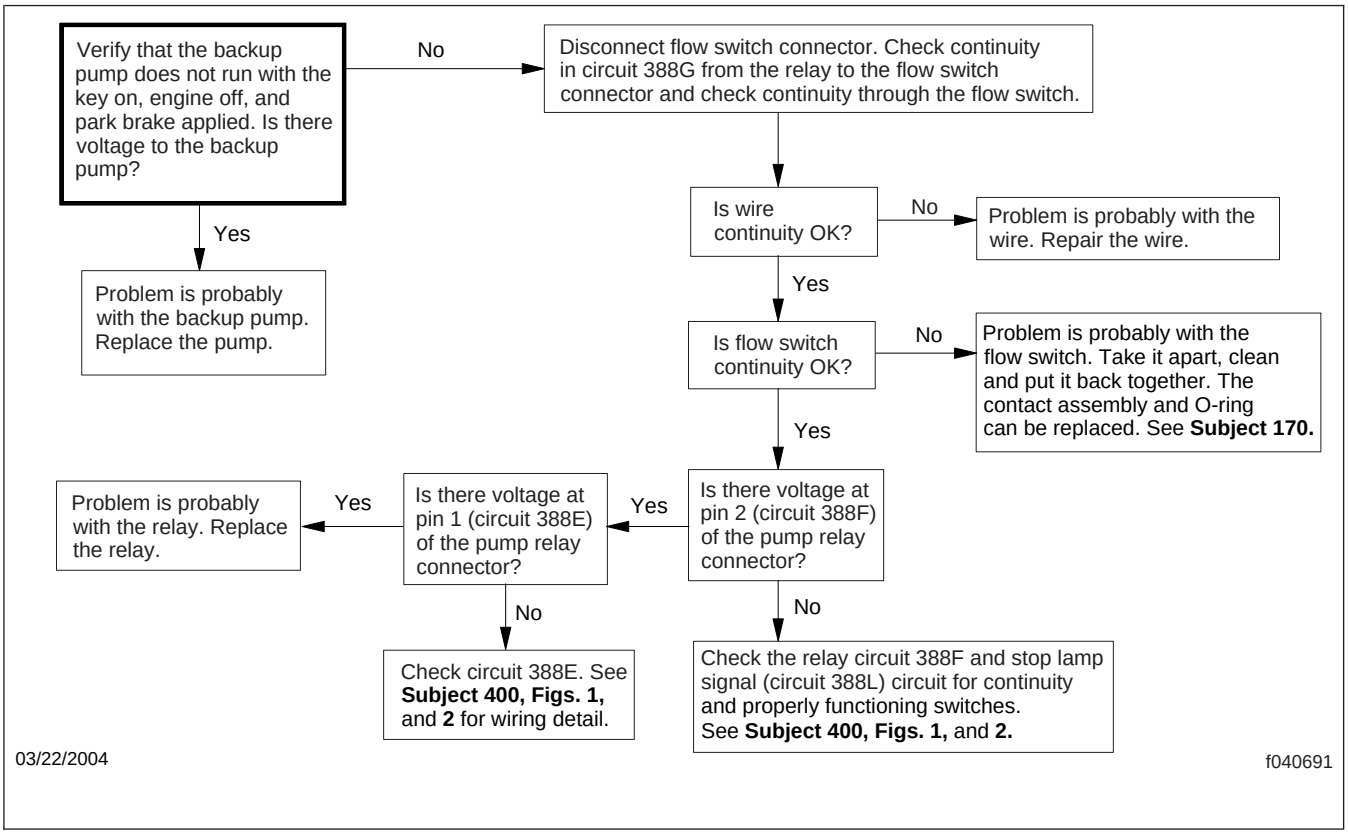


Fig. 5, Flow Chart: Backup Pump Does Not Run

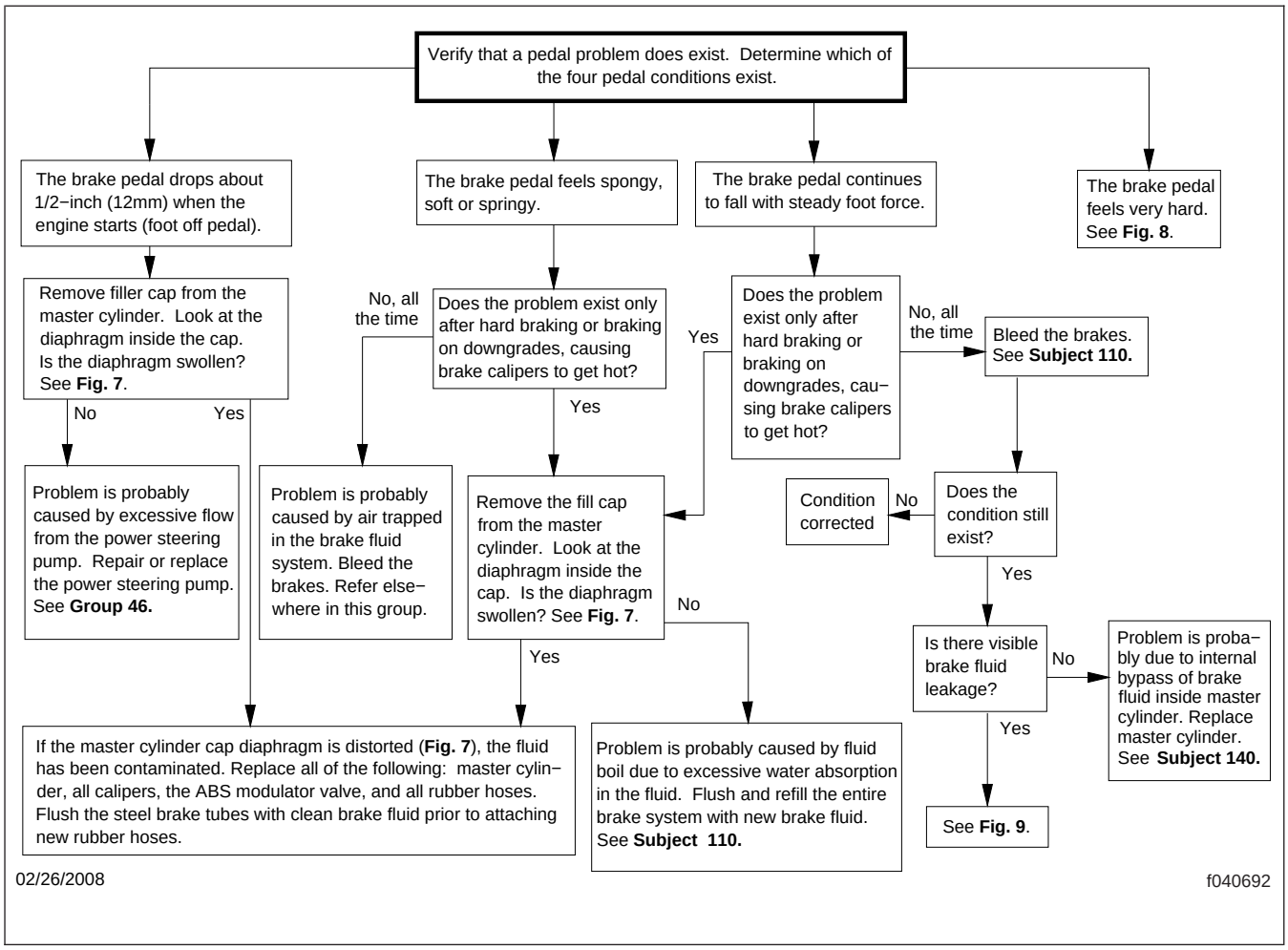
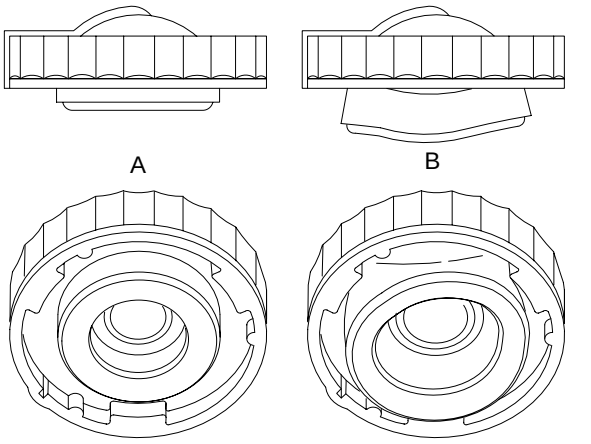


Fig. 6, Flow Chart: Abnormal Brake Pedal Conditions

Troubleshooting



A. Reservoir cap and diaphragm from uncontaminated system.
B. Reservoir cap and diaphragm from a system contaminated with power steering fluid, motor oil, or ATF.

Fig. 7, Undamaged and Damaged Master Cylinder Fluid Reservoir Caps and Diaphragms

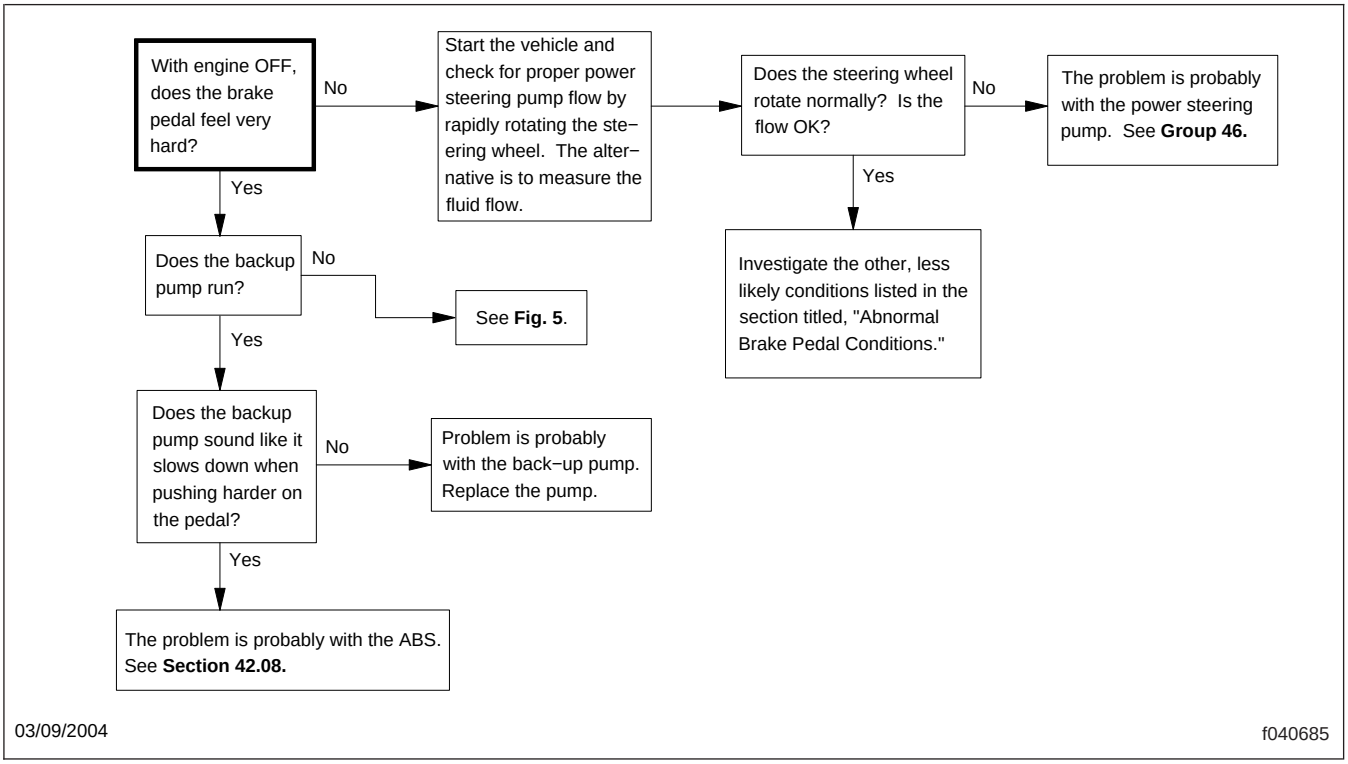


Fig. 8, Flow Chart: Brake Pedal Feels Very Hard

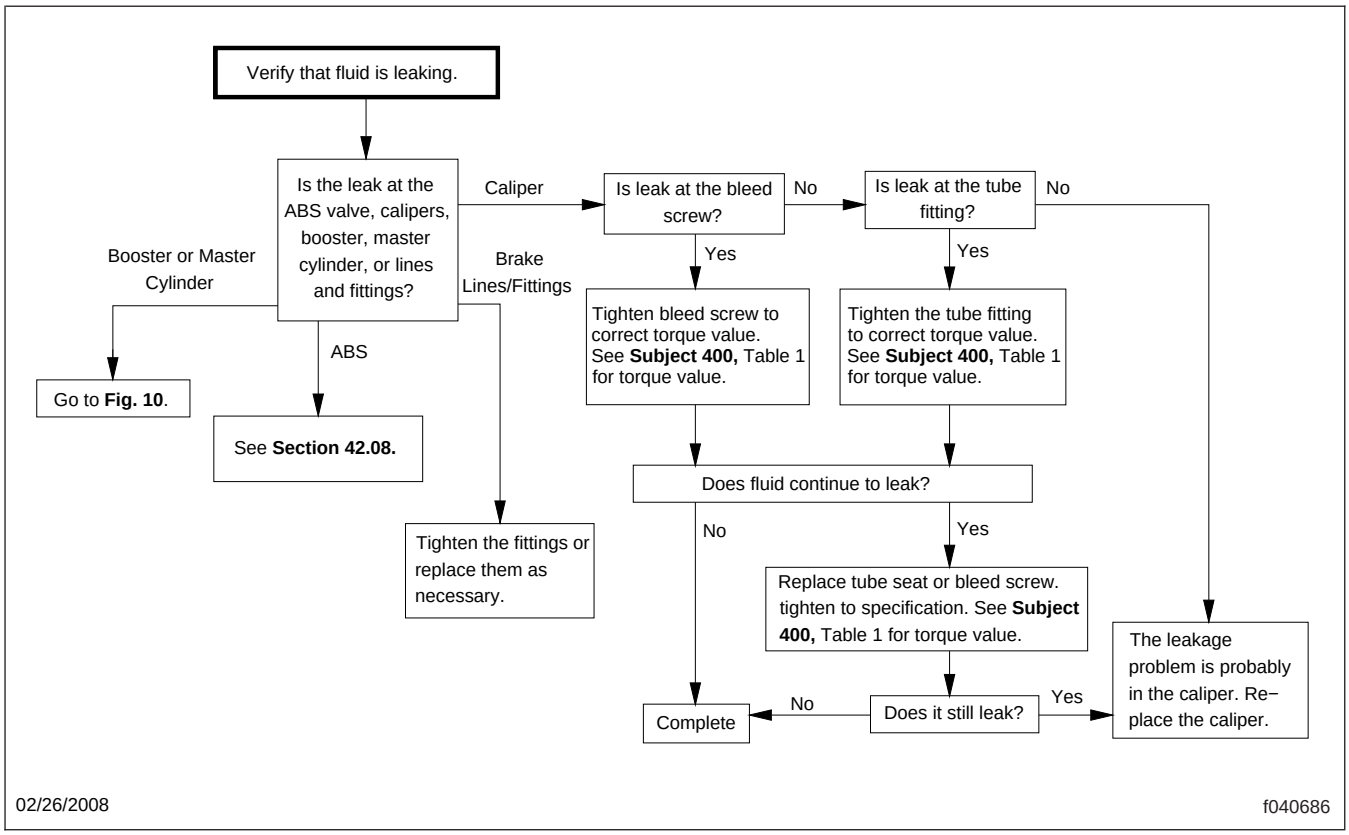


Fig. 9, Flow Chart: Hydraulic System Leakage

Troubleshooting

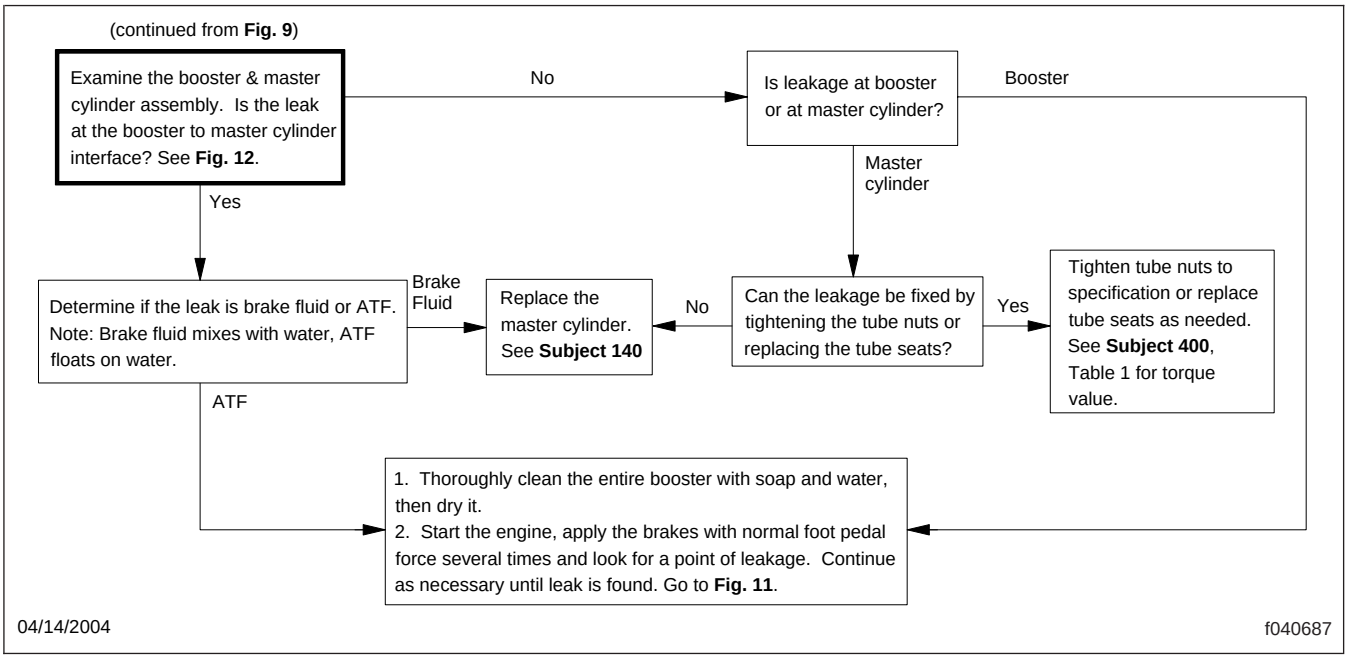


Fig. 10, Flow Chart: Hydraulic System Leakage (cont.)

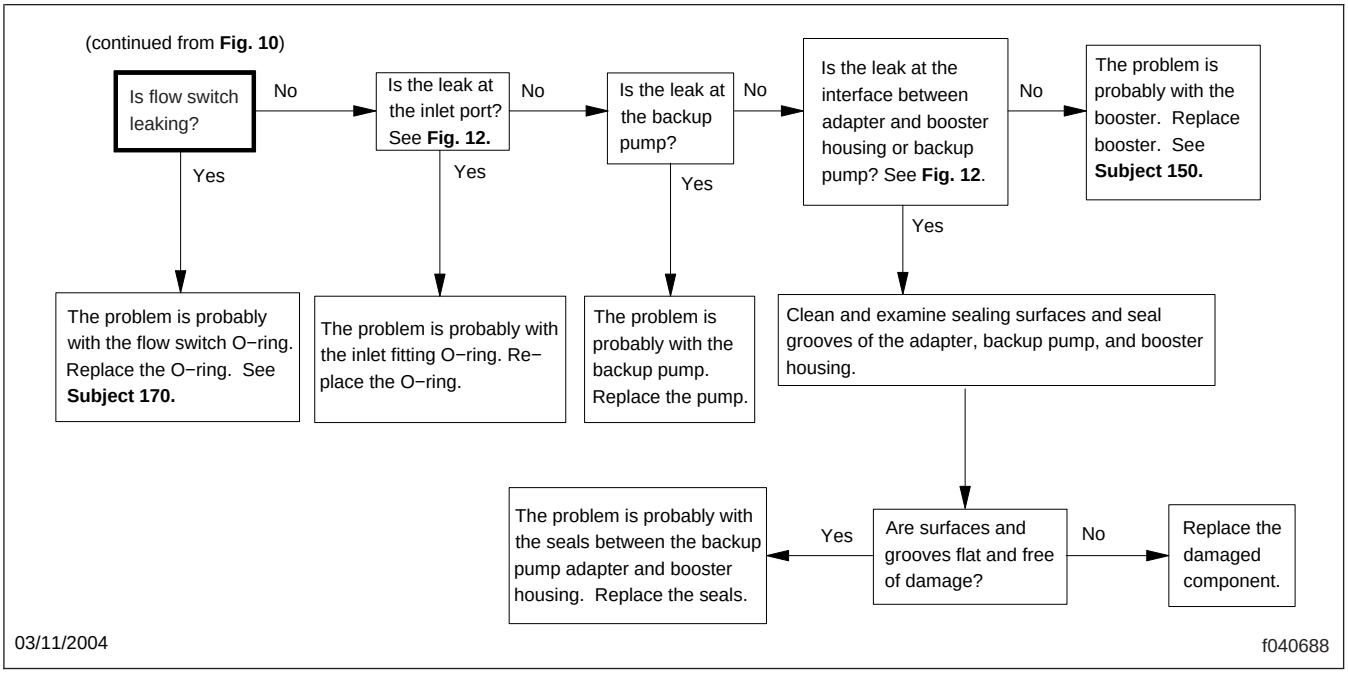
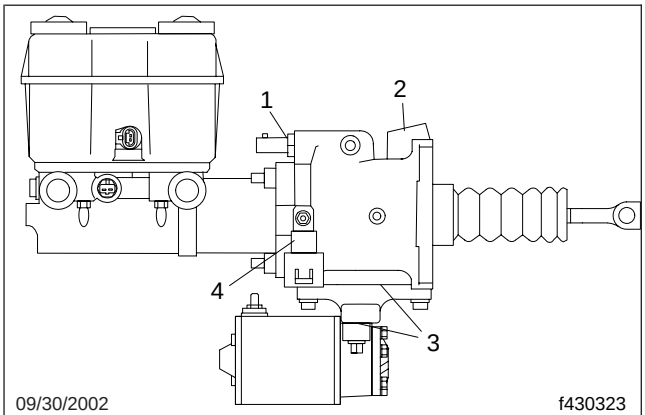


Fig. 11, Flow Chart: Hydraulic System Leakage (cont.)



1. Flow Switch and Power Brake Booster Interface
2. Inlet Port
3. Booster, Adapter and Pump Interface
4. Power Brake Booster and Master Cylinder Interface

Fig. 12, Potential Hydraulic Fluid Leak Points

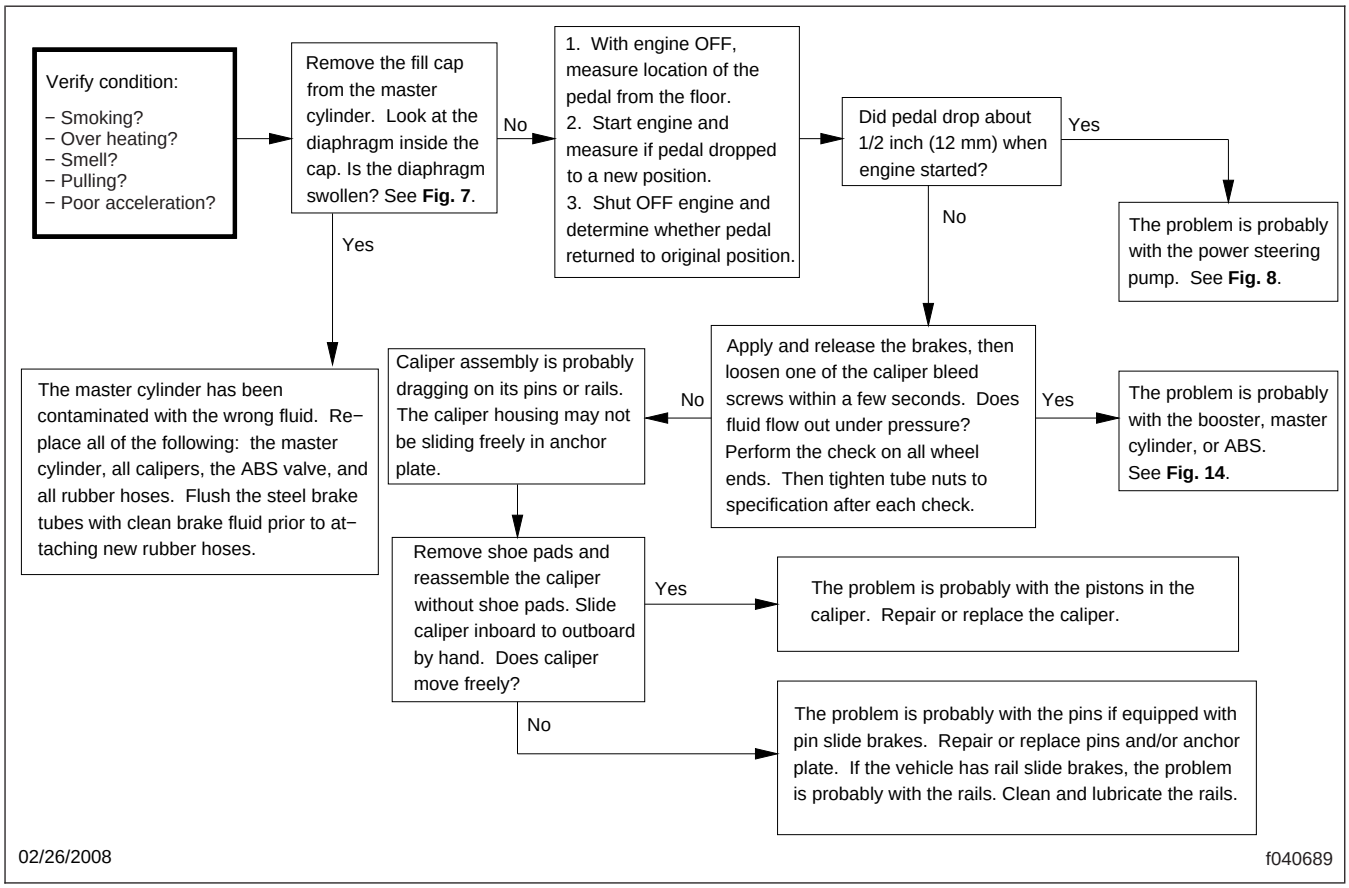


Fig. 13, Flow Chart: Brakes are Dragging

Troubleshooting

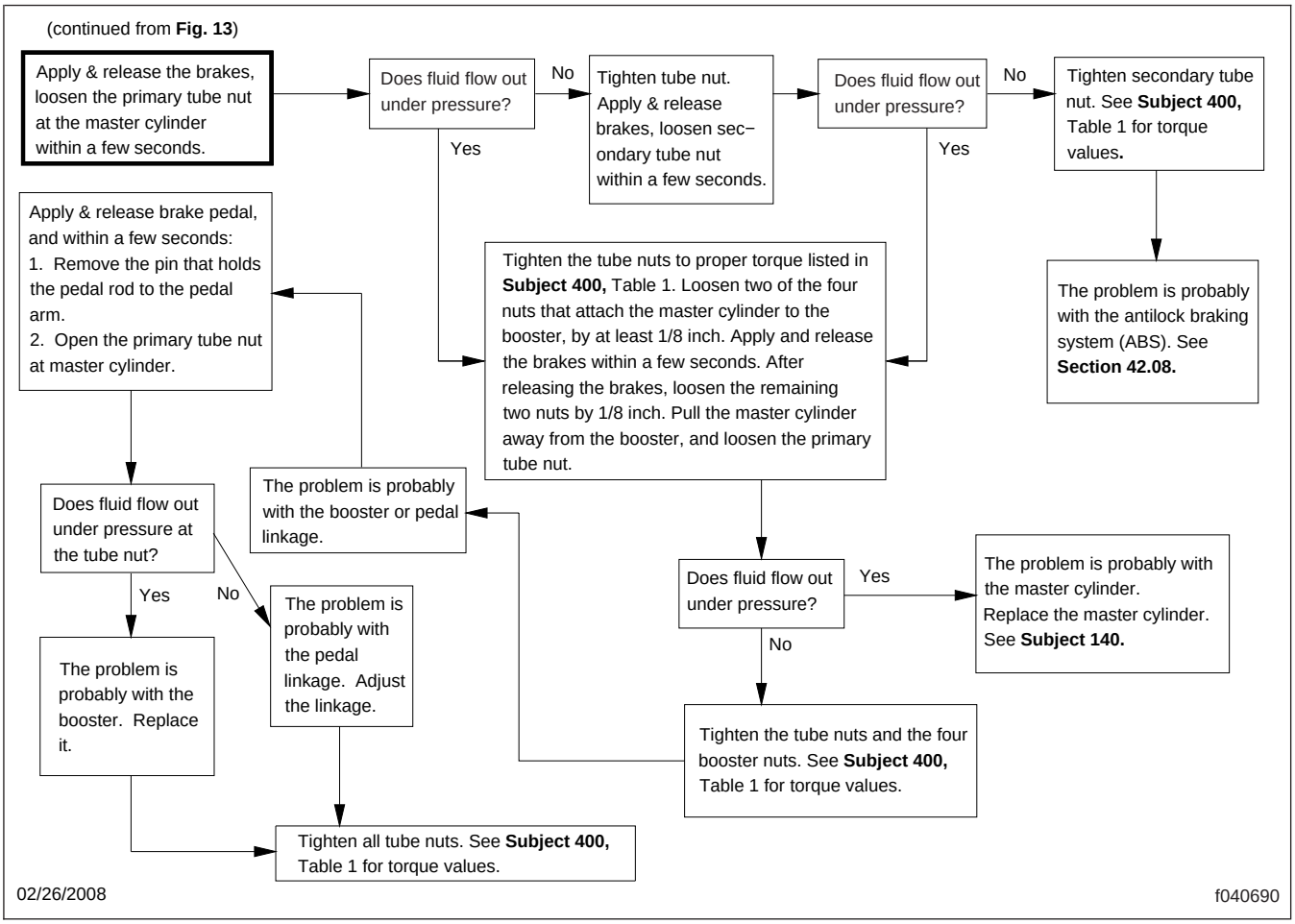
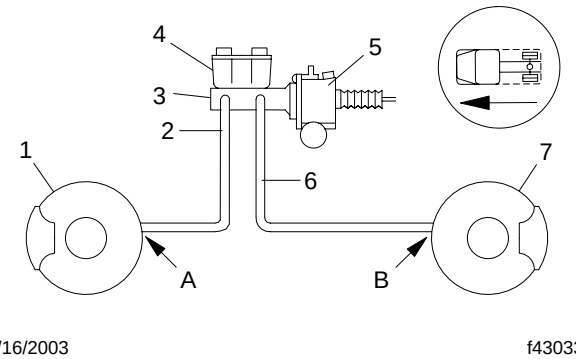


Fig. 14, Flow Chart: Brakes are Dragging (cont.)

Brake System Pressure Tests

NOTE: On most vehicles in the field, the primary master cylinder piston controls the rear brakes, the secondary piston, the front brakes. But on some vehicles the primary master cylinder piston controls the front brakes, the secondary master cylinder piston controls the rear brakes. Either configuration is considered normal and they are functionally identical. Technicians should check vehicle configuration for appropriate diagnosis and repair.

1. Install two low-pressure gauges with a range of 0 to 50 psi (345 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.



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A. Install gauge #2 here.
B. Install gauge #1 here.
1. Front Brake
2. Front Brake Lines
3. Master Cylinder
4. Reservoir
5. Power Brake Booster
6. Rear Brake Lines
7. Rear Brake

Fig. 1, Gauge Installation

2. Bleed the brakes following the procedure in **Subject 110**.
3. With the ignition off, lightly apply the brakes several times. Do not push hard on the brake pedal or you may damage the low-pressure gauges.
4. Release the brakes. Read the residual pressure on both gauges. Record the information.
5. If the residual pressure on either gauge is less than 2 psi (14 kPa), go to "System Pressure Test" below.

   If the residual pressure on one or both gauges is more than 2 psi (14 kPa), check the linkage between the brake pedal and the booster. Repair the linkage if needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue these steps.
6. Check the hydraulic lines for internal blockage or kinking and replace them as needed. Repeat steps 3 and 4. If the problem is solved, go to "System Pressure Test" below. If the problem is not solved, continue with these steps.
7. Check for residual pressure at the master cylinder. Replace as needed. Go to "System Pressure Test" below.

System Pressure Test

1. Install two pressure gauges with a range of 0 to 2500 psi (17 238 kPa) — one at the rear wheels, and one at the front wheels. See **Fig. 1**.
2. Bleed the brakes following the procedure under **Subject 110**.
3. Make a copy of **Table 1**. Use this copy to record the results from the next step.

Test Results				
Pressure Test	**Gauge 1 (installed at rear wheel)**		**Gauge 2 (installed at front wheel)**	
Rapid Pressure Rise	Yes	No	Yes	No
Slow Pressure Rise	Yes	No	Yes	No
Highest Reading (psi)		psi		psi
Pressure Constant	Yes	No	Yes	No

Table 1, Test Results

4. Start the engine. Quickly apply the brakes using full pedal force. Hold the pedal down for 15 to 20 seconds. Record the speed of the pressure rise, the highest pressure registered on each gauge and whether the pressure stayed constant while the pedal was held down. Use a copy of **Table 1** to record your observations.
5. If the pressure reading on both gauges is not within 10 percent, the ABS may be affecting readings. Replace the master cylinder if needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

Pressure Testing

6. If the pressure reading on both gauges is within 10 percent but the gauges show less than 1770 psi (12 204 kPa), turn off the engine but leave the ignition on. Apply the brakes hard and hold the pedal down 15 to 20 seconds to test pressure from the backup pump.

   If both gauges show at least 860 psi (5930 kPa), replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If both gauges do not show at least 860 psi (5930 kPa), replace the power brake booster. Bleed the system following the instructions in **Subject 110**.

7. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 204 kPa), but the pressure came up slowly on both gauges, turn off the engine leaving the ignition on. Apply the brakes hard, hold down the pedal 15 to 20 seconds. If there was a rapid pressure rise on both gauges, repair or replace the power steering pump. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

   If the pressure rose slowly on both gauges, repair or replace the power brake booster. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

8. If the pressure reading on both gauges is within 10 percent and the gauges show at least 1770 psi (12 204 kPa), but the pressure comes up rapidly on one gauge and slowly on the other, there is probably a restriction in the brake system with the slow gauge. Remove the gauge and install it closer to the master cylinder until the pressure rises rapidly. The restriction is between that point and the point of previous installation. Repair or replace the brake line as needed. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**.

9. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa) and the pressure came up rapidly on both gauges but the gauges do not hold constant pressure while the pedal is held down, turn off the engine. Leave the ignition on. Push hard on the brake pedal and hold it down for 15 to 20 seconds. If both gauges hold constant pressure while the pedal is down, repair or replace the power steering pump. Bleed the system following the instructions in **Subject 110**.

   If either gauge does not show constant pressure with the pedal held down, there is probably leakage between the master cylinder and the calipers.

10. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa), the pressure comes up rapidly on both gauges and there is constant gauge pressure while the pedal is depressed but the brake pedal did not stay firm, there is probably leakage in the lines between the master cylinder and calipers.

11. If the pressure reading on both gauges is within 10 percent, the gauges show at least 1770 psi (12 204 kPa), the pressure comes up rapidly on both gauges, there is constant gauge pressure while the pedal is depressed and the brake pedal stays firm, the system is good. Remove the pressure gauges. Bleed the system following the instructions in **Subject 110**. If the problem still exists, check the foundation brakes.

See **Fig. 1** and **Fig. 2** for views of the hydraulic brake system wiring.

NOTE: Technicians can refer to wiring diagrams in PartsPro, Module 877, in addition to those shown here.

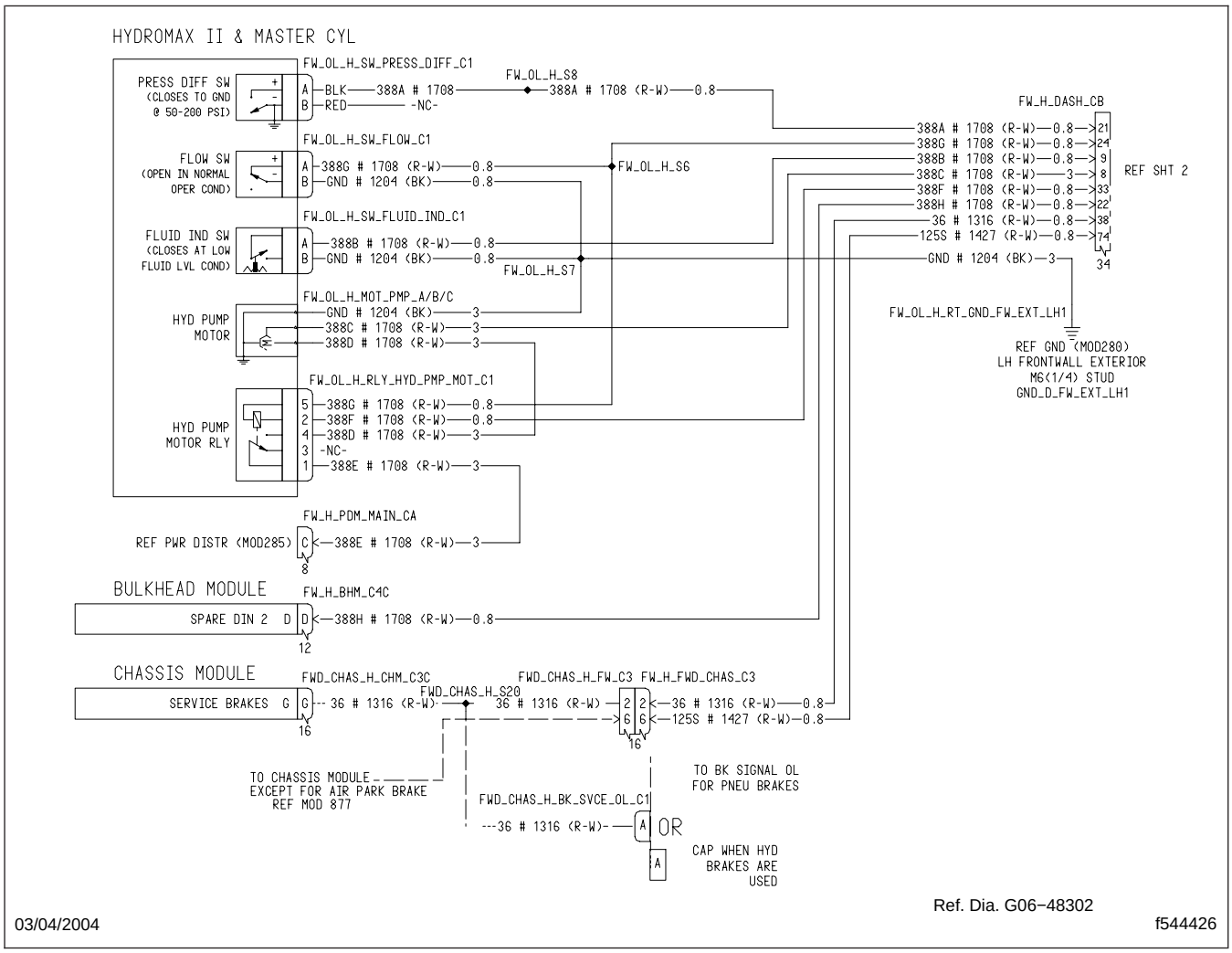


Fig. 1, Hydraulic Brake Frontwall Wiring

Specifications

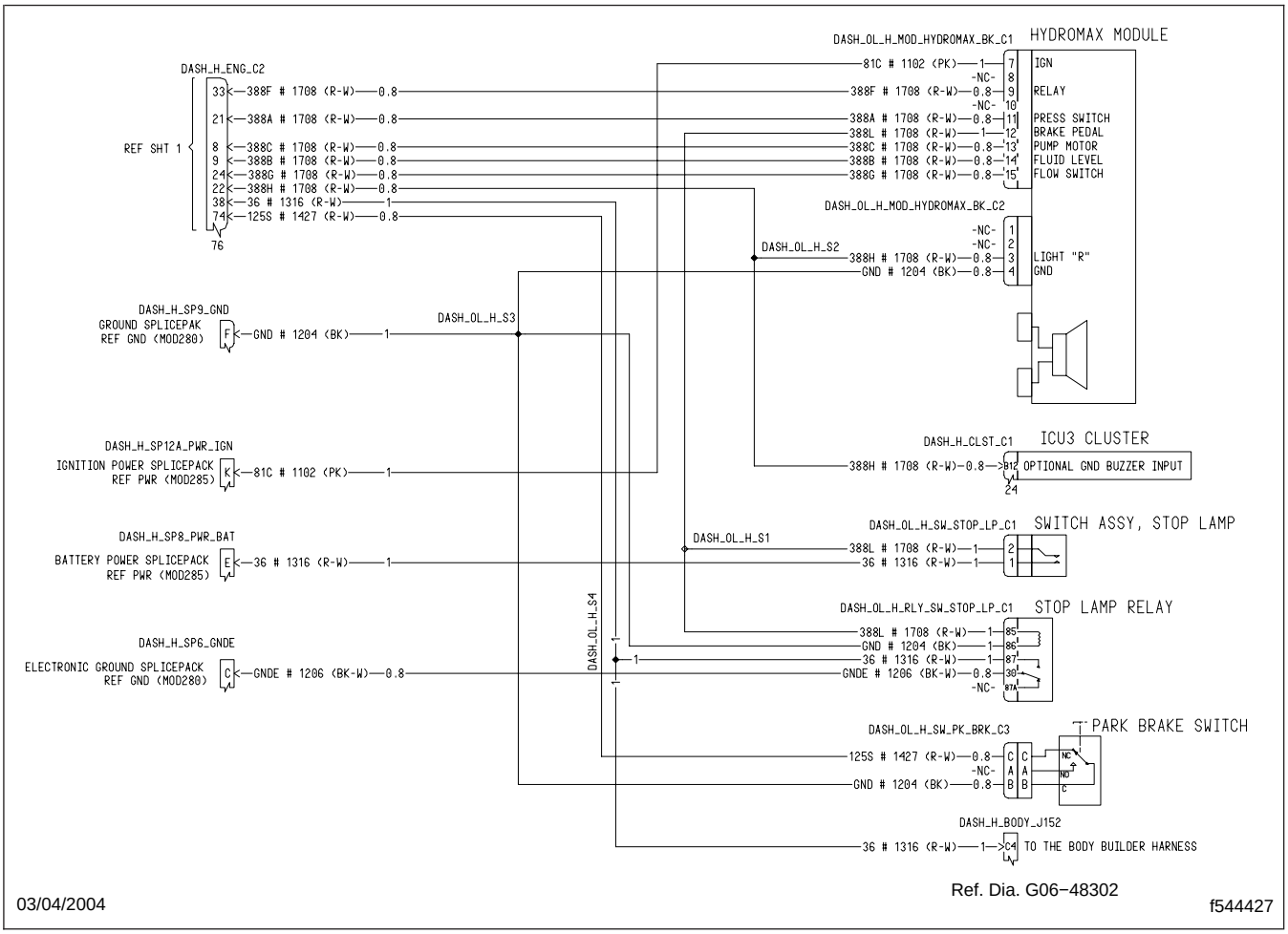


Fig. 2, Hydraulic Brake Dash Wiring

Fastener Torques		
Description	**Torque: lbf·in (N·cm)**	**Torque: lbf·ft (N·m)**
Power Brake Booster Mounting Bolts	—	16–24 (22–32)
Master Cylinder Tube Nuts	—	16 (22)
Master Cylinder Mounting Nuts	—	25–29 (37–40)
Power Brake Booster Supply Line Fitting	—	16–26 (20–34)
Backup Pump Mounting Screws	—	18–25 (24–34)
Relay Mount Screw	75–81(846–914)	—
Flow Switch Contact Assembly	27–33 (306–374)	—
Differential Pressure Switch Contact Assembly	9–15 (106–174)	—
Backup Pump Terminal Nut	13–21 (145–235)	—

Table 1, Fastener Torques

Approved Fluid for Power Brake Booster	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid (ATF)	Dexron II®

Table 2, Approved Fluid for Power Brake Booster

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluid**
DOT 3 Brake Fluid	Wagner-Premium Plus Super HD Delco Supreme II Dow HD 50-4

Table 3, Approved Brake Fluid for Brake System

General Information

The air management unit (AMU) is a collection of pneumatic and electronic valves and pressure switches of modular form that fasten together in a row on a common rail. The AMU is usually located in the rear suspension area of the vehicle. However, it could be located anywhere on the vehicle chassis or body.

The AMU performs functions such as indicating various air pressure levels (switches), supplying either constant air or electrically controlled air to various chassis components (via an electric solenoid or pressure protected port). It also provides for pneumatic logic controls via double-check, inversion, relay, and pressure regulation, therefore replacing double-check, inversion, and relay valves on the vehicle.

The typical AMU layout contains one or more of the following. See **Fig. 1**.

- Pressure Switch Module
- Pressure Protection Valve Module
- Solenoid Valve Module
- Double-Check Valve Module
- Inversion Valve Module
- Relay Valve Module
- Regulator Module
- End Block Module

The switch modules will provide pressure level indication for low air tank pressure, brake application, park, and other optional pressures.

The pressure protection modules supply constant air to components such as air suspension, transmission, accessories, and solenoid modules.

The solenoid modules control ON-OFF air options.

The double check, inversion, and relay modules provide for air system logic used in various park brake interlocks, and other features.

Principles of Operation

Pressure Switch Module "A"

This pressure switch module receives three different air pressure inputs and closes or opens the appropriate switches when the pressures exceed the specified switch settings. See **Fig. 2**. There may be a total of 3 or 4 separate switches in this module.

There are three external application supply air ports and one external secondary air port.

Pressure Switch Module "B" and "C"

Pressure Switch Module "B" receives one or two pressure inputs and opens or closes the switch(es) when the pressure exceeds the specified switch setting. See **Fig. 3**.

Pressure switch module "C" contains a low current pressure switch, which receives a single pressure input and closes a switch when the pressure exceeds the specified switch setting. This module also contains a relay for delivering high current.

Pressure Protection Valve Module

The pressure protection valve module shuts off all delivery air if the supply falls below the determined setting. See **Fig. 4**. It also shuts off the supply air to

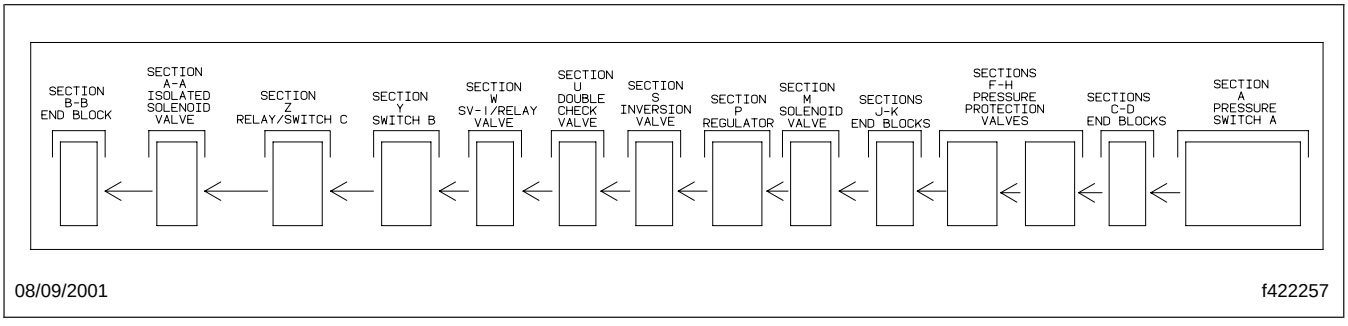
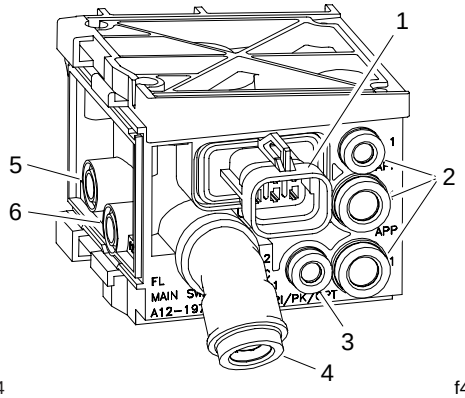


Fig. 1, Typical AMU Layout

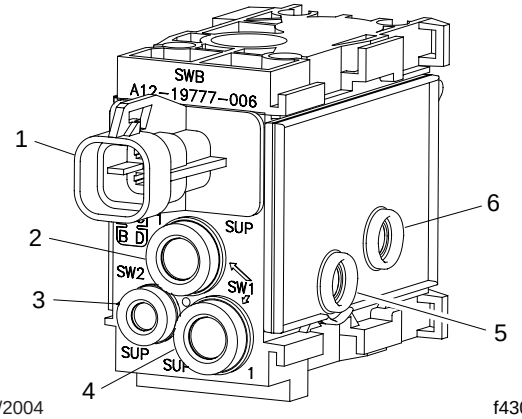
General Information



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1. Electrical Connector
2. Application Supply Air Ports
3. Primary Supply Air Port
4. Secondary Supply Air Port
5. Non-Thru Port
6. Secondary Air Internal Delivery Port

Fig. 2, Pressure Switch Module "A"



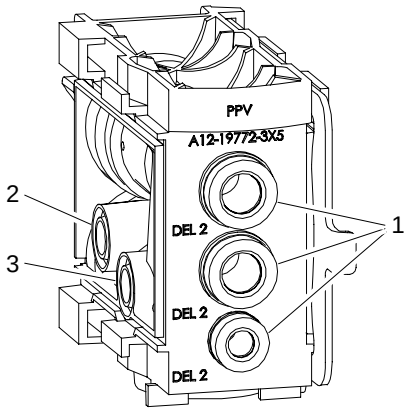
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1. Electrical Connector
2. Switch 1 Supply Port
3 Switch 2 Supply Port
4. Switch 1 Supply Port
5. Non-Thru Port
6. Internal Delivery Port

Fig. 3, Pressure Switch Module "B"

the valve if the delivery pressure falls below the determined setting.

The inlet to the pressure protection valve module is via an internal port on the right side that mates to the



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1. External Delivery Ports
2. Internal Delivery Port (LH side - delivery only)
3. Internal Supply Port (thru-port)

Fig. 4, Pressure Protection Valve Module

secondary air port on Switch Module "A" or the adjacent pressure protection valve module. This non-pressure protected air from Switch Module "A" will pass through the module from the internal supply port and out of the internal delivery port on the left side to supply the next valve (pressure protection, or solenoid). There is another delivery port on the left side that delivers pressure protected air to the adjacent module(s).

Solenoid Valve Module

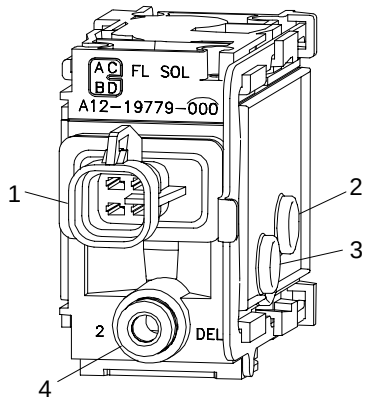
All solenoid valve modules are normally closed (N.C.). See **Fig. 5**. The solenoid valve module delivers air when electrically activated.

The inlet to the solenoid valve module mates to the port on the adjacent pressure protection module or another solenoid valve module. Pressure protected air will pass through the module from the internal supply port and out of the internal delivery port to supply the next solenoid valve module.

Each solenoid valve module is a three-way (supply, delivery, and exhaust) on-off air valve. Every solenoid valve module has an internal pressure switch that monitors delivery pressure.

Double Check Valve Module

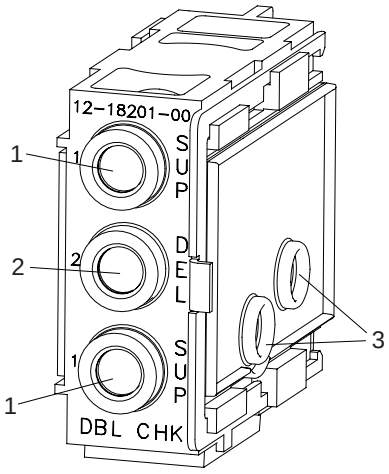
The double check valve module delivers the higher air pressure of two separate supply pressures. See



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1. Electrical Connector
2. Thru Port (supply)
3. Non-Thru Port
4. Delivery Port

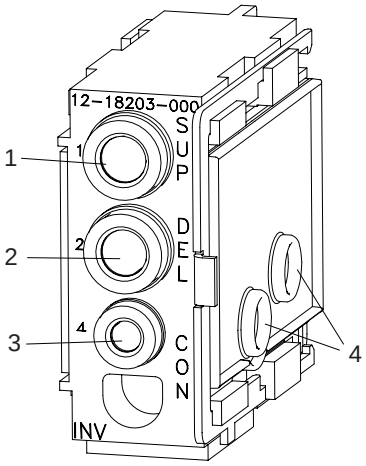
Fig. 5, Solenoid Valve Module



12/19/2001 f543864

1. External Supply Port
2. External Delivery Port
3. Non-Thru Ports

Fig. 6, Double-Check Valve Module



12/19/2001 f543862

1. External Supply Port
2. External Delivery Port
3. External Control Port
4. Closed, Non-Thru Ports

Fig. 7, Inversion Valve Module

Fig. 6. There are no internal air supply or delivery ports. There is one external delivery port on the face of the double check valve module.

Inversion Valve Module

The inversion valve module is a normally open (N.O.) air valve that delivers system air pressure when the control pressure falls below the specified level. See **Fig. 7**. There are no internal supply, delivery, or control ports in this module.

The external supply, control, and delivery ports are on the face of the module.

Relay Valve Module

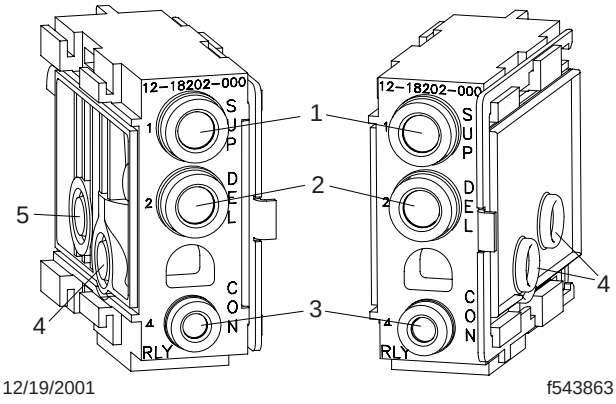
The relay valve is a normally closed air valve that delivers system air pressure when the control pressure exceeds the specified level. See **Fig. 8**. There is one internal control port on the left side of the module that will mate with pressure switch "B" module to receive parking brake air. See **Fig. 3**. The control, supply, and delivery ports are on the face of the module.

End Block Module

The ported end block module contains ports that are used to deliver air to another AMU on the vehicle or to modules at the other end of the AMU. See **Fig. 9**.

A non-ported end block is also available.

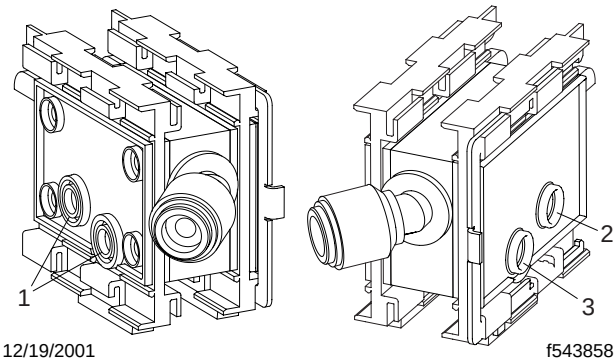
General Information



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1. External Supply Port
2. External Delivery Port
3. External Control Port
4. Non-Thru Ports
5. Internal Control Port (left-hand only)

Fig. 8, Relay Valve Module



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1. Non-Thru Ports
2. Internal Pressure Protected Port
3. Non-Thru Port

Fig. 9, End Block Module

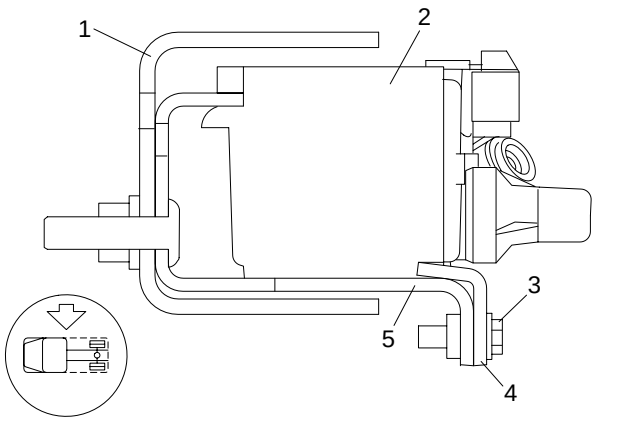
Replacement

Individual modules within the air management unit (AMU) can be replaced. The replacement may vary slightly for each module. The following is a general replacement procedure.

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Drain the air reservoirs.

IMPORTANT: Clean the AMU and the area around it of all dirt and road debris before removing any modules. Failure do to so can result in dirt or road debris between the modules and their seals, causing air leakage.

4. Loosen the bolts on the L-bracket that secures the AMU to the frame rail mounting bracket. See **Fig. 1**. This will allow the AMU to separate, allowing for easy removal of the module.



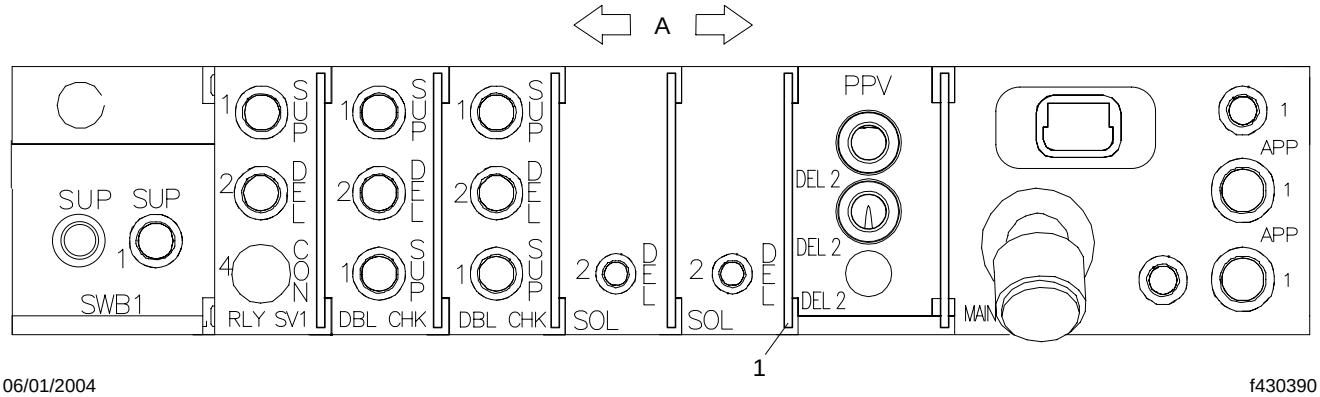
1. Crossmember
2. AMU
3. L-Bracket Bolt
4. L-Bracket
5. AMU Mounting Bracket

Fig. 1, Air Management Unit (AMU)

IMPORTANT: Be sure to mark all air lines before removing them from the modules.

5. Mark and disconnect the air lines (and electrical connectors, if applicable) from the module to be replaced.
6. Pull out the locking keys from both sides of the module to be removed and slide the AMU apart. See **Fig. 2**.
7. Remove the module.
8. Install the new seals on the sides of the module.
9. Place the new module in position and slide the module AMU together.
10. Push in the locking keys.
11. Install all air lines and electrical connectors as previously marked.
12. Firmly tighten the bolts on the L-bracket, securing the AMU in the mounting bracket. See **Fig. 1**.
13. Connect the batteries.
14. Remove the chocks from the tires.

AMU Module Replacement



A. Separate the AMU to remove the module.

1. Lock Key

Fig. 2, AMU Module Replacement

AMU Diagnostics

Test Apparatus

To test several of the modules, a simple test apparatus can be constructed consisting of a regulator valve, two valves, a pressure gauge, a few fittings, and some air line. See **Fig. 1** for the configuration.

Pressure Switch "A" Testing

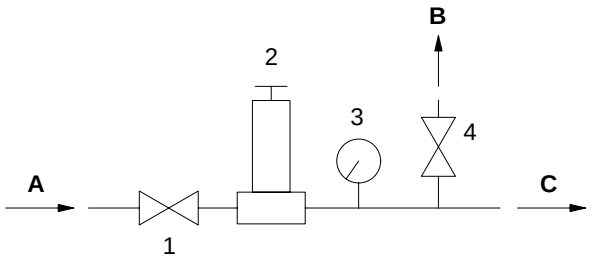
Pressure switch module "A" contains pressure switches. Pressure switch module "A" is used only on vehicles with air brakes and comes in two different configurations depending on whether or not an engine fan pressure switch is needed. See **Table 1**.

The low-air-pressure switches monitor the air pressure in the primary and secondary supply air systems. The pressure switches are internal to the Pressure switch module "A." The primary and secondary low air switches are wired in series. Each pressure switch closes when air pressure reaches approximately 65 to 75 psi (448 to 517 kPa). When both systems have reached 65 to 75 psi (448 to 517 kPa) and both switches are closed, a circuit to ground is completed to the Chassis Module (CHM).

The engine fan pressure switch monitors air pressure in the secondary air system. The purpose is to prevent the engine fan solenoid from activating when the system air pressure is too low. This switch closes at approximately 80 to 94 psi (552 to 648 kPa).

The stop lamp pressure switch monitors pressure in the service brake system. Its main purpose is to control the stop lamps. This switch closes at approximately 2 to 5 psi (14 to 34 kPa).

For complete troubleshooting of a system (i.e. low air pressure warning lamp), refer to the appropriate section in this manual. The following tests are component tests only and do not troubleshoot the entire system.



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A. Shop Air
B. Exhaust to Atmosphere
C. To Port Being Tested

1. Valve "A"
2. Pressure Regulator
3. 0 to 150 psi (0 to 1000 kPa) Gauge
4. Valve "B"

Fig. 1, AMU Module Test Apparatus

Pressure Switch "A" Configurations (Air Brake)			
Part No.	**No. of Pressure Switches**	**Pressure Switch Function**	
A12-19776-000	3	Low Air Warning (primary air)	N.O.* (closes @ 65–75 psi [448–517 kPa])
		Low Air Warning (secondary air)	N.O. (closes @ 65–75 psi [448–517 kPa])
		Stop Lamp (application air)	N.O. (closes @ 2–5 psi [14–34 kPa])
A12-19776-001	4	Low Air Warning (primary air)	N.O. (closes @ 65–75 psi [448–517 kPa])
		Low Air Warning (secondary air)	N.O. (closes @ 65–75 psi [448–517 kPa])
		Stop Lamp (application air)	N.O. (closes @ 2–5 psi [14–34 kPa])
		Optional (engine fan)	N.O. (closes @ 80–94 psi [552–648 kPa])

* N.O. is "Normally Open"

Table 1, Pressure Switch "A" Configurations (Air Brake)

Troubleshooting

Pressure Switch "A" (low air pressure switches tests)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Low Air Pressure Switch Ground Circuit	Key OFF, engine OFF. Battery disconnected. Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin B (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Low Air Pressure Switch (testing if switches close)	Build system air to 80 psi (552 kPa) (both tanks). Key OFF, engine OFF. Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin A and B (switch side).	Less than 1 ohm. NOTE: If meter reads OL, the low air switches are not closing at 65 to 75 psi (448 to 517 kPa).	Pressure switch "A" is faulty. Replace it.
Low Air Pressure Switch (testing if switches open)	Adjust system air to 60 psi (414 kPa) (both tanks). Key OFF, engine OFF. Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin A and B (switch side).	Greater than 10,000 ohms. NOTE: If meter reads less than 1 ohm, the low air switches are not opening below 65 psi (448 kPa).	Pressure switch "A" is faulty. Replace it.

Table 2, Pressure Switch "A" (low air pressure switches tests)

Pressure Switch "A" (Engine Fan Pressure Switch Tests) (A12-19776-001 only)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Engine Fan Pressure Switch (testing if switch closes)	Bring the air system up to full pressure (governor cutout), then bleed air pressure off by making several brake applications until the secondary air pressure is approximately 100 PSI (689 kPa) (or just slightly above). Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pins E and F (switch side).	Less than 1 ohm. NOTE: If the meter reads OL, the engine fan pressure switch is not closing between 80 and 94 psi (551 to 648 kPa).	Pressure switch "A" is faulty. Replace it.
Engine Fan Pressure Switch (testing if switch opens)	Make several more brake applications until the secondary air pressure is approximately 75 psi (517 kPa) (or just slightly lower). Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pins E and F (switch side).	Greater than 10,000 ohms. NOTE: If the meter reads less than 1 ohm, the engine fan pressure switch is not opening below 80 psi (551 kPa).	Pressure switch "A" is faulty. Replace it.

Table 3, Pressure Switch "A" (Engine Fan Pressure Switch Tests) (A12-19776-001 only)

Pressure Switch "A" (stop lamp switch tests)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Stop Lamp Ground Circuit	Key OFF, engine OFF. Battery disconnected. Pressure switch "A" 6-way connector disconnected.	Resistance Check: Measured between pin C (harness side) and the negative battery terminal.	Less than 1 ohm.	Check ground circuit wiring.
Stop Lamp Switch (testing if switch closes)	Key OFF, engine OFF. Pressure switch "A" 6-way connector disconnected. Drain air tanks. Disconnect one of the APP ports on the face of the module and connect the test apparatus to the port. See **Fig. 1**. Close Valve "A" and Valve "B" of the test apparatus. Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A." Apply 10 psi (69 kPa) to the APP port by adjusting the pressure regulator. This should cause the stop lamp pressure switch to close.	Resistance Check: Measured between pins C and D (switch side).	Less than 1 ohm. NOTE: If meter reads OL, then the stop lamp switch is not closing between 2 and 5 psi (14 and 34 kPa).	Pressure switch "A" is faulty. Replace it.
Stop Lamp Switch (testing if switch opens)	Key OFF, engine OFF. Pressure switch "A" 6-way connector disconnected. Drain air tanks. Remove test apparatus from previous (if applicable).	Resistance Check: Measured between pins C and D (switch side).	Greater than 10,000 ohms. NOTE: If meter reads less than 1 ohm, then the stop lamp switch is stuck closed.	Pressure switch "A" is faulty. Replace it.

Table 4, Pressure Switch "A" (stop lamp switch tests)

Pressure Protection Valve Modules

General Information

The pressure protection valve (PPV) module shuts off all delivery air if the supply falls below the determined setting. It also shuts off the supply to the valve if the delivery pressure falls below the determined setting. Refer to **Table 5** for PPV open and closing pressures.

Troubleshooting

Pressure Protection Valve Specifications			
Part Number	**No. of Delivery Ports (Ext.)**	**Open psi (kPa)**	**Close psi (kPa)**
A12-19772-255	2	47–63 (324–434)	40–50 (276–354)
A12-19772-285	2	77–93 (531–641)	62–72 (428–496)
A12-19772-355	3	47–63 (324–434)	40–50 (276–354)
A12-19772-385	3	77–93 (531–641)	62–72 (428–496)

Table 5, Pressure Protection Valve Specifications

Troubleshooting

See **Table 6** for pressure protection valve tests.

Pressure Protection Valve Tests		
Test	**Test Procedure**	**If Test Fails:**
Supply pressure drop protection	Drain the air tanks. Disconnect one of the delivery ports on the face of the module and connect an accurate pressure gauge. Connect an accurate pressure gauge to the secondary air tank. Start the engine and build air to maximum air pressure. Shut the engine off. Drain the secondary air tank while watching the gauges. The pressure on the delivery port of the pressure protection valve module should stop falling at approximately the closing pressure in **Table 5**, while the pressure on the secondary tank gauge continues to fall to zero.	Replace pressure protection module.
Delivery pressure drop protection	Drain the air tanks. Disconnect one of the delivery ports on the face of the module and connect a valve (use fittings and air line as necessary). Close the valve. Connect an accurate pressure gauge to the secondary air tank. Start the engine and build air to maximum air pressure. Shut the engine off. Open the valve installed on the delivery port of the module. When air stops flowing through the valve, observe the pressure gauge on the secondary air tank. The pressure should not fall below approximately the closing pressure listed in **Table 5**.	Replace pressure protection module.
Opening pressure	Drain the air tanks. Disconnect one of the delivery ports on the face of the module and connect an accurate pressure gauge. Connect an accurate pressure gauge to the secondary air tank. Start the engine and observe the gauges. The gauge on the delivery port of the module should remain at 0 psi (0 kPa) until the pressure in the secondary air tank pressure gauge reaches approximately the opening pressure listed in **Table 5**.	Replace pressure protection module.

Table 6, Pressure Protection Valve Tests

Solenoid Valve Module

General Information

The solenoid valve controls ON-OFF air options. Solenoid valves are supplied with pressure-protected secondary air. Therefore, they are always positioned to the left of the pressure protection valves on the air management unit (AMU). The normally closed solenoid valves come with various delivery port collar colors. This helps in manufacturing to match colored air lines to the correct solenoid valve. Other than that, they are functionally the same. Normally closed solenoid valve modules have a black cover. Each solenoid valve module has an internal pressure switch that monitors delivery pressure. The solenoid coils each have a diode wired in parallel to prevent voltage spikes.

Solenoid Valve Module Tests

Solenoid Coil Resistance and Diode Check*			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
Key OFF, engine OFF. Solenoid valve connector disconnected.	Coil Resistance and Diode Check: Measured between pin C and D (switch side). Then, reverse test leads and check again.	Approx. 16 ohms with leads both ways. NOTE: If result was much greater than 16 ohms one way and 0 ohms with the leads reversed, then the coil is open. If the result was 0 ohms both ways, then the diode or coil is shorted. There is no way to specifically check the internal diode.	Replace solenoid valve.

* The solenoid has an internal diode wired in parallel with the coil.

Table 7, Solenoid Coil Resistance and Diode Check

Solenoid Valve Functional Test			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
Drain the air tanks. Solenoid valve connector disconnected. Disconnect the air line to the external delivery port on the solenoid valve and connect an accurate pressure gauge in its place. Start the engine and build air to full pressure. Shut the engine off. Key OFF, engine OFF.	Using a fused jumper wire, connect solenoid pin C (solenoid valve side) to the positive battery post. Using another jumper wire, connect solenoid pin D (solenoid valve side) to ground. **Do not reverse the polarity of the solenoid coil, damage to the internal diode may result.**	For Normally Closed Valves: Before connecting the jumper wires, the pressure gauge should read zero pressure. The solenoid should switch on and deliver air to the external delivery port (pressure should read on the gauge).	Replace solenoid valve.

Table 8, Solenoid Valve Functional Test

Troubleshooting

Solenoid Valve Pressure Switch Functional Test (normally closed valves)			
Conditions	**Test Point**	**Good Result**	**If Test Fails:**
Drain the air tanks. Solenoid valve connector disconnected. Disconnect the air line to the external delivery port on the solenoid valve and connect an accurate pressure gauge in its place. Start the engine and build air to full pressure. Shut the engine OFF. Key OFF, engine OFF.	Using a fused jumper wire, connect solenoid pin C (solenoid valve side) to the positive battery post. Using another jumper wire, connect solenoid pin D (solenoid valve side) to ground. **Do not reverse the polarity of the solenoid coil, damage to the internal diode may result.** Once the solenoid has been energized, measure the resistance across pins A and B. Remove the jumpers and check resistance across pins A and B again.	With the Solenoid Energized: The resistance should be approximately zero and the pressure gauge should read pressure (55 or 85 psi [379 or 586 kPa]) depending on upstream pressure protection valve. With the Solenoid De-energized: The resistance should be greater than 10,000 ohms. The pressure gauge should read zero pressure.	Replace solenoid valve.

Table 9, Solenoid Valve Pressure Switch Functional Test (normally closed valves)

Double Check Valve Module

General Information

The double check valve module takes supply air from two sources and delivers the higher of the two to the delivery port. These modules do not have any internal through ports to other modules.

Troubleshooting

Double Check Valve Module Functional Test		
Test	**Test Procedure**	**If Test Fails:**
Double Check Valve Module	Drain the air tanks. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge. Apply shop air to the upper supply port. The pressure gauge on the delivery port should read shop air pressure. Check for leakage at the lower supply port using a soapy water solution. There should be virtually no leakage (less than 3/8-inch [1-cm] bubble in 1 minute). Next, apply shop air to the lower supply port. The pressure on the delivery port gauge should read shop air pressure. Check for leakage at the upper supply port using a soapy water solution. There should be virtually no leakage (less than 3/8-inch [1-cm] bubble in 1 minute). Disconnect both supply ports.	Replace double check valve module.

Table 10, Double Check Valve Module Functional Test

Inversion Valve Module (Normally Open Relay)

General Information

The inversion valve module is basically a normally open relay, meaning that when no pressure is applied to the control port, supply air is delivered to the delivery port. When pressure is applied to the control port, the supply air is cut off from the delivery port and the delivery air is exhausted to atmosphere. There are no internal supply, delivery, or control ports on this module.

When rising pressure applied to the control port reaches 40 to 50 psi (276 to 345 kPa), the delivery port is cut off from the supply port and delivery port air is exhausted to atmosphere. When applied pressure to the control port releases and reaches 20 to 30 psi (138 to 207 kPa), the delivery port is no longer exhausted to atmosphere and supply air is delivered to the delivery port.

Troubleshooting

Relay Valve Module (normally closed)

General Information

The relay valve module delivers supply air to the delivery port when the air is applied to the control port. When air pressure is released from the control port, the delivery port is exhausted to atmosphere. This module comes in two versions. In one version, there is an internal control port in addition to the one on the face of the module. In the other version, there is an internal delivery port in addition to the one on the face of the module. In both versions, there are no other internal ports.

Inversion Valve Module Functional Test		
Test	**Test Procedure**	**If Test Fails:**
Inversion Valve Module (pressure application)	Drain the air tanks. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge. Disconnect the control port on the face of the module and connect the test apparatus to the control port. See **Fig. 1**. Start the engine, build system air to full pressure. Shut engine off. Close Valve "A" and Valve "B" of the test apparatus. Back the regulator screw off so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A." The gauge on the delivery port of the inversion module should read pressure. Apply rising pressure to the control port by adjusting the pressure regulator. While increasing the pressure, observe the pressure gauges. When the control port pressure (regulated) reaches approximately 30 to 45 psi (207 to 310 kPa), the delivery port (on inversion module) should exhaust (the delivery port gauge on the inversion valve module should drop to zero pressure). Once the delivery port on the inversion valve module has exhausted (pressure goes to zero), close valve "A" on the test apparatus. Next, open valve "B" slightly so as to relieve the control port pressure very slowly while observing the pressure gauges. When the control port pressure drops (pressure gauge on the test apparatus) to approximately 20 to 30 psi (138 to 207 kPa), the pressure at the delivery port of the inversion valve should read pressure.	Replace inversion valve module.

Table 11, Inversion Valve Module Functional Test

Troubleshooting

Relay Valve Module Functional Tests		
Test	**Test Procedure**	**If Test Fails:**
Relay Valve Module (pressure application).	Drain the air tanks. Disconnect the delivery port on the face of the module and connect an accurate pressure gauge. Disconnect the control port on the face of the module and connect shop air through the test apparatus to the control port. See **Fig. 1**. Start the engine, build system air to full pressure. Shut the engine off. Close Valve "A" and Valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open Valve "A." The gauge on the delivery port of the relay valve module should read zero pressure. Apply rising pressure to the control port by adjusting the pressure regulator. While increasing the pressure, observe the pressure gauges. When the control port pressure (regulated) reaches approximately 18 to 24 psi (124 to 165 kPa), the delivery port (on relay module) should read pressure. Once the delivery port gauge reads system pressure, close valve "A" on the test apparatus. Next, open valve "B" slightly to relieve the control port pressure very slowly while observing the pressure gauges. When the control port pressure drops (pressure gauge on the test apparatus) to approximately 8 to 14 psi (55 to 96 kPa), the pressure at the delivery port of the relay valve should exhaust and read zero pressure.	Replace relay valve module.

Table 12, Relay Valve Module Functional Tests

When rising pressure applied to the control port reaches 18 to 24 psi (124 to 165 kPa), the delivery port is cut off from the exhaust to atmosphere and the supply port delivers air to the delivery port. When applied pressure to the control port releases and reaches 8 to 14 psi (55 to 96 kPa), the delivery port is cut off from the supply air, and delivery port air is exhausted to atmosphere.

Troubleshooting

Pressure Switch Module "B"

General Information

Pressure Switch module "B" comes in various configurations. All have at least one normally closed pressure switch. Some versions have internal ports and some do not. See **Table 13** for the variations of this module.

Pressure Switch Module "B" Tests

For testing the pressure switches in pressure switch module "B", first determine if the pressure switch to be tested is normally open or normally closed. See **Table 13** for the variations of this module. Then test the pressure switch using the appropriate tables that follow.

Pressure Switch Module "B" Configurations							
Part #	Sw 1	Sw 2	# of Ports to Sw 1		# of Ports to Sw 2		Cover Color
			Int.	Ext.	Int.	Ext.	
A12-19777-001	N.C.* (opens @ 70–84 psi [482–579 kPa])	—	1	2	—	—	Beige
A12-19777-003	N.C. (opens @ 70–84 psi [482–579 kPa])	—	0	1	—	—	Black
A12-19777-005	N.C. (opens @ 70–84 psi [482–579 kPa])	N.O.* (closes @ 65–75 psi [448–517 kPa])	0	2	0	1	Black
A12-19777-006	N.C. (opens @ 70–84 psi [482–579 kPa])	N.C. (opens @ 70–84 psi [482–579 kPa])	0	2	0	1	Black
A12-19777-010	N.C. (opens @ 70–84 psi [482–579 kPa])	N.O. (closes @ 65–75 psi [448–517 kPa])	0	2	0	1	Black
A12-19777-011	N.C. (opens @ 70–84 psi [482–579 kPa])	N.C. (opens @ 70–84 psi [482–579 kPa])	0	2	0	1	Black
A12-19777-012	N.C. (opens @ 70–84 psi [482–579 kPa])	N.C. (opens @ 70–84 psi [482–579 kPa])	1	2	0	1	Beige
A12-19777-013	N.C. (opens @ 70–84 psi [482–579 kPa])	—	0	2	—	—	Black
A12-19777-014	N.O. (closes @ 2–5 psi [14–34 kPa])	N.O. (closes @ 65–75 psi [448–517 kPa])	0	2	0	1	Black
A12-19777-015	—	N.O. (closes @ 80–94 psi [551–648 kPa])	—	—	0	1	Black
A12-19777-016	—	N.O. (closes @ 65–75 psi [448–517 kPa])	—	—	0	1	Black
A12-19777-017	N.O. (closes @ 2–5 psi [14–34 kPa])	N.O. (closes @ 2–5 psi [14–34 kPa])	0	2	0	1	Black

* N.C. is Normally Closed, N.O. is Normally Open

Table 13, Pressure Switch Module "B" Configurations

Troubleshooting

Pressure Switch Module "B", Pressure Switch 1 (all with normally closed pressure switch 1)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if switch opens at proper pressure	Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Disconnect one of the SW1 ports on the face of the module and connect the test apparatus to the SW1 port. See **Fig. 1**. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) above the maximum opening pressure to the SW1 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (482–579 kPa), then apply 89 psi (613 kPa) to the SW1 port. This should cause switch 1 to open.	Resistance Check: Measured between pin A and B (switch side).	Greater than 10,000 ohms. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not open within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.
Test if switch closes at proper pressure	Using the same apparatus as in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW1 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) below the minimum opening pressure to the SW1 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (482–579 kPa), then apply 65 psi (448 kPa) to the SW1 port. This should cause switch 1 to close.	Resistance Check: Measured between pins A and B (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 10,000 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.

Table 14, Pressure Switch Module "B", Pressure Switch 1 (N.C.)

Pressure Switch Module "B", Pressure Switch 1 (all with normally open pressure switch 1)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if switch opens at proper pressure	Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected.	Resistance Check: Measured between pin A and B (switch side).	Greater than 10,000 ohms. NOTE: If the meter reads less than 1 ohm, then the pressure switch is stuck closed, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.
Test if switch closes at proper pressure	Disconnect one of the SW1 ports on the face of the module and connect a regulated air supply setup to the SW1 port. See **Fig. 1**. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) above the maximum closing pressure to the SW1 port by adjusting the pressure regulator. For example, if the closing pressure is 2–5 psi(14–34 kPa), then apply 10 psi (69 kPa) to the SW1 port. This should cause switch 1 to close.	Resistance Check: Measured between pins A and B (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 10,000 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.

Table 15, Pressure Switch Module "B", Pressure Switch 1 (N.O.)

Troubleshooting

Pressure Switch Module "B", Pressure Switch 2 (all with normally closed pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if switch opens at proper pressure	Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Disconnect one of the SW2 ports on the face of the module and connect the test apparatus to the SW2 port. See **Fig. 1**. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) above the maximum opening pressure to the SW2 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (482–579 kPa), then apply 89 psi (613 kPa) to the SW2 port. This should cause switch 2 to open.	Resistance Check: Measured between pin C and D (switch side).	Greater than 10,000 ohms. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not opening within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.
Test if switch closes at proper pressure	Using the same apparatus as in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW2 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) below the minimum opening pressure to the SW2 port by adjusting the pressure regulator. For example, if the opening pressure is 70–84 psi (482–579 kPa), then apply 65 psi (448 kPa) to the SW2 port. This should cause switch 2 to close.	Resistance Check: Measured between pins C and D (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 10,000 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.

Table 16, Pressure Switch Module "B", Pressure Switch 2 (N.C.)

Pressure Switch Module "B", Pressure Switch 2 (all with normally open pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if switch opens at proper pressure	Key OFF, engine OFF. Drain air tanks. Pressure switch "B" 4-way connector disconnected. Do the following for all N.O. SW2 modules, except A12-19777-012 (for A12-19777-012, apply no pressure to the SW2 port): Disconnect one of the SW2 ports on the face of the module and connect a regulated air supply setup to the SW2 port. See **Fig. 1**. Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) below the minimum closing pressure to the SW2 port by adjusting the pressure regulator. For example, if the closing pressure is 65–75 psi (448–517 kPa), then apply 60 psi (413 kPa) to the SW2 port. This should cause switch 2 to open.	Resistance Check: Measured between pin C and D (switch side).	Greater than 10,000 ohms. NOTE: If the meter reads less than 1 ohm, then the pressure switch is not open within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.

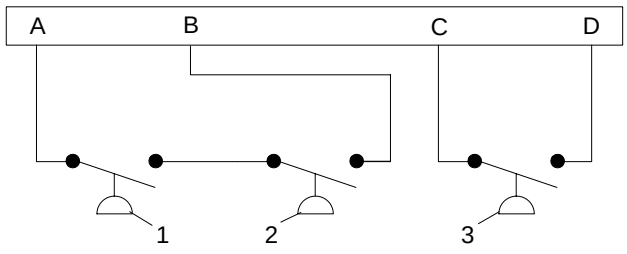
Troubleshooting

Pressure Switch Module "B", Pressure Switch 2 (all with normally open pressure switch 2)				
Test	**Conditions**	**Test Point**	**Good Result**	**If Test Fails:**
Test if switch closes at proper pressure	Using the same apparatus as in the previous test, close valve "A", then back the regulator off and bleed off all pressure to the SW2 port using valve "B". Close valve "A" and valve "B" of the test apparatus. Back off the regulator screw so that the downstream pressure is zero. Connect shop air to the test apparatus. Open valve "A". Apply 5 psi (34 kPa) above the maximum closing pressure to the SW2 port by adjusting the pressure regulator. For example, if the opening pressure is 65–75 psi (448–517 kPa), then apply 80 psi (551 kPa) to the SW2 port. This should cause switch 2 to close.	Resistance Check: Measured between pins C and D (switch side).	Less than 1 ohm. NOTE: If the meter reads greater than 10,000 ohms, then the pressure switch is not closing within the proper pressure range, and is therefore faulty.	Pressure switch "B" is faulty. Replace it.

Table 17, Pressure Switch Module "B", Pressure Switch 2 (N.O.)

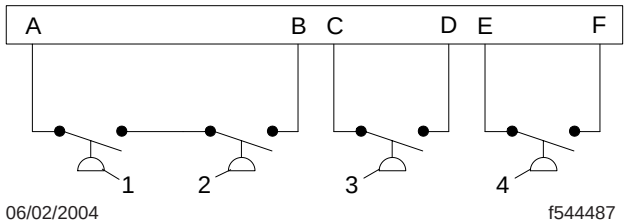
Refer to the following figures for electrical schematics for internal components of individual air management unit (AMU) modules.

- See **Fig. 1** for pressure switch "A" with three pressure switches (p/n A12-19776-000).
- See **Fig. 2** for pressure switch "A" with four pressure switches (p/n A12-19776-001).
- See **Fig. 3** for pressure switch "B" wiring (p/n A12-19777-001, 003, 013).
- See **Fig. 4** for pressure switch "B" wiring (p/n A12-19777-006, 011, 012).
- See **Fig. 5** for pressure switch "B" wiring (p/n A12-19777-015, 016).
- See **Fig. 6** for pressure switch "B" wiring (p/n A12-19777-005, 010).
- See **Fig. 7** for pressure switch "B" wiring (p/n A12-19777-014, 017).
- See **Fig. 8** for solenoid module wiring.



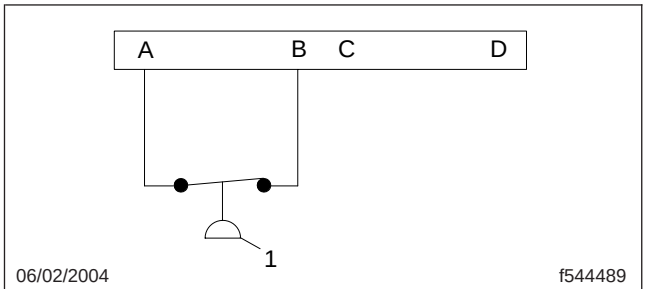
NOTE: A–D correspond to pins on electrical connector.
1. Low Air Warning (secondary)
2. Low Air Warning (primary)
3. Application Air Warning (stop lamp)

Fig. 1, Pressure Switch Module "A" for Air Brake Systems (p/n A12-19776-000)



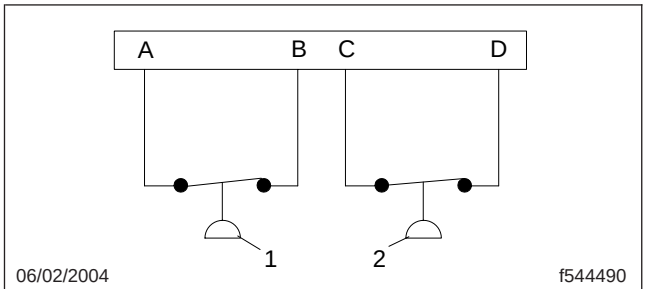
NOTE: A–F correspond to pins on electrical connector.
1. Low Air Warning (secondary)
2. Low Air Warning (primary)
3. Application Air (stop lamp)
4. Optional Secondary (engine fan)

Fig. 2, Pressure Switch Module "A" for Air Brake Systems (p/n A12-19776-001)



NOTE: A–D correspond to pins on electrical connector.
1. Park/Auxiliary #1

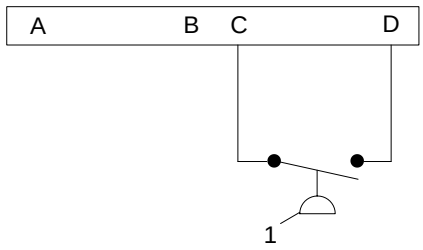
Fig. 3, Pressure Switch Module "B" (p/n A12-19777-001, 003, 013)



NOTE: A–D correspond to pins on electrical connector.
1. Park/Auxiliary #1
2. Park/Auxiliary #2

Fig. 4, Pressure Switch Module "B" (p/n A12-19777-006, 011, 012)

Specifications

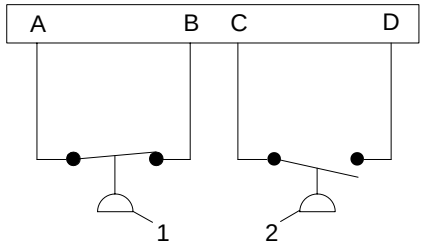


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NOTE: A–D correspond to pins on electrical connector.

1. Park/Auxiliary #2

Fig. 5, Pressure Switch Module "B" (p/n A12-19777-015, 016)

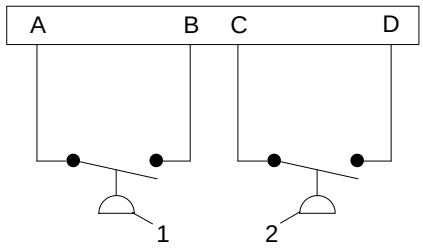


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NOTE: A–D correspond to pins on electrical connector.

1. Park/Auxiliary #1
2. Park/Auxiliary #2

Fig. 6, Pressure Switch Module "B" (p/n A12-19777-005, 010)

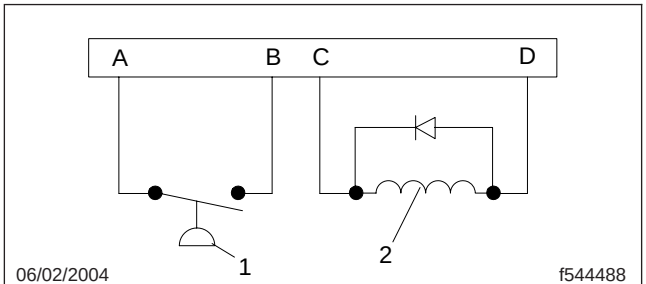


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NOTE: A–D correspond to pins on electrical connector.

1. Park/Auxiliary #1
2. Park/Auxiliary #2

Fig. 7, Pressure Switch Module "B" (p/n A12-19777-014, 017)



06/02/2004 f544488

NOTE: A–D correspond to pins on electrical connector.

1. Pressure Switch (confirms solenoid activation)
2. Solenoid Coil

Fig. 8, Solenoid Valve Module (p/n A12-19779-000 thru 009)

General Information

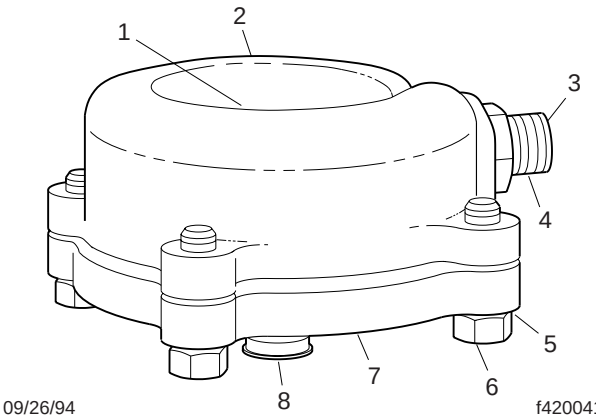
The DV-2 automatic reservoir drain valve automatically ejects moisture and contaminants from the reservoir in which it is connected. It operates automatically and requires no manual assistance or control lines from other sources.

The automatic reservoir drain valve has a die-cast aluminum body and cover and is nomally mounted either in the bottom of the reservoir using the top port of the drain valve, or in the end of the reservoir using the side port of the valve. See **Fig. 1**.

The DV-2 is also available with a heater and thermostat cast into the cover for vehicles operated in subfreezing temperatures. See **Fig. 2**. A 1/4-inch male pipe adaptor is supplied with all DV-2 drain valves; end drain and bottom drain, both standard and heated. This adaptor should be installed directly into the valve.

With no pressure in the system, the drain valve's inlet and exhaust valves are closed. See **Fig. 3**. Upon charging the system, a slight pressure opens the inlet valve which permits air and contaminants to collect in the sump. See **Fig. 4**. 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. 5**. When the reservoir 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. 6**.

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.



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, Standard DV-2 Valve

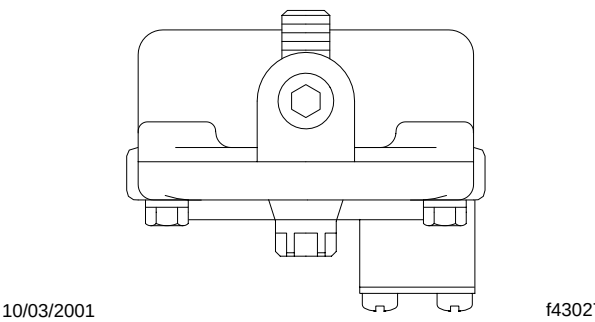


Fig. 2, DV-2 Valve with Heater/Thermostat

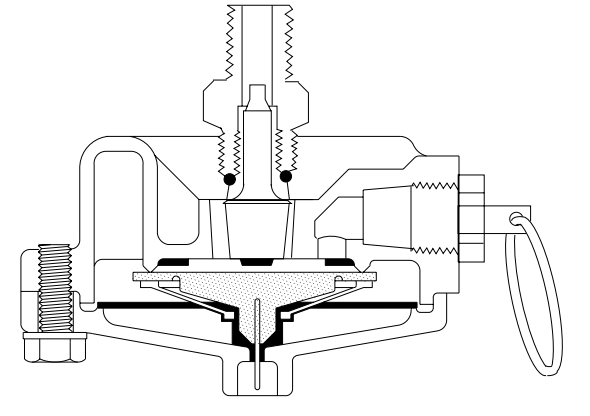


Fig. 3, No System Pressure

General Information

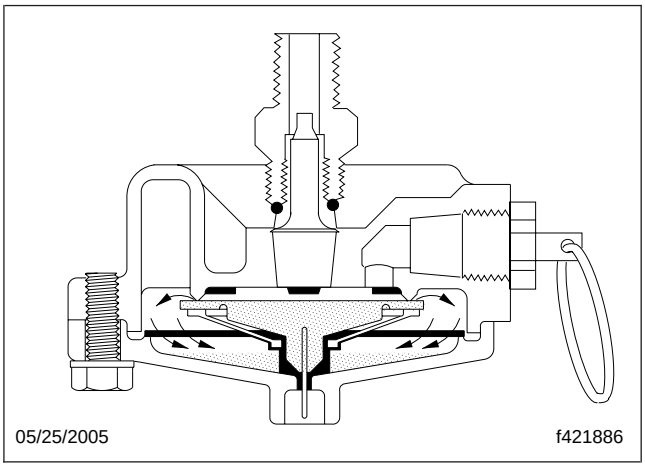


Fig. 4, Start of System Pressure Charging

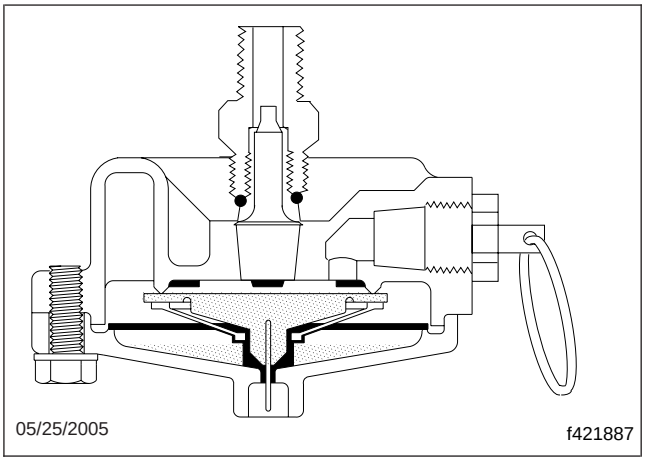


Fig. 5, System Pressure Rising

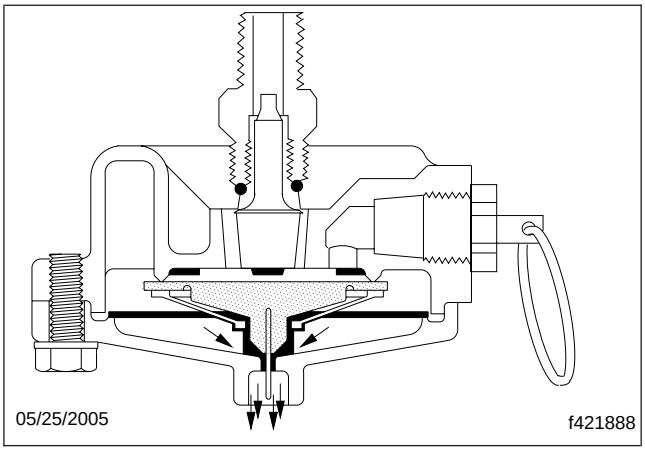


Fig. 6, Exhaust Cycle

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions:

- The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements in order to eliminate the possibility of component failure, used reservoirs must not be used as replacements.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured, in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures, note and be guided by the warning tags on such units.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

⚠ 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, replace it following the instructions in **Subject 120**.

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 it following the instructions 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.

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.
3. If a DV-2 with heater/thermostat is installed, disconnect the heater wire from the valve.
4. Remove the drain valve assembly from the end of the wet tank air reservoir.

Installation

IMPORTANT: When installing a DV-2 drain valve equipped with a heater and thermostat, the 14-gauge lead wire on the valve should be connected to the ON position of the engine control or ignition switch. Use an 8 amp fuse for one valve, a 15 amp fuse for two valves, and a 20 amp fuse for three valves. All electrical connections must be waterproof.

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 if solvents were used during cleaning.
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. If installing a DV-2 with heater/thermostat, connect the heater wire.
4. Close the drain cocks to the supply and service reservoirs. Start the vehicle engine to pressurize the air system.
5. Leak test the drain valve following the instructions in **Subject 110**.
6. Remove the chocks from the tires.

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.

NOTE: For a cutaway view of the standard DV–2 valve, see **Fig. 1**.

Disassembly

1. Remove the drain valve, following the instructions in **Subject 120**.
2. Remove the four capscrews that hold the valve cover to the valve body.
3. Remove the valve cover and sealing ring.

NOTE: For vehicles equipped with the DV-2 with heater/thermostat, the heater and thermostat are not serviceable. See **Fig. 2**. If the heater or thermostat has failed, the entire cover must be replaced. Do not remove the thermostat cover plate. It is moisture-sealed and removal could result in early thermostat failure.

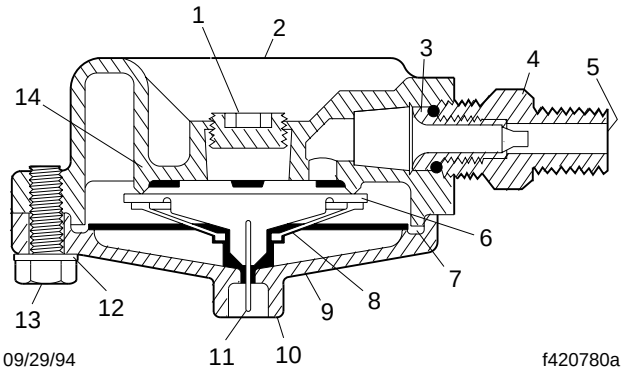
4. Remove the valve guide, and the inlet and exhaust valve from the valve body.
5. If equipped, remove the adaptor and filter assembly, filter retainer, and filter.
6. Remove the hexhead nipple from the valve body.

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 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.



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, Standard DV-2 Valve (cutaway view)

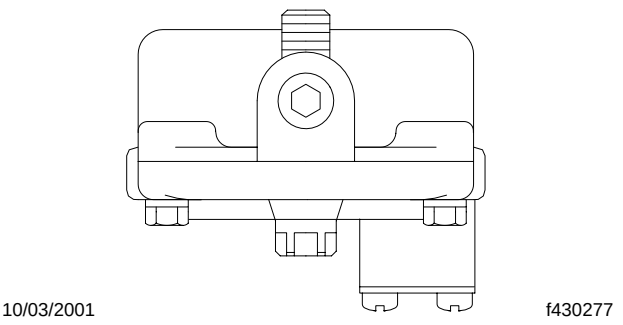


Fig. 2, DV-2 Valve with Heater/Thermostat

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. Discard the filter screen, if present.

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.

Valve Disassembly, Cleaning and Inspection, and Assembly

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 72 to 96 lbf·in (820 to 1080 N·cm).
5. Install the hexhead nipple onto the valve body, and tighten it 48 to 72 lbf·in (540 to 820 N·cm).
6. Install the drain valve on the wet tank, following the instructions in **Subject 120**.

Specifications

Torque Values	
Description	**Torque: lbf·in (N·cm)**
Valve Cover Capscrews	72–96 (820–1080)
Hexhead Nipple	48–72 (540–820)

Table 1, Torque Values

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 automatically maintains brake chamber pushrod stroke, which controls lining-to-drum clearance during operation.

Meritor automatic slack adjusters automatically adjust the clearance between the brake lining and the brake drum. When linings wear, this clearance increases and causes the chamber pushrod to move a greater distance to apply the brakes.

During operation, if the chamber stroke exceeds the design limit, the automatic slack adjuster will automatically adjust the pushrod's return stroke to control clearance between the lining and the drum and reset the stroke to the correct length. See **Fig. 1**.

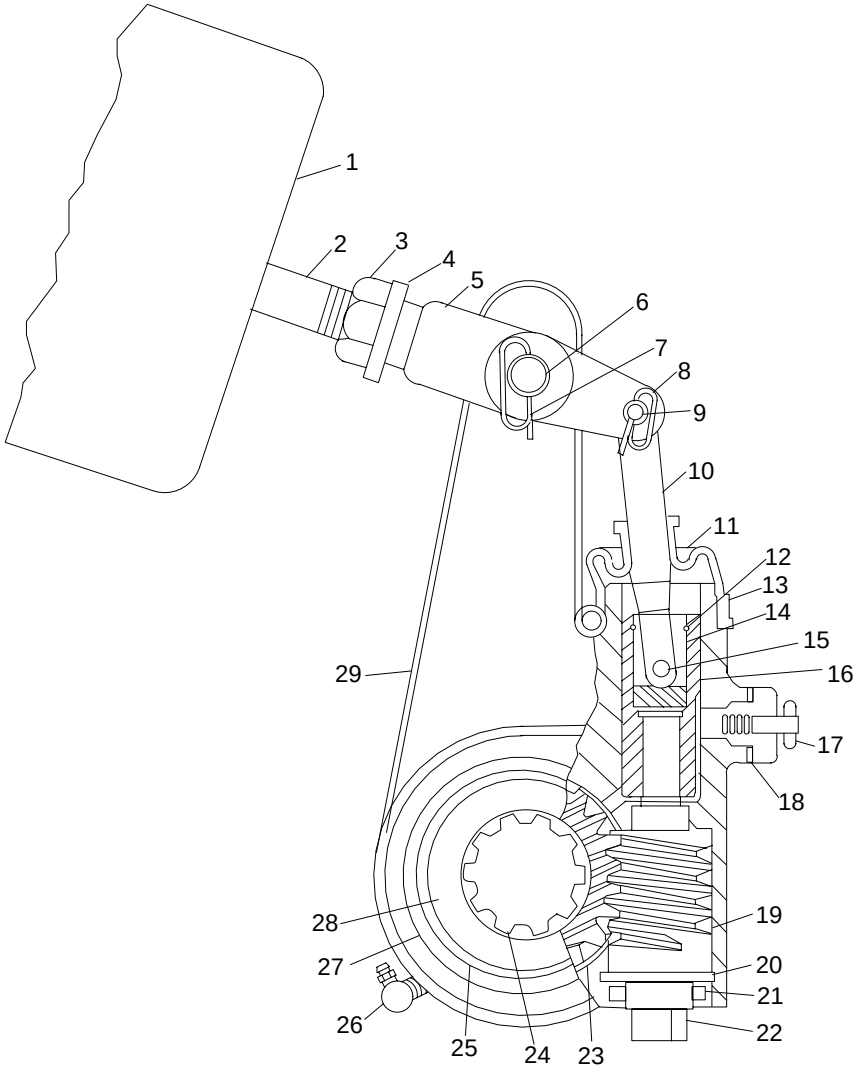
A pressed-in, sealed actuator boot is standard equipment on Meritor slack adjusters. The boot features a metal retaining ring with additional material that extends beyond the base of the retainer. The boot forms a seal once it is pressed into the slack adjuster body.

Meritor automatic slack adjusters, including the factory-installed slack adjusters on the Q Plus cam brakes, have a one-piece threaded clevis. See **Fig. 2**.

The one-piece threaded clevis:

- has a threaded hole for the pushrod;
- can be straight or offset;
- is used on all service replacement automatic slack adjusters.

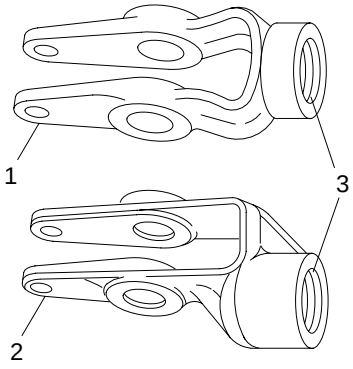
General Information



06/14/2000 f422134

1. Brake Air Chamber
2. Brake Chamber Pushrod
3. Clevis Jam Nut
4. Collar
5. Clevis
6. Large Clevis Pin
7. Large Clevis Pin Retainer Clip
8. Small Clevis Pin Retainer Clip
9. Small Clevis Pin
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Screw)
17. Pull-Pawl Assembly
18. Gasket
19. Worm
20. Worm Retaining Snap Ring
21. Worm Seal
22. Manual (Worm) Adjusting Nut
23. Gear-to-Body Seal
24. Camshaft Splines
25. Gear Retainer/Seal
26. Grease Fitting (if equipped)
27. Gear Thrustwasher
28. Gear
29. Slack Adjuster Arm

Fig. 1, Automatic Slack Adjuster (sectional view)



07/20/2000 f430163

1. Straight Clevis
2. Offset Clevis
3. Threads

Fig. 2, One-Piece Threaded Clevis Configurations

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 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 when replacing tubes or hoses 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

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**.

⚠ CAUTION

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.

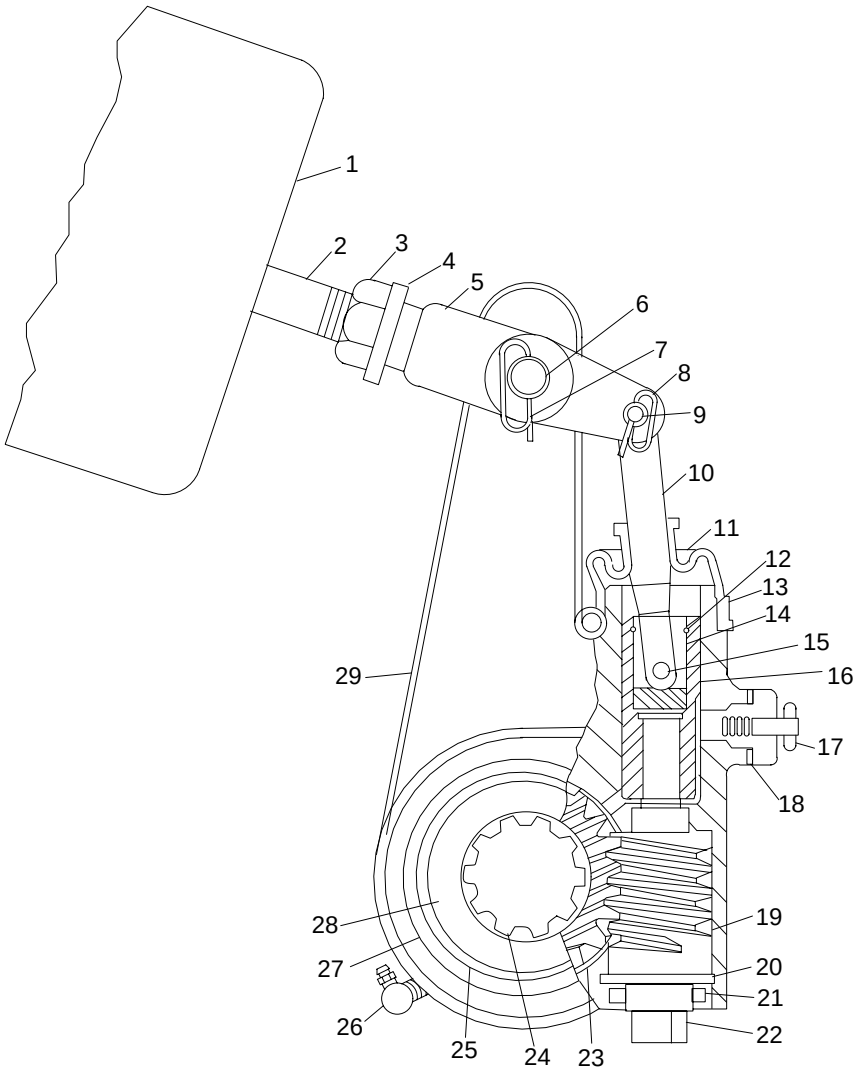
3. Coat the camshaft splines and the splines of the slack adjuster gear with Meritor 0-637, Meritor 0-695 (LX500 and MX500 only), Southwest SA 8249496, or an equivalent.
4. Apply the service brake several times. Make sure the return spring retracts the pushrod quickly and completely. Replace the return 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.

⚠ CAUTION

Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could

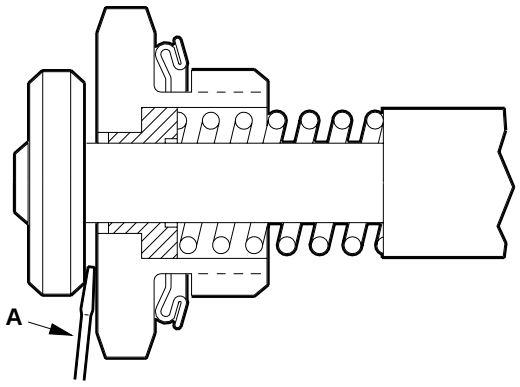
Slack Adjuster Removal and Installation



06/14/2000 f422134

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

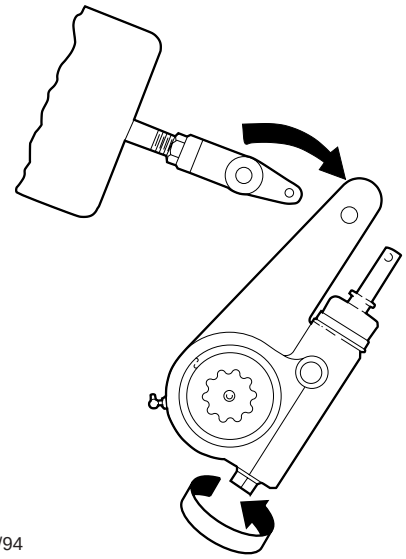
Fig. 1, Meritor Automatic Slack Adjuster



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A. Insert a screwdriver here to pry the pull-pawl button out about 1/32 inch (0.8 mm).

Fig. 2, Pull-Pawl Assembly



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Turn the manual adjusting nut clockwise.

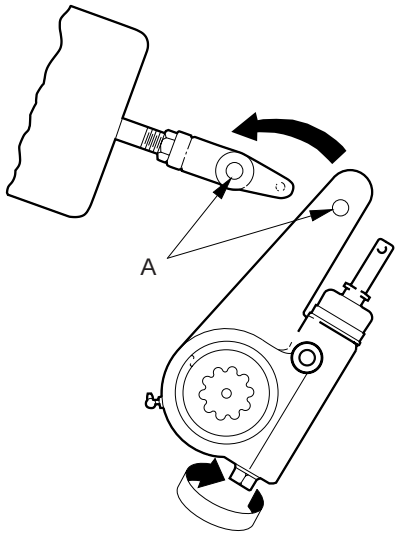
Fig. 3, Slack Adjuster Removal

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:

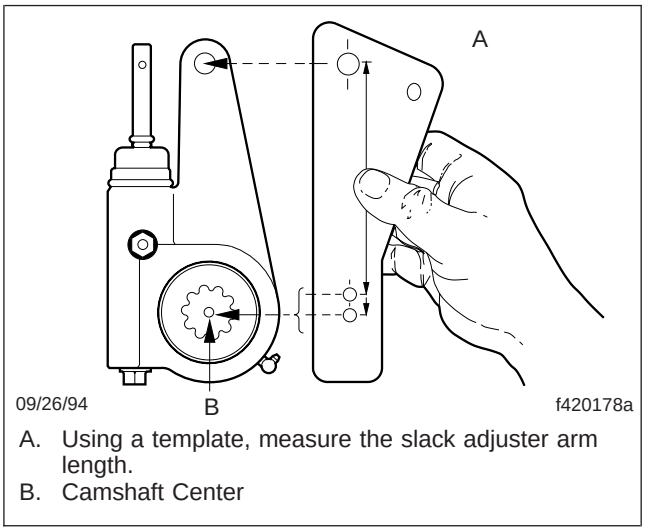
7.1 Using an installation template, measure the old and new slack adjusters. Measure from the center of the large clevis-pin hole to the center of the camshaft opening. See **Fig. 5**.

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.

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.

Slack Adjuster Removal and Installation



A. Using a template, measure the slack adjuster arm length.
B. Camshaft Center

Fig. 5, Slack Adjuster Measurement

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).

⚠ CAUTION

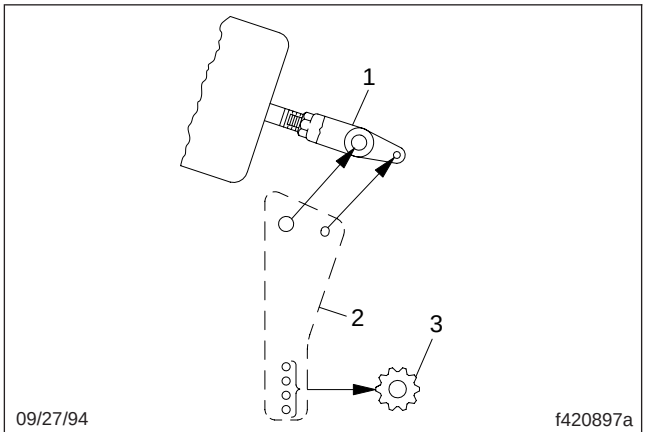
Disengage the pull-pawl before turning the manual adjusting nut. Failure to do so could damage the pull-pawl teeth. The brake clearance will not automatically adjust if the pull-pawl is damaged.

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.

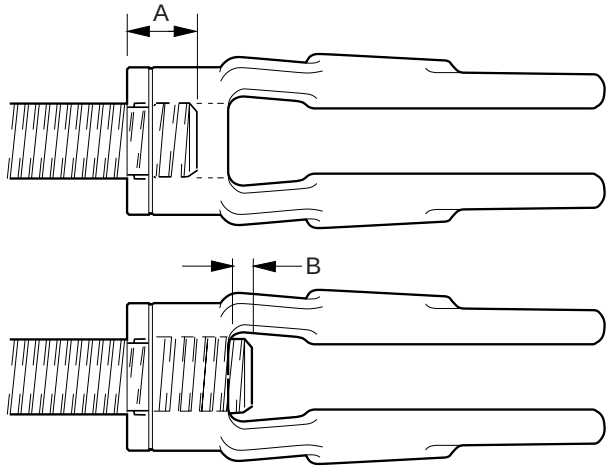
If it is not, loosen the clevis jam nut, and turn the clevis adjusting nut to adjust the position of the clevis on the pushrod until the small clevis hole is completely visible.

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.

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.



A. Minimum 1/2 inch (13 mm).
B. Maximum 1/8 inch (3 mm).

Fig. 7, Check Pushrod Engagement

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).

⚠ CAUTION

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.

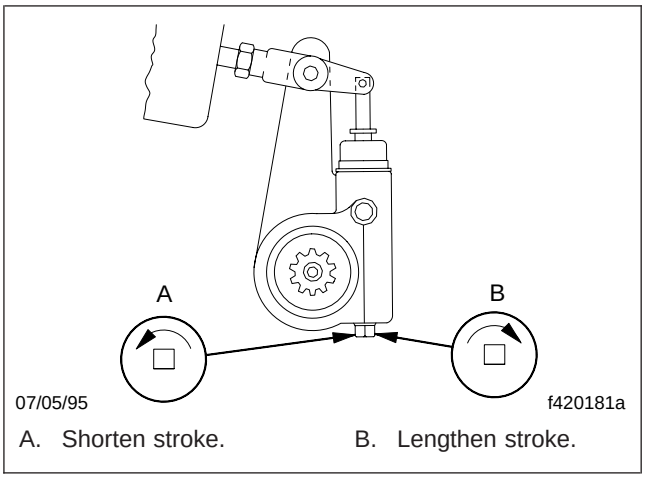
3. Using a screwdriver, pry the pull-pawl button out at least 1/32 inch (0.8 mm) to disengage the pull-pawl teeth from the slack adjuster actuator. See **Fig. 2**. Wedge the screwdriver in place. The pull-pawl will need to be disengaged until the brake adjustment is complete.

Slack Adjuster Removal and Installation

NOTE: When the screwdriver is removed, the pull-pawl will engage automatically.

4. Using the manual adjusting nut on the slack adjuster, adjust the brake chamber stroke (coarse adjustment), as follows. See **Fig. 8**.

   4.1 Turn the adjusting nut counterclockwise until the brake linings touch the brake drum.



A. Shorten stroke. B. Lengthen stroke.

Fig. 8, Adjusting the Stroke

   4.2 Then, turn the adjusting nut clockwise 1/2 turn.

5. Measure and adjust the free-stroke, as follows.

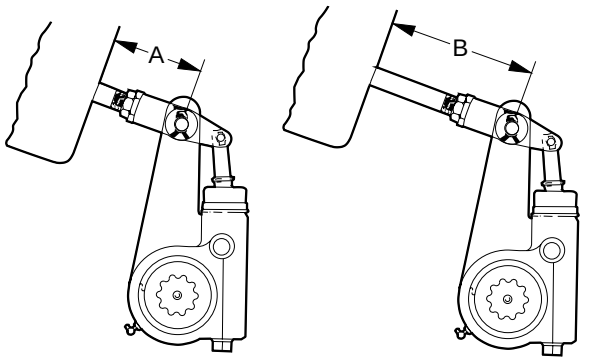
   5.1 With the brakes released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. Record this measurement as dimension A. See **Fig. 9**.

   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.



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. Measure and adjust the applied chamber stroke (fine adjustment), as follows.

   6.1 If system pressure is not already at 100 psi (689 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**.

   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.

CAUTION

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, Subject 150**.

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 (550–620 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

Specified Lubricant	
Lubricant Type	**Temperature**
Amoco Super Permalube No. 2	–40°F (–40°C) or Above
Aralub 3837	
Citco Premium Lithium EP No. 2	
Exxon Ronex MP No. 2	
Kendall L–427 Super Blu No. 2	
Mobilith AW No. 1	
Meritor 0–616–A	
Meritor 0–692	
Shell Darina No. 1	
Sohio Factran EP No. 2	
Texaco Hytherm EP No. 1	
Texaco Thermotex EP No. 1	
Tribolube 12, Grade 1	
Mobil 28	Below –40°F (–40°C)
Meritor 0–645	

Table 1, Specified Lubricant

Slack Adjuster Arm Length	
Arm Length: inch (mm)	**Chamber Size**
5 (127)	9, 12, 16, 20, 24, 30
5-1/2 (140)	9, 12, 16, 20, 24, 30
6 (152)	24, 30
6-1/2 (165)	30

Table 2, Slack Adjuster Arm Length

Maximum Adjusted Brake Chamber Stroke	
Chamber Size	**Stroke: inch (mm)**
9	Less than 1-1/2 (38)
12	Less than 1-1/2 (38)
16	Less than 1-3/4 (44)
20	Less than 1-3/4 (44)
24	Less than 1-7/8 (48)
24 Long Stroke	Less than 2 (51)
30	Less than 2 (51)

Table 3, Maximum Adjusted Brake Chamber Stroke

Chamber Pushrod Thread Size	
Chamber Size	**Pushrod Thread Size**
9, 12, 16	1/2–20
20, 24, 30, 36	5/8–18

Table 4, Chamber Pushrod Thread Size

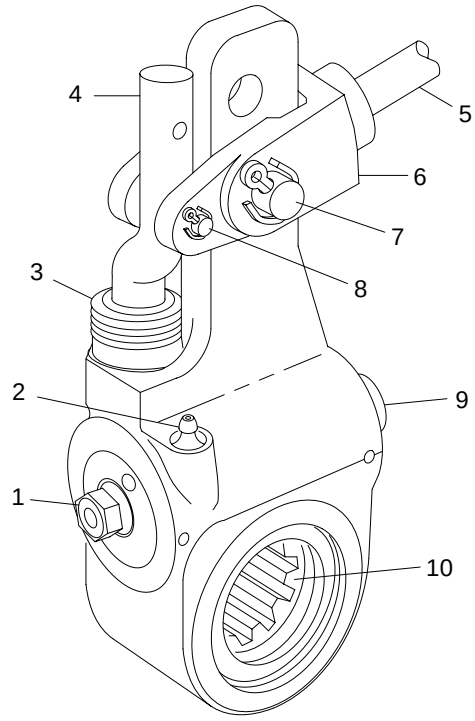
General Information

The Gunite 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 drum.
- As an automatic slack adjuster, it maintains the lining-to-drum clearance needed for proper brake chamber pushrod stroke.

The slack adjuster is installed between the brake chamber pushrod and the brake camshaft. A clevis is either welded to the brake chamber pushrod or screwed on. See **Fig. 1**. The clevis is connected to the top of the slack adjuster. 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 pushrod 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 pushrod. 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 Pushrod
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

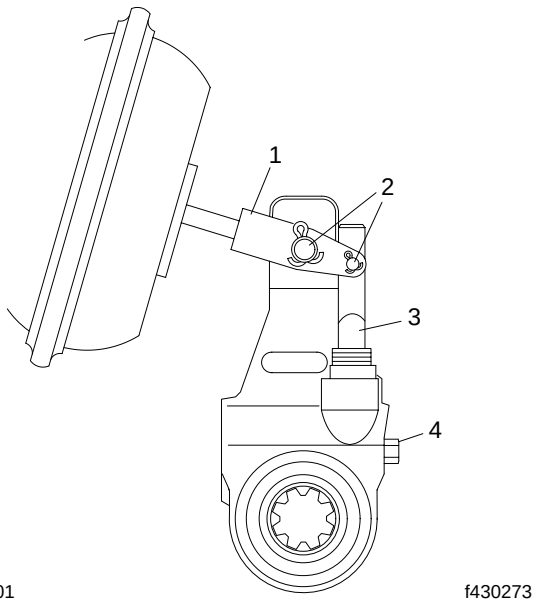
When working on or around a vehicle, observe the following precautions:

- 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 you 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

IMPORTANT: This automatic slack adjuster cannot be rebuilt. If it is damaged or inoperative, replace the unit.

Each factory-installed brake chamber has a clevis welded onto the pushrod. See **Fig. 1**. On a replacement brake chamber, the clevis is threaded onto the pushrod, and has a jam nut installed. See **Fig. 2**.

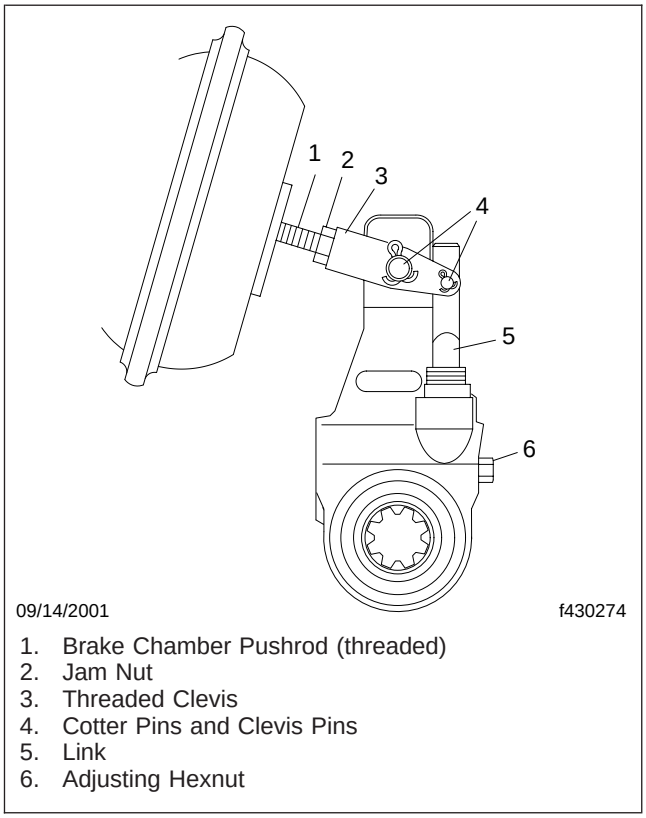


1. Brake Chamber Pushrod and Clevis Assembly
2. Cotter Pins and Clevis Pins
3. Link
4. Adjusting Hexnut

Fig. 1, Slack Adjuster (attached to welded clevis)

Removal

1. With the vehicle parked on a level surface, chock the tires. If you are removing a rear slack adjuster, 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.
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.



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)

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. Coat the camshaft splines, and the splines of the slack adjuster gear with an anticorrosion 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.

Slack Adjuster Removal and Installation

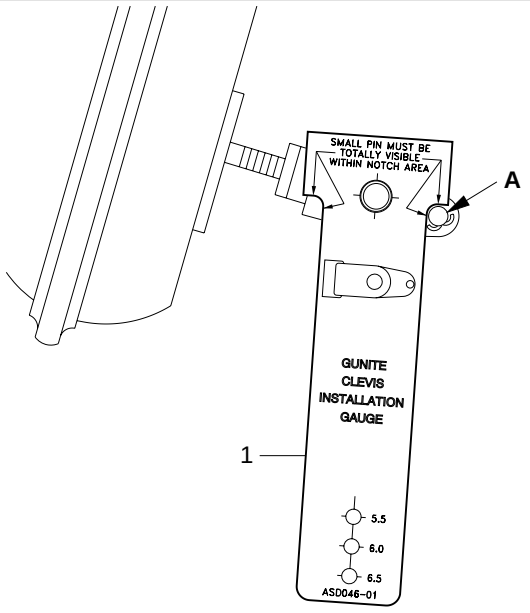
4. Install the clevis pins and cotter pins.

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.

5. If the pushrod has a threaded clevis, use the gauge supplied with a new slack adjuster to check the adjustment of the clevis, as follows. See **Fig. 3**.



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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

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, as follows.

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, as follows.

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.

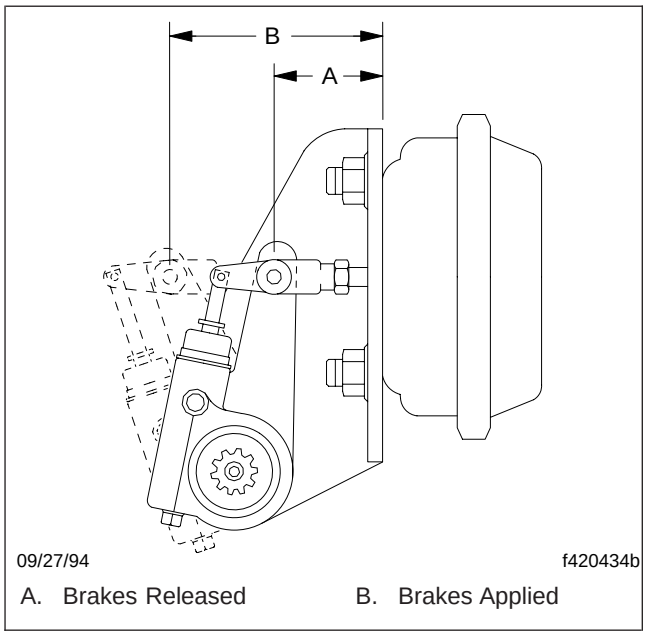


Fig. 4, Measuring Brake Chamber Stroke

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.

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 (550–620 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

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

Standard Clamp-Type Brake Stroke Specifications			
Type	**Outside Diameter: inches (mm)**	**Rated Stroke: inches (mm)**	**Maximum Stroke at Which Brakes Must be Readjusted: inches (mm)**
9	5–1/4 (133)	1–3/4 (44)	1–3/8 (46)
12	5–11/16 (144)	1–3/4 (44)	1–3/8 (46)
16	6–3/8 (161)	2–1/4 (57)	1–3/4 (44)
20	6– 25/32 (172)	2–1/4 (57)	1–3/4 (44)
24	7–7/32 (183)	2–1/4 (57)	1–3/4 (44)
30	8– 3/32 (205)	2–1/2 (63)	2 (51)
36*	9–(228)	3 (76)	2–1/4 (57)

* If type 36 chamber is used, slack length should be less than 6".

Table 2, Standard Clamp-Type Brake Chamber Stroke Specifications

Long Stroke Clamp-Type Brake Chamber Data			
Type	**Outside Diameter: inches (mm)**	**Rated Stroke: inches (mm)**	**Maximum Stroke at Which Brakes Must be Readjusted: inches (mm)**
16	6–3/8 (161)	2–1/2 (6)	2 (5)
20	6–25/32 (172)	2–1/2 (6)	2 (5)
24	7–7/32 (183)	2 (6)	2 (5)
24*	7– 7/32 (183)	3 (8)	2–1/2 (6)
30*	8–3/32 (20)	3 (8)	2–1/2 (6)

* Identified by square air port bosses.

Table 3, Long Stroke Clamp-Type Brake Chamber Data

General Information

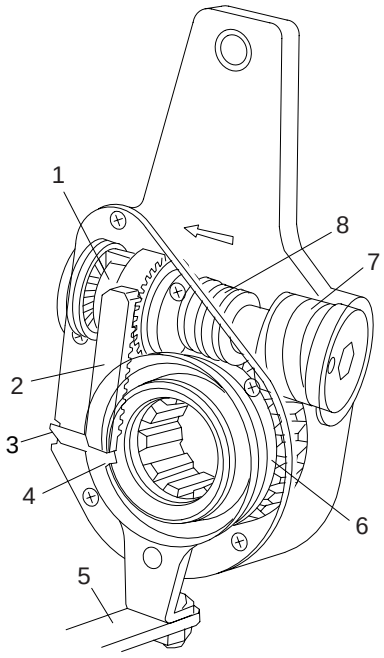
The Haldex automatic slack adjuster serves two main functions:

- 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.

When the brakes are applied, the slack adjuster rotates and moves the shoes into contact with the drum. The clearance notch corresponds to the normal lining-to-drum clearance. See **Fig. 1**. Different notches are available to meet the requirements of various vehicles and brake duty cycles. As the brake application continues, the rack moves upward and rotates the one-way clutch, which slips in this direction.

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 rotate the wormshaft through the locked cone clutch. The wormshaft then rotates the worm wheel and camshaft, adjusting the brakes.



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NOTE: Older slack adjusters may not have an installation indicator.

1. Clutch Assembly
2. Enclosed Rack
3. Installation Indicator (aligned with indicator notch)
4. Clearance Notch
5. Control Arm Anchor Bracket (design varies depending on the axle)
6. Worm Wheel
7. Coil Spring
8. Wormshaft

Fig. 1, Haldex 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 you 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.

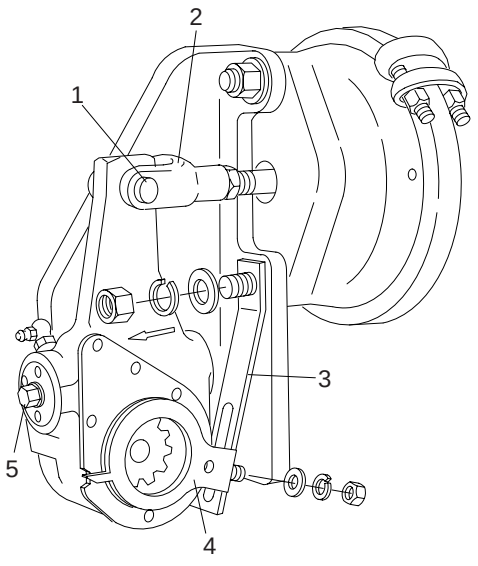
Slack Adjuster Removal and Installation

⚠ 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. With the vehicle parked on a level surface, set the parking brakes, and shut down the engine. Chock the 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.

⚠ CAUTION

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 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. Check that the brake-chamber pushrod is fully retracted.
2. Apply antiseize compound to the camshaft splines.

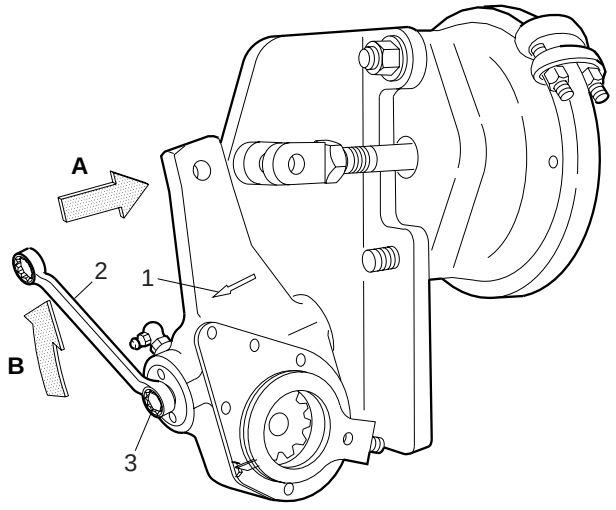
IMPORTANT: When correctly installed, the brake-chamber pushrod pushes in the direction of the arrow on the slack adjuster housing.

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 and Installation



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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 inch
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.

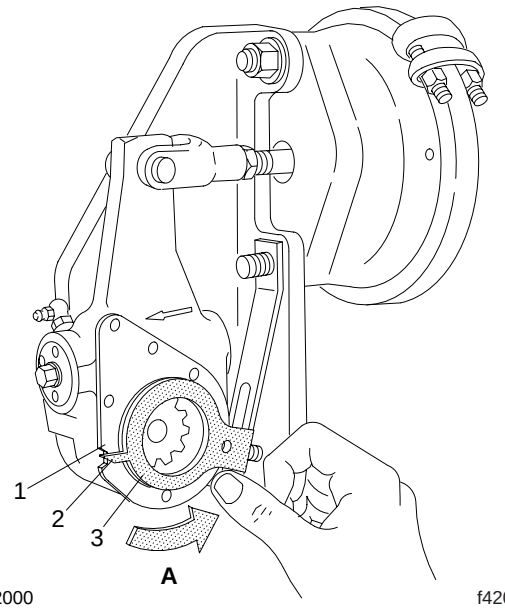
CAUTION

Never hammer the control arm. Hammering may damage the slack adjuster or camshaft splines.

7. Rotate the control arm away from the adjusting hexnut toward the brake chamber until it comes to a definite internal stop. Make sure the installation indicator is in the center of the indicator notch on the slack adjuster. See **Fig. 3**.

IMPORTANT: If the installation indicator is not aligned with the indicator notch, the brakes will be too tight.

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.



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NOTE: The installation indicator must be aligned with the indicator notch.

A. Rotate the control arm counterclockwise until it stops.

1. Indicator Notch
2. Installation Indicator
3. Control Arm

Fig. 3, Aligning the Control Arm

8. Install the control-arm anchor bracket, as follows. See **Fig. 1**.
   - 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.

Slack Adjuster Removal and Installation

⚠ 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. 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.

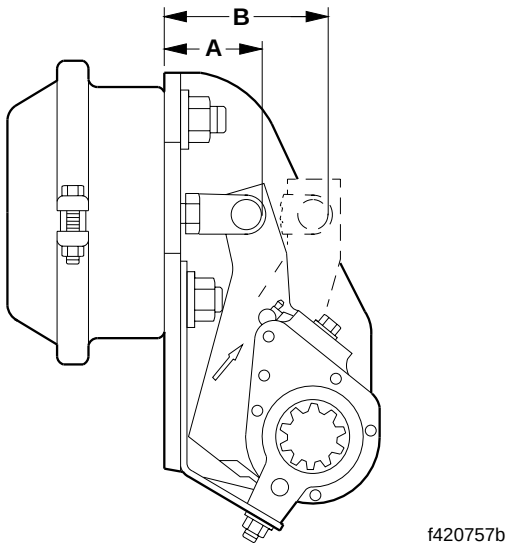
   5.3 Subtract measurement A from measurement B to determine the free stroke. For new brake installations, the free stroke should be 5/8 to 3/4 inch (16 to 19 mm). For in-service brakes, the free stroke should be 1/2 to 5/8 inch (13 to 16 mm). If it is not in this range, refer to **Troubleshooting 300**.

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 (551 kPa) brake application. Measure the distance from the bottom of the brake chamber to the far

Slack Adjuster Removal and Installation



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

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**.

6.4 If the stroke varies or is greater than the maximum allowed length, refer to **Troubleshooting 300**.

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.

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.

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

Troubleshooting Tables

Problem—Tight or Dragging Brakes

Problem—Tight or Dragging Brakes	
Possible Cause	**Remedy**
Improperly positioned control arm anchor bracket.	See instructions in **Subject 110**.
System air pressure too low to fully release spring brake.	Check that the air governor cuts out at the recommended setting.
Loose brake linings.	Repair or replace the linings as required.
Pushrod binds on chamber housing.	Check for correct alignment and correct chamber mounting bracket. Adjust or replace parts as needed.
Air supply does not exhaust completely.	Test the air system valves for leakage and correct operation.
Out-of-round brake drums.	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, see the brake manufacturer's service manual.
Extreme differences in lining-to-drum clearances between shoes on same wheel.	Check for proper operation of the brake mechanism. Lubricate or overhaul as needed.
Out-of-adjustment wheel bearings.	Adjust the wheel bearings, or replace them if damaged. For instructions see **Section 33.01** for front axles and **Section 35.00** for rear axles.
Broken brake shoe return spring.	Replace the brake shoe return spring.

Problem— Brake Chamber Pushrod Travel Is Excessive

Problem— Brake Chamber Pushrod Travel Is Excessive	
Possible Cause	**Remedy**
Loose, broken, or bent control arm anchor bracket.	Tighten or replace the anchor bracket as required.
Worn camshaft bushings.	Replace the worn camshaft bushings.
Camshaft binds.	Lubricate the camshaft or overhaul the brake mechanism as needed.
Loose brake chamber mounting.	Tighten the brake chamber mounting fasteners.
Worn slack adjuster clutch assembly.	Replace the slack adjuster.

Specifications

Stroke Specifications		
Chamber Size	**Maximum Applied Stroke: inch (mm)**	**Desired Free Stroke: inch (mm)**
12	1-3/8 (35)	3/8–1/2 (10–13)
16 and 20	1-3/4 (44)	
24	1-3/4 (44)	3/8–5/8 (10–16)*
	2 to 2-1/2 (51 to 64) Extended Stroke	
	2-1/2 to 3 (64 to 76) Extended Stroke	
30	2 (51)	
	2-1/2 (64) Long Stroke	

* Without drag.

Table 1, Stroke Specifications

General Information

This section is a general guide to locating problems in the air brake system. The fixes given here supplement, but do not replace, detailed information found elsewhere.

This section does not cover ABS components. See **Section 42.00** for troubleshooting air brake ABS.

Air manifold unit (AMU) troubleshooting information is available in **Section 42.09**.

Do the following before you try to find an air brake system problem.

- 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 pre- and post-trip inspections and maintenance chapter of the *S2 Chassis Operator's Manual.*
- Be sure that all relay valves are operating.
- Check the operation of the brake chambers.
- Examine all tubing for kinks, dents, and other damage. Replace damaged tubing.

IMPORTANT: The front brake lines flex continuously in vehicle operation. They require the following special inspection, near where the air brake lines connect to the front air brake chambers.

1. This inspection requires two people, one in the driver's seat and another to inspect both front brake line connections at the wheels.

   Prepare the vehicle as follows:

   - air pressure at 80 to 90 psi (550 to 620 kPa)
   - parking brake released
   - engine idling
   - rear wheels chocked
   - brake pedal held down

2. Turn the wheels to full lock in one direction, and inspect both air lines where they connect to the air chambers. Then, turn them to full lock in the other direction and inspect both lines again. If a hose is leaking, replace it.
3. Examine all hoses for cracks, drying out, overheating, and other damage. Replace damaged hoses.
4. Examine all air line fittings. Tighten loose connections; replace fittings that are damaged.
5. Examine leaking pipe connections for cracks or thread damage. Replace as needed. If there is no damage, tighten the fitting.

Safety Precautions

⚠ WARNING

Carefully follow the manufacturer's procedures while working on any air device. There are very strong mechanical springs and pneumatic pressure which can send parts flying with enough energy to cause severe personal injury or property damage.

Careful precautions must be followed whenever it is necessary to release pressure in the air brake system.

1. Chock the tires to prevent the vehicle from rolling accidentally when air is released from the brake system.
2. Do not disconnect pressurized hoses; they will whip as air escapes from the line. Drain the air system before disconnecting the air hoses.
3. When draining the air system, wear eye protection. Do not look into the air jets or let them point at another person: the air stream may blast dirt particles or sludge with great force. The compressed air acting alone can carry enough force to damage an eye or rupture an eardrum.
4. As air pressure is drained and the parking/emergency brakes apply, keep your hands away from the brake chamber pushrods and parking brake chambers. They 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.	Stay within the recommended maximum load limits.
Low air pressure in the brake system, about 60 psi (413 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. If the setting is incorrect replace the governor.
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 components.
Brake valve delivery pressure is below normal.	Replace the brake valve as necessary.
Worn or glazed brake linings.	Install new brake linings on the brake shoes on both sides of the axle.
Brakes need adjustment or lubrication.	Adjust and lubricate the brakes.
Automatic slack adjusters are not working.	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 brake cam has flipped over.	Replace the linings and the cam on both ends of the axle.
One or more of the brake drums is broken or cracked.	Replace faulty brake drums.
Wrong size brake linings were installed.	Replace the brake linings with the recommended size.
Wrong size brake chambers were fitted.	Replace the brake chambers with the recommended size. Be sure the brake chambers on each end of the axles are the same 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 chamber.	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.
Brake system components need lubrication.	Lubricate brake system components as necessary.
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.
The exhaust port of the brake foot valve or quick-release valve is plugged.	Clear the exhaust port of obstruction.

Troubleshooting

Problem—Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The brake foot valve or quick-release valve is not working.	Replace valves as necessary.
The camshaft and bushings are binding.	Clean and lubricate the camshaft bushings.
The brake shoe return spring is weak or broken.	Replace if necessary.

Problem—Service Brakes Do Not Apply or Apply Too Slowly

Problem—Service Brakes Do Not Apply or Apply Too Slowly	
Possible Cause	**Remedy**
Foundation brake assembly needs lubrication.	Lubricate the foundation brake assembly components.
There is insufficient air pressure in the brake system.	Check all parts of the air pressure system for leaks or faulty components.
The brake foot valve or relay valve is not working.	Repair or replace the brake foot valve or relay valve.
The camshaft bushings are binding.	Clean and lubricate the camshaft bushings.

Problem—Service Brakes and Parking Brakes Apply When the Parking Brake Release Knob is Pushed

Problem—Service Brakes and Parking Brakes Apply When the Park Brake Release Knob is Pushed	
Possible Cause	**Remedy**
The air delivery lines to the brake chamber are reversed.	Connect the brake chamber air lines properly.

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.	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.
The brake foot valve is not working.	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 minimized.
A broken power spring may be blocking the parking brake piston movement.	Replace the parking brake chamber.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
Adjustment of the brakes on one axle is uneven.	Adjust the brakes.
Brake system components need lubrication.	Lubricate brake system components as necessary.
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 clevis pin and camshaft bushings. Replace if necessary.
A brake spider is loose.	Tighten the mounting bolts or replace the brake spider.
A slack adjuster is damaged.	Replace the damaged slack adjuster.
The air chamber pushrods or slack adjusters are a different length.	Replace the components with the correct size and material.
The brake foot valve is not working.	Replace the brake foot valve.
There is a flat or dent on the S-head camshaft or on the cam roller(s).	Replace damaged components.
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.
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.
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 hub 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.
Grease has saturated the brake linings or the linings are glazed.	Install a new, matched set of brake linings. Clean, turn, or replace both brake drums on that axle.
The brake drum is out-of-round to unacceptable limits.	Turn or replace both the brake drums on that axle.

Troubleshooting

Problem—Uneven Service Brakes	
Possible Cause	**Remedy**
A service brake chamber diaphragm is leaking.	Tighten the clamp ring. If leakage persists, 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**.
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 quick-release valve or the foot valve.	Test the air system valves for leakage and operation.
Binding is occurring in the camshaft linkage.	Lubricate the camshaft linkage. Replace bent or broken parts.

Problem—Parking Brake Does Not Hold (park brake applied)

Problem—Parking Brake Does Not Hold (park brake applied)	
Possible Cause	**Remedy**
The brakes are improperly adjusted.	Adjust the brakes.
A power spring is broken.	Replace the parking/emergency brake chamber.
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 Parking Brake Mechanism

Problem—Dragging Brakes Due to 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.	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
The compressor is not working (can be excessive leakage from the compressor).	Replace the compressor.
The air reservoir drain cock has been left open.	Close the drain cock.
The air governor cutout setting is incorrect.	Check the setting with an accurate test gauge. If incorrect, replace the governor.
There is inadequate clearance at the compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
Carbon is building up in the compressor cylinder head or discharge line.	Remove the carbon or replace the compressor as necessary.
The compressor 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. If incorrect, replace the governor.
The air governor is not operating.	Replace the air governor.
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 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.	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 a factory-rebuilt or a new unit.
The air governor is leaking.	Replace the air governor.

Troubleshooting

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. If leaks persist, replace the diaphragm or assembly.
The brake foot valve or relay valve is leaking.	Repair or replace faulty components or assembly.
Service brake air line leaks.	Replace as necessary.

Problem—Compressor Knocks (continuously or intermittently)

Problem—Compressor Knocks (continuously or intermittently)	
Possible Cause	**Remedy**
There is a damaged or broken coupling or gear.	Replace components as necessary.
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 compressor.
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.	Replace the compressor.
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.

Problem—Frequent Compressor Cycling/Air Dryer Purge (Dash pressure gauges do not drop to cut-in pressure)

Problem—Frequent Compressor Cycling/Air Dryer Purge (Dash pressure gauges do not drop to cut-in pressure)	
Possible Cause	**Remedy**
A leak in the supply system. This would be characterized by frequent compressor cycling or dryer purging with no change in primary or secondary air pressure.	Repair leaks as necessary.

General Description

The Bendix PP–DC parking brake air valve is installed on vehicles with air 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. The valve uses air pressure from the air system (primary or secondary) with the higher pressure for the parking brakes. If the pressure drops below 20 to 30 psi (138 to 207 kPa) in both air systems, the brakes will automatically apply. The parking brakes will not apply 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; 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.

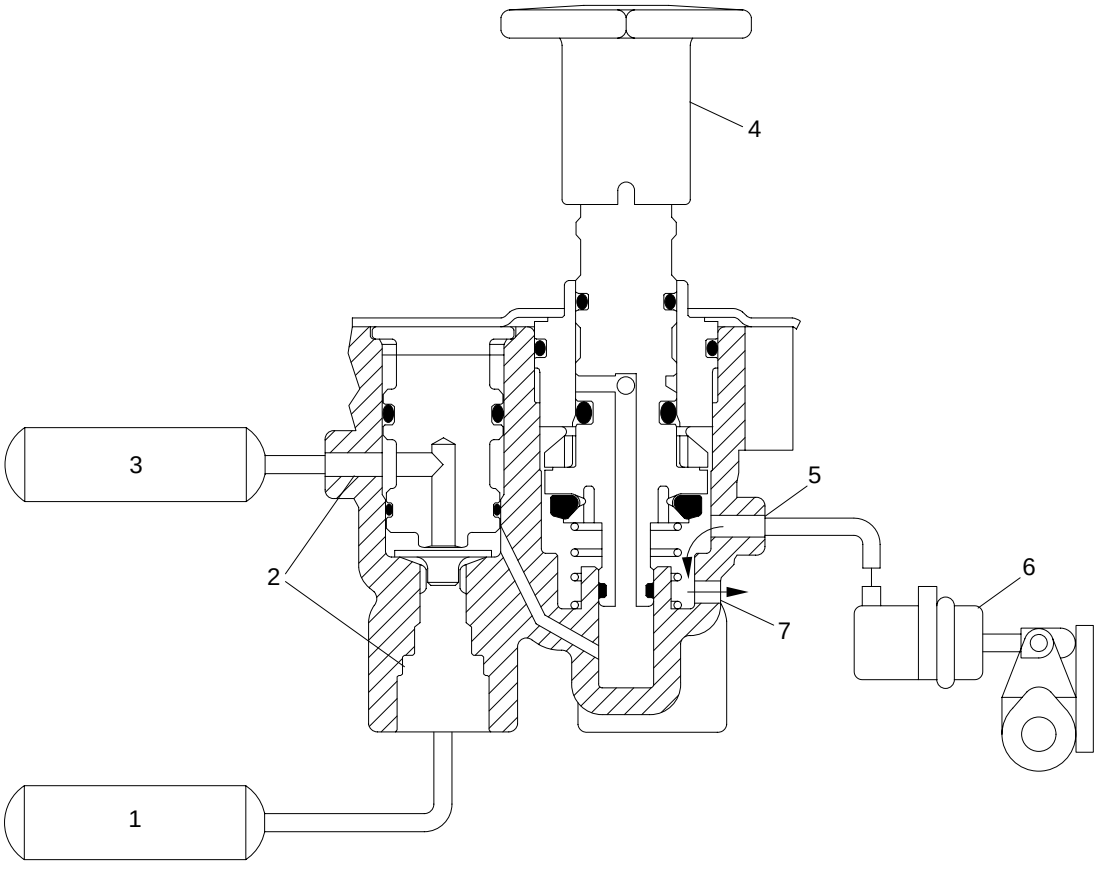
Parking Brake Dash Valve Tests

IMPORTANT: To do the following tests, connect two separate 120 psi (827 kPa) air sources to the PP–DC supply ports. See **Fig. 1**. Tee an accurate test gauge into the supply lines, and provide for a means to control supply line pressure. Connect a small volume air source with a gauge to the delivery port.

Operating Test

1. Chock the tires.
2. Start the engine, and build 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 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.



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 Hand Valve (sectional view)

Parking Brake Dash Valve Tests

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, replace it following instructions under **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 5 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 3 seconds. If it does, replace the valve, following instructions in **Subject 120**.

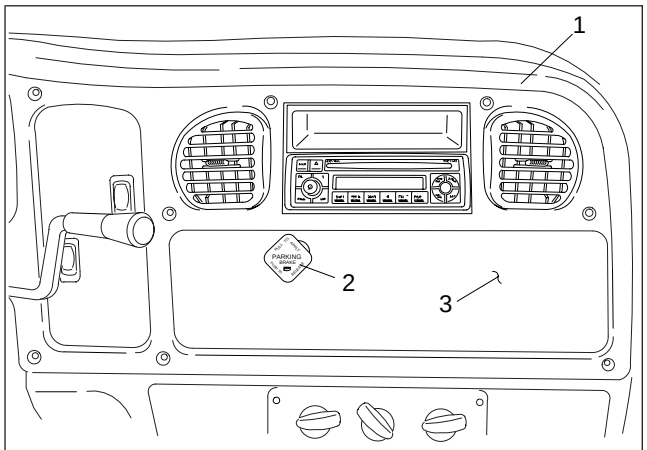
Parking Brake Dash Valve Removal and Installation

Removal

WARNING

Review the precautions under Safety Precautions, 100 before doing any work on the parking brake valve. Failure to do so could result in personal injury.

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 dash trim panel. See **Fig. 1**.

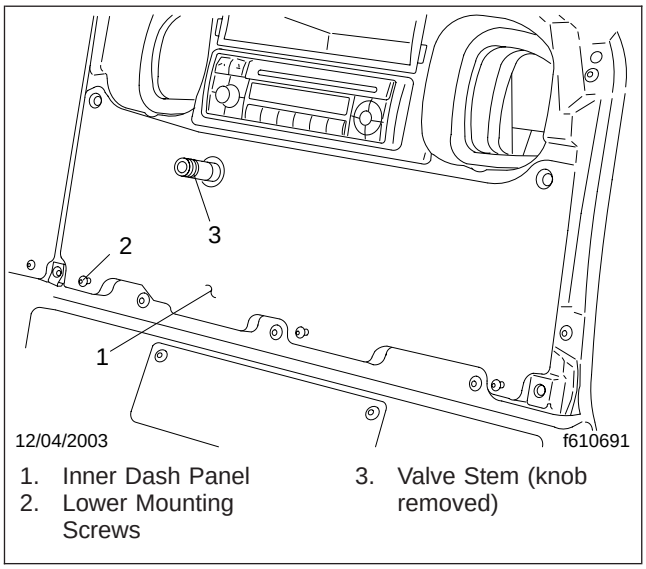


1. Dash Trim Panel
2. Park Brake Valve
3. Inner Dash Panel

Fig. 1, S2 Chassis Center Dash

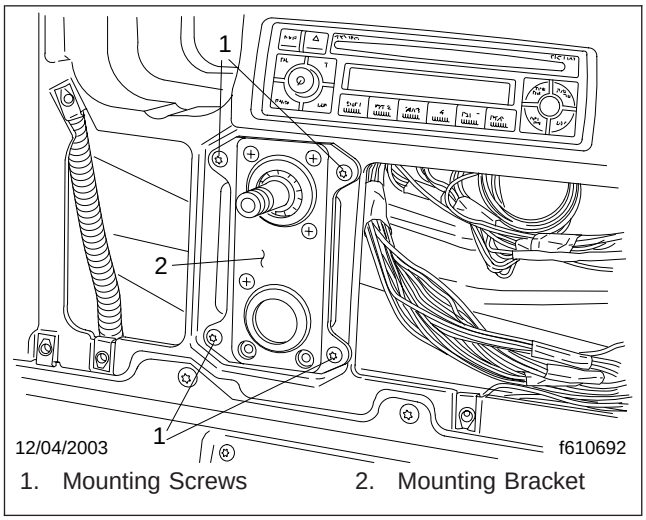
4. Remove the inner dash panel by removing the remaining lower three screws. See **Fig. 2**
5. Remove the four mounting screws that attach the valve-and-bracket assembly to the dash. See **Fig. 3**.
6. Mark the air lines for later reference, then disconnect them from the valve assembly. Remove the valve.

NOTE: The primary supply line is green; the secondary supply line is red; the exhaust line is black and 1/2-inch (13-mm) in diameter; the delivery line is black and 3/8-inch (9.6-mm) in diameter.



1. Inner Dash Panel
2. Lower Mounting Screws
3. Valve Stem (knob removed)

Fig. 2, Inner Dash Panel



1. Mounting Screws
2. Mounting Bracket

Fig. 3, Valve and Mounting Bracket

Installation

1. Connect the air lines to the applicable fittings by pushing the lines all the way into the fitting.
2. Install the valve and bracket assembly onto the dash with the four screws. See **Fig. 3**.
3. Using a wrench, tighten the fittings until the connections feel firm, then tighten an additional one-sixth turn.

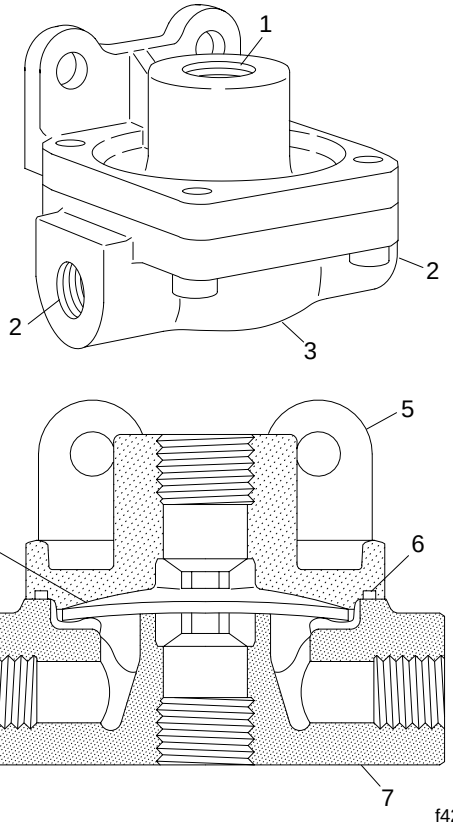
Parking Brake Dash Valve Removal and Installation

4. Leak test the fittings, following the instructions in **Subject 110**.
5. Fasten the inner panel to the dash with the three lower screws. See **Fig. 2**.
6. Screw the valve knob onto the valve stem.
7. Attach the dash trim panel. See **Fig. 1**.
8. Remove the chocks from the tires.

General Information

QR-1 Valve

The function of the QR–1 quick release valve is to speed up the release of air pressure from the front service brake chambers. See **Fig. 1**. 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. Cover
6. O-Ring
7. 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. Its primary function is to speed up the release of air pressure from the service brake chambers. See **Fig. 2**. 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 the axle and serves two 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.
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.

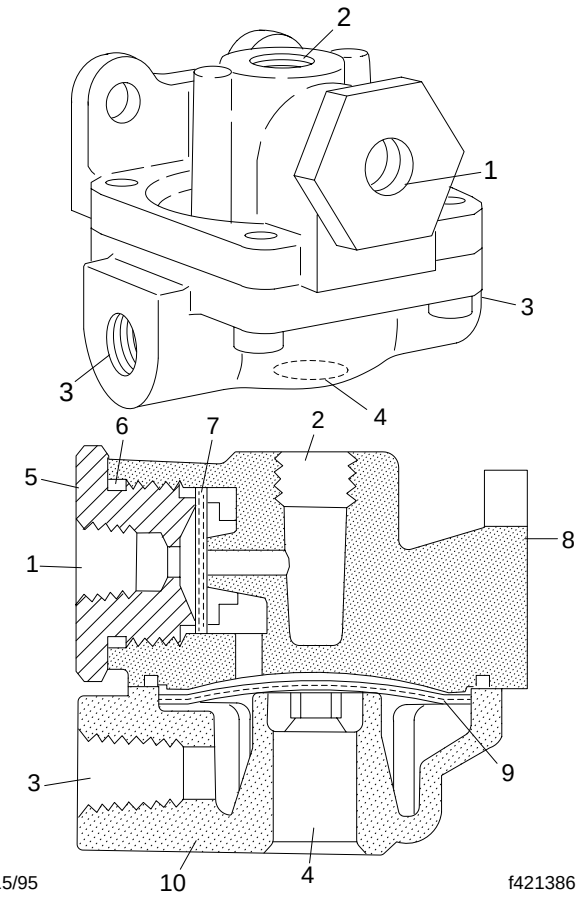
Principles of Operation

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 body seat. The exhaust port is still sealed by the

General Information



1. Supply Port
2. Balance Port
3. Delivery Port
4. Exhaust
5. Cap Nut
6. Sealing Ring
7. Double Check Diaphragm
8. Body
9. Quick Release Diaphragm
10. Cover

Fig. 2, QR-1C Valve and Cross-Section

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 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 when replacing tubes or hoses 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.

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.

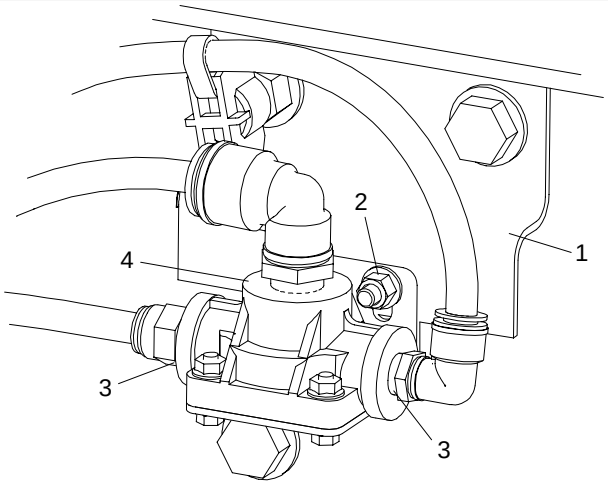
1. Park the vehicle on a level surface and set the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. On QR-1C valves, remove the air line from the valve balance port. Build system air pressure to 120 psi (827 kPa). Coat the exhaust and balance ports with a soap solution; leakage of 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 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.
9. Remove the chocks from the tires.

Removal

WARNING

Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so could result in personal injury.

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)

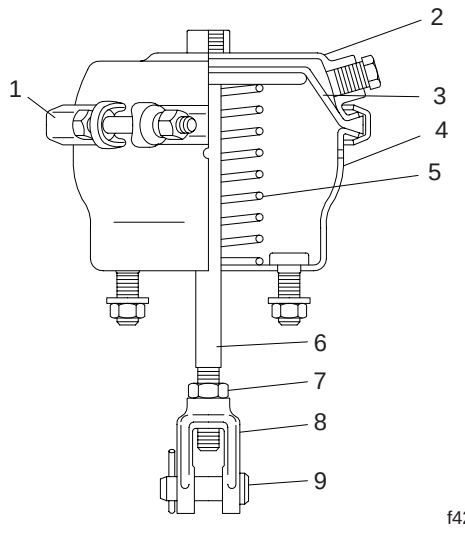
Installation

1. Install the quick release valve with the exhaust port facing down. Securely tighten the mounting bolts.
2. Connect the air lines to the quick release valve in the locations previously marked.
3. Remove the chocks from the tires.
4. Perform the operating and leakage tests in Subject 110.

General Description

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-neoprene diaphragm. A metal two-segment clamp ring holds the assemblies together. See **Fig. 1**.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
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 (415 kPa) is admitted to a type 16 brake chamber, the force on the end of the piston rod is about 960 lbf (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.

NOTE: For both of these tests, the air system must be pressurized to at least 80 psi (550 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 manual.

Leakage Test

1. Apply the brakes and hold them on full line pressure of at least 80 psi (550 kPa).
2. Using a soap solution, coat the clamp ring. Leakage is excessive if it produces a 1-inch (25-mm) bubble within five seconds.

⚠ CAUTION

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

3. If the leakage is excessive, tighten the clamp ring flange nuts evenly until the leakage is reduced. For acceptable torque ranges, see **Specifications 400**.
4. Using a soap solution, coat the area around the piston-rod hole. No leakage is permitted. If there is leakage, replace the diaphragm. For instructions, see **Subject 110**.

Replacement

NOTE: This procedure is for service of a leaking brake chamber *diaphragm only*. If there are any other problems, refer to the applicable subjects elsewhere in this section.

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 anyone. Do not disconnect pressurized hoses, since they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

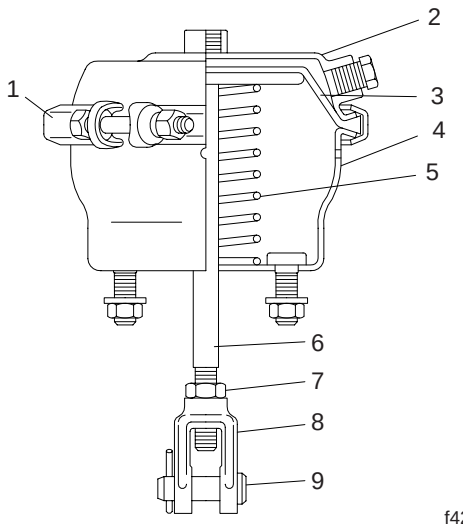
Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Back off the slack adjuster; for instructions, refer to the applicable slack adjuster section in this manual. Pull out the piston rod. See **Fig. 1**. Clamp the rod at the chamber body to protect it from damage.
4. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
5. Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
6. Remove the cover assembly, and replace the diaphragm.

⚠ CAUTION

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

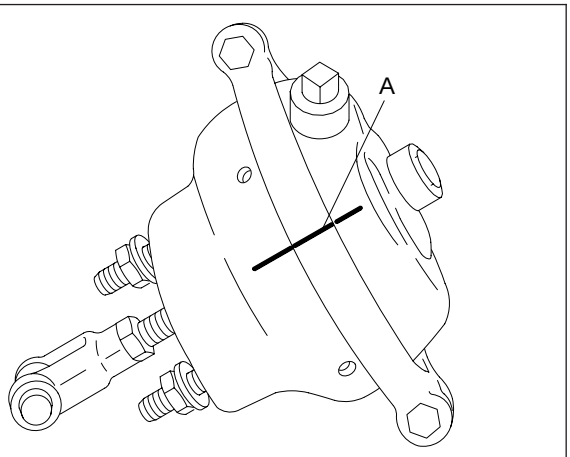
7. Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, see **Specifications 400**.
8. Release the clamp on the piston rod.
9. Do both of the tests in **Subject 100**.
10. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
11. Remove the chocks from the tires.



1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

Diaphragm Replacement



A. Reference Line

Fig. 2, Marking a Reference Line

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.
4. Remove the cotter pins from the clevis pins. See **Fig. 1** .

NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

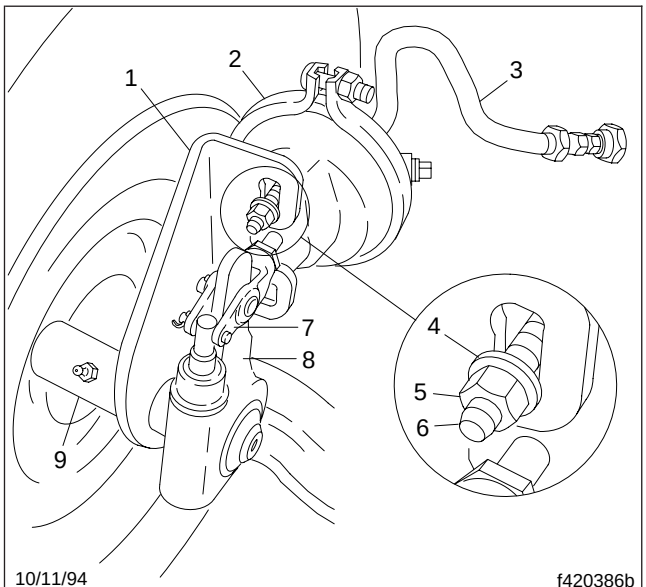
5. Remove the clevis pins from the slack adjuster.
6. From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation

1. Before installing a new chamber, be sure it is the same size and make as the brake chamber on the other side of the axle. To ensure the proper supply of compressed air to the chamber, the left-hand brake chamber air fitting should be positioned at the 11 o'clock position and the right-hand brake chamber air fitting should be positioned at the 1 o'clock position. See **Fig. 2**.

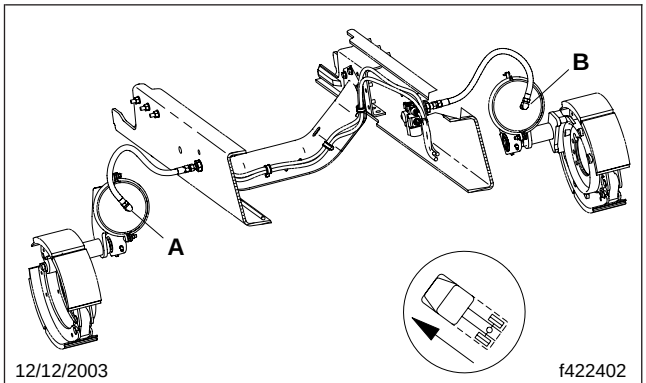
⚠ WARNING

Ensure the air fittings on the brake chamber are in the 11 o'clock and 1 o'clock positions or the flow of compressed air to the brake chamber may



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



A. Fitting Located at 11 o'clock Position, Left Hand Brake Chamber
B. Fitting Located at 1 o'clock Position, Right Hand Brake Chamber

Fig. 2, Brake Chamber Fitting Position

Brake Chamber Removal and Installation

be restricted, resulting in loss of control of the vehicle and personal injury or property damage.

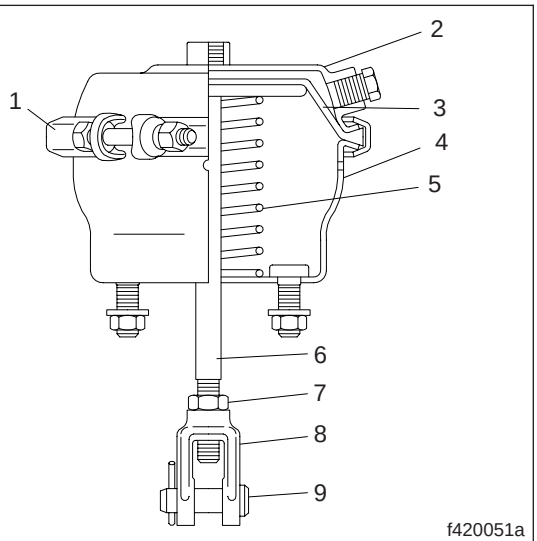
2. Attach the brake chamber to the mounting bracket using a hardened flatwasher and prevailing torque locknut. Install the flatwasher between the locknut and the mounting bracket. See **Fig. 1**.
3. Tighten the locknuts. See **Specifications 400** for the correct torque value.
4. Connect the clevis pins to the slack adjuster.
5. Install and lock new cotter pins to secure the clevis pins.

NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

6. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
7. Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
8. Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
9. Before connecting the air line, make sure the fittings are clean and free of debris.
10. Connect the air line as follows: tighten the nut finger-tight. Using a wrench, further tighten the nut until there is resistance, then tighten one-sixth turn more.
11. Do both of the tests in **Subject 100**.
12. Remove the chocks from the tires.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

Refer to **Fig. 1** during chamber disassembly and assembly.



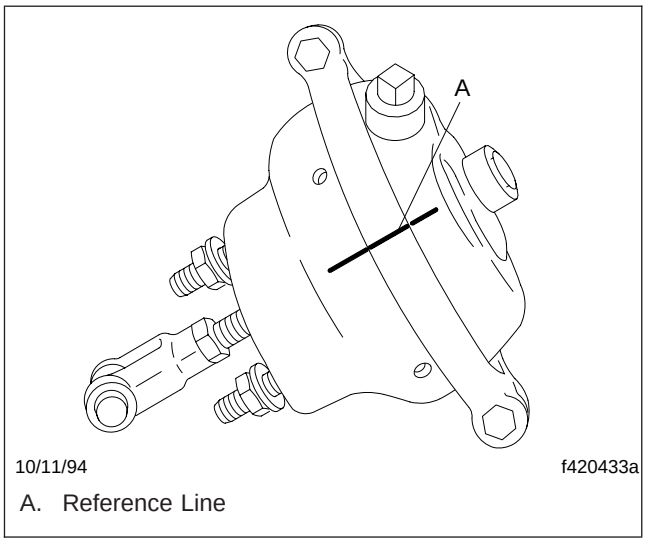
1. Clamp Ring
2. Cover Assembly
3. Diaphragm
4. Body Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Piston Rod Nut
8. Clevis
9. Clevis Pin

Fig. 1, Brake Chamber (sectional view)

Disassembly

NOTE: If the brake chamber is to be disassembled without removing the body assembly from the vehicle, first back off the slack adjuster. For instructions, refer to the applicable slack adjuster section in this manual.

1. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
4. Remove the cover assembly and the diaphragm.
5. Remove the clevis locknut and clevis from the piston rod, and release the clamp on the piston rod, being careful to contain the piston rod assembly and body until the return spring is relaxed.
6. Remove the piston rod assembly and spring.



A. Reference Line

Fig. 2, Marking a Reference Line

Inspection and Cleaning

1. Clean all metal parts with cleaning solvent.
2. Check the cover and the body for dents. If any are too deep to be pounded out, replace as needed.
3. Check the diaphragm for wear or deterioration and replace it if necessary. Haldex recommends replacement of the diaphragm whenever the service brake chamber is opened for inspection.
4. Inspect all other parts not considered serviceable. Replace if necessary.

Assembly

1. Stand the piston rod assembly upright on a flat surface (if the chamber was removed from the vehicle).
2. Place the return spring on the piston rod.
3. Place the body on the piston rod assembly, and press the body down, working against the tension of the spring, until the body bottoms out on the flat surface. Clamp the body rod at the body,

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

making sure to protect the rod from damage. Insert the piston rod assembly through the body and clamp the rod (if the body wasn't removed from the vehicle).

4. Place the diaphragm in the body.

CAUTION

Do not overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

5. Install the clevis locknut and clevis, and release the clamp on the piston rod.
6. If the brake chamber was removed from the vehicle, install it. For instructions, see **Subject 120**.
7. Do both of the tests found in **Subject 100**.

Specifications

Fastener Torque Specifications		
Fastener Description	**Chamber Size: in^2**	**Torque: lbf·ft (N·m)**
Brake Chamber Mounting-Stud Locknuts	12	30 (41)
	16 (5/8-inch stud)	100 (136)
	20	100 (136)
	24	100 (136)
Clamp Ring Flange Nuts	12	17–21 (22–28)
	16	17–21 (22–28)
	20	9–19 (12–26)
	24	13–19 (17–26)
Piston Rod Nuts	12	20–30 (27–41)
	16 (5/8-inch stud)	33–90 (45–122)
	20	33–90 (45–122)
	24	33–90 (45–122)

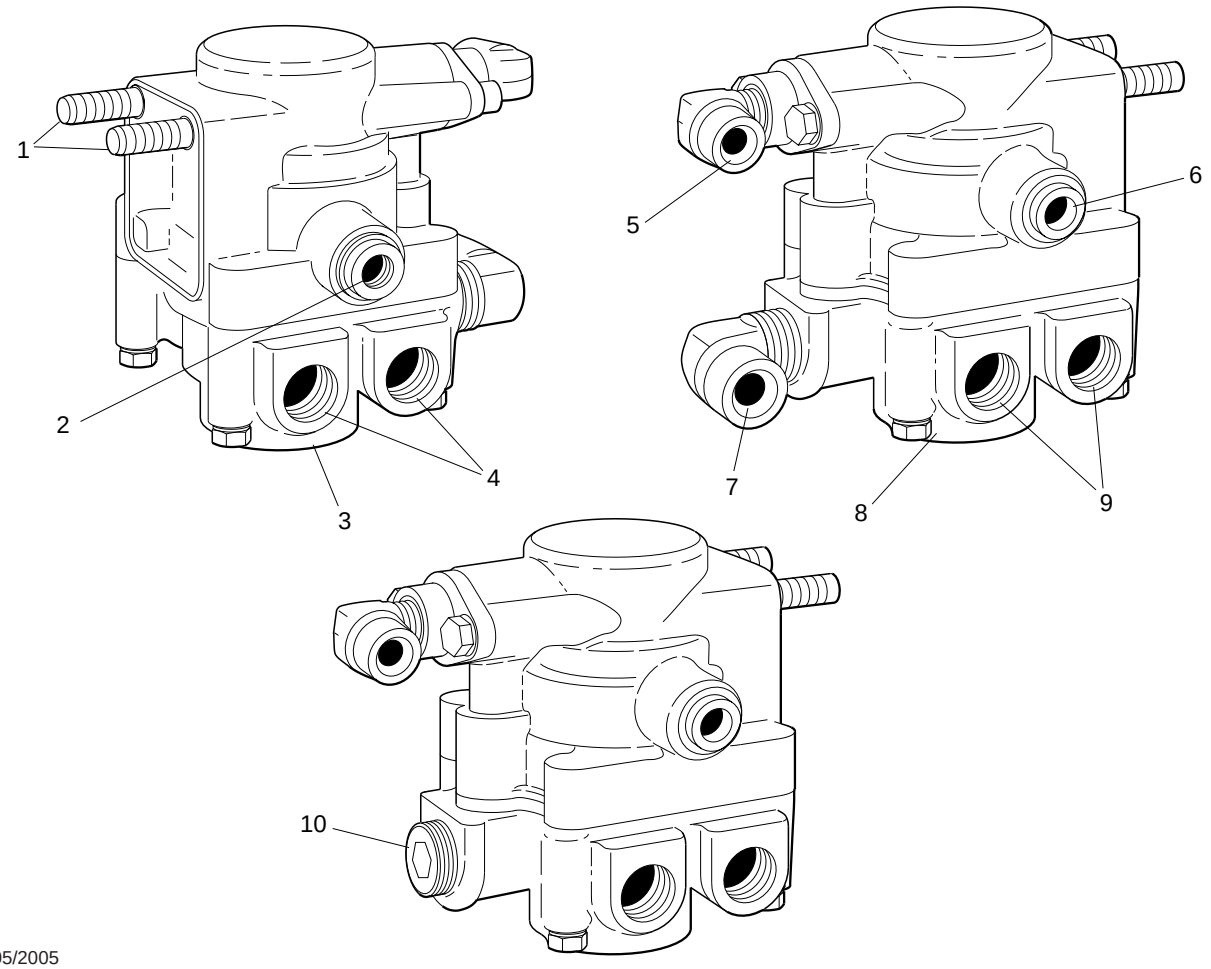
Table 1, Fastener Torque Specifications

Description

The Bendix SR-7™ spring brake modulating valve is used in conjunction with a dual air brake system and spring brake actuator, and performs the following functions. See **Fig. 1** and **Fig. 2**.

- Provides a rapid application of the spring brake actuator when parking.
- Modulates the spring brake actuator application using the dual brake valve should a primary failure occur in the service brake system.
- Prevents compounding of service and spring brake forces.

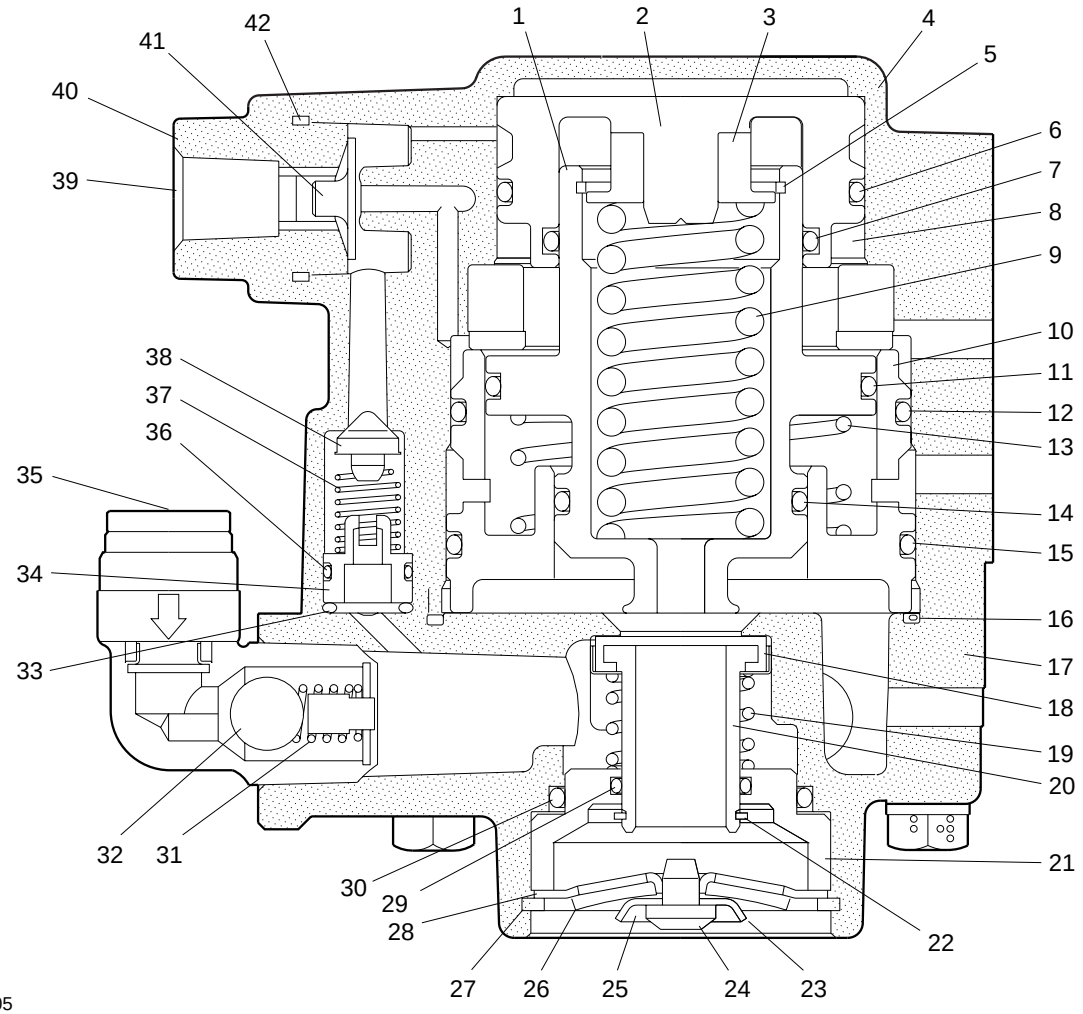
The SR-7 valve has one park control, one service control, one supply, one balance, four delivery NPT ports, and an exhaust port protected by an exhaust diaphragm. The valve incorporates two mounting



1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

General Information



10/07/2005 f422420

1. Main Piston
2. Control Piston
3. Spring Guide
4. Upper Body
5. Retaining Ring
6. O-Ring
7. O-Ring
8. Spacer
9. Main Piston Spring
10. Static Piston
11. O-Ring
12. O-Ring
13. Static Piston Spring
14. O-Ring
15. O-Ring
16. O-Ring
17. Lower Body
18. Valve Retainer
19. Spring
20. Inlet/Exhaust Valve
21. Lower Valve Guide
22. Retaining Ring
23. Exhaust Port
24. #10 Torx Screw
25. Diaphragm Washer
26. Diaphragm
27. Retaining Ring
28. Valve Seat
29. O-Ring
30. O-Ring
31. Spring
32. Ball Check Valve
33. O-Ring
34. Check Valve Guide
35. Supply Port
36. O-Ring
37. Spring
38. Inline Single Check Valve
39. Park Control Port
40. Check Valve Cover
41. Double Check Valve
42. O-Ring

Fig. 2, SR-7 Spring Brake Modulating Valve (sectional view)

studs for mounting the valve to the frame rail or crossmember.

⚠ WARNING

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

Operation

The operation guidelines shown in this manual represent the relay-valve-based SR-7. A quick-release-based valve functions similarly to the relay-valve-based version with the exception that all air delivered to the spring brakes passes through the park control port through the in-line single check valve. The SR-7 quick-release style can be easily identified by the pipe plug in the supply port of the valve. See **Fig. 1**. For vehicle-specific plumbing diagrams, go to **EZWiring**.

Charging the Spring Brake Actuators Below 107 psi (737 kPa)

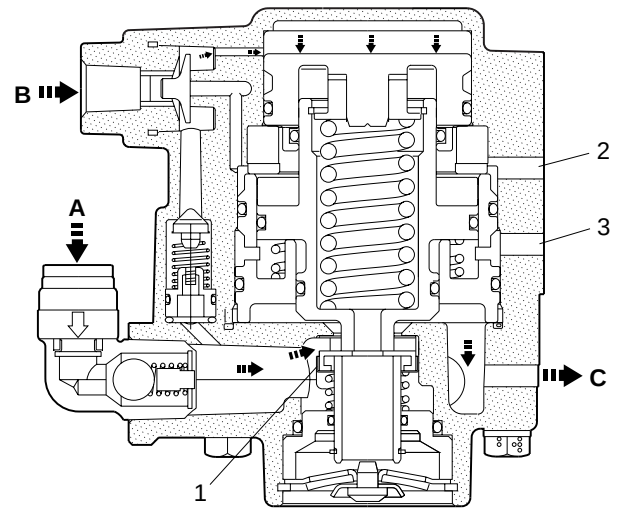
With the air brake system charged and the parking brakes released (by pushing in the dash valve button), air enters the park control port. This opens the SR-7 valve, to supply air pressure to the spring brake chambers. As illustrated, air pressure in the chambers is below 107 psi (737 kPa) (nominal). See **Fig. 3**.

Charging the Spring Brake Actuators Above 107 psi (737 kPa)

Once the SR-7 valve delivery pressure reaches 107 psi (nominal), the inlet and exhaust are closed (valve lap position). This maintains the spring brake hold-off pressure at 107 psi (nominal). See **Fig. 4**.

Normal Service Application

During a service brake application, the valve remains in the lap position. The SR-7 valve monitors the presence of air pressure in both primary and secondary delivery circuits. See **Fig. 5**.



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A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes

1. Inlet/Exhaust Valve Open
2. Balance Port
3. Control Port

Fig. 3, Charging the Spring Brake Actuators Below 107 psi (737 kPa)

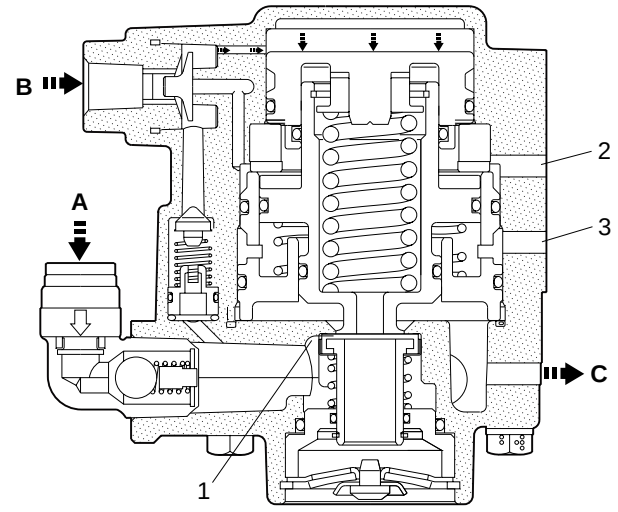
Parking

Actuating the parking brakes (by pulling out the dash valve button) exhausts spring brake air pressure through the SR-7 valve exhaust port. See **Fig. 6**.

Service Application with Loss of Air in Primary Circuit

With the parking brakes released (dash valve button in) and the absence of air in the primary circuit delivery, a service brake application from the secondary circuit causes the pressure in the spring brakes to be exhausted proportionally to this application. This is known as spring brake modulation. A 30 psi (207 kPa) service brake application will exhaust the spring brake pressure to approximately 60 psi (414 kPa). See **Fig. 7**.

General Information

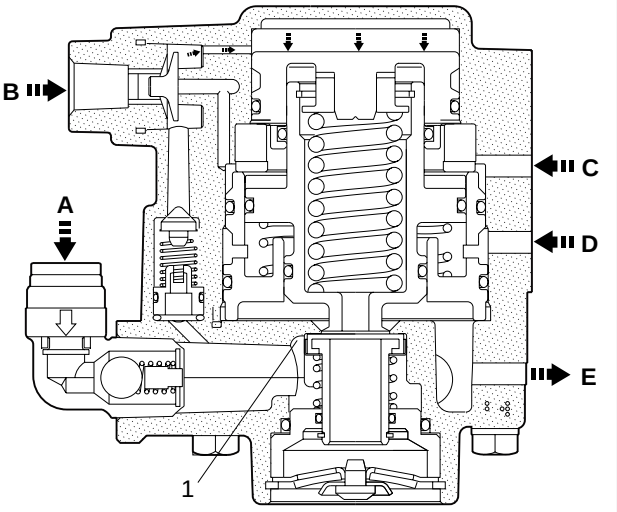


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A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes

1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

Fig. 4, Charging the Spring Brake Actuators Above 107 psi (737 kPa)



10/11/2005 f422423

A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes

1. Inlet/Exhaust Valve Seated

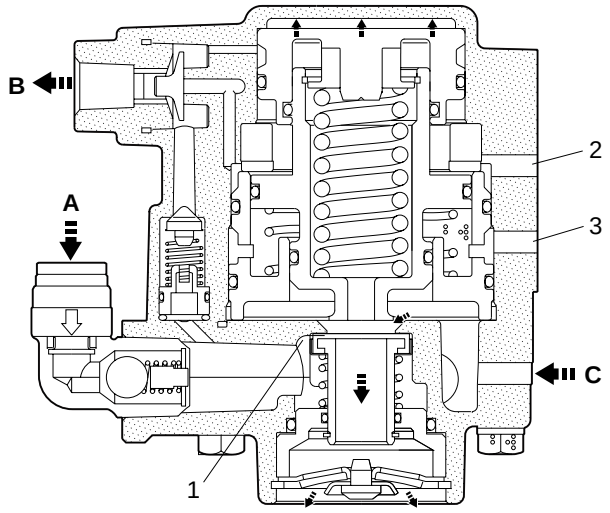
Fig. 5, Normal Service Application

Service Application with Loss of Air in Secondary Circuit

With the parking brakes released (dash valve button in) and the absence of air in the secondary circuit reservoir, the external single check valve in the supply port seals to prevent air leakage to atmosphere from the SR-7 valve. The dash valve delivery air flows through the inline single check valve and becomes SR-7 valve supply air. This air is delivered to maintain at least 107 psi (737 kPa) (nominal) in the spring brake chambers. See **Fig. 8**.

Anti-Compounding

The SR-7 valve provides anti-compounding of the service and spring brake forces. When the parking brakes are actuated (by pulling out the dash valve button), a service brake application will cause the SR-7 valve to deliver air pressure to the spring brake chambers. Thus the vehicle is held stationary using a service brake application. When the service brake application is released, the delivery pressure is exhausted from the spring brake chambers and the vehicle remains parked using the spring brake actuators. See **Fig. 9**.

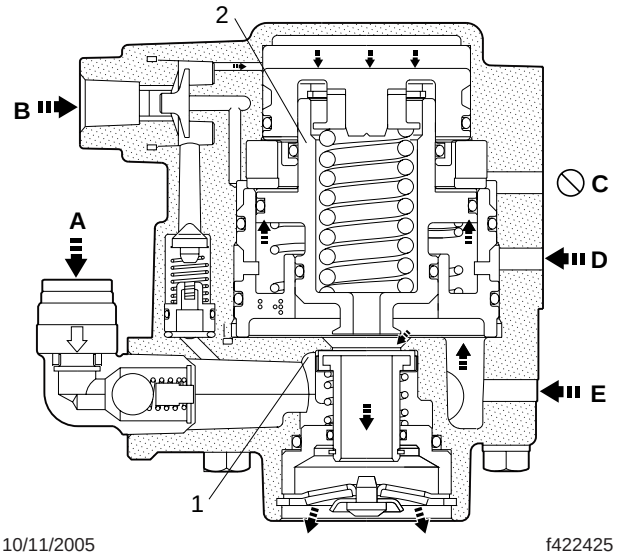


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A. Secondary reservoir constant pressure
B. Control line pressure
C. Delivery to spring brakes

1. Inlet/Exhaust Valve Seated
2. Balance Port
3. Control Port

Fig. 6, Parking



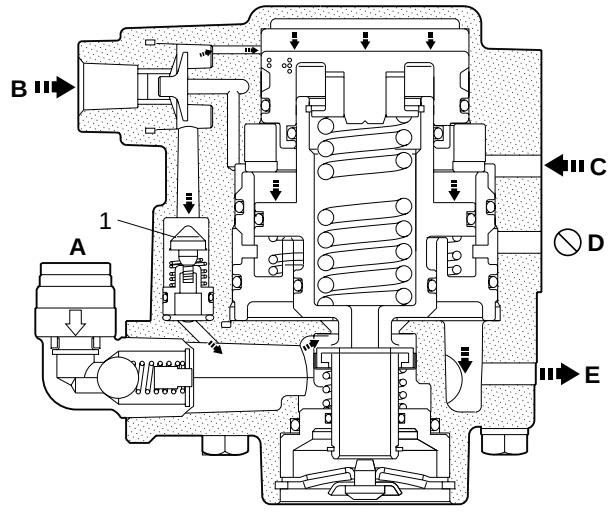
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A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—loss of primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes

1. Inlet Valve Seated
2. Main Piston Moves Up

Fig. 7, Service Application with Loss of Air in Primary Circuit

General Information

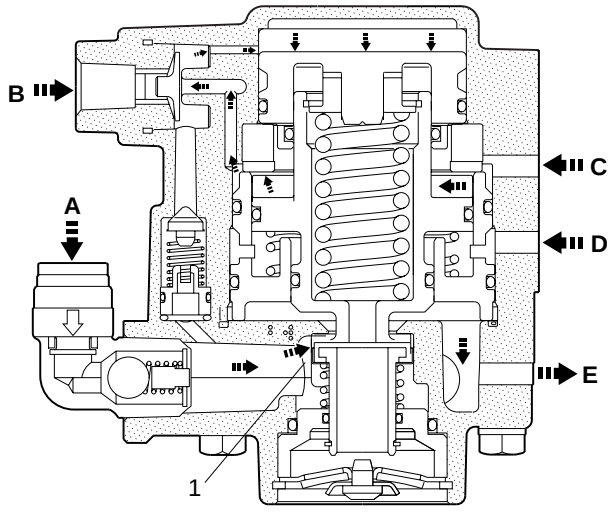


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A. Secondary reservoir no pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—loss of secondary circuit pressure
E. Delivery to spring brakes

1. Inline Single Check Valve

Fig. 8, Service Application with Loss of Air in Secondary Circuit



10/11/2005 f422427

A. Secondary reservoir constant pressure
B. Control line pressure
C. Balance port—primary circuit pressure
D. Control port—secondary circuit pressure
E. Delivery to spring brakes

1. Inlet/Exhaust Valve Open

Fig. 9, Anti-Compounding

Safety Precautions

Before attempting to work on the air brake system, observe the following precautions.

- Since the compression and storage of air can be compared to energy in a coiled spring, when released, it can present a hazard if not properly recognized.
- The wheels of the vehicle must always be chocked so that depletion of air will not permit the vehicle to roll.
- When draining the system, do not look into the air jets or direct them toward a person, as dirt or sludge particles can be carried in the air stream.
- Hoses will whip dangerously if disconnected under pressure. Follow the manufacturer's recommended procedures when working on any air devices so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or pneumatic propulsion.
- As system pressure is drained and the emergency brakes apply, hands must be away from the air chamber pushrods and spring actuators that apply automatically with the loss of pressure. This also applies when checking the service brake system.
- Reservoirs that are closest to the sources of compressed air (compressors or auxiliary sources) must contain a safety valve in known working order and sufficient capacity to limit the reservoir pressure to a safe maximum level.
- Used reservoirs must not be used as replacements, in order to eliminate the possibility of component failure.
- The safety valves must not be reset higher than specified by the reservoir manufacturer, vehicle manufacturer, or code to which the reservoir had been manufactured, in order to prevent valve failure.
- Various actuators contain powerful internal springs that require special handling procedures. Note and be guided by the warning tags on such units to avoid personal injury or property damage.
- To avoid injury, keep clear of the air chamber pushrod when brakes are applied or when air is exhausted from the system.

Modulating Valve Removal and Installation

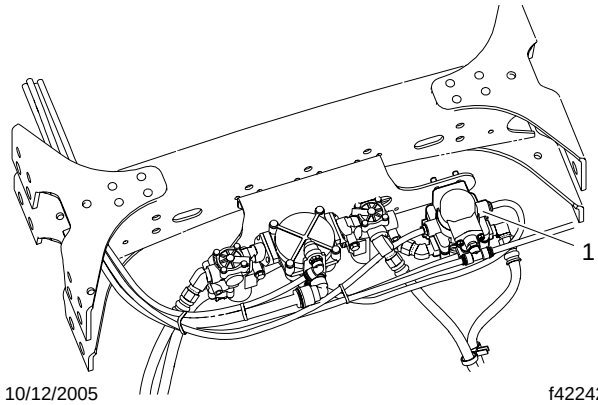
Removal

WARNING

Before working on or around air brake systems and components, see Safety Precautions. Failure to do so could result in personal injury.

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Park the vehicle on a level surface, set the parking brake, and shut down the engine. Chock the tires.
2. Drain the air system.
3. Identify all the air lines attached to the valve, for reinstallation. See **Fig. 1** for a view of a typical installation, or access EZWiring for vehicle-specific plumbing diagrams.



1. SR-7 Valve

Fig. 1, SR-7 Spring Brake Modulating Valve Installation (typical)

4. Disconnect all the air lines from the valve.
5. Remove the two mounting nuts that secure the valve to the crossmember bracket, and remove the valve.
6. If the valve is being replaced, note the orientation of all fittings, then remove the fittings for use on the new valve.

Installation

1. If a new valve is being installed, install the fittings removed from the old valve.
2. Position the valve on the crossmember bracket and install the mounting nuts. Tighten the nuts to 15 to 18 lbf·ft (20 to 24 N·m).
3. Attach all the air lines as noted during removal.
4. Before returning the vehicle to service, perform the operating and leakage tests in **Subject 120**, *Tests*.

Operating Test

⚠ WARNING

Before working on or around air brake systems and components, see Safety Precautions. Failure to do so could result in personal injury.

Do not attempt to disassemble the SR-7 valve. The valve contains high spring forces that could result in personal injury if disassembly is attempted.

1. Chock the tires.
2. Charge the air brake system to governor cut-out pressure.
3. Place the parking control valve in the PARK position. Observe that the spring brake actuators apply promptly.
4. Remove one line from a delivery port of the SR-7 valve and install a test gauge that is known to be accurate. See **Fig. 1** for the port locations.
5. Place the parking control valve in the RELEASE position. Observe that the spring brake actuators fully release.
6. With the parking control valve still in the RELEASE position, note the gauge pressure reading. Correct spring brake actuator hold-off pressure is 107 psi (737 kPa) nominal.
7. Place the parking control valve in the PARK position. The gauge reading should drop to zero promptly. A lag (more than 3 seconds) in the drop of pressure would indicate faulty operation.
8. With the parking control valve still in the PARK position, gradually apply the foot brake valve and note a pressure reading increase on the gauge installed in the SR-7 valve delivery port.
9. Place the parking control valve in the RELEASE position.
10. Drain the reservoir that supplies the rear service brake circuit; apply the foot brake valve several times and note that the pressure reading on the gauge decreases each time the foot brake valve is applied (spring brake modulation). After the foot brake valve has been applied several times, the pressure reading on the gauge will drop to the point where release of the spring brake actuators will no longer occur.

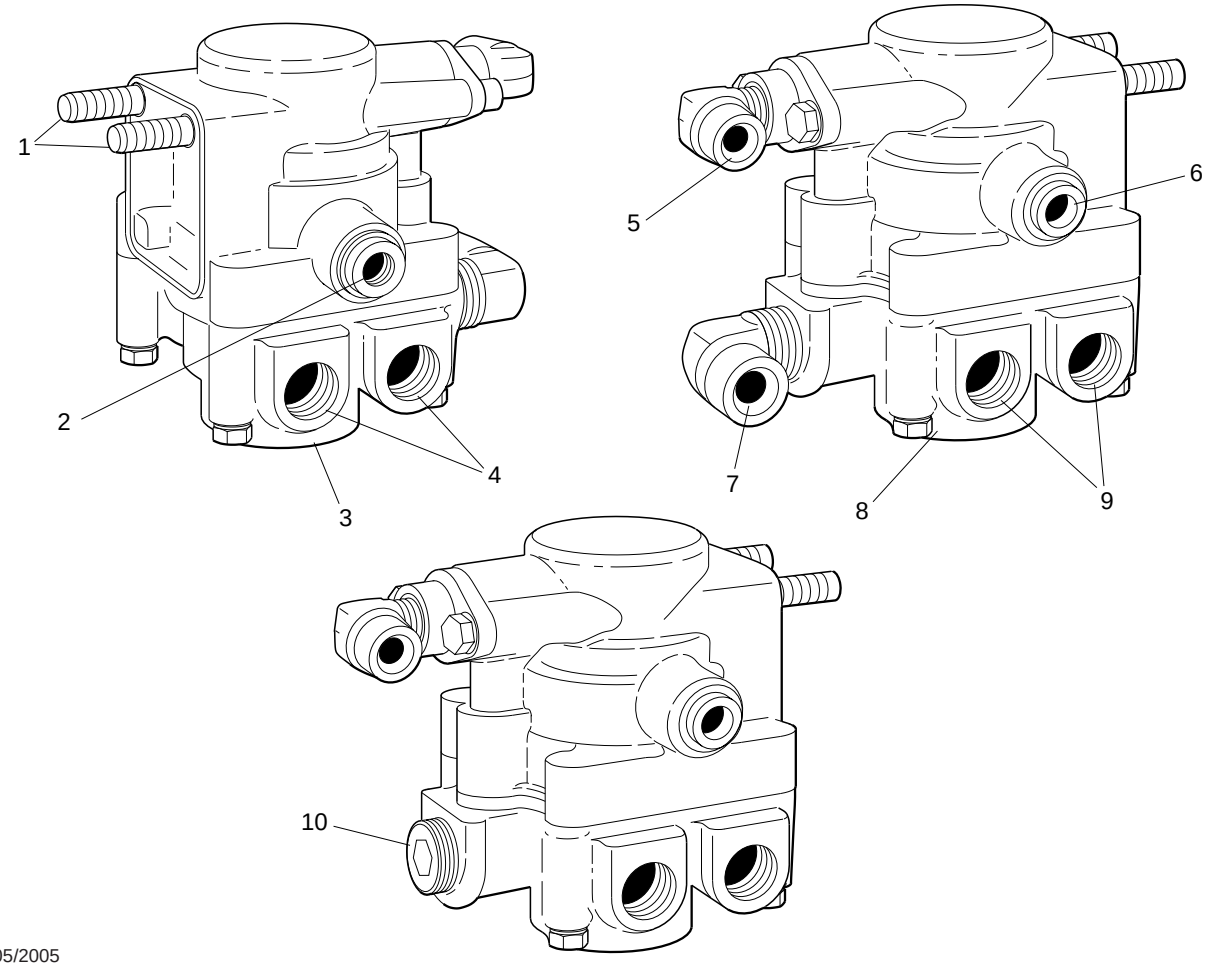
NOTE: The SR-7 valve is not serviceable. If the valve does not function as described, replace it.

Leakage Test

Place the parking control valve in the RELEASE position. Using a soap solution, coat all ports including the exhaust port. A 1-inch (25-mm) bubble in three seconds is permitted.

NOTE: The SR-7 valve is not serviceable. If the valve does not function as described, or if leakage is excessive, replace it.

Tests



1. Mounting Studs
2. 42 Control Port
3. Exhaust
4. Delivery
5. 41 Park Control (from dash valve)
6. 41 Balance Port
7. Supply Port
8. Exhaust
9. Delivery
10. Pipe Plug (QRV applications only)

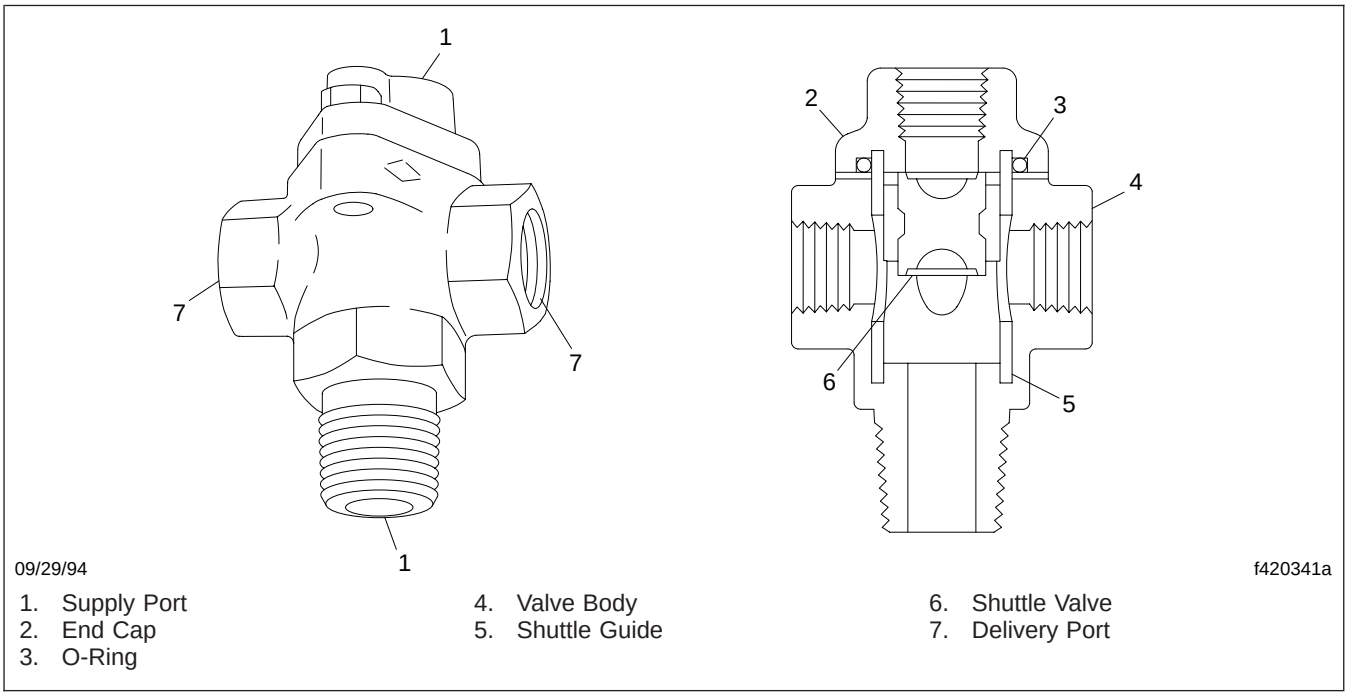
Fig. 1, SR-7 Spring Brake Modulating Valve (exterior views)

General Information

The Bendix DC–4 shuttle-type double check valve is 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. See **Fig. 1**. 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.

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.



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

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

1. 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 push rods and slack adjusters; they will apply as air pressure drops.
2. 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.
3. 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.
4. 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.

Operating and Leakage Test

1. Connect two separately controlled air supplies to the inlet ports.
2. If bench testing the valve, proceed as follows.

   2.1 Apply and release air to one inlet port (foot brake pedal) while checking that the test gauge registers the application and release.

   2.2 Apply and release air to the other inlet port (trailer control valve) while checking that the gauge registers the application and release.

   2.3 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.

   2.4 If the double check valve does not function as described, or if the leakage is excessive, replace it. See **Subject 120** for instructions.

Double Check Valve Removal and Installation

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. Disconnect the air lines from the double check valve.
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

Disassembly

See **Fig. 1** for a cross-sectional view of the check valve.

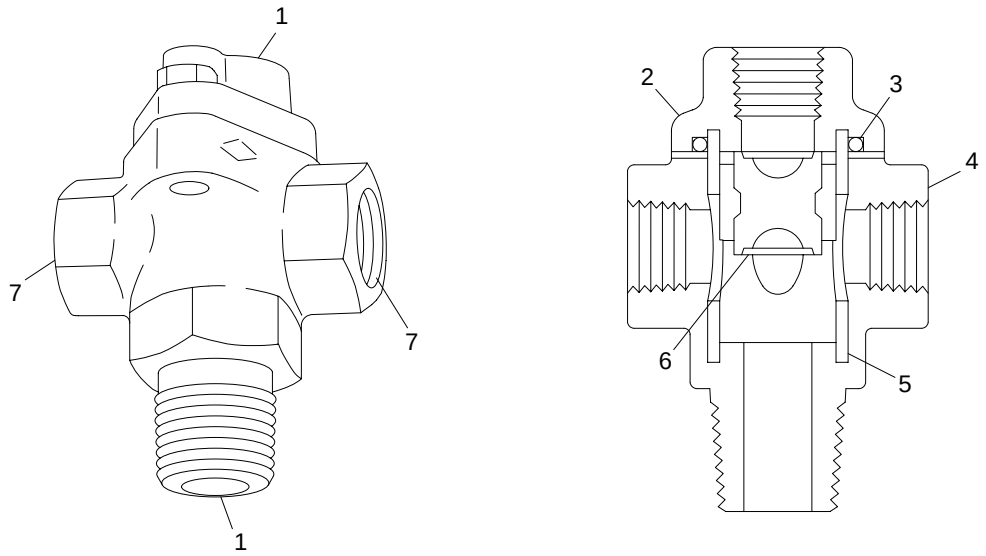
1. Remove the valve from the vehicle. For instructions, see **Subject 120**.
2. Remove the end cap from the valve.
3. Remove the O-ring.
4. Remove the shuttle valve and shuttle guide.

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 the 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 120**.
6. Test the valve. For instructions, see **Subject 110**.



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

General Description

The dual circuit brake valve (foot valve) controls the air supply and delivery of the dual circuit brake system. See **Fig. 1**. The brake valve is mounted on the frontwall.

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.

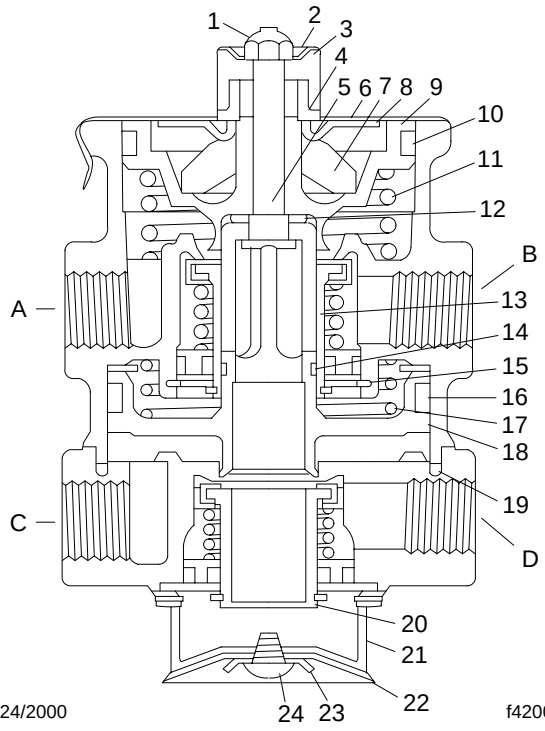
Holding

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 push rod 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-Head Screw

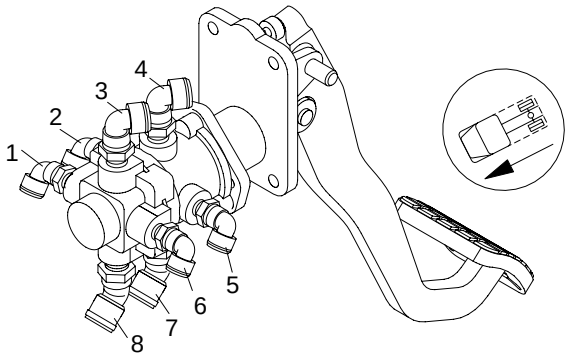
Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

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**.



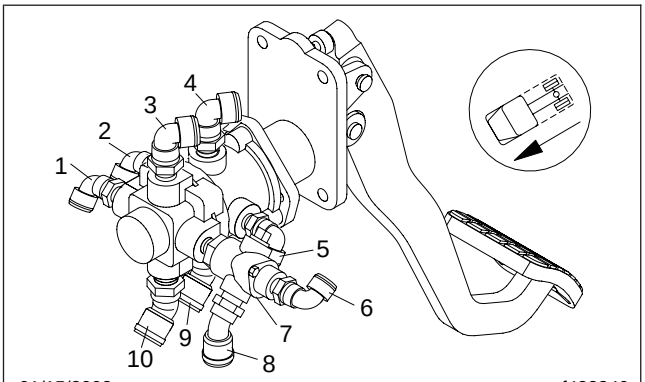
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1. Secondary Delivery Circuit to Front Brake Valve
2. Delivery Circuit to Rear Brake Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Primary Delivery Circuit to Tractor Protection Valve
6. Secondary Delivery 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

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).



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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)

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."

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.

Brake Valve Operating and Leakage Checks

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.

4. Remove the chocks from the tires.

Removal

1. Chock the tires, then 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.

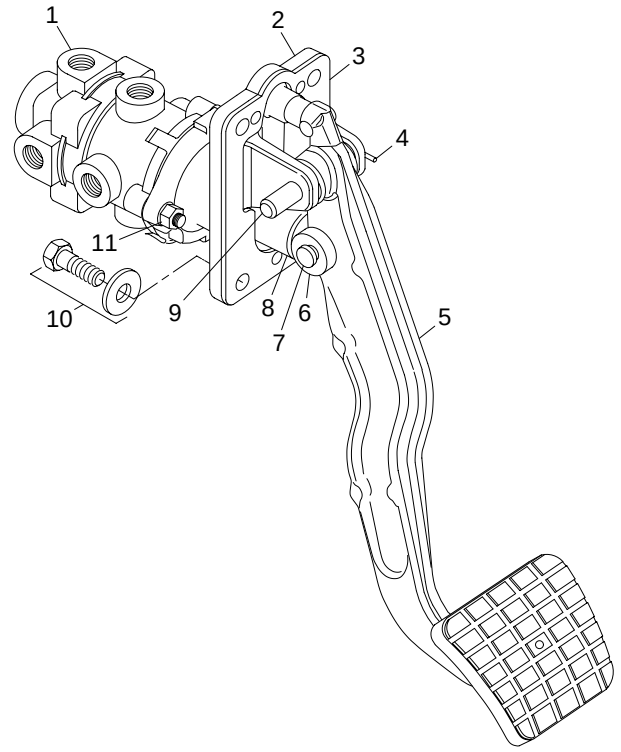
2. Drain all of the air reservoirs.
3. Mark the brake valve air supply and delivery lines for assembly reference. Disconnect the air lines from the brake valve, and plug them to keep out contaminants.
4. Remove the 5/16–18 capscrews and flatwashers that attach the brake valve and mounting adaptor to the front cab mount plate. See **Fig. 1**.
5. Remove the 5/16–18 locknuts and washers that attach the brake valve to the mounting adaptor.
6. Remove the plunger from the mounting adaptor. Wipe off the old grease from the plunger and adaptor.
7. Note the location and position of the double check valve (if equipped), then remove it 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.

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 the double check valve and the elbows.



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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. 5/16–18 Capscrew and Flatwasher
11. 5/16–18 Locknut and Washer

Fig. 1, Brake Valve Mounting

Install the double check valve and elbows in the ports of the brake valve. Tighten the valve finger-tight, then tighten one additional turn with a wrench. As needed, further tighten until the valve is 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.

Brake Valve Removal and Installation

3. Using the 5/16–18 locknuts and washers, attach the mounting adaptor to the brake valve. Tighten the locknuts 10 to 13 lbf·ft (14 to 18 N·m).
4. Install the brake valve and mounting adaptor on the outside of the front cab mount plate. Install the adaptor mounting capscrews and flatwashers. Tighten the capscrews 10 to 13 lbf·ft (14 to 18 N·m). See **Fig. 1**.
5. 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.
6. Check and secure the air lines and electrical wires so they can't interfere with the movement of the brake pedal.
7. Return the hood to the operating position.
8. Perform the operating and leakage checks. For instructions, see **Subject 100**.
9. Remove the chocks from the tires.
10. 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.

Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

Disassembly

Refer to **Fig. 1** while performing the disassembly procedure.

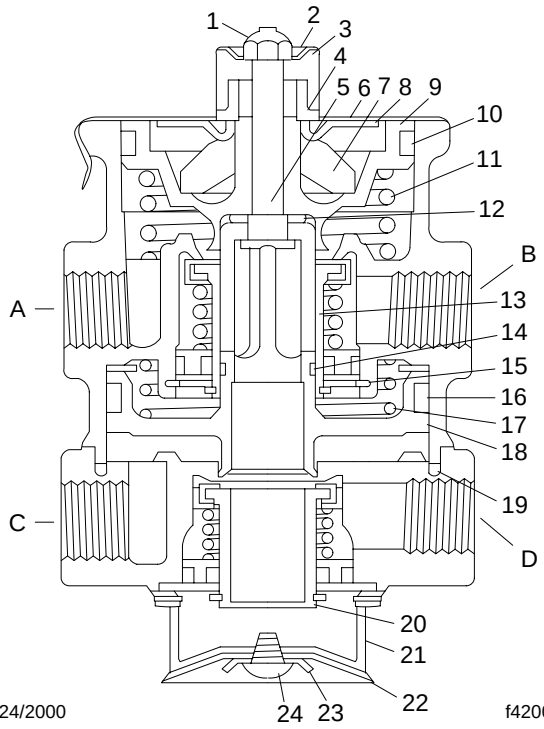
1. Remove the valve from the vehicle. For instructions, see **Subject 110**.
2. Remove the four screws that attach the exhaust cover to the lower valve body.
3. Remove the lower inlet and exhaust valve assembly.
4. Remove the four hexhead capscrews and washers that attach the lower and upper valve bodies. Separate the valve bodies.
5. Remove the rubber seal ring from the lower valve body.

⚠ 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 pounds (220 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.

6. 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.
7. Using the screwdriver to keep the stem from turning, remove the locknut, spring seat, and the stem spring.
8. Being careful to avoid damaging the valve seats, remove the relay piston, relay piston spring, and the primary piston and primary piston return spring.
9. Remove the small washer from the cavity in the lower side of the primary piston.

IMPORTANT: Be sure not to damage the piston when removing the spring seat nut. A damaged piston can cause air leakage and premature wear of the piston.



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)

10. Turn the spring seat nut counterclockwise, and separate the spring seat nut, spring seat, and the rubber spring. Remove the primary piston O-ring.

Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

11. Remove the small and large O-rings from the relay piston.
12. 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

Refer to **Fig. 1** while performing the assembly procedure.

NOTE: Keep the work area, tools, and brake valve parts clean during assembly.

1. Using Dow Corning 55-M pneumatic grease, or equivalent, 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 pounds (220 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 rubber seal ring in the lower valve body.
16. Attach the lower and upper valve bodies. Install the four hexhead capscrews and washers. Tighten the capscrews 11 lbf·ft (15 N·m).
17. Install the lower inlet and exhaust valve assembly (Item 20).
18. Install the four screws that attach the exhaust cover to the lower valve body.
19. Install the brake valve. For instructions, see **Subject 110**.

General Information

The Bosch parking brake is a lever-actuated, duo-servo, single-anchor drum brake. See **Fig. 1**. The brake is designed for driveline-mounted applications, typically on the rear axle yoke. Its self-adjusting feature enables the brake to maintain a consistent functional clearance between the brake shoes and the drum as the shoe linings wear.

Major Components

The foundation of the brake is a ductile iron backing plate that mounts to the differential pinion housing with four capscrews. Major actuating components are a cam and a lever, which are fastened to the backing plate by an anchor screw. An anti-rattle spring under the head of this screw prevents clatter. The anchor point for brake actuation and shoe abutment is located at the 12 o'clock position when the assembly is properly mounted. See **Fig. 2**.

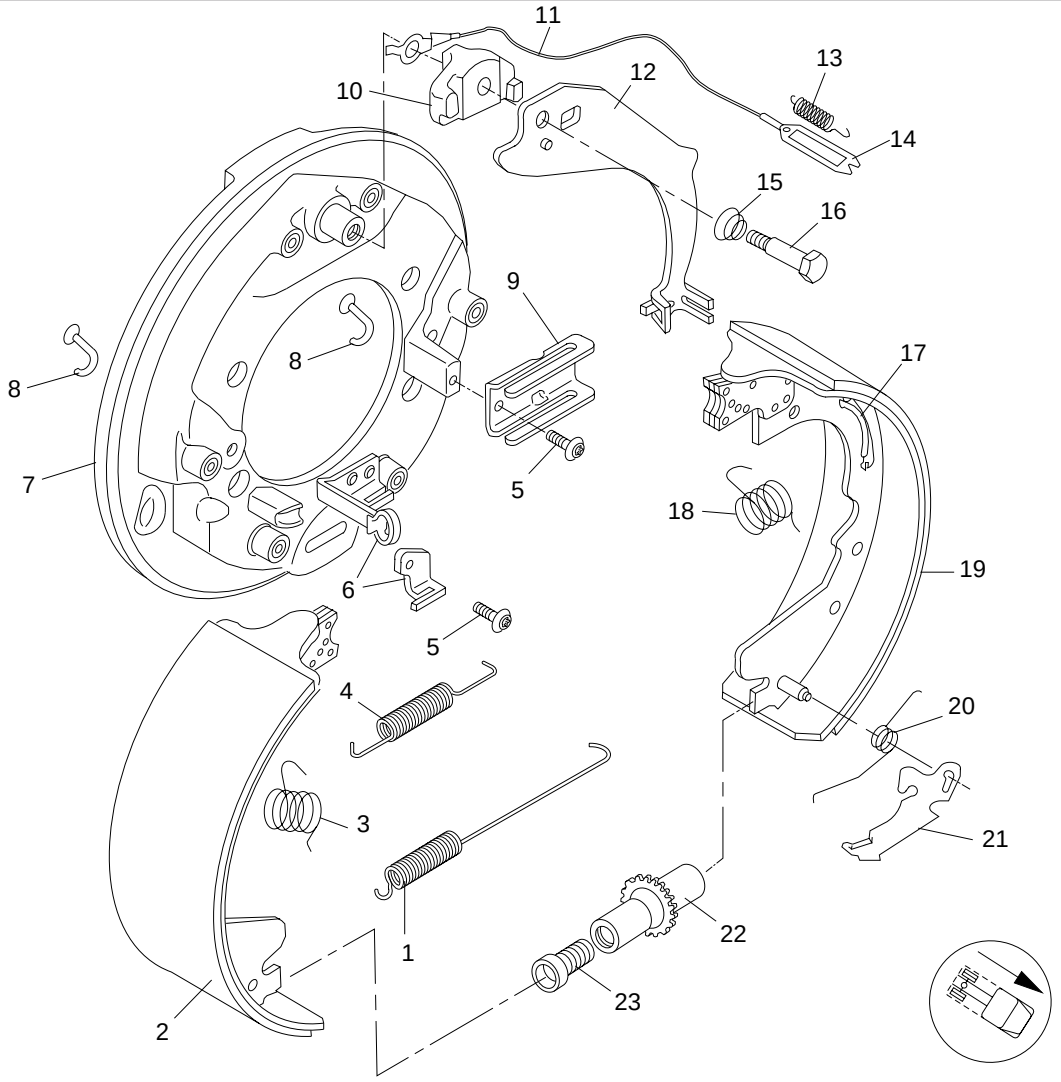
NOTE: The parking brake drum is not a Bosch part, it is a stamped steel drum supplied by Meritor.

Brake Shoes and Related Components

Brake shoes are attached to the backing plate by hold-down springs and pins. See **Fig. 2**. Both shoes seat against the backing plate anchor post at the top and are connected by the adjuster nut and screw assembly at the bottom. Shoe hold-down brackets are permanently mounted to the backing plate to assist in guiding the shoes. The shoes are pulled toward each other by two low-tension shoe-return springs. Proper orientation of the various springs, including their hook ends, must be maintained for the brake to function properly. The starwheel used for adjusting shoe clearance to the drum is on the adjuster nut. See **Fig. 3**.

The clearance between the shoe linings and the inside drum surface is adjusted in response to excessive movement of a given shoe when the brake is actuated. This excessive movement is typically due to normal wear of the lining during use. The adjuster cable is anchored at the top, by the anchor screw, routed along the side of the shoe by a cable guide, and attached to the auto-adjuster lever via a spring, assembled on the cable end-fitting, at the bottom of the brake. The adjuster lever seats against the starwheel on the adjuster nut and rotates the starwheel when adjustment is necessary. See **Fig. 4**.

General Information

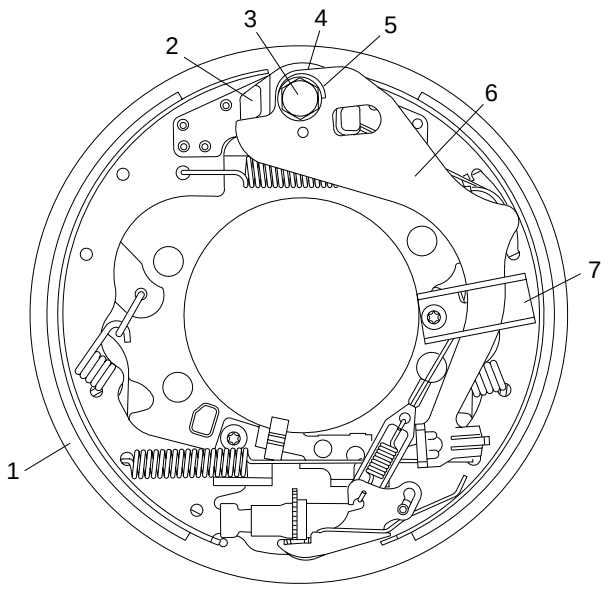


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NOTE: The brake drum and brake mounting components are not shown.

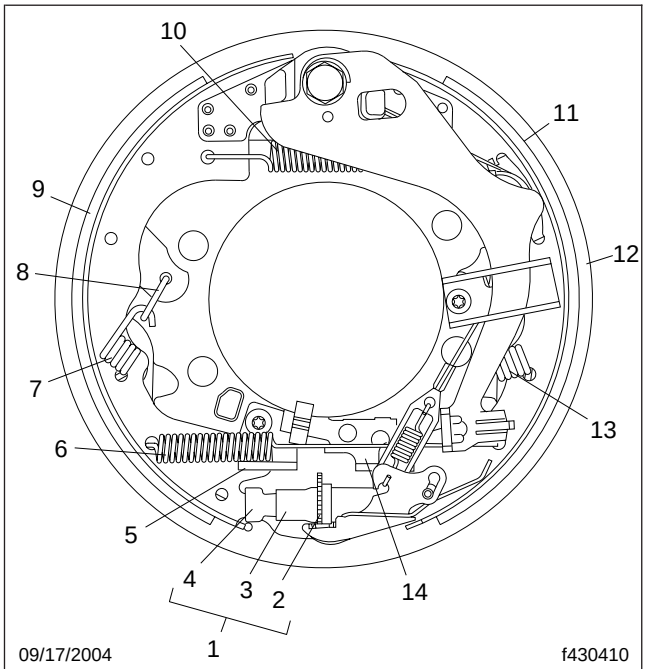
1. Lower Return Spring
2. Right Brake Shoe
3. Hold-Down Spring
4. Upper Return Spring
5. Screw
6. Hold-Down Bracket
7. Backing Plate
8. Hold-Down-Spring Pin
9. Lever Guide
10. Cam
11. Adjuster Cable
12. Lever
13. Adjuster Cable Spring
14. Spring End Fitting
15. Anti-Rattle Spring
16. Anchor Screw
17. Adjuster Cable Guide
18. Hold-Down Spring
19. Left Brake Shoe
20. Auto-Adjuster Spring
21. Auto-Adjuster Lever
22. Adjuster Nut
23. Adjuster Screw

Fig. 1, Bosch Parking Brake (exploded view)



1. Backing Plate
2. Cam
3. Anchor Screw
4. Anchor Point
5. Anti-Rattle Spring
6. Lever
7. Lever Guide

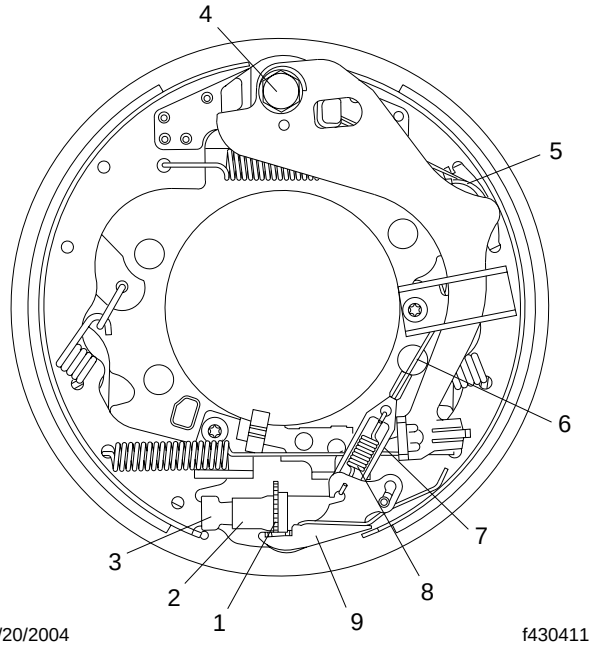
Fig. 2, Parking Brake Major Components



1. Adjuster Nut and Screw Assembly
2. Starwheel
3. Adjuster Nut
4. Adjuster Screw
5. Shoe Hold-Down Bracket
6. Lower Shoe Return Spring
7. Hold-Down Spring
8. Pin (opposite side not shown)
9. Brake Shoe
10. Upper Shoe Return Spring
11. Brake Shoe
12. Backing Plate
13. Hold-Down Spring
14. Shoe Hold-Down Bracket

Fig. 3, Brake Shoes and Related Components

General Information



1. Starwheel
2. Adjuster Nut
3. Adjuster Screw
4. Anchor Screw
5. Cable Guide
6. Adjuster Cable
7. Spring End Fitting
8. Adjuster-Cable Spring
9. Auto Adjust Lever

Fig. 4, Shoe Cage Adjusting Components

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. Occupational Safety and Health Administration (OSHA) has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by Mining Safety and Health Administration (MSHA) or National Institute for Occupational Safety and Health (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

Safety Precautions

and filter must be approved by MSHA or NIOSH, and worn during all procedures.

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.

General Information

The driveline parking brake uses a stamped steel drum supplied by Meritor. See **Fig. 1**. The drum can be removed without removing the axle-input-flange-yoke from the pinion shaft. However, if you are going to work on the rest of the parking brake assembly, it is easier to remove the flange-yoke along with the drum.

Removal

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

IMPORTANT: Do not use a drum puller or a torch to remove a brake drum. Drum distortion may result.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Raise the vehicle so that the axles can turn freely, and secure it on jack stands.

NOTE: Flange and driveshaft configurations will vary with the axle application.

3. Mark the position of the driveshaft in relation to the differential flange-yoke, then unbolt the driveline and secure it out of the way. See **Group 41**.
4. If you are removing the drum only, mark the position of the drum on the flange-yoke, then remove the eight capscrews and washers that hold the drum to the yoke flange, then pull the drum off of the flange. If the drum is difficult to remove, insert a narrow screwdriver through the brake adjusting hole in the backing plate and disengage the adjuster lever from the adjuster nut teeth. With the adjuster lever disengaged (see **Fig. 2**), insert a brake adjusting tool through the adjusting hole to engage the adjusting nut teeth. Move the teeth upward enough times to retract the brake shoes to clear the drum. If the drum is rusted to the axle-input-flange-yoke pilot, tap the center of the brake drum with a non-metallic mallet to loosen it.
5. If you are removing the drum and flange, mark the position of the flange on the pinion shaft, then remove the flange nut and slide the drum and flange off of the pinion shaft spline as an assembly.

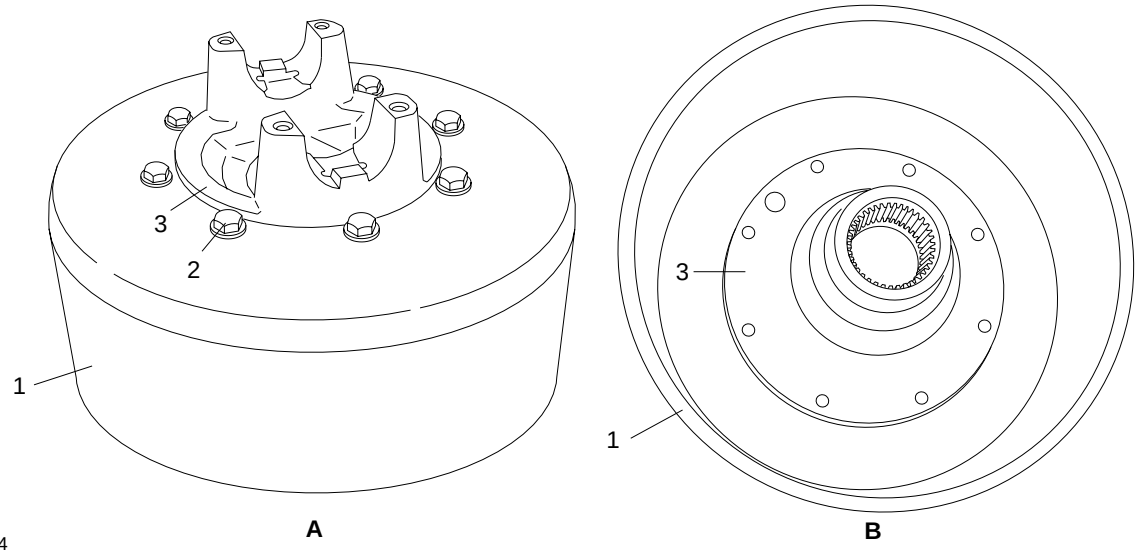
Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

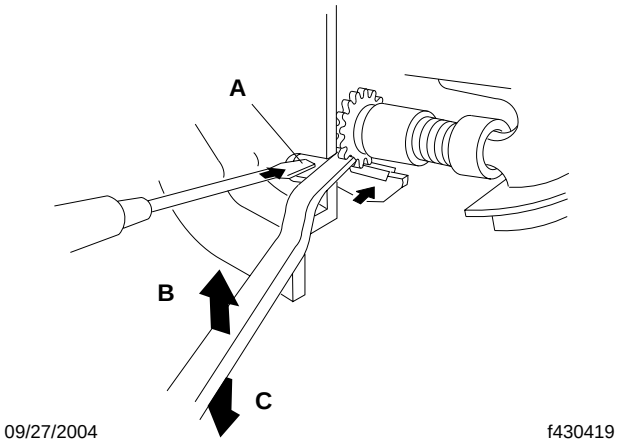
1. Clean the mounting surface of all dirt, debris, grease, and oil.
2. If you removed the drum only, position the drum on the flange-yoke as marked during removal, then install the capscrews and washers. Tighten to 48 lbf·ft (65 N·m).
3. If you removed the drum and flange as an assembly, position the assembly on the pinion spline as marked during removal, then install the pinion nut. See **Group 35**.
4. Attach the driveline. See **Group 41**.
5. Adjust the brake shoes. See **Subject 140**.
6. Lower the vehicle.
7. Test the brake for proper operation before returning the vehicle to service.

Drum Removal and Installation



A. Outside View
B. Inside View
1. Drum
2. Capscrew and Washer
3. Flange-Yoke

Fig. 1, Drum and Flange Assembly (typical)



A. Push the lever away from the starwheel to decrease the brake shoe spread.
B. Expand shoe spread.
C. Decrease shoe spread.

Fig. 2, Brake Adjustment

Brake Shoe Removal and Installation

Removal

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

1. Park the vehicle on a level surface, shut down the engine, and chock the front wheels.
2. Place the transmission in gear and release the parking brake.
3. Raise the rear of the vehicle so the wheels clear the floor, and install jack stands.
4. Mark the position of the driveshaft in relation to the differential, then unbolt the driveshaft from the differential and secure it out of the way. See **Group 41**.
5. Remove the drum. See **Subject 110**.
6. Inspect the brake. See **Subject 170**.

NOTE: Special tools are available for many of the steps in this procedure. See **Subject 400**.

7. Detach the adjuster cable from the adjuster lever and slide the cable off of the adjuster cable guide. See **Fig. 1**.
8. Remove the adjuster lever and the adjuster spring. See **Fig. 1**. Save the parts for installation.
9. Using pliers, or a special tool, remove both shoe-return springs. See **Fig. 2**.
10. Detach the parking brake cable and the lever return spring from the lever.
11. Remove the anchor bolt and move the lever to provide access to the shoe hold-down spring. See **Subject 130** for the procedure.
12. Using a brake shoe spring tool or needlenose pliers, remove both of the shoe hold-down springs. See **Fig. 3**.
13. Remove the brake shoes from the backing plate.
14. Disassemble the adjuster nut and screw assembly for cleaning and inspection of the threads.

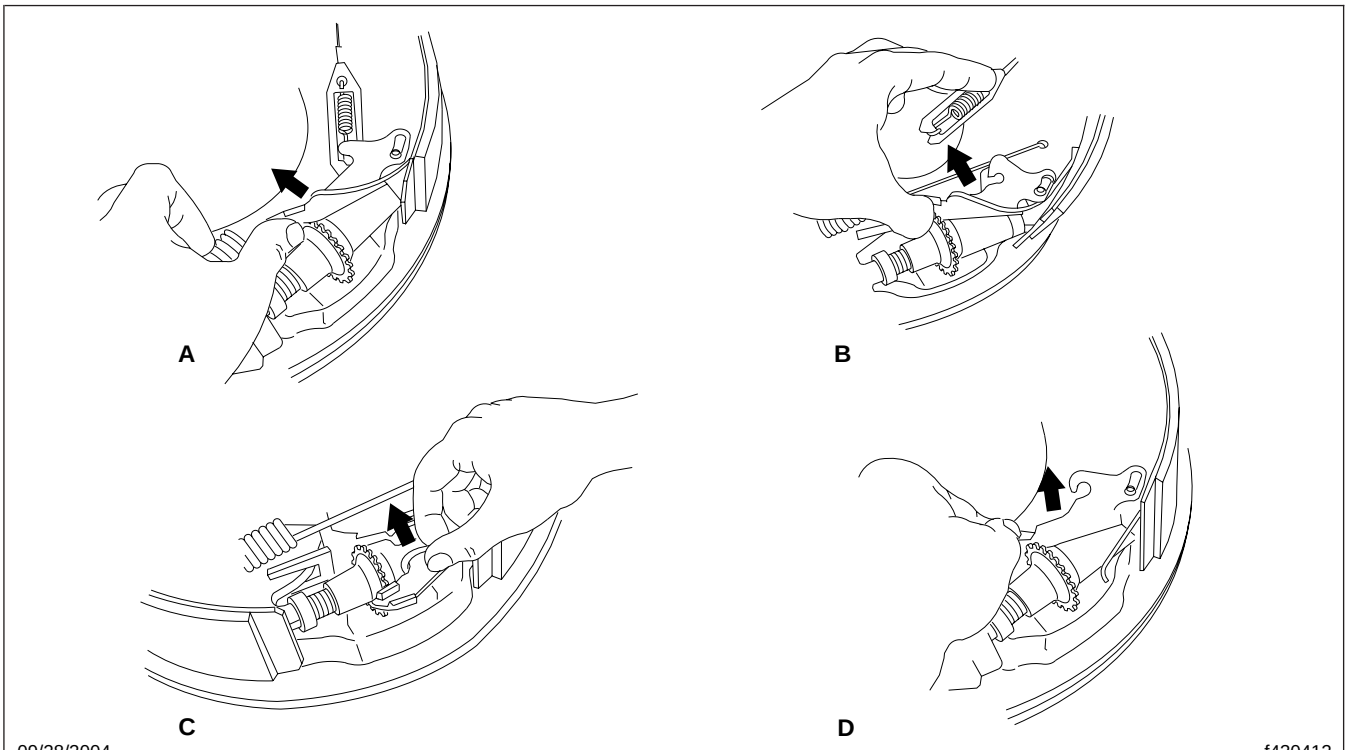
Installation

Proper orientation of all brake components, particularly the various springs, including their hook-ends must be maintained for proper brake function.

1. Clean the backing plate.
2. Apply a light film of Wolfrakote paste ledge grease, or an equivalent, to the six backing plate shoe ledges and the anchor post. See **Fig. 4**.
3. Apply a Chevron heavy-duty, lithium complex, extreme-pressure grease, or equivalent, to the cam plate lugs where they contact the shoe ends and the brake lever.
4. Apply a Chevron heavy-duty, lithium complex, extreme-pressure grease, or an equivalent, to the threads of the adjuster screw and the socket end of the adjuster nut. Install the screw fully into the adjuster nut. Ensure the screw moves in and out freely. If any damage to the threads prohibits free movement, or if the starwheel is damaged, replace the adjuster assembly.
5. Place one shoe in the installed position. See **Fig. 5**. Make sure the shoe with the adjuster cable guide and adjuster pin is installed on the correct side.
6. Install the shoe hold-down pin. See **Fig. 5**.
7. Position the second shoe and the adjuster nut and screw assembly. See **Fig. 3**. The adjuster nut should be seated against the shoe with the adjuster cable guide and pin. Attach the shoe hold-down spring to the shoe hold-down pin, using a brake spring tool. See **Fig. 3**.
8. Install both shoe-return springs. See **Fig. 5**.
9. Install the adjuster spring and the adjuster lever. Ensure that the adjuster lever is properly seated against the starwheel. See **Fig. 5**.
10. If the lever has been removed, install the lever and its associated components. See **Subject 130**.
11. Route the adjuster cable around the adjuster cable guide, under the shoe hold-down spring, and attach it to the adjuster lever.

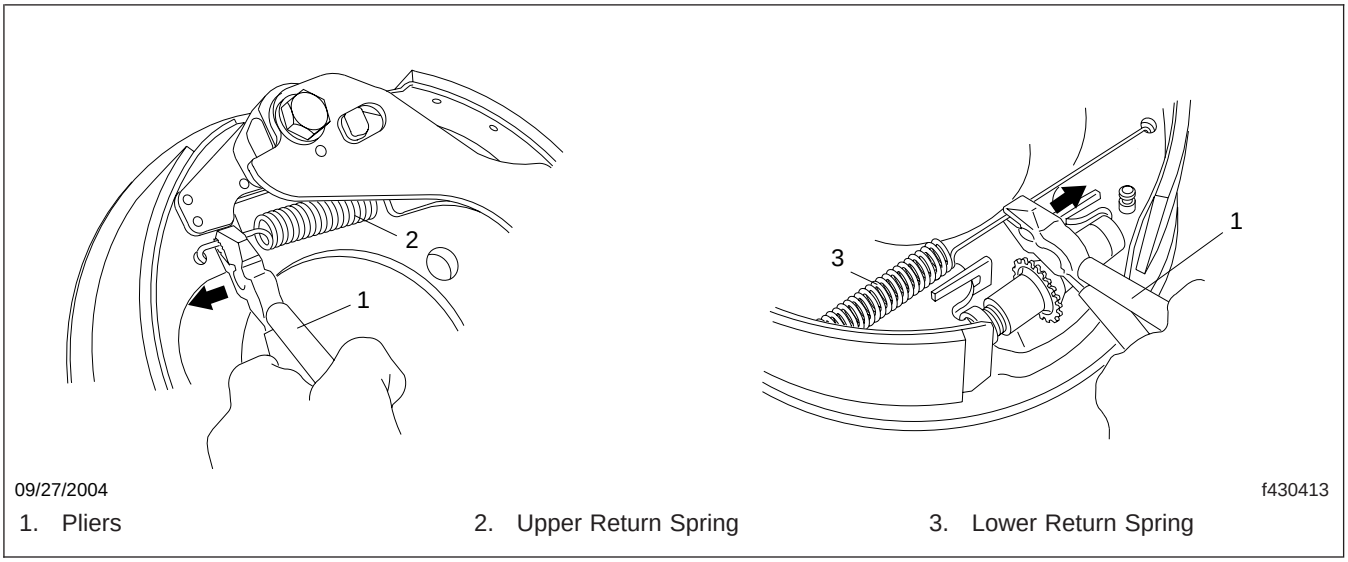
    Correctly assembled, the adjuster cable end-fitting is behind the adjuster lever, with the spring hook facing out. See **Fig. 6**.

Brake Shoe Removal and Installation



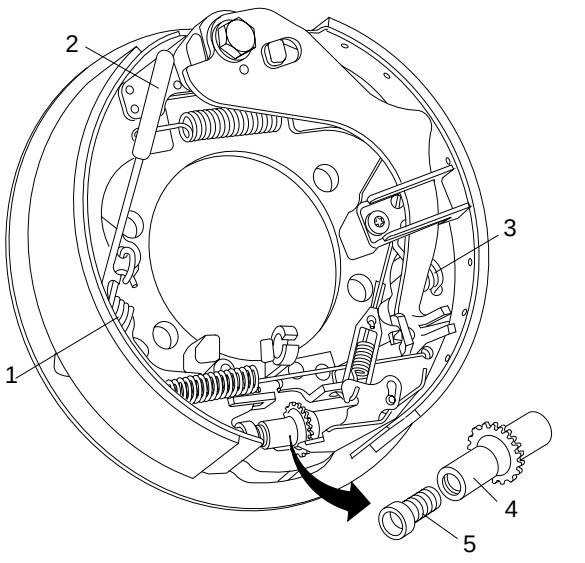
A. Raise the lever off the starwheel and push up.
B. Disengage the spring.
C. Disengage the lever spring.
D. Remove the lever and lever spring.

Fig. 1, Adjuster Lever and Adjuster Spring Removal



1. Pliers
2. Upper Return Spring
3. Lower Return Spring

Fig. 2, Shoe Return Spring Removal

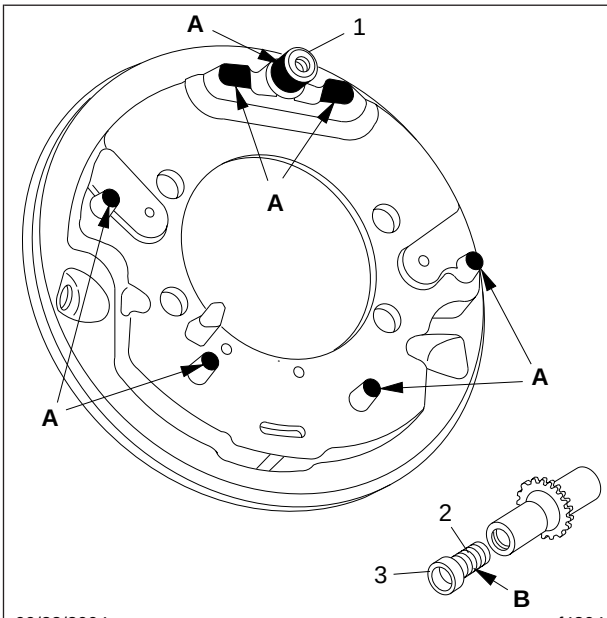


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1. Hold-Down Spring
2. Hold-Down Spring Tool
3. Hold-Down Spring
4. Adjuster Nut
5. Adjuster Screw

Fig. 3, Shoe Hold-Down Spring Removal

12. Adjust the shoe cage. See **Subject 140**.
13. Inspect, service, and install the brake drum. See **Subject 110**.
14. Attach the driveshaft. See **Group 41**.
15. Lower the vehicle.
16. Test the brake for proper function before returning the vehicle to service.



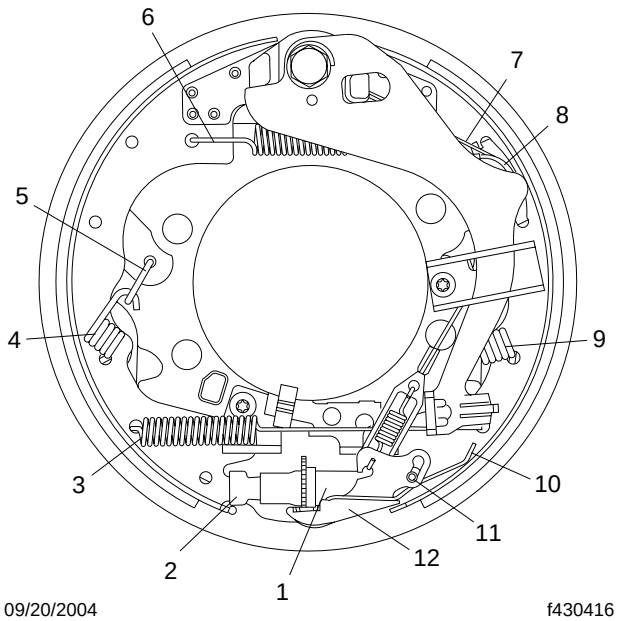
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A. Apply Wolfrakote paste ledge grease.
B. Apply Chevron lithium grease.

1. Anchor Post
2. Threads
3. Socket

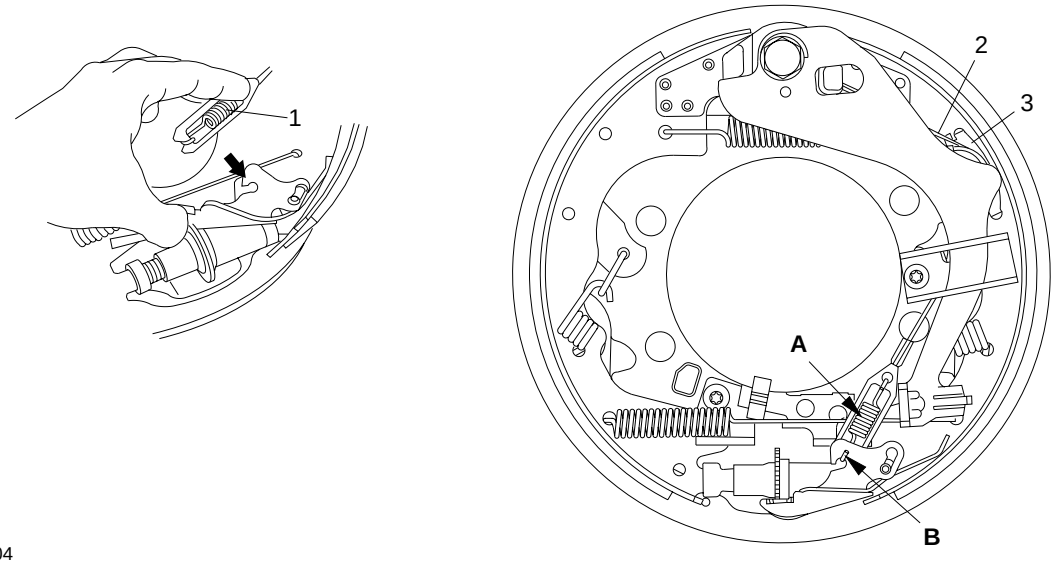
Fig. 4, Grease Application Points

Brake Shoe Removal and Installation



1. Adjuster Nut
2. Adjuster Screw
3. Lower Shoe Return Spring
4. Hold-Down Spring
5. Hold-Down Pin (opposite side not shown)
6. Upper Shoe Return Spring
7. Adjuster Cable
8. Adjuster Cable Guide
9. Hold-Down Spring
10. Adjuster Spring
11. Adjuster Pin
12. Adjuster Lever

Fig. 5, Brake Shoe Installation



09/27/2004 f430417

A. Correct adjuster spring position.
B. Spring hook faces out when properly installed.

1. Adjuster Spring
2. Adjuster Cable
3. Adjuster Cable Guide

Fig. 6, Adjuster Cable Installation

Anchor Screw, Lever, and Cam Replacement

⚠ WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Replacement

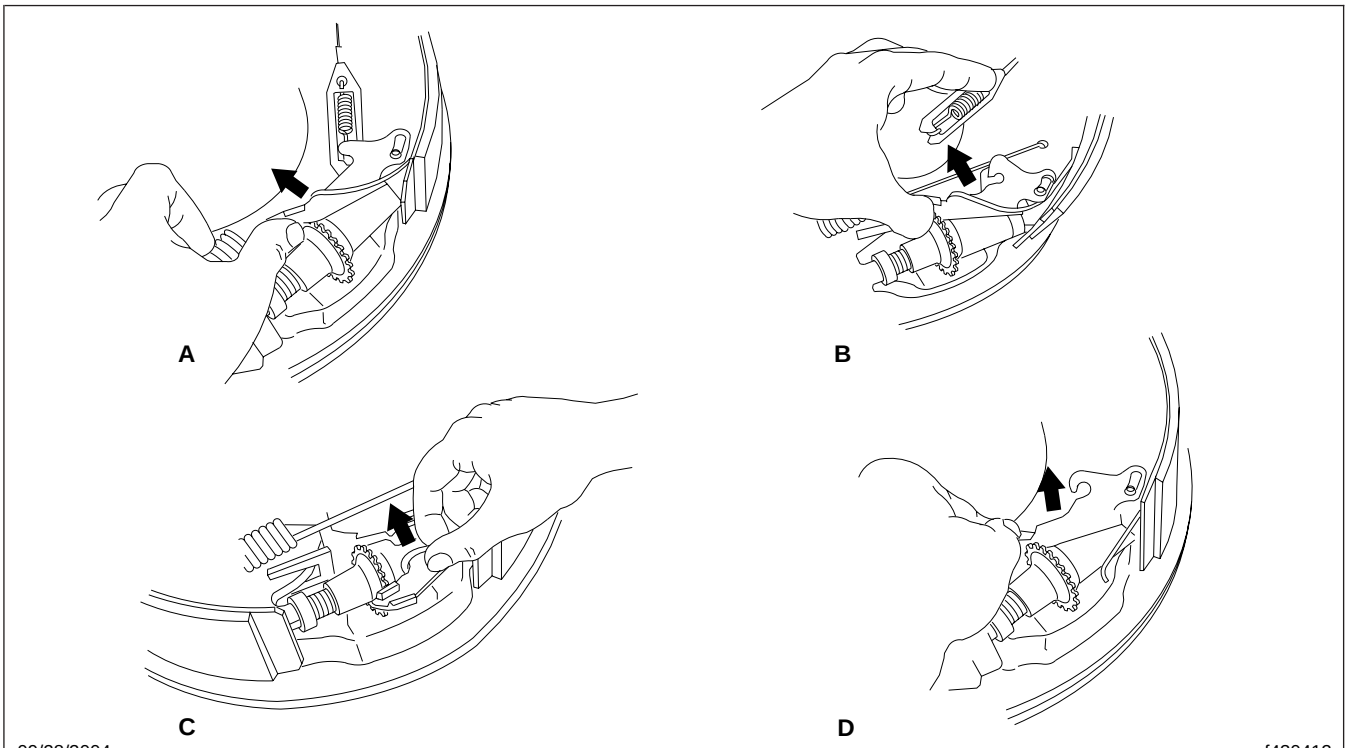
The anchor screw, lever, and cam should all be replaced at the same time. Do not replace just one or two of the three parts at any time. If for any reason the cam, lever, and anchor screw assembly is removed, a complete new set is recommended for service.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Place the transmission in gear and fully release the parking brake.
3. Raise the rear of the vehicle so the wheels clear the floor, and install safety stands.
4. Disconnect the driveshaft and support it out of the way. See **Group 41**.
5. Remove the drum. See **Subject 110**.
6. Inspect the brake. See **Subject 170**.
7. Detach the parking brake cable and spring from the end of the brake lever.
8. Detach the adjuster cable from the adjuster lever and slide the cable off of the adjuster-cable guide. See **Fig. 1**.
9. Remove the anchor screw. See **Fig. 2**.
10. Remove the anti-rattle spring, lever, cam, and adjuster cable. See **Fig. 2**.
11. Remove the cured thread-locking compound from the anchor post threads. Run an M12 x 1.75 tap completely into the anchor post, and back it out. Blow out the hole with compressed air to remove any remaining debris.
12. Lubricate all parts with Chevron RPM high temperature grease or equivalant.
13. Install the adjuster cable, new cam, new lever, anti-rattle spring (small coil end toward screw head), and new anchor screw. See **Fig. 2**. Make sure the offset in the adjuster cable end is facing in the proper direction. Only thread the anchor screw into the anchor post one to two turns to temporarily hold the assembly together. Do not thread it in completely until you are ready to tighten it to specification. A faulty installation will result if the thread-locking compound is activated and begins to cure, prior to tightening the screw. When installing the anchor screw, care should be taken to ensure that the adjuster cable-end fitting is not clamped underneath the shoulder of the anchor screw. Clamping the adjuster cable may prevent proper functioning of the brake self-adjust feature.
14. Tighten the anchor screw to 74 lbf·ft (100 N·m).
15. Attach the lever return spring and the parking brake cable to the end of the brake lever.

IMPORTANT: When it is correctly assembled, the adjuster cable end-fitting is behind the adjuster lever with the spring hook facing out. See **Fig. 3**. Failure to do so may result in reduced brake operation.

16. Route the adjuster cable around the adjuster cable guide, under the shoe hold-down spring, and attach it to the adjuster lever. See **Fig. 3**.
17. Adjust the shoe cage. See **Subject 140**.
18. Make a final inspection of the shoe linings and the inside of the drum to ensure that no grease or other contamination is present.
19. Inspect, service, then install the drum. See **Subject 110**.
20. Attach the driveshaft. See **Group 41**.
21. Lower the vehicle.
22. Test the brake for proper function before returning the vehicle to service.

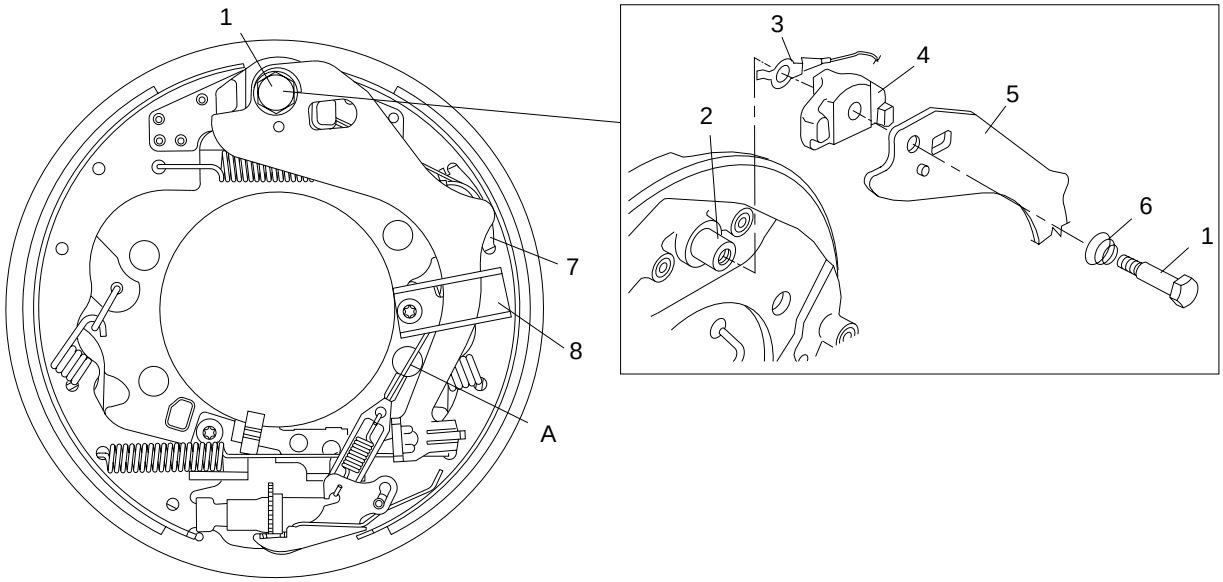
Anchor Screw, Lever, and Cam Replacement



A. Raise the lever off the starwheel and push up.
B. Disengage the spring.
C. Disengage the lever spring.
D. Remove the lever and lever spring.

Fig. 1, Adjuster Lever and Adjuster Spring Removal

Anchor Screw, Lever, and Cam Replacement



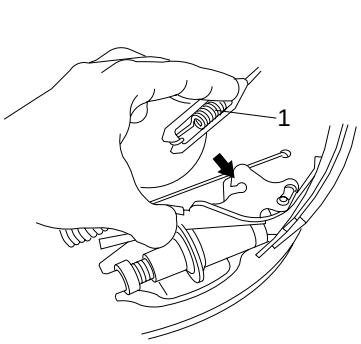
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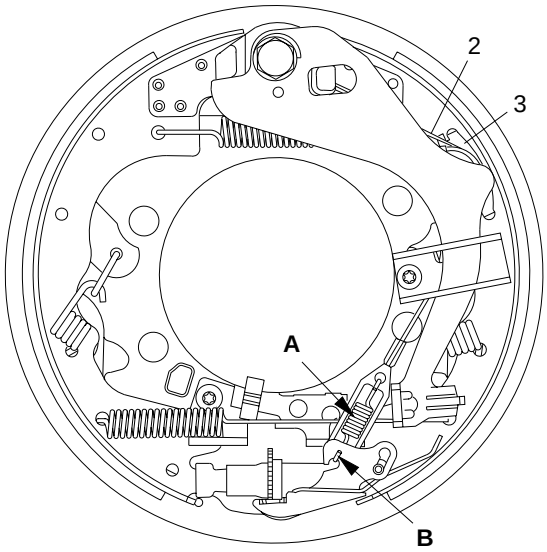
A. Adjuster Cable Routing and Spring Attachment to Adjuster Lever

1. Anchor Screw
2. Anchor Post
3. Adjuster Cable
4. Cam
5. Lever
6. Anti-Rattle Spring
7. Adjuster Cable Guide
8. Lever Guide

Fig. 2, Adjuster Components Removal/Installation

Anchor Screw, Lever, and Cam Replacement





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A. Correct Spring Position
B. Spring Hook Facing Out
1. Adjuster Spring
2. Adjuster Cable
3. Adjuster Cable Guide

Fig. 3, Adjuster Cable Installation

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Brake Shoe Adjustment with Drum Off

After replacing parking brake components, follow these instructions to properly adjust the parking brake. Once adjusted, the self-adjuster should keep the brake adjusted throughout the life of the brake shoes.

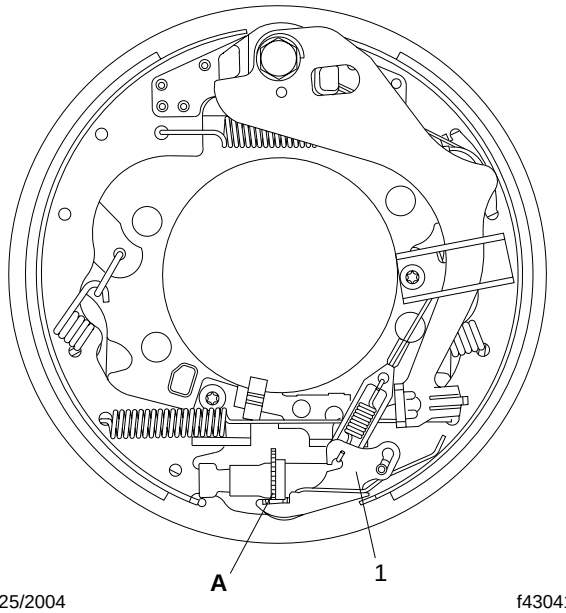
1. Using a 12-inch caliper, measure the inside diameter (i.d.) of the drum. Subtract 0.025 inches (0.6 mm) from the drum i.d. measurement. Set the measurement caliper to this value, and lock the setscrew.
2. Rotate the axle input yoke so the yoke is in the vertical position to provide clearance for the caliper.
3. Place the pre-adjusted caliper over the shoes at the center of the shoes.
4. To adjust the brake, move the adjuster lever away from the starwheel, and rotate the starwheel until the shoes touch the caliper jaws. See **Fig. 1**.

   During adjustment, move the calipers up and down around the shoe center points to ensure adjustment at the highest points on the shoes.

Brake Shoe Adjustment with Drum Installed

The following procedure can be used to perform fine adjustments to the parking brake after the brake is assembled. If adjustment is necessary during the normal life of the brake, see **Subject 300** to determine if there is a problem with the parking brake.

1. Park the vehicle on a level surface, shut down the engine, chock the tires, place the transmission in gear, and fully release the parking brake.



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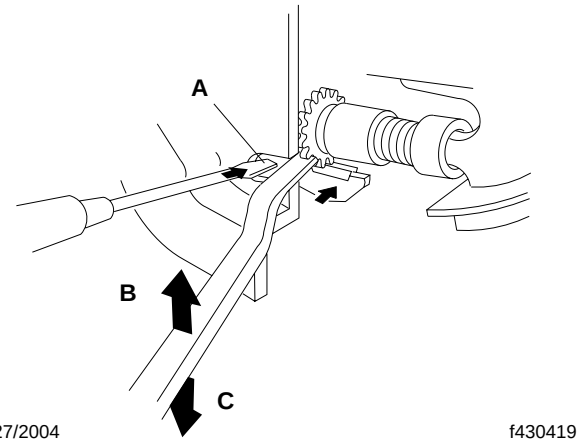
A. Rotate starwheel to adjust shoe spread.

1. Adjuster Lever

Fig. 1, Initial Brake Shoe Adjustment with Drum Off

2. Raise the rear wheels off the ground, and support the vehicle with jack stands.
3. Insert a brake adjusting tool through the adjusting slot and move the teeth downward to expand the brake shoes outward. See **Fig. 2**. Continue expanding the shoes until the drum can not be rotated.
4. Insert a thin screwdriver through the adjusting slot in the brake backing plate and push the adjusting lever away from the starwheel, then move the teeth upward to retract the shoes until the drum just begins to rotate without dragging.
5. Lower the vehicle.
6. Test the brake for proper operation before returning the vehicle to service.

Shoe Cage Adjustment Procedures



A. Push the lever away from the starwheel to decrease the brake shoe spread.
B. Expand shoe spread
C. Decrease shoe spread

Fig. 2, Brake Adjustment With Drum On

General Information

The Bosch driveline parking brake is self-adjusting and should not require adjustment of the cable under normal operating conditions.

NOTE: With time and use, all cables will stretch. The driveline parking brake actuation cable should be checked for proper adjustment whenever the brake is serviced.

There are three methods of actuation for the driveline parking brake. Depending on vehicle configuration, the brake is actuated by one of the following:

- a foot pedal under the dash
- a hand valve located on the dash
- the column-mounted shifter, when placed in "Park"

The hand-valve and the column-mounted shifter control an air-actuated spring chamber, mounted on the frame rail near the parking brake. Follow the appropriate procedure below when adjusting the brake cable after replacing the parking brake, parking brake components, or any of the parking brake actuation components.

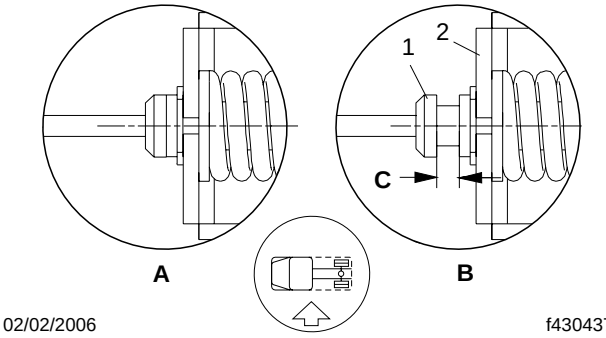
Cable Adjustment, Foot-Pedal-Actuated Parking Brake

WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

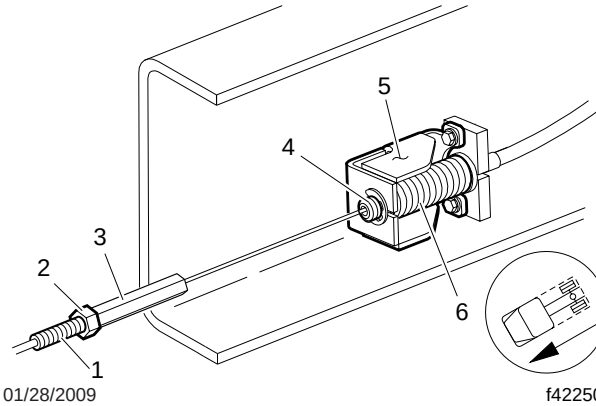
1. Apply the parking-brake pedal until it bottoms out. Measure the sleeve extension at the bracket. See **Fig. 1**. If it is approximately 3/8 inch (9 mm), it is properly adjusted; no further work is needed. If not, release the parking-brake pedal and go to the next step.
2. At the right frame rail, forward of the parking brake, back off the jam nut a few turns, then thread the cable adjuster onto the cable end to the jam nut. See **Fig. 2**.

   Repeat Step 1. Continue tightening the adjuster until the sleeve extends from the bracket approximately 3/8 inch (9 mm).



A. Before adjustment
B. Sleeve extended
C. 3/8 inch (9 mm)
1. Sleeve
2. Bracket

Fig. 1, Cable Sleeve Extended



1. Cable End
2. Jam Nut
3. Adjuster Nut
4. Sleeve
5. Bracket
6. Spring

Fig. 2, Cable Adjustment, Foot-Pedal-Actuated Parking Brake

3. Release and apply the parking brake three times, assuring a solid application.
4. If needed, tighten the adjuster again until the sleeve again extends from the bracket approximately 3/8 inch (9 mm).
5. Tighten the jam nut.

Parking Brake Cable Adjustment

6. Test the brake for proper operation before returning the vehicle to service.

Cable Adjustment, Air-Actuated Parking Brake

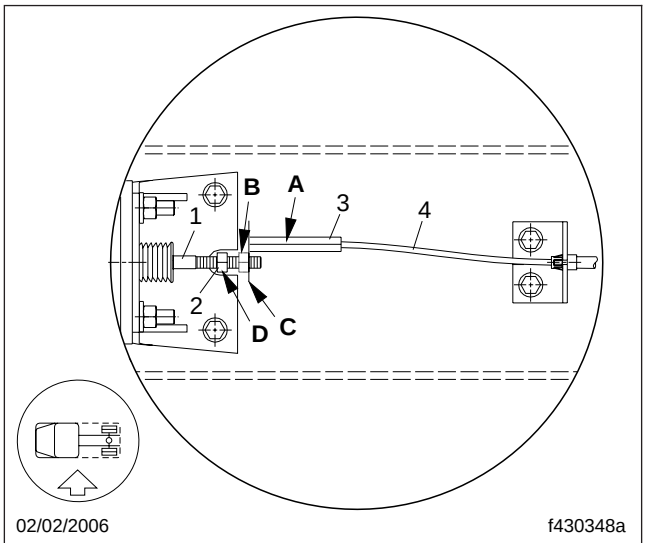
WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

CAUTION

The parking brake chamber is spring-loaded to the applied position and pressurized to the released position. This chamber can not be caged. Keep hands clear while working around the brake chamber. Loss of air pressure will cause the parking brake to apply, and may cause serious personal injury.

1. Release the parking brake.
2. If the cable is attached to the pushrod, loosen the jam nut and back off the adjuster nut to disconnect it from the pushrod.
3. Pull the adjuster nut forward until the cable slack is removed. See **Fig. 3**.
4. Reposition the jam nut to line up with the end of the adjuster nut.
5. Thread the adjuster nut onto the pushrod and against the jam nut. Tighten the jam nut. See **Fig. 4**.
6. Test the brake for proper operation before returning the vehicle to service.

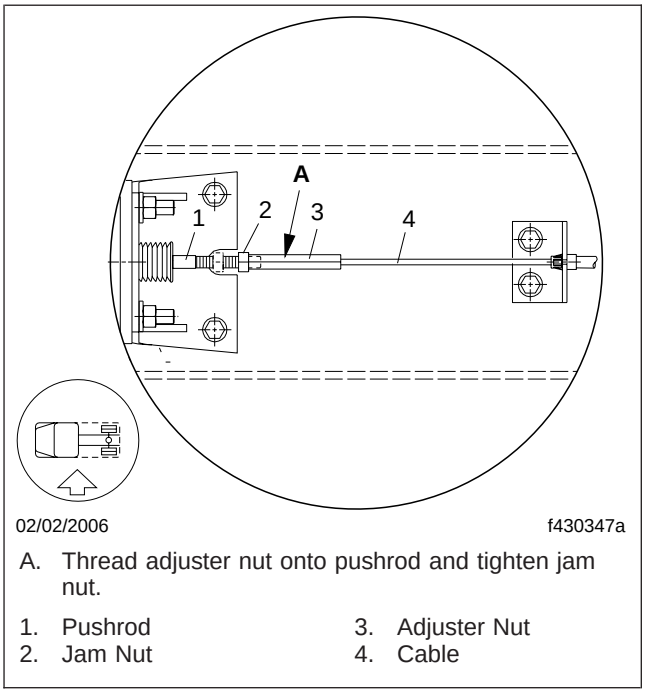


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A. Pull adjuster nut forward until cable slack is removed.
B. Reposition jam nut to align with end of adjuster nut.
C. End of adjuster nut when pulled tight.
D. Jam nut before repositioning

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 3, Cable Adjustment, Air-Actuated Parking Brake



A. Thread adjuster nut onto pushrod and tighten jam nut.

1. Pushrod
2. Jam Nut
3. Adjuster Nut
4. Cable

Fig. 4, Air-Actuated Parking Brake Cable Adjustment

Driveline Parking Brake Assembly Removal and Installation

WARNING

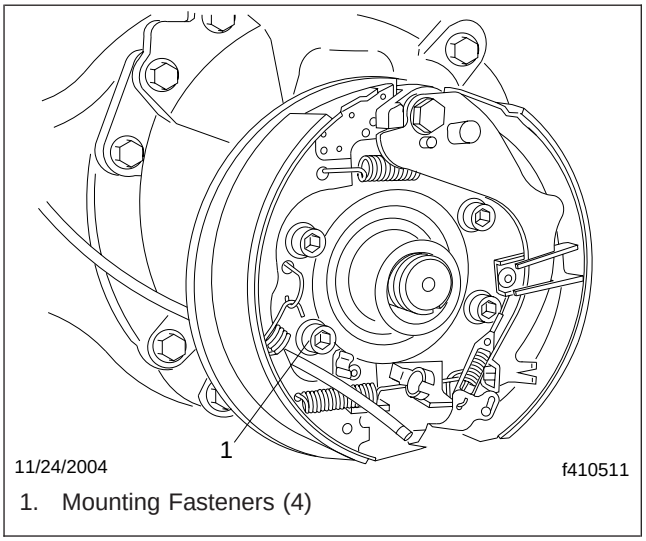
Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

Removal

1. Park the vehicle on a level surface, chock the front tires, and shut down the engine.
2. If necessary, raise the vehicle and set it on jack stands.

NOTE: The driveshaft and yoke-flange may vary depending on vehicle configuration.

3. Disconnect the driveshaft and secure it out of the way. See **Group 41**.
4. Remove the drum and axle-input flange as an assembly. See **Subject 110**.
5. Disconnect the actuation cable from the lever.
6. Compress the sheath prongs and pull the cable housing and the cable from the backing plate opening.
7. Remove the backing plate mounting fasteners. See **Fig. 1**.



1. Mounting Fasteners (4)

Fig. 1, Backing Plate Assembly (flange removed)

8. Remove the parking brake assembly.

Installation

1. Clean any dirt, debris, grease, or oil from the differential mounting surfaces.

NOTE: When properly installed, the anchor point for the actuation lever should be in the 12 o'clock position.

2. Position the parking brake assembly on the differential and install the backing plate mounting fasteners. Tighten to 236 lbf·ft (320 N·m).
3. Slide the actuation cable and housing into the opening in the backing plate and secure the cable housing in the backing plate. Make sure all the prongs are set.
4. Attach the actuation cable to the lever.
5. Adjust the shoes if needed. See **Subject 140**.
6. Install the drum and axle-input flange-yoke assembly. See **Subject 110**.
7. Attach the driveshaft. See **Group 41**.
8. Lower the vehicle.
9. Test the brake for proper operation before returning the vehicle to service.

Inspection

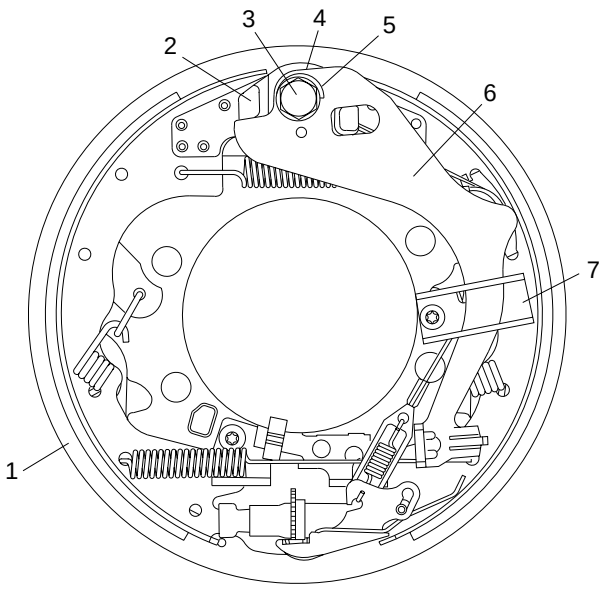
WARNING

Before starting the procedures below, read the information in Safety Precautions, 100. Failure to follow the safety precautions during service operations on the brake system can cause personal injury.

NOTE: It is not necessary to raise the vehicle for inspection in most cases.

Any time service is required, inspect all components in the parking brake assembly.

1. Park the vehicle on a level surface, shut down the engine, and chock the front tires.
2. Remove the drum. See **Subject 110**.
3. Clean the individual brake components, removing dust and grease to the extent reasonable.
4. Inspect the brake shoes. Shoes should be replaced if:
   - there is uneven lining wear, or when the remaining lining reaches approximately 1/32 inch (0.76 mm) thickness, or less, above the shoe;
   - grease, automotive fluids, or other foreign material that would compromise operation is found on, soaked into, or embedded in the linings;
   - cracks, excessive deformation, or wear at either end of the shoe is found.
5. Inspect the brake lever and cam. See **Fig. 1**. If cracks, excessive wear, or abnormal deformation are found in either part, replace as an assembly, the brake lever, cam, and anchor screw. Light wear, which typically shows up as polishing, or as shiny spots, is acceptable. If you are unsure, replace, as an assembly, the brake lever, cam, and anchor screw. See **Subject 130**.
6. Inspect the springs and hold down pins (see **Fig. 2**) for excessive wear, heat discoloration, heavy corrosion, or other damage. Replace damaged parts as necessary. See **Subject 120**.
7. Inspect the adjuster cable assembly for damage or wear. See **Fig. 2**. Replace as necessary. See **Subject 120**.

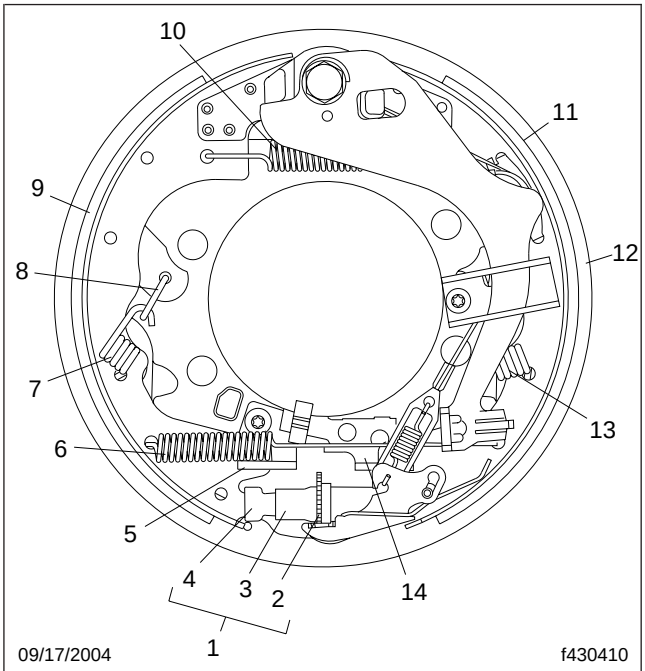


1. Backing Plate
2. Cam
3. Anchor Screw
4. Anchor Point
5. Anti-Rattle Spring
6. Lever
7. Lever Guide

Fig. 1, Parking Brake Major Components

8. Inspect the adjuster nut and screw (see **Fig. 2**) for any damage to the threads, or burrs, chips, or other damage to the teeth on the adjuster-nut starwheel. Damaged teeth or threads may prevent proper function of the brake self-adjusting function. Replace as necessary. See **Subject 120**.
9. Clean-out all dust or grease from the inside of the drum. Using a 12-inch caliper, or an inside-diameter micrometer, measure the inside diameter of the drum. Replace the drum if it exceeds the manufacturer's recommended maximum inside diameter (which typically is stamped on the inside of the drum near the mounting holes), if it is worn unevenly, has deep grooves, heavy corrosion, or excessive runout.
10. Inspect the parking-brake lever apply cable for excessive wear or damage. Replace it if necessary.
11. Inspect the differential pinion seal for evidence of leakage that can contaminate the parking brake system parts. Replace the seal as necessary.

Inspection



1. Adjuster Nut and Screw Assembly
2. Starwheel
3. Adjuster Nut
4. Adjuster Screw
5. Shoe Hold-Down Bracket
6. Lower Shoe Return Spring
7. Hold-Down Spring
8. Pin (opposite side not shown)
9. Brake Shoe
10. Upper Shoe Return Spring
11. Brake Shoe
12. Backing Plate
13. Hold-Down Spring
14. Shoe Hold-Down Bracket

Fig. 2, Brake Shoes and Related Components

See the differential manufacturer's service literature for repair information.

Troubleshooting

Problem—Light Force or Lack of Resistance When Applying Brake Lever (on manual apply systems)

Problem—Light Force or Lack of Resistance When Applying Brake Lever (on manual apply systems)	
Cause	**Remedy**
Shoe cage under-adjusted	Adjust shoes; see **Subject 140**.
Worn or deformed actuation components (lever, cam lugs, shoe ends)	Inspect and replace damaged components; see **Subject 130** or **Subject 120**.
Apply system is not operating properly	Inspect application components and repair as necessary; see **Subject 130** or **Subject 120**.

Problem—Heavy Force or Excessive Resistance When Applying Brake Lever (on manual apply system)

Problem—Heavy Force or Excessive Resistance When Applying Brake Lever (on manual apply system)	
Cause	**Remedy**
Over-adjusted brake	Adjust shoes; see **Subject 140**.
Apply system is over-adjusted	Inspect application components and repair/adjust as necessary; see **Subject 150**.

Problem—Brake Does Not Release

Problem—Brake Does Not Release	
Cause	**Remedy**
Internal damage to brake	Inspect brake components and repair as necessary; see **Subject 170**.
Apply cable is binding	Check cable for corrosion, binding, kinks, and damage. Adjust or repair as needed; see **Subject 150**.
Apply system is not operating properly	Inspect application components and repair as necessary; see **Subject 150**.

Problem—Brake Does Not Hold Vehicle On Hill

Problem—Brake Does Not Hold Vehicle On Hill	
Cause	**Remedy**
Grease, oil, or other foreign material on or embedded in shoe linings	Replace shoes and clean drum; see **Subject 120**. Inspect rear pinion seal for leakage that can contaminate parking brake system parts, and repair as necessary.
Damaged or incorrect shoes	Replace with correct shoes; see **Subject 120**.
Worn out lining (metal shoe rim contacting drum)	Replace shoes; see **Subject 120**. Resurface or replace drum as necessary; see **Subject 110**.
Shoe cage is under-adjusted	Adjust shoes; see **Subject 140**.
Worn or deformed actuation components (lever, cam lugs, shoes)	Inspect and replace damaged components; see **Subject 130** or **Subject 120**.

Troubleshooting

Problem—Brake Does Not Hold Vehicle On Hill	
Cause	**Remedy**
Apply system is not operating properly	Inspect and replace damaged components and adjust as necessary; see **Subject 160**.

Specifications

Component Specifications		
Item	**Dimension**	**Specifications**
Shoe Lining:	thickness, new (above shoe)	0.277 inch (7 mm) (at center)
	thickness, replace (above shoe)	0.030 inch (0.76 mm)
	width	3 inch (75 mm)
Drum (typical): (non-Bosch part)	inside diameter	12.000 inch (304.8 mm)
	maximum inside diameter	12.035 inch (305.7 mm)
	thickness	0.315 inch (8 mm)
	surface finish	125 micro inch (3.2 micro m) or less

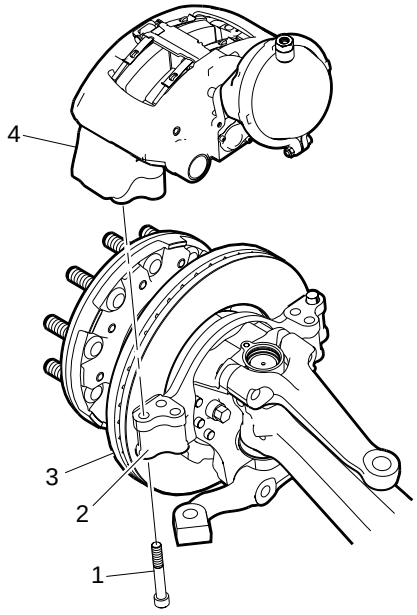
Table 1, Component Specifications

Fastener Torque Specifications		
Fastener	**Size**	**Torque**
Anchor Screw	M12 x 1.75	74 lbf·ft (100 N·m)

Table 2, Fastener Torque Specifications

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

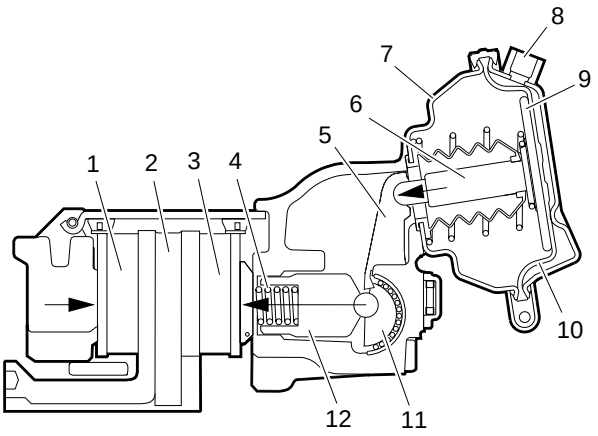
Fig. 1, Caliper/Carrier Installation

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.



05/29/2008 f422472

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.

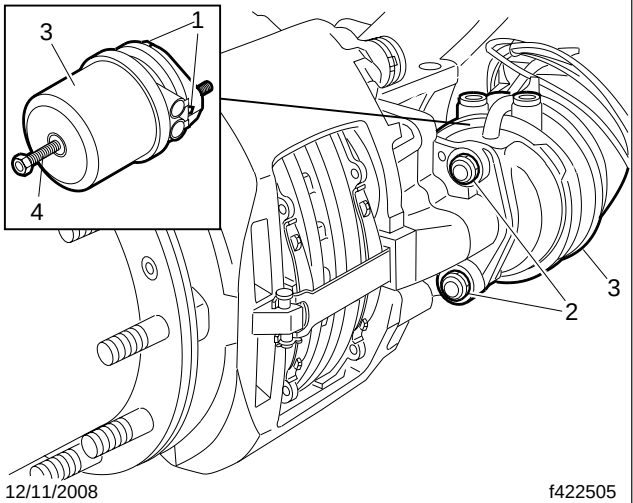
Removal

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**.

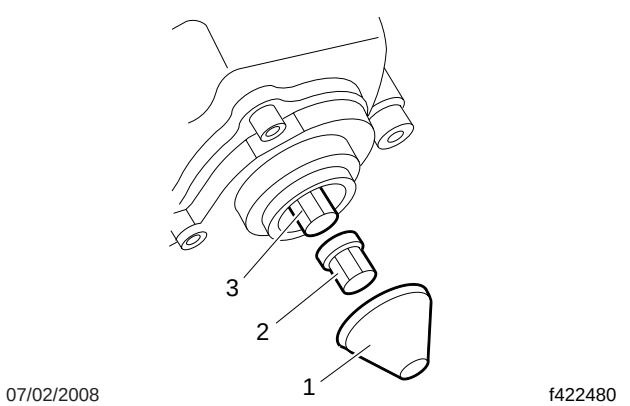
IMPORTANT: Before removing the brake pads, check the adjuster mechanism for proper operation.

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 in Position

NOTICE

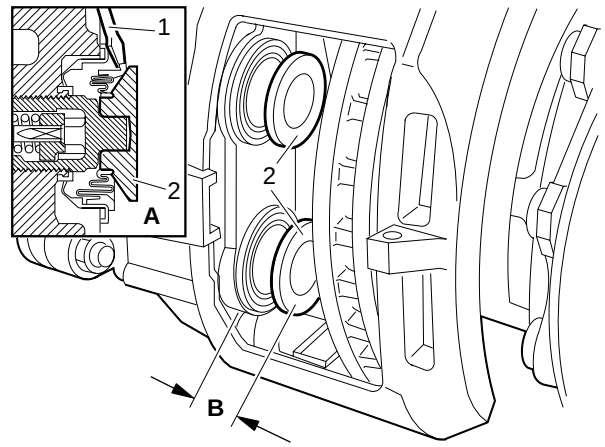
Do not use an open-ended wrench, as this may damage the adaptor.

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

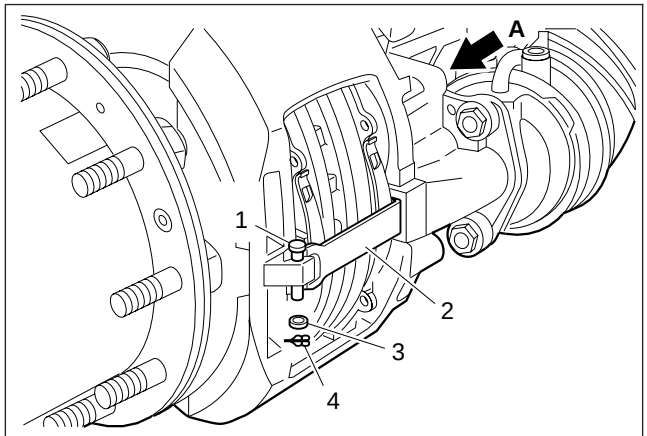
Fig. 3, Tappet and Boot Assembly

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.

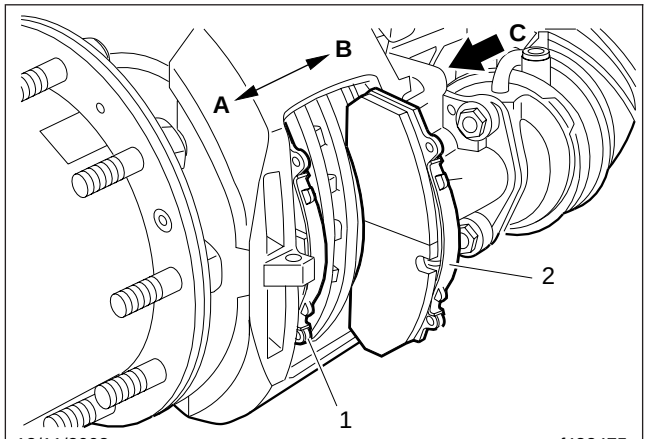


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A. Shear Adjuster Location

1. Pad Retainer Pin
2. Pad Retainer
3. Washer
4. Clip

Fig. 4, Caliper Assembly



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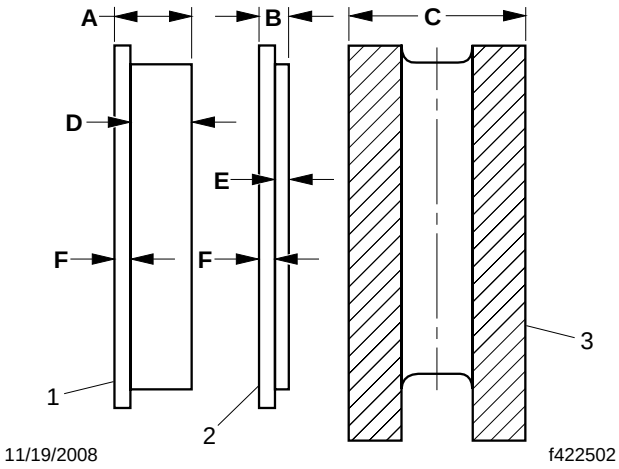
A. Outboard
B. Inboard
C. Area of Shear Adaptor

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**.

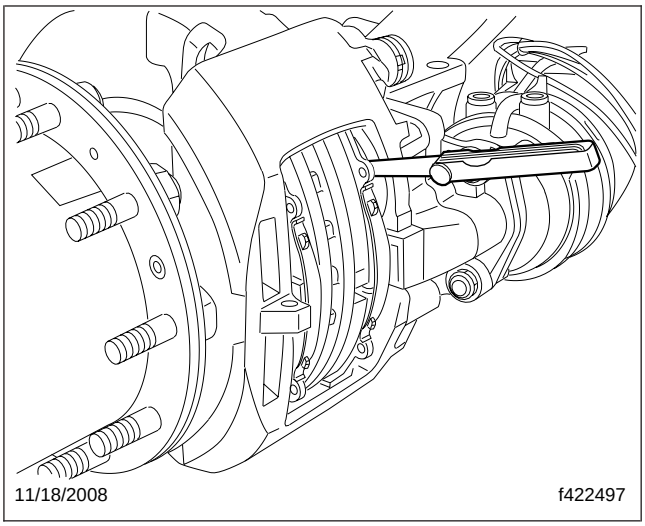


Fig. 7, Checking Brake Pad Running Clearance

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.

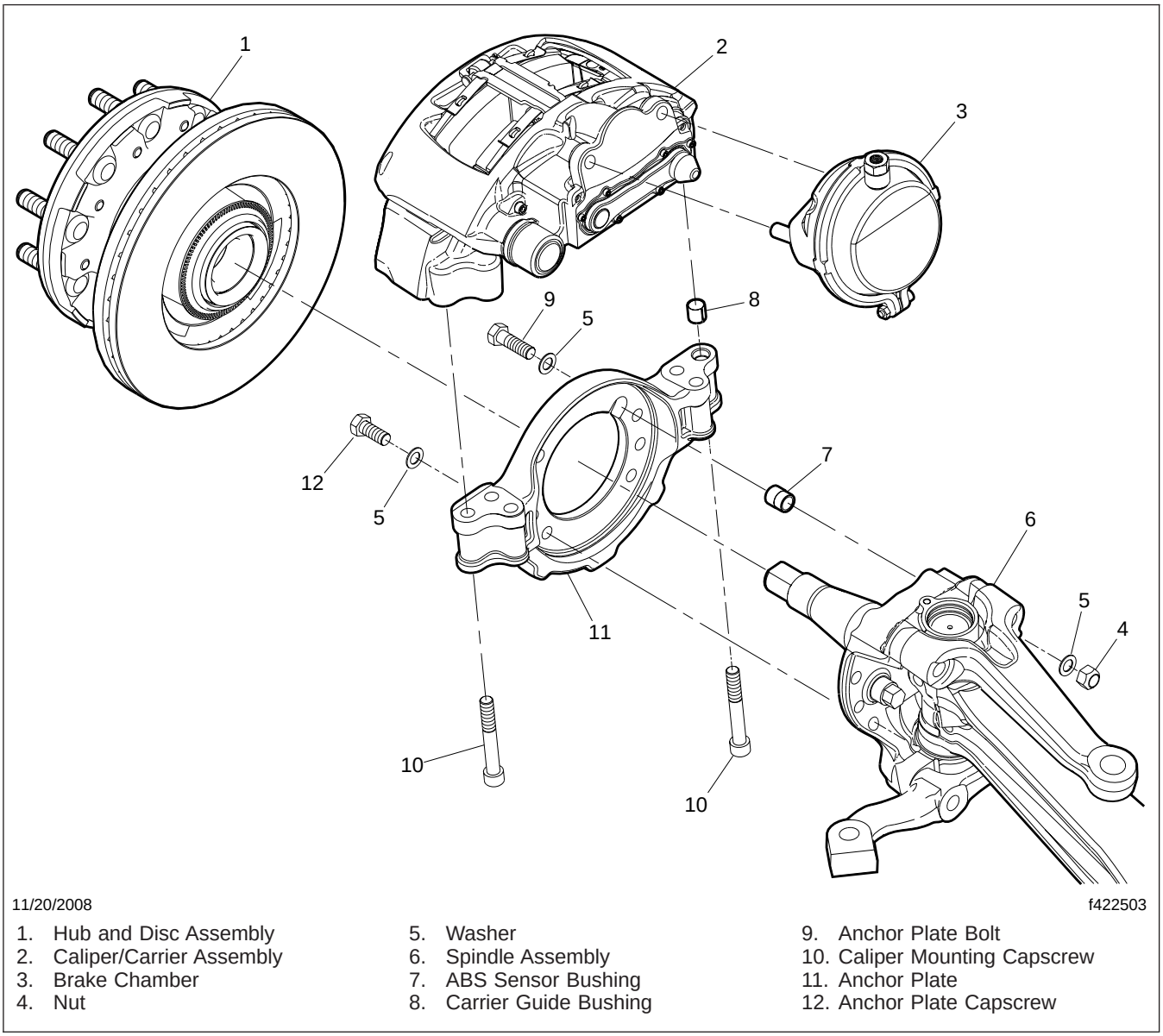
8. In a safe area, check for proper brake operation, as follows, before you put the vehicle in service.
   - 8.1 Apply and release the brakes several times to check for air leaks and proper operation.
   - 8.2 Perform six low-speed stops to ensure proper parts replacement and full vehicle control.
   - 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**.

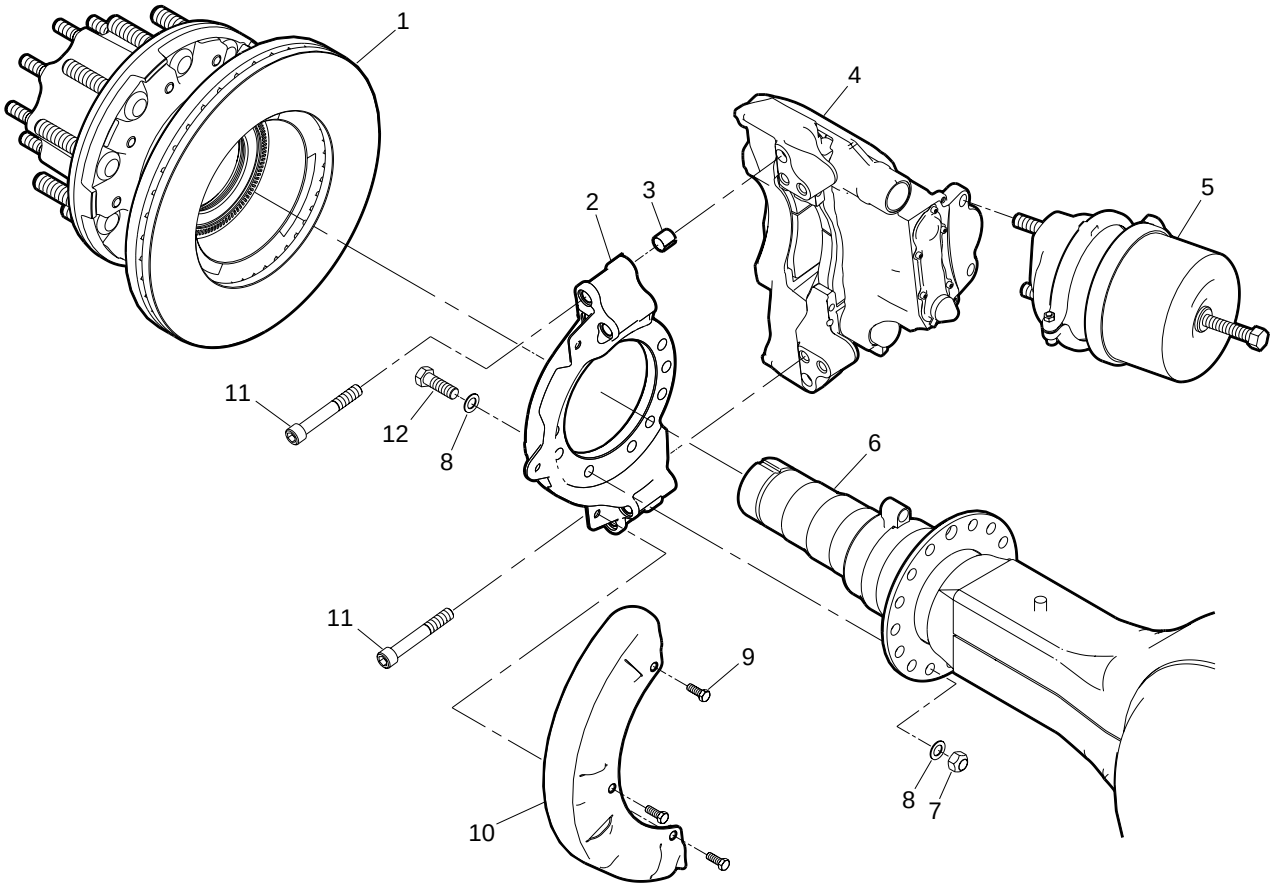
⚠ WARNING

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



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

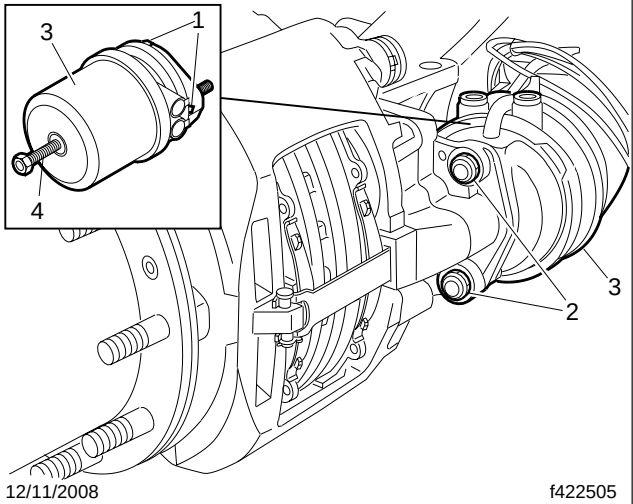
Fig. 2, Rear Caliper and Carrier Assembly Installation

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.

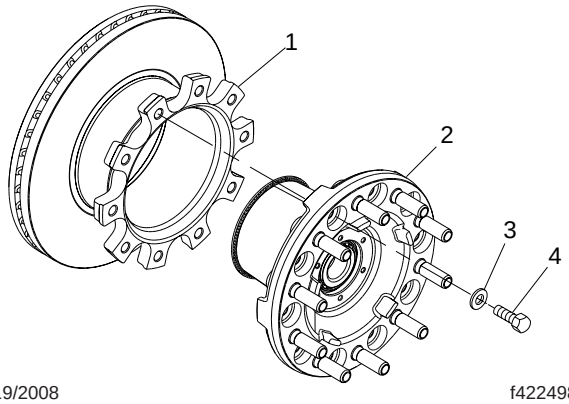
Brake Rotor Removal

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.

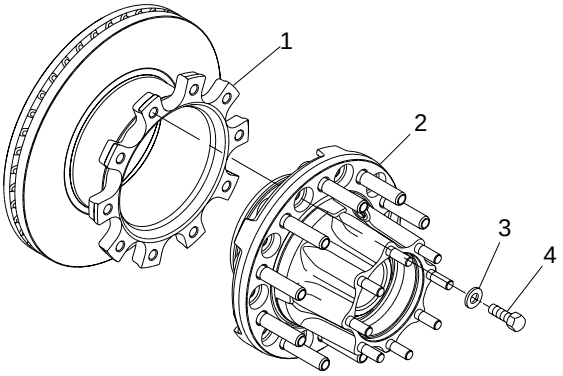
Brake Rotor Installation

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

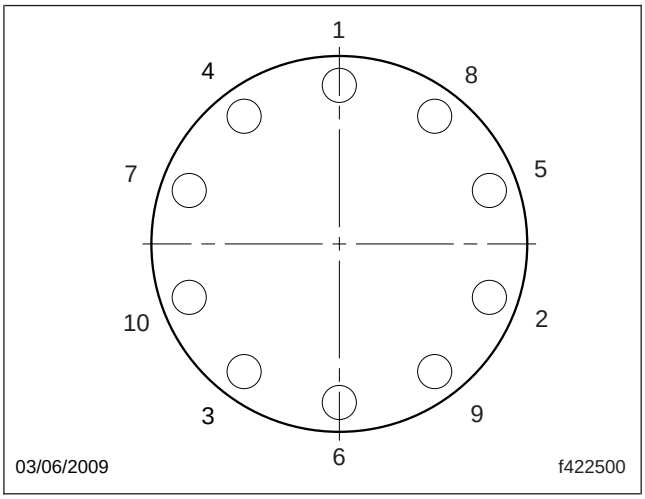


Fig. 3, Tightening Sequence

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

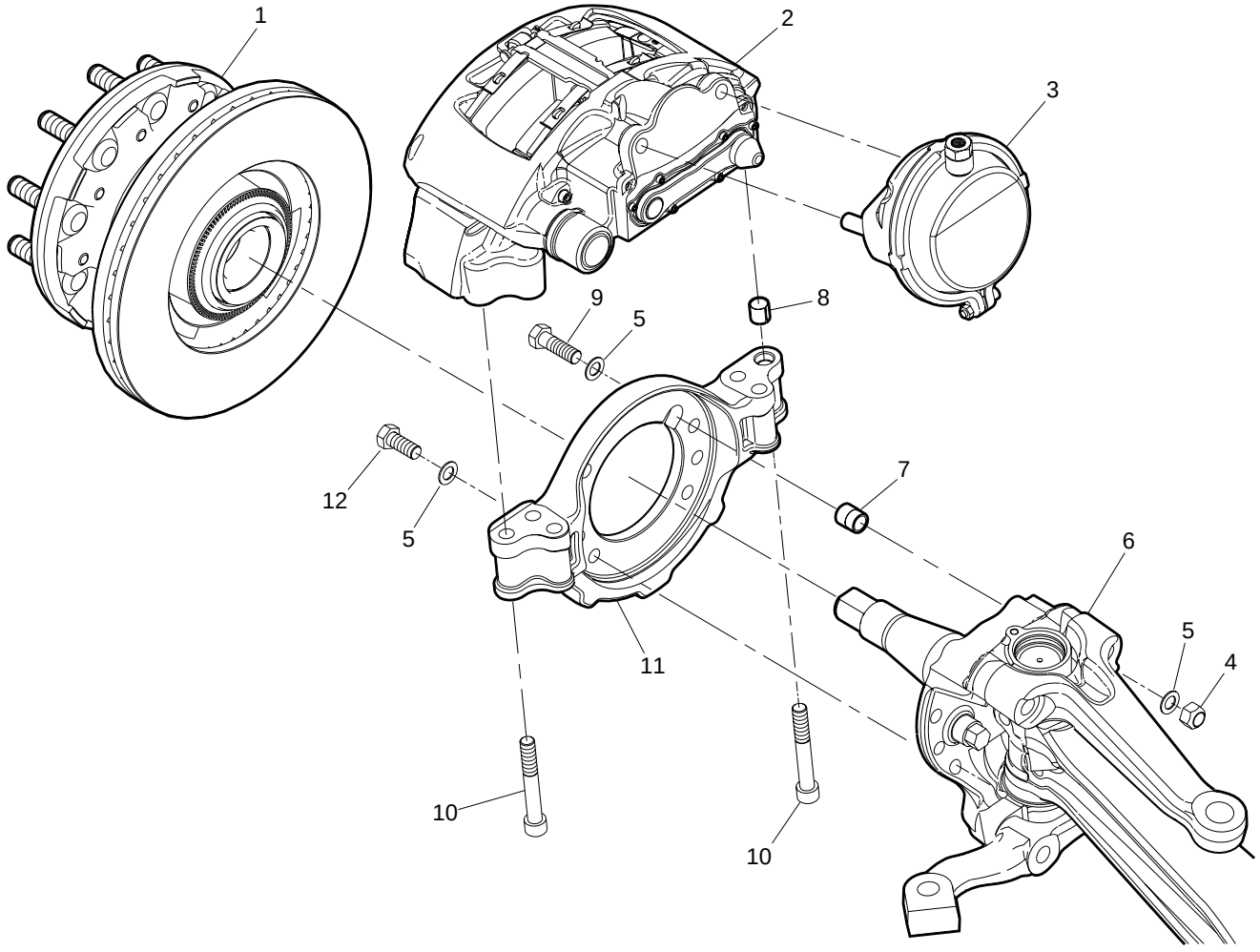
If replacing the anchor plate, it is not necessary to clean and inspect it. If the anchor plate will be reused, clean and inspect it as follows.

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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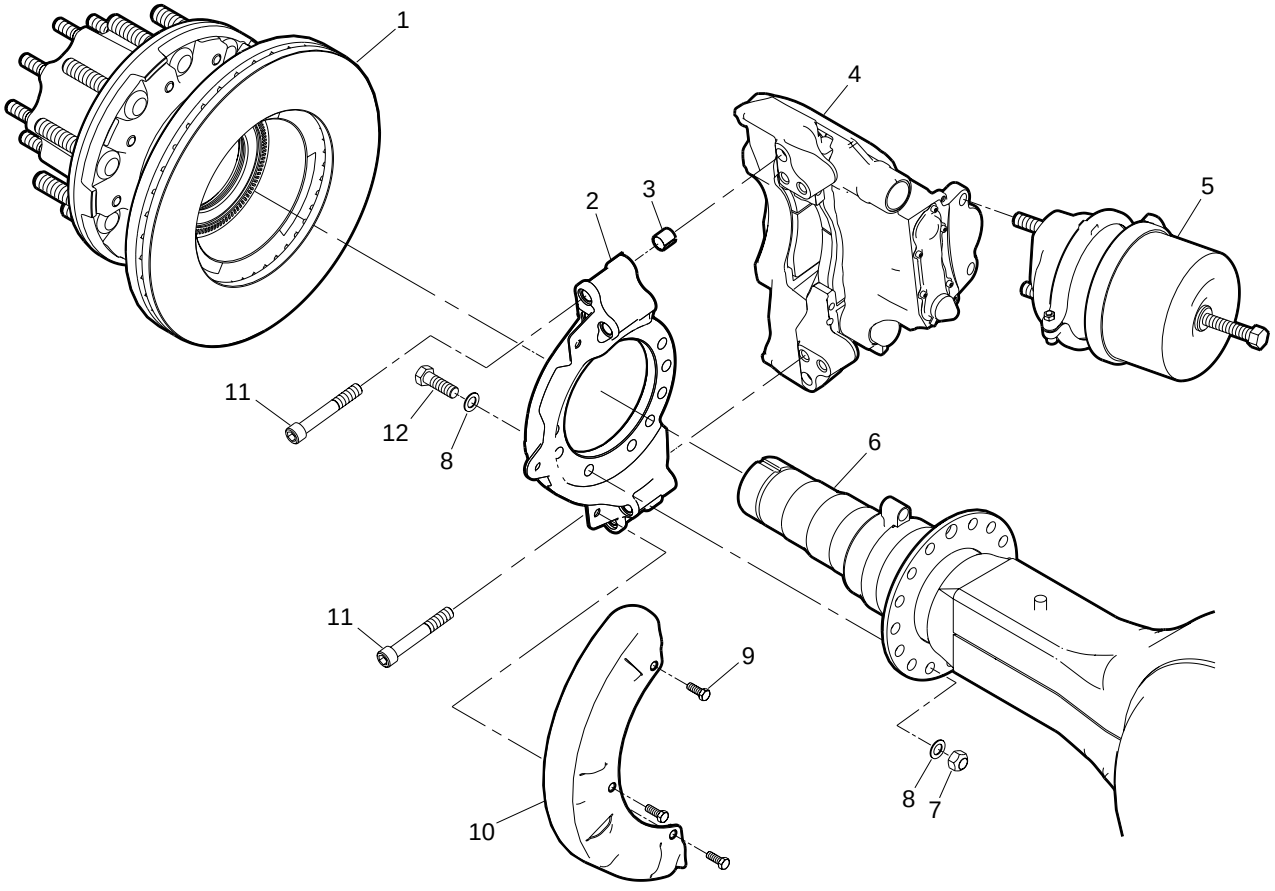
1. Hub and Disc Assembly
2. Caliper/Carrier Assembly
3. Brake Chamber
4. Nut
5. Washer
6. Spindle Assembly
7. ABS Sensor Bushing
8. Carrier Guide Bushing
9. Anchor Plate Bolt
10. Caliper Mounting Capscrew
11. Anchor Plate
12. Anchor Plate Capscrew

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

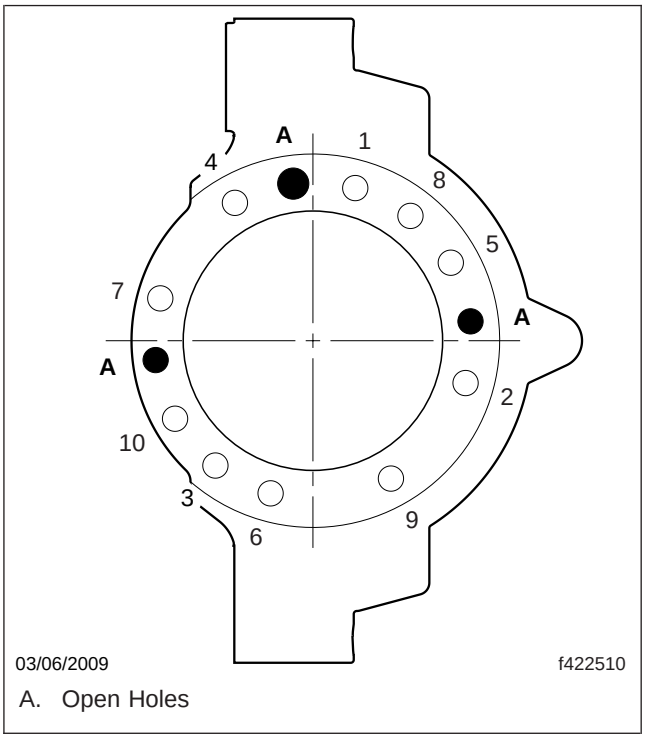


Fig. 3, Tightening Sequence

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.

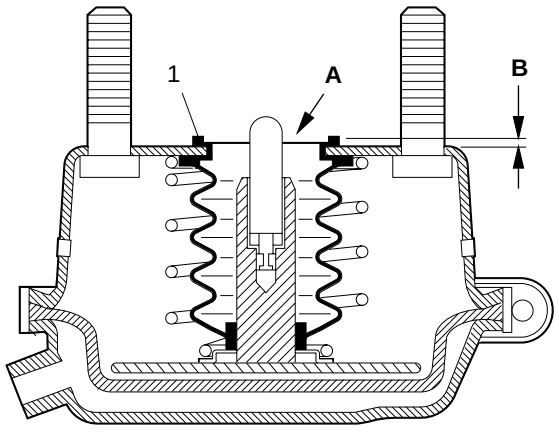
Brake Chamber, or Spring Brake Chamber, Removal and Installation

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 in. (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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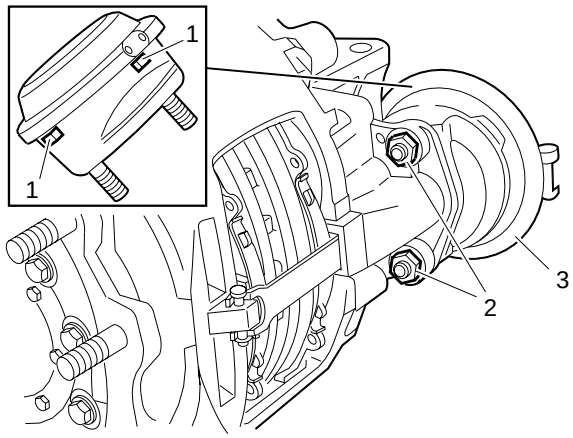
A. Pushrod Area
B. Do Not Use if Thickness is Less than 0.12 in (3 mm)

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

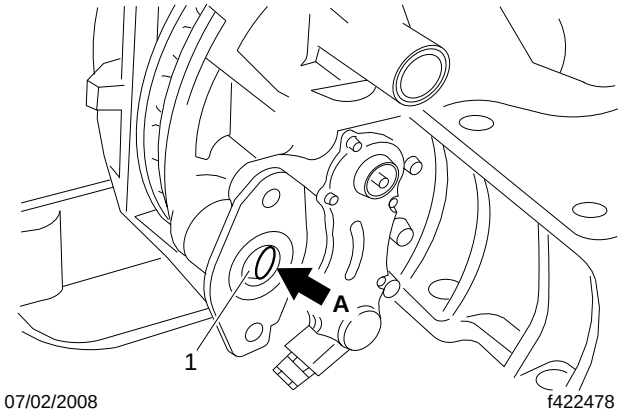
Fig. 2, Brake Chamber Installation

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

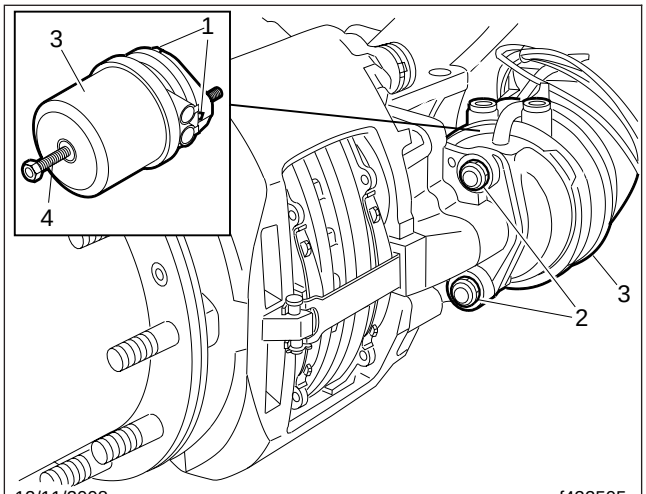
1. Set the brakes and chock the tires.
2. Remove the wheels.

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**.
4. Drain all the air pressure from the air brake system.



1. Drain Plugs
2. Brake Chamber Nuts
3. Brake Chamber
4. Release Bolt

Fig. 4, Spring Brake Chamber Installation

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.

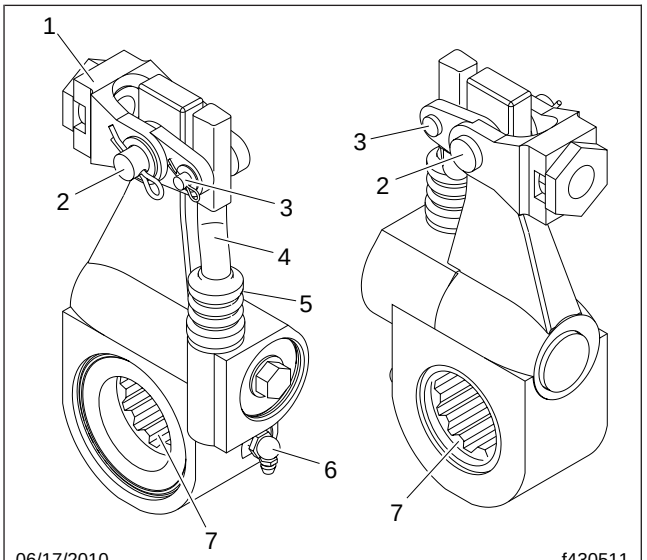
Specifications

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 Description[1]

The Bendix® ASA-5® automatic slack adjuster is designed for use on cam actuated drum brakes of the type in use on most highway vehicles. See **Fig. 1**. Like a manual slack adjuster, the ASA-5 slack adjuster multiplies and transforms the linear force of the air actuator into a rotational force or torque, which is used to apply to foundation brake. Additionally, the automatic slack adjuster adjusts the clearance between the brake lining and drum to compensate for wear.



1. Yoke
2. Yoke Pin
3. Link Pin
4. Link
5. Boot
6. Lube Fitting
7. Worm Gear

Fig. 1, ASA-5 Automatic Slack Adjuster

A variety of ASA-5 slack adjuster configurations are offered, including both straight arm and 5/8-inch yoke offset models.

IMPORTANT: The manual hex adjuster is **only** intended for use during installation.

⚠ 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.

Either of two yoke designs (easy-on and quick-connect) in combination with an external manual hex adjuster provides easy installation and maintenance of the ASA-5 slack adjuster.

Operation

The automatic adjustment provided by the ASA-5 slack adjuster results in consistent brake lining to drum clearance and brake actuator stroke. The key to its operation is the ability to complete the brake adjustment during the early part of each brake application and to cease adjusting as resistance to brake cam rotation begins to build. This aspect of the adjuster mechanism's operation prevents over-adjustment caused by lining compression, actuator bracket deflection, drum and foundation brake component distortion, or brake component wear.

The ASA-5 slack adjuster incorporates a clutch-type adjuster mechanism that continuously adjusts in very small increments as lining and drum wear occurs. Therefore, the adjustments made by the ASA-5 slack adjuster are not in specific increments relative to actuator stroke.

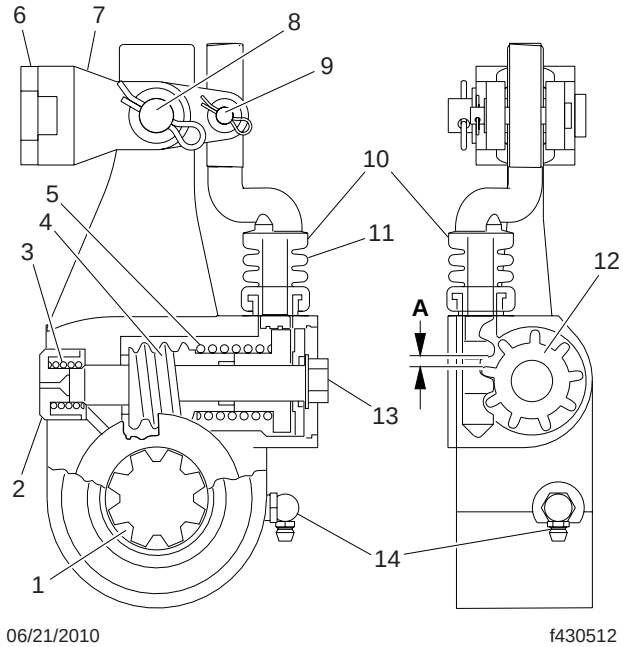
Brake Application

When the brakes are applied, the linear travel of the brake actuator's pushrod causes the ASA-5 slack adjuster to rotate the foundation brake camshaft, which in turn begins to force the brake shoes into contact with the drum. When the ASA-5 slack adjuster rotates, the yoke assembly pivots on the yoke pin causing the link to be pulled upward. See **Fig. 2** for a sectional view of the ASA-5 slack adjuster.

The teeth on the link mesh with the adjuster mechanism pinion. As the link is pulled, it travels first through its free play and then causes the pinion to rotate. Rotation of the pinion is transmitted through the clutch spring to the worm and shaft. Worm and shaft rotation results in worm gear rotation, which adjusts the brake camshaft.

[1] The instructions and illustrations in this section are provided by Bendix Commercial Vehicle Systems, LLC and are used with permission.

General Information



A. Free-Play

1. Worm Gear
2. Spring Retainer
3. Anti-Reverse Spring
4. Worm
5. Clutch Spring
6. Adaptor Bushing
7. Yoke
8. Yoke Pin
9. Link Pin
10. Boot
11. Lube Relief Opening
12. Pinion
13. Manual Hex Adjuster
14. Lube Fitting

Fig. 2, ASA-5 Automatic Slack Adjuster (sectional view)

When the foundation brake shoes contact the drum, the camshaft begins to resist rotation and friction between the worm gear and worm builds, preventing further rotation of the worm. Brake adjustment ceases at this point and further rotation of the ASA-5 slack adjuster will cause the pinion and clutch spring to slip. The free-play between the link teeth and pinion results in a predetermined lining-to-drum clearance.

Brake Release

When the brake application is released, the brake actuator pushrod returns the ASA-5 slack adjuster to the released position. During release, the ASA-5 slack adjuster rotates back toward the actuator causing the brake camshaft to again rotate, but in the opposite direction, and the brake shoes begin to move away from the drum. As the ASA-5 slack adjuster rotates back to the release position, the yoke again pivots, causing the link to be pushed downward into the slack adjuster body. The free-play between the link teeth and pinion is taken up during the initial part of the release. Continued movement of the ASA-5 slack adjuster toward the released position causes the link to rotate the pinion. The anti-reverse spring prevents counterclockwise rotation of the shaft and worm causing the pinion and clutch spring to slip. The gripping action of the anti-reverse spring and slippage of the clutch spring during release is due to the direction of the coil windings of each.

Yoke Designs

ASA-5 slack adjusters may be equipped with either of two yoke designs. Both are designed to permit installation or removal of the slack adjuster along with its yoke body and its attached adjusting linkage.

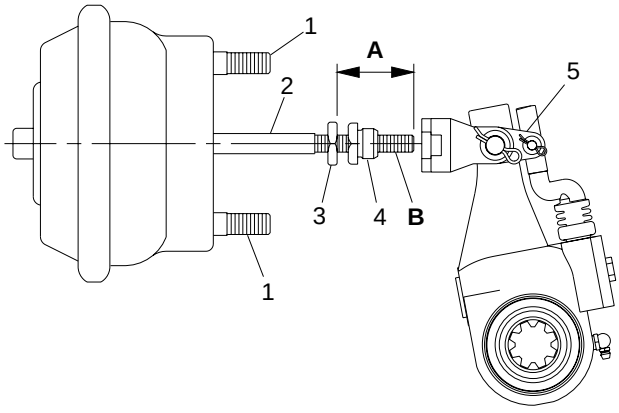
The brake actuator pushrod must thread into the adapter a minimum of 1/2 inch and must not extend more than 7/64 inch beyond the other end of the adaptor. The yoke adaptors, quick-connect and easy-on, have either a 1 or 1-1/4 inch adjuster hex to allow tightening of the brake actuator pushrod jam nut.

Easy-On Yoke

The easy-on yoke assembly, shown in **Fig. 3**, consists of an adaptor which is threaded internally to match the pushrod threads and external to match female threads in the yoke. A special extended yoke adaptor is also available as a separate service item. The extended adaptor is 1/2 inch longer than the standard and it is intended for use when the existing brake actuator pushrod is too short.

Quick-Connect Yoke

For the quick-connect yoke, the adaptor bushing is threaded internally to match the pushrod, but is designed to slide into the yoke. A retainer ring is used to secure the adaptor bushing in the yoke. See **Fig. 4**.

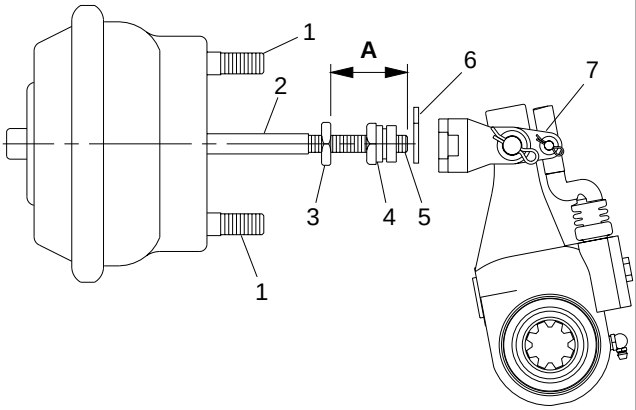


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A. 1-5/16"
B. 3/8" Out

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor
5. Yoke

Fig. 3, Easy-On Yoke Assembly



06/22/2010 f430514

A. 1"

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor Bushing
5. Flush
6. Retaining Ring
7. Yoke

Fig. 4, Quick-Connect Yoke Assembly

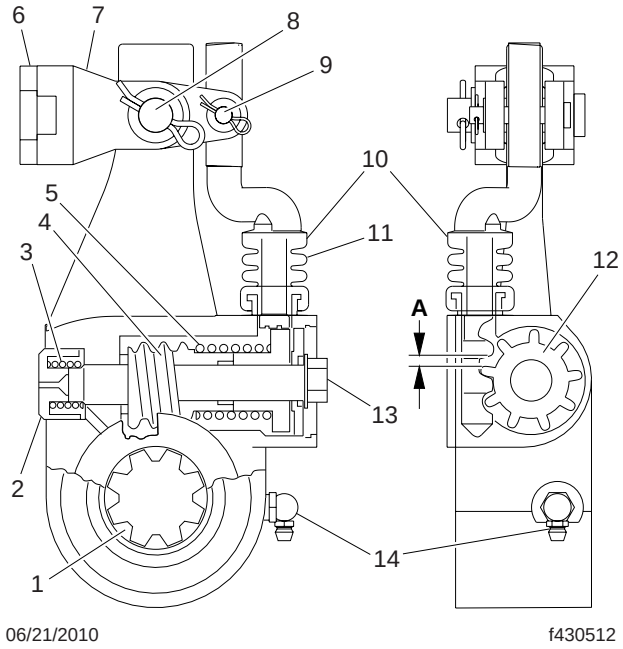
Safety Precautions

When working on or around a vehicle, observe the following precautions:

- Park the vehicle on a level surface, 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 the 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 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.

Removal

NOTE: Refer to **Fig. 1** for an example of the ASA-5 slack adjuster when completing this procedure.



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A. Free-Play

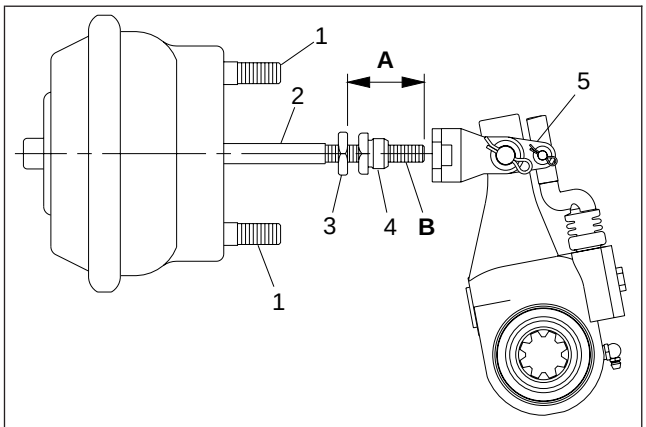
1. Worm Gear
2. Spring Retainer
3. Anti-Reverse Spring
4. Worm
5. Clutch Spring
6. Adaptor Bushing
7. Yoke
8. Yoke Pin
9. Link Pin
10. Boot
11. Lube Relief Opening
12. Pinion
13. Manual Hex Adjuster
14. Lube Fitting

Fig. 1, ASA-5 Automatic Slack Adjuster (sectional view)

ASA-5 Slack Adjuster with Easy-On Yoke Assembly

1. Loosen the brake actuator pushrod jam nut and run it back on the brake actuator pushrod approximately 5/8 inch. See **Fig. 2**.
2. Loosen the easy-on yoke adaptor and run it back on the brake actuator pushrod until it is free of the yoke.

NOTE: Considerably more torque is required to rotate the manual hex adjustment counterclockwise than is necessary to rotate it clockwise. The torque may be as high as 70 lbf·ft (95 N·m).



07/13/2010 f430513

A. 1-5/16"
B. 3/8" Out

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor
5. Yoke

Fig. 2, Easy-On Yoke Assembly

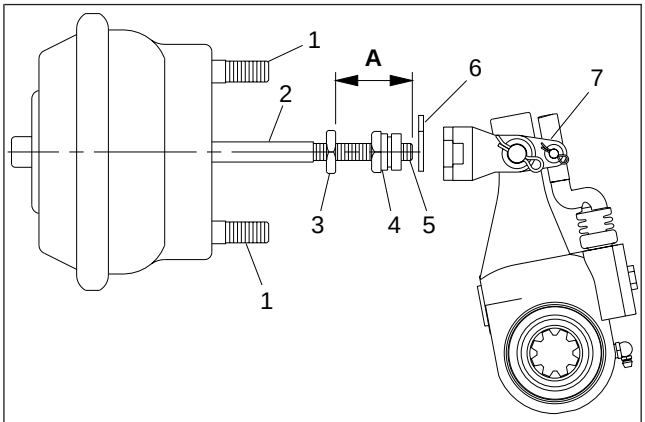
3. Rotate the manual hex adjustment counterclockwise until the ASA-5 slack adjuster is clear of the brake actuator pushrod.
4. Remove the ASA-5 slack adjuster from the camshaft of the foundation brake by removing the retaining clip and any spacers or washers that may be present.

ASA-5 Slack Adjuster with Quick-Connect Yoke

NOTE: Considerably more torque is required to rotate the manual hex adjustment counterclockwise than is necessary to rotate it clockwise. The torque may be as high as 70 lbf·ft (95 N·m).

1. Rotate the ASA-5 manual hex adjustment counterclockwise until the brake actuator pushrod just begins to move out of the actuator. See **Fig. 3**
2. Pinch the 'legs' of the retaining ring together and pull the ASA-5 slack adjuster away from the brake actuator pushrod until the adaptor bushing is free of the yoke. Remove the retaining ring from the adaptor bushing.

Slack Adjuster Removal and Installation



A. 1"

1. Mounting Stud
2. Pushrod
3. Jam Nut
4. Adaptor Bushing
5. Flush
6. Retaining Ring
7. Yoke

Fig. 3, Quick-Connect Yoke Assembly

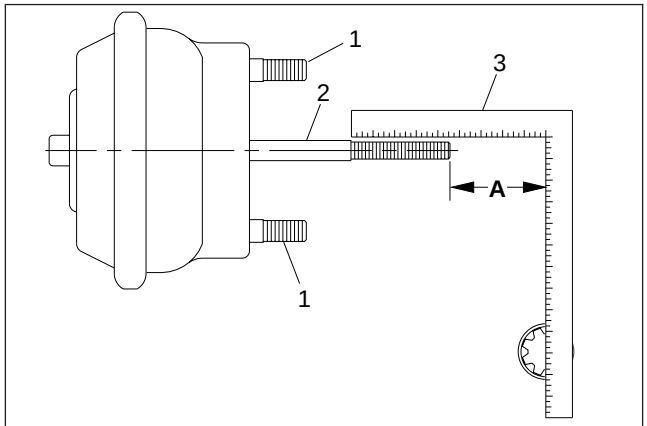
3. Rotate the manual hex adjustment counterclockwise until the ASA-5 slack adjuster is clear of the brake actuator pushrod.
4. Remove the ASA-5 slack adjuster from the camshaft of the foundation brake by removing the retaining clip and any spacers or washers that may be present.

Installation

1. Before mounting the ASA-5 slack adjuster on the camshaft, check the brake chamber pushrod length to determine if shortening or replacement are required.

   1.1 With the brake chamber in the released position, place a square (or equivalent object) so that one edge is parallel to the actuator pushrod while the other edge bisects the brake camshaft. Measure the distance from the pushrod end to the vertical edge of the square as shown in **Fig. 4** and compare it to the values in **Table 1**.

   1.2 If measurement A is less than the minimum values shown in **Table 1**, the brake actuator pushrod must be shortened. If measurement A is greater than the maximum values, the brake actuator pushrod may require replacement.



A. Distance

1. Mounting Stud
2. Brake Actuator Pushrod
3. Square

Fig. 4, Measuring the Brake Actuator Pushrod

NOTE: The extended adaptor is available as a separate part (5/8–18 and 1/2–20), and may avoid the need to replace the brake actuator pushrod. The extended adaptor is only available for the easy-on yoke assembly.

IMPORTANT: Installing any other type of pushrod extender is not recommended, because they may loosen over time and result in an improperly adjusted brake.

2. Inspect the foundation brake, brake chamber and related components. Make certain the camshaft bushings and seals are not excessively worn. Lubricate the camshaft bushings. Check the brake chamber bracket for cracks and corrosion. The brake actuator pushrod should not be loose or bent, and the return spring should be firm. Replace parts as needed.

Brake Actuator Pushrod Measurement		
Slack Adjuster Arm Length (inches)	**Standard Easy-On or Quick-Connect Adaptor (inches)**	**Extended Easy-On Adaptor (inches)**
5	1-15/16 to 3-1/32	2-7/16–3-17/32
5-1/2	1-15/16 to 3-3/16	2-7/16–3-11/16
6	1-3/16 to 3-3/16	1-11/16–3-11/16

Table 1, Brake Actuator Pushrod Measurement

3. Install the ASA-5 slack adjuster on the brake camshaft.

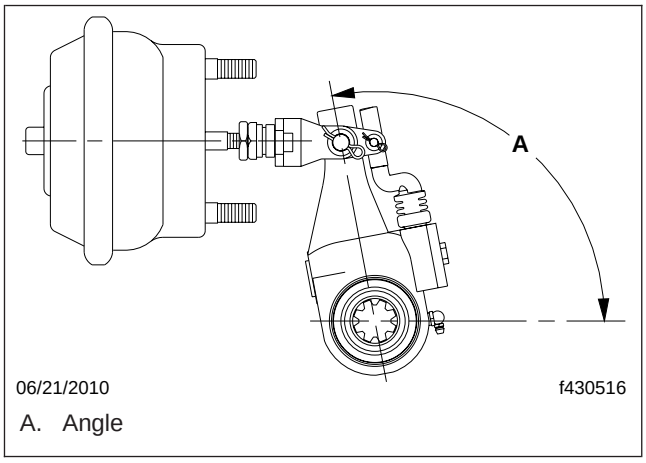
   3.1 If the adjuster has the easy-on yoke shown in **Fig. 2**, position the brake actuator pushrod jam nut approximately 1-5/16 inches from the end of the brake actuator pushrod. Thread the easy-on yoke adaptor on the brake actuator pushrod until it is approximately 3/8 inch from the end of the brake actuator pushrod end.

   Turn the slack adjuster manual hex adjustment clockwise until the adaptor extends into the threaded bore of the yoke approximately 1/8 inch. Thread the adaptor into the yoke and tighten 120 lbf·in (1356 N·cm).

   3.2 If the adjuster has the quick-connect yoke shown in **Fig. 3**, position the brake actuator pushrod jam nut approximately 1 inch from the end of the brake actuator pushrod. Thread the quick-connect adaptor bushing on the brake actuator pushrod until it is flush with the end of the brake actuator pushrod. Install the retaining ring on the adaptor bushing, making certain it is in the adaptor bushing groove.

   Turn the slack adjuster manual hex adjustment clockwise until the adaptor bushing begins to enter the yoke. Fully compress the retaining ring 'legs' and continue turning the manual hex adjustment until the adaptor bushing is completely in the yoke. Allow the retaining ring to expand into the corresponding groove in the yoke. Make certain the retaining ring is seated in both the yoke and the adaptor bushing groove by manually pulling the slack adjuster arm, attempting to separate the adaptor bushing and yoke.

Figure 5 shows the angle of a properly installed ASA-5 slack adjuster. See **Table 2** for a list of slack adjuster arm lengths and allowable range of angles.



A. Angle

Fig. 5, Installation Angle

Slack Adjuster Angle	
Arm Length (inches)	**Angle (degrees)**
5	99–113
5.5	98–111
6	90–109

Table 2, Slack Adjuster Angle

4. Run the brake actuator pushrod jam nut down against the adaptor or adaptor bushing. Hold the adaptor or adaptor bushing hex with a wrench and tighten the jam nut 25 to 33 lbf·ft (34 to 45 N·m) for the 1/2–20 thread and 33 to 50 lbf·ft (45 to 68 N·m) for the 5/8–18 thread.

IMPORTANT: The vehicle brakes should be adjusted using the vehicle or brake manufacturer's

Slack Adjuster Removal and Installation

recommendation. If they are not available, the following procedure can be used.

5. Manually adjust the brakes.

   Rotate the manual hex adjustment clockwise until the linings are snug against the drum. Turn the hex adjustment counterclockwise 1/2 turn. Pull the actuator pushrod to confirm that approximately 1/2 inch of pushrod free stroke exists. Apply 85 psi (586 kPa) to the brake pedal, and check that the pushrod stroke is below the readjustment limit. If the stroke exceeds the limit, check the condition of the foundation brakes. See the *Brake Inspection* instructions below.
6. Manually uncage the spring brakes before returning the vehicle to service.
7. Once the slack adjuster is installed, check to ensure clearance requirements with the brake fully released and at the actuator's maximum stroke. Also consider clearances with the vehicle suspension springs depressed to the jounce bumpers, as well as in rebound.

Brake Inspection

The following test can be used to inspect the condition of the foundation brake and to determine how much of the chamber stroke is caused by the condition of the foundation brake.

1. If not already done, chock the tires.
2. Raise the axle so that the wheel can be rotated.
3. Adjust the slack adjuster to produce light brake drag with wheel rotation.
4. Apply 80 to 90 psi (552 to 621 kPa) to the brake pedal and measure the stroke.
5. If the stroke significantly exceeds the values shown in **Table 3**, the brake may be out of the norm and brake maintenance may be required. For maintenance procedures, see maintenance operation **42-04** in the *S2 Chassis Maintenance Manual*.

Brake Stroke*			
Area Length (AL) Factor†	**15 x 4 Front Brake**	**16.5 x 7 Tractor, Truck, or Bus Brake**	**16.5 x 7 Trailer Brake**
12 x 5.0	1/2	N/A	N/A
12 x 5.5	1/2	N/A	N/A
16 x 5.0	5/8	1/2	N/A
16 x 5.5	3/4	1/2	N/A
16 x 6.0	7/8	5/8	N/A
20 x 5.0	5/8	1/2	3/8
20 x 5.5	3/4	5/8	1/2
20 x 6.0	7/8	3/4	5/8
24 x 5.0	N/A	5/8	1/2
24 x 5.5	N/A	5/8	5/8
24 x 6.0	N/A	3/4	5/8
30 x 5.0	N/A	3/4	5/8
30 x 5.5	N/A	7/8	3/4
30 x 6.0	N/A	1	7/8

* All values listed are in inches.

† 'A' is the area of chamber diaphragm multiplied by 'L', the length of the slack adjuster. More braking force is available with a larger AL factor.

Table 3, Brake Stroke

Troubleshooting Tables

Problem—Brake Actuator Stroke is Too Long

Problem—Brake Actuator Stroke is Too Long	
Possible Cause	**Remedy**
Loose actuator pushrod jam nut.	Reposition components and tighten to specification.
Excessive clearance between the adaptor/ adaptor bushing and yoke due to wear.	Replace damaged or worn parts.
Excessive clearance between components— • yoke pin–yoke; • link pin–link; • yoke pin–body.	Replace worn parts.
Damaged (worn) splines on slack or camshaft.	Replace damaged parts.
Weak or broken brake actuator return springs. Weak or broken brake shoe return spring.	Replace weak or broken springs.
Worn or broken foundation brake components, including camshaft bushings, brake chamber bracket, etc.	Repair or replace damaged or worn parts.
ASA-5® adjuster mechanism not functioning.	Lubricate and then test the adjuster mechanism. Repair or replace components as necessary.
Brake drum worn, excessively machined, bell-mouthed, excessive thermal expansion.	Replace or repair as necessary.
ASA-5 slack adjuster is damaged.	Replace component(s) or slack adjuster.
ASA-5 slack adjuster is improperly installed.	Correct the installation position.

Problem—Brakes Dragging–Over-Adjustment of Brakes

Problem—Brakes Dragging–Over-Adjustment of Brakes	
Possible Cause	**Remedy**
ASA-5 slack adjuster is improperly installed. Slack adjuster is too close to the actuator–brakes can not fully release.	Correct the ASA-5 slack adjuster installation.
Loose actuator pushrod jam nut.	Reposition the components and tighten to specification.
Spring brakes are not fully retracting.	Check the spring brake release air pressure. Repair or replace air valves as necessary. Repair or replace the spring brake.
Broken foundation brake components, including camshaft bushings.	Repair or replace damaged or worn parts.

Troubleshooting

Problem—Brakes Dragging–Over-Adjustment of Brakes	
Possible Cause	**Remedy**
Vehicle brake torque imbalance (more work is being done by some brakes than others; thermal expansion of drums).	Check all brakes to make sure they are working. Check the air pressure balance and threshold pressure (refer to Bendix publication BW-1555). Check driver braking habits such as use of the park brake valve. Use same friction material on all axles.
Brake drum out-of-round, excessive thermal expansion.	Repair or replace damaged or worn parts.
Air system malfunction, not exhausting completely.	Inspect and correct as necessary.
New lining swells during break-in.	Back-off adjustment until brakes are free.

Specifications

Bendix Extended Adaptors	
Extended Adaptor	**Bendix Part Number**
5/8–18	297700
1/2–20	297701

Table 1, Bendix Extended Adaptors

Brake Actuator Pushrod Measurement		
Slack Adjuster Arm Length (inches)	**Standard Easy-On or Quick-Connect Adaptor (inches)**	**Extended Easy-On Adaptor (inches)**
5	1-15/16 to 3-1/32	2-7/16 to 3-17/32
5-1/2	1-15/16 to 3-3/16	2-7/16 to 3-11/16
6	1-3/16 to 3-3/16	1-11/16 to 3-11/16

Table 2, Brake Actuator Pushrod Measurement

Actuator Stroke–Standard Stroke	
Brake Actuator Size	**Recommended Maximum Operating Stroke (Inches)**
30	2
24	1-3/4
20	1-3/4
16	1-3/4
12	1-3/8

Table 3, Actuator Stroke–Standard Stroke

Actuator Stroke–Long Stroke	
Brake Actuator Size	**Recommended Maximum Operating Stroke (Inches)**
30 Long Stroke	2-1/2
24 Long	2
24 Long Stroke	2-1/2
20 Long	2
16 Long	2

Table 4, Actuator Stroke–Long Stroke

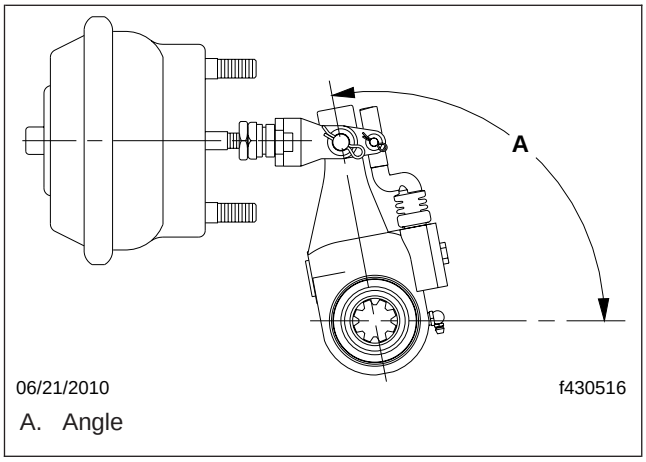


Fig. 1, Installation Angle

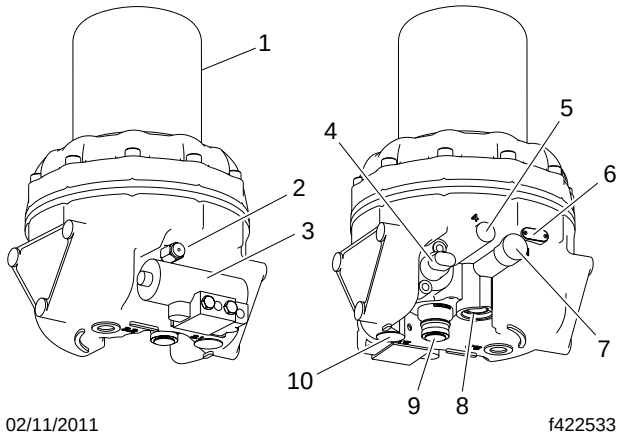
Slack Adjuster Angle	
Arm Length (inches)	**Angle (degrees)**
5	99–113
5.5	98–111
6	90–109

Table 5, Slack Adjuster Angle

Figure 1 shows the angle of a properly installed ASA-5 slack adjuster. See **Table 5** for a list of slack adjuster arm lengths and allowable range of angles.

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.

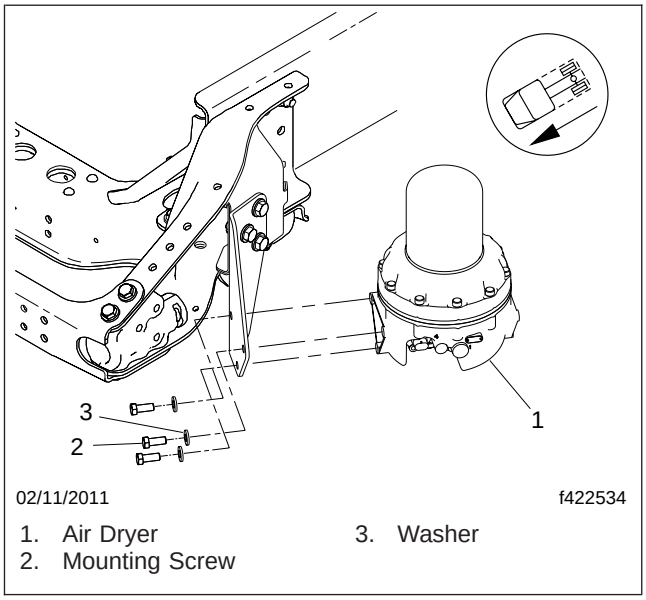
Refer to **Fig. 1** for removal and installation of the air dryer.

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)

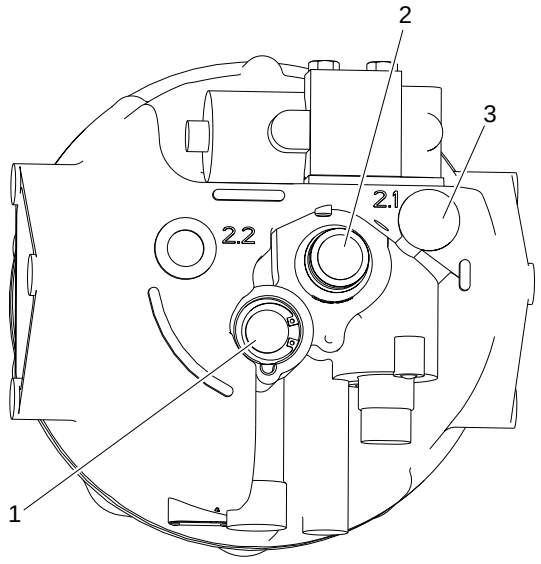
⚠ WARNING

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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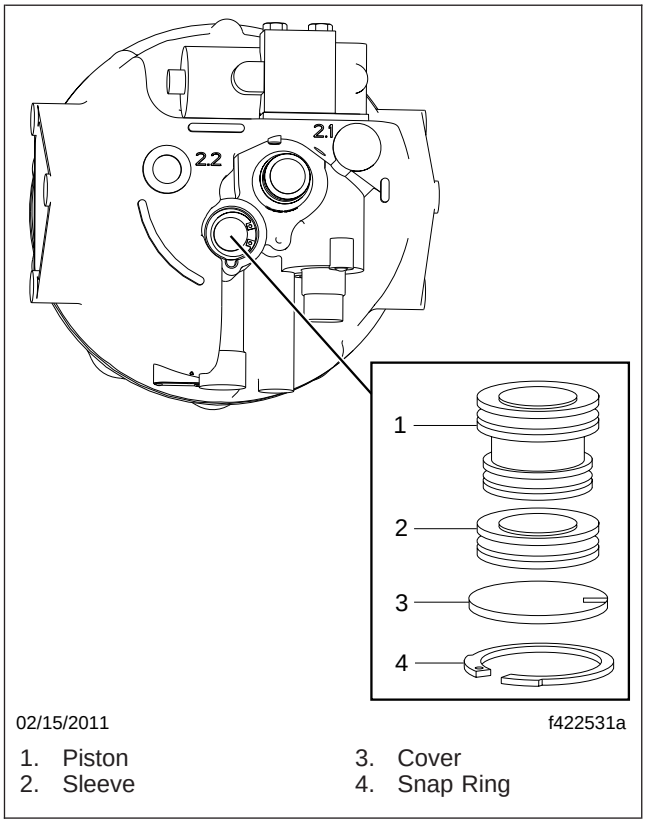
1. Turbocharger Cutoff Valve (has an orange cover)
2. Exhaust Port (Purge Valve Assembly)
3. Delivery/Outlet Port (to the air supply reservoir)

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

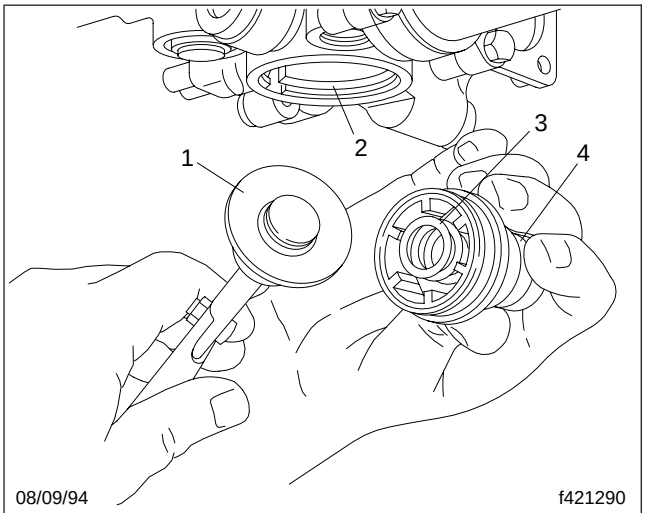
5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-rings and the valve cavity.
6. Press the piston into the sleeve.
7. Press the new piston and sleeve assembly into the air dryer.
8. Install the cover and snap ring to hold the 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

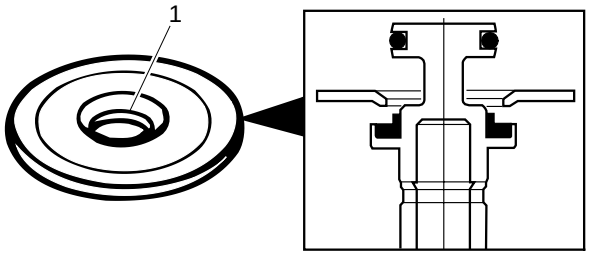
1. Drain the air system.
2. Remove the snap ring, valve head, and the spring from the exhaust port.
3. Pull the valve assembly out of the exhaust port.
4. Remove the O-ring from the base of the exhaust port.
5. Clean the purge valve cavity area with a commercial cleaning solvent.

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.

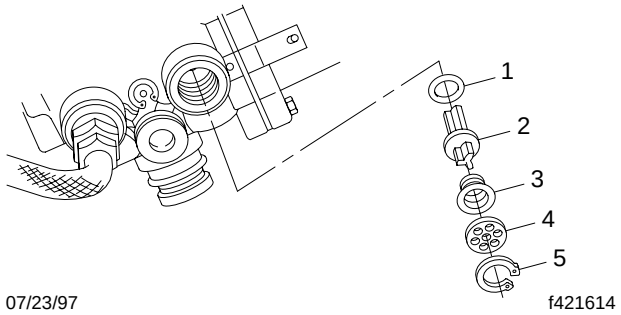
NOTE: Make certain the snap ring is fully seated or the assembly will leak from the purge valve.

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

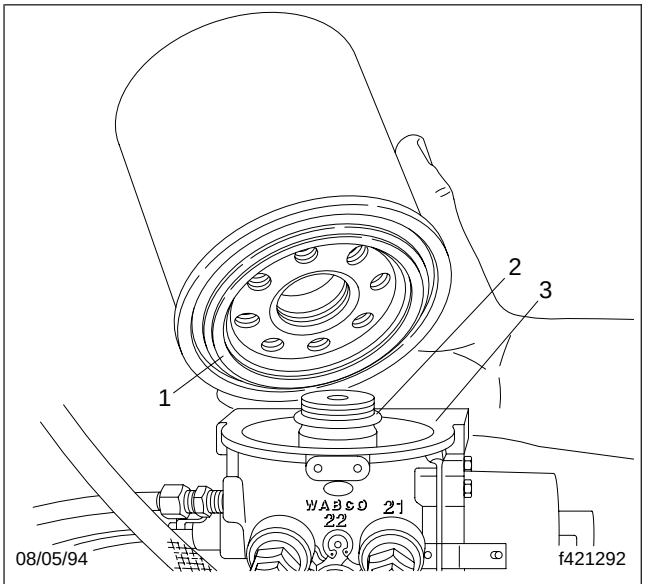
Before working on or around air brake systems and components, see Safety Precautions 100. Failure to do so may result in personal injury.

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. Seal
2. O-Ring
3. Air Dryer Base

Fig. 1, Desiccant 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.

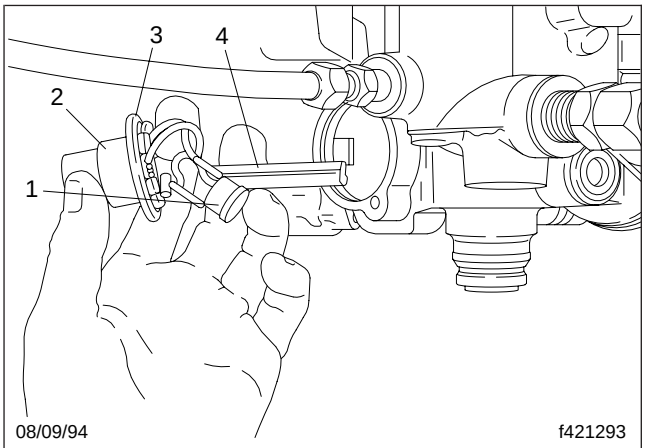
5. Using a multipurpose, high-temperature grease that resists water, steam, and alkali, lightly coat the surfaces of the new O-ring and the dryer base. Install the O-ring.
6. Thread the desiccant cartridge onto the dryer base (turn clockwise). When the seal contacts the base, tighten the cartridge one complete turn more. Do not overtighten.

⚠ 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

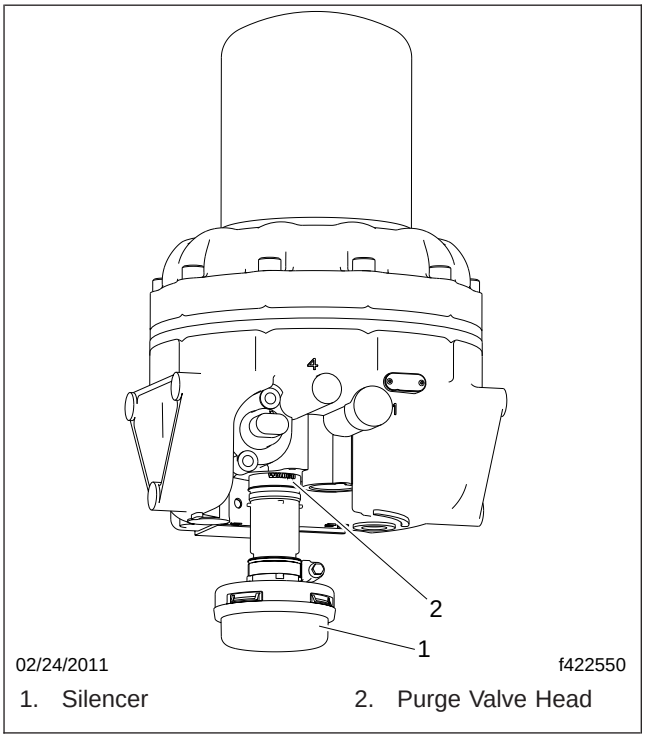
1. Drain the air system.
2. Disconnect the wiring harness.
3. Remove the screws that attach the heater/thermostat receptacle. Remove the receptacle and the O-ring.
4. Remove the retaining screw that holds the assembly in place. Remove and discard the heater/thermostat assembly.
5. Clean the heater/thermostat 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

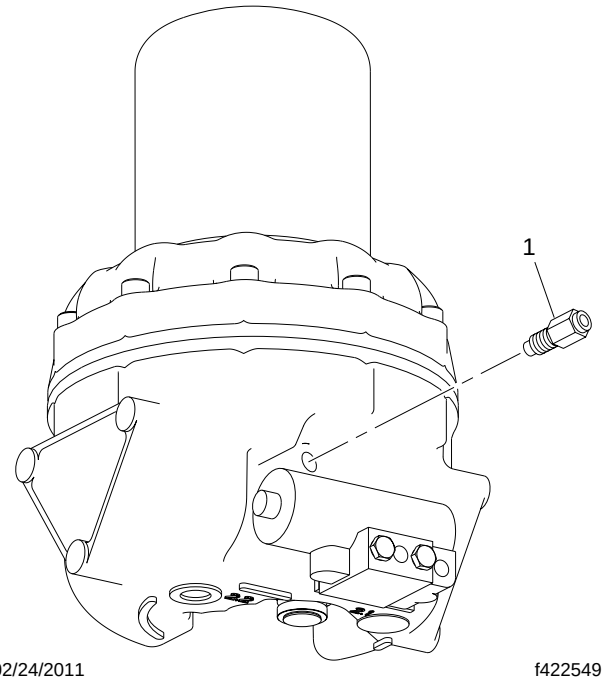
1. Using snap ring pliers, expand the snap ring and pull the silencer off of the purge valve head.
2. Push the new silencer onto the purge valve head until the silencer snaps into place.

⚠ 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.

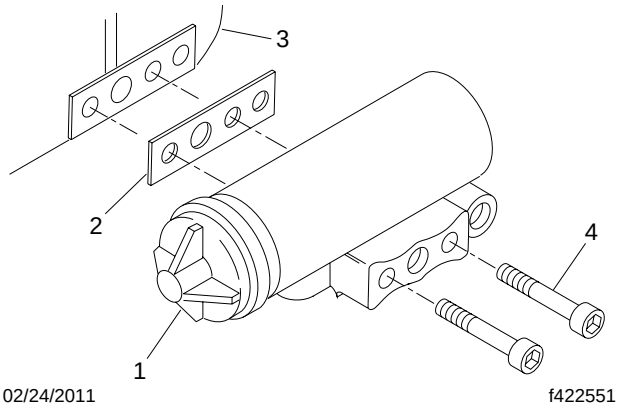
⚠ WARNING

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.

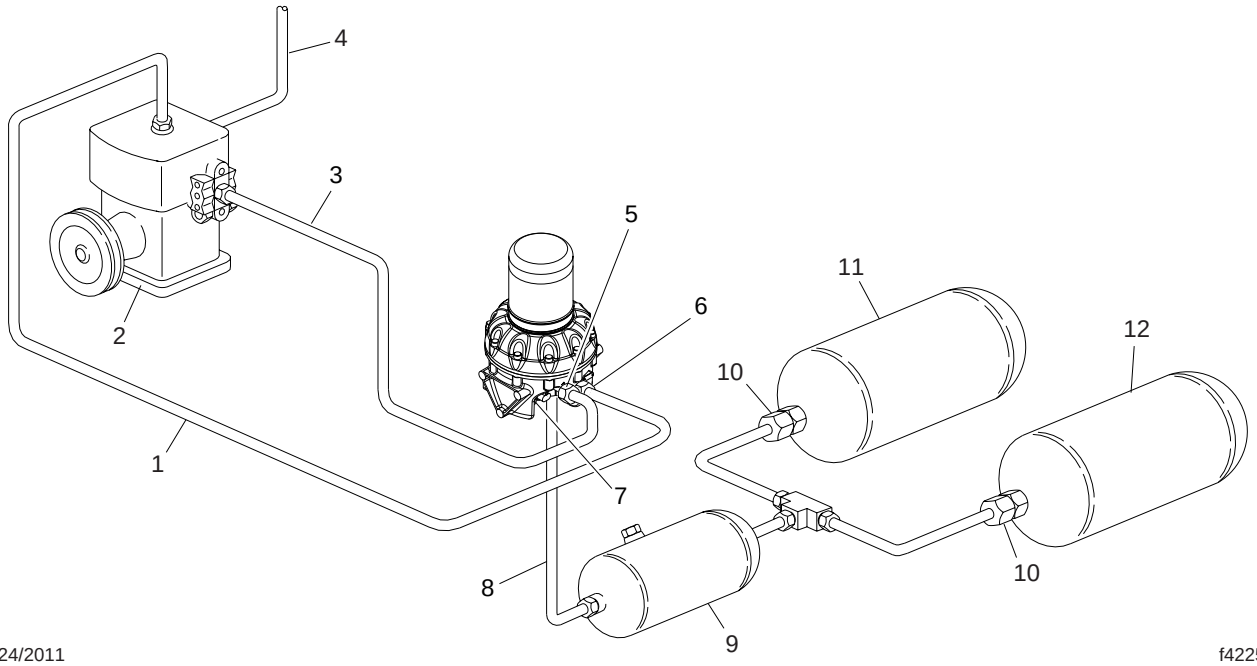
Problem—The regeneration cycle is too short (less than 20 seconds)

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 Information

As of April 5, 2010, the auxiliary air valve assembly (AAVA) replaced the air management unit (AMU). The AAVA is a collection of electronic valves and pressure switches of modular form attached in a row on the frame rail. The AAVA is usually located in the rear suspension area of the vehicle. However, it could be located anywhere on the vehicle chassis or body.

The AAVA performs air-controlled functions such as axle differential locks, power takeoff (PTO), and fifth wheel slide. It also provides for pneumatic logic controls via double-check, inversion, relay, and pressure regulation, therefore replacing double-check, inversion, and relay valves on the vehicle.

The typical AAVA layout contains one or more of the following. See **Fig. 1** for a typical AAVA installation.

- AAVA Module
- Solenoid Valve Module

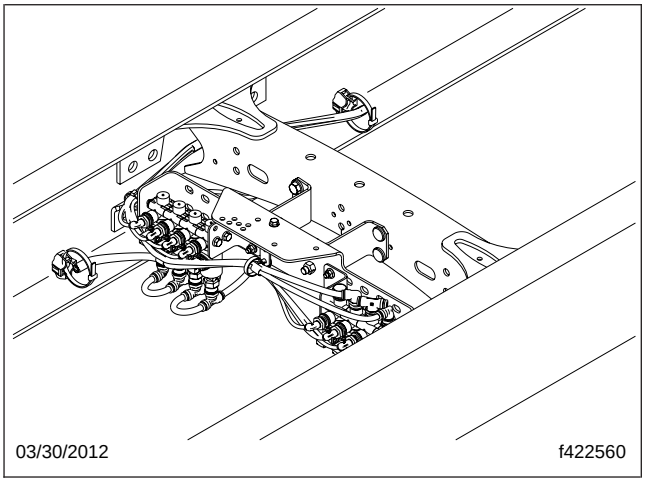


Fig. 1, Typical AAVA Installation

Principles of Operation

AAVA Module

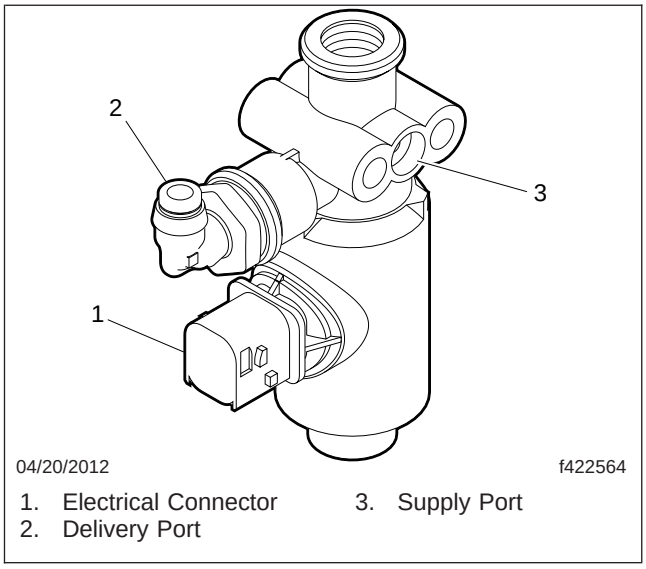
The AAVA is a solenoid-only assembly with a common air supply for the normally closed solenoids. The AAVA solenoids are located on the suspension crossmember, where the AMU was located on earlier vehicles. Pressure switches that were previously in the AMU are now located under the dash.

The AAVA solenoid current is about 1.5 amps. Vehicles built with chassis module (CHM) version 3.4 use a chassis power distribution module (PDM) with relays that switch power to the AAVA solenoids. Vehicles with CHM version 4.1 or later drive the AAVA solenoids directly with no need for relays in a chassis PDM. See **Specifications 400** for further information.

Solenoid Valve Module

The solenoid modules control ON-OFF air options. All solenoid valve modules are normally closed (NC). See **Fig. 2**. The solenoid valve module delivers air when electrically activated.

The inlet to the solenoid valve module mates to the port on the adjacent AAVA. Pressure protected air will pass through the AAVA from the internal supply port and out of the internal delivery port to supply the next solenoid to the next AAVA.



1. Electrical Connector
2. Delivery Port
3. Supply Port

Fig. 2, Solenoid Valve Module

Auxiliary Air Valve Assembly Module Replacement

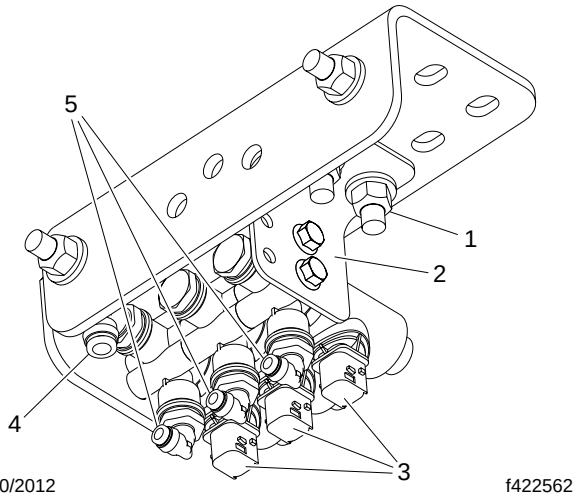
Replacement

Individual modules within the auxiliary air valve assembly (AAVA) can be replaced. The following is a general replacement procedure.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Disconnect the batteries.
3. Drain the air reservoirs.

IMPORTANT: Clean the AAVA and the area around it of all dirt and road debris before removing any modules. Failure to do so can result in dirt or road debris between the modules and their seals, causing air leakage.

4. Loosen the bolts on the L-bracket that secures the AAVA to the frame rail mounting bracket. See **Fig. 1**. This will allow the AAVA to separate, allowing for easy removal of the module.



1. L-Bracket Bolt
2. L-Bracket
3. Solenoid Valves
4. Air Supply Port
5. Delivery Ports

Fig. 1, Auxiliary Air Valve Assembly (AAVA)

IMPORTANT: Be sure to mark all air lines, the harness connector, and solenoid before removing them from the air valve.

5. Mark and disconnect the air lines, harness connector, and the solenoid from the air valve to be replaced. Refer to PartsPro® for harness and solenoid color coding.
6. Remove the bolts from the L-bracket and remove the AAVA.
7. Install the new seals on the AAVA module.
8. Place the new AAVA module on the L-bracket and install the bolts.
9. Install all air lines and electrical connectors as previously marked.
10. Firmly tighten the bolts on the L-bracket, securing the AAVA in the mounting bracket. See **Fig. 1**.
11. Connect the batteries.

Troubleshooting

To troubleshoot the auxiliary air valve assembly (AAVA) system, test the 12 V supply from the power distribution module (PDM) to the 12 V solenoid, and verify that the solenoid opens and closes. The fuses and relays for this functionality are located in the PDM. Refer to EZWiring™ for specific vehicle wiring information.

Figure 1 illustrates how AAVA works with a power distribution module (PDM). Refer to EZWiring™ for specific vehicle wiring information.

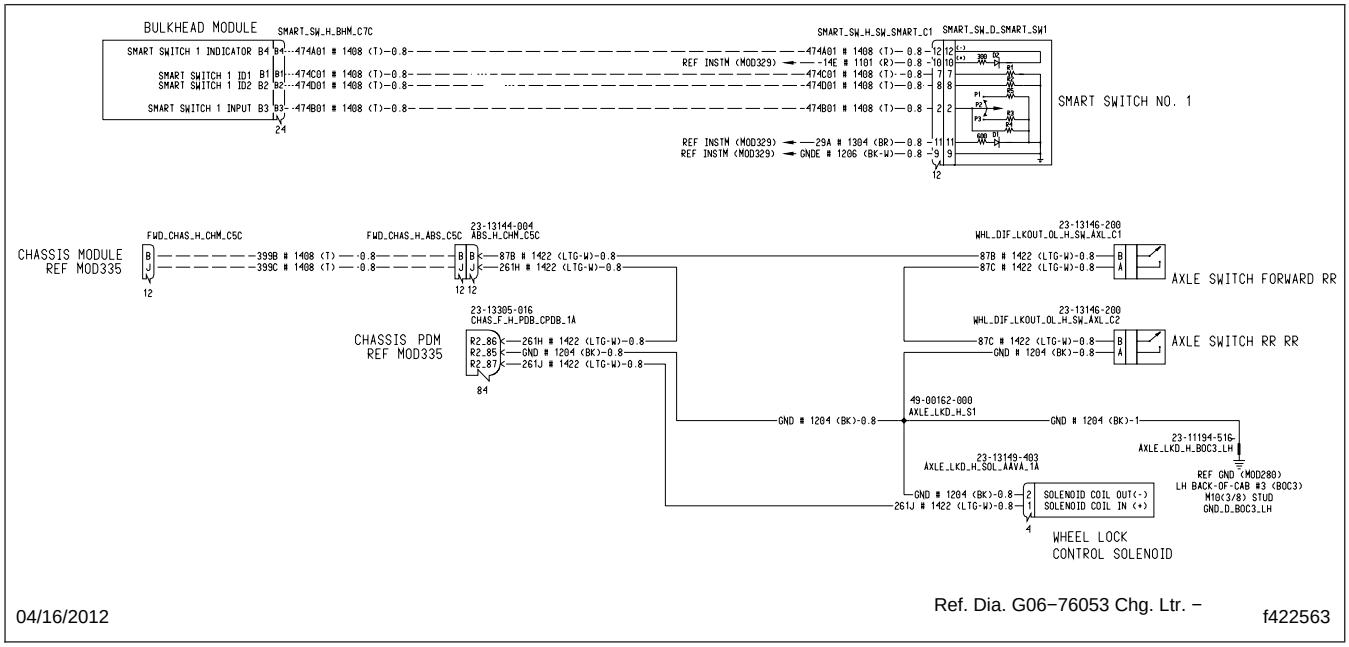
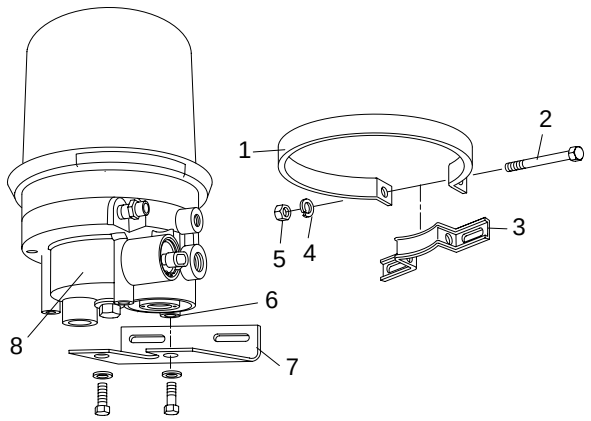


Fig. 1, AAVA Connected to a Chassis PDM (typical installation)

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. Daily manual draining of the reservoirs is eliminated.



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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

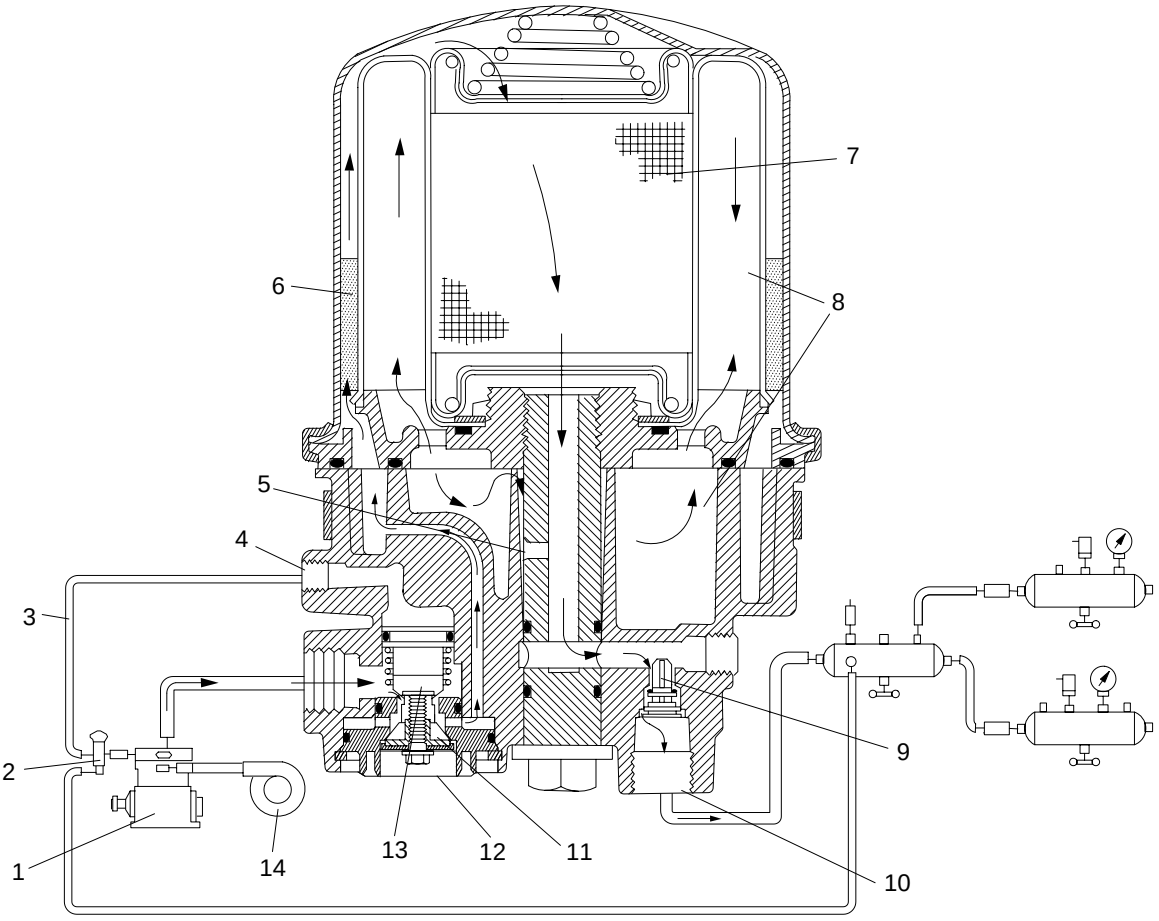
When the compressor is loaded (compressing air), compressed air, along with oil, oil vapor, water, and water vapor flows through the compressor discharge line to the supply port of the air dryer body.

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

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

drying bed. Air flowing down through the column of desiccant becomes progressively dryer as water 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.

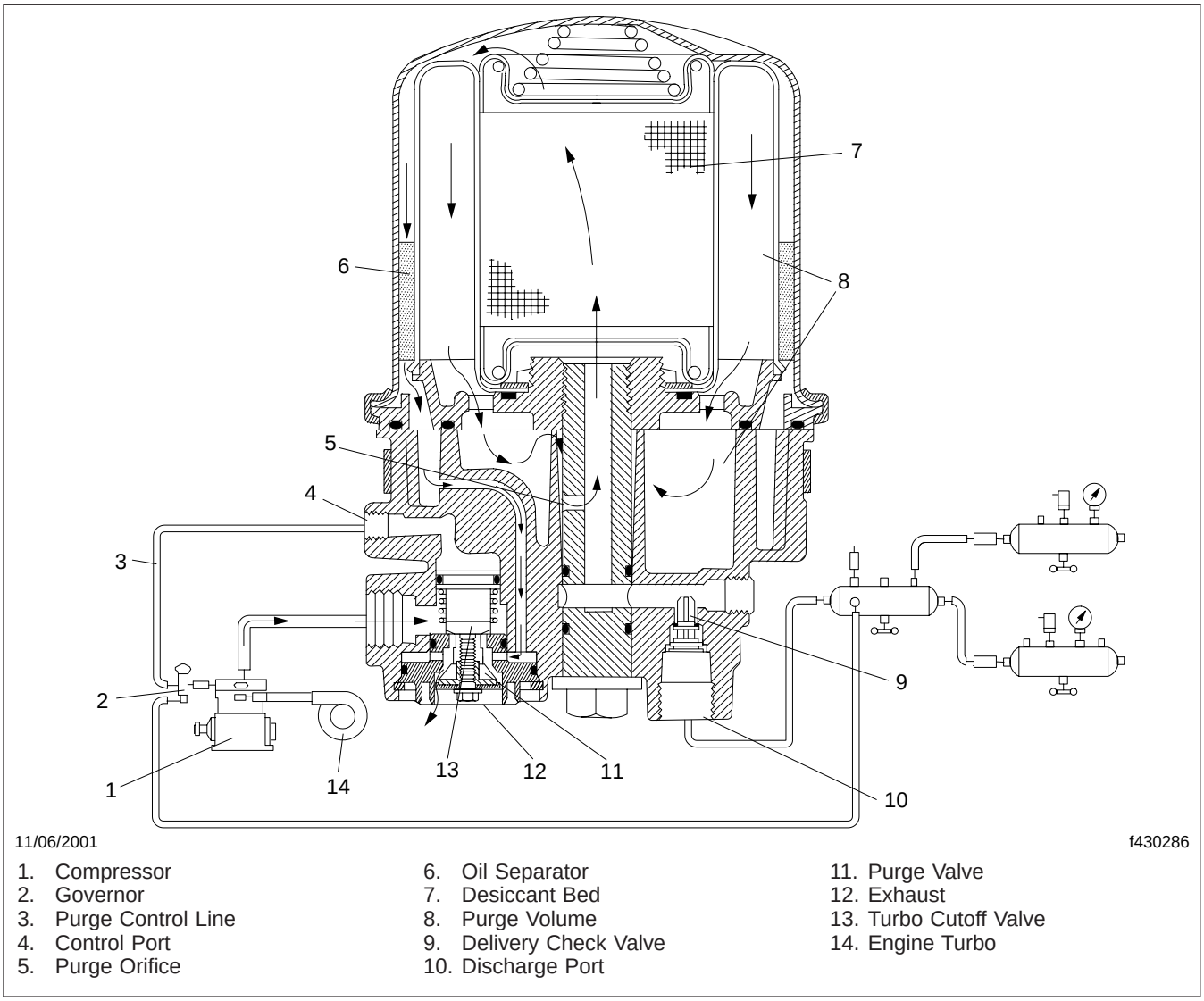
Dry air exits the bottom of the desiccant cartridge and flows through the center of the bolt used to secure the cartridge to the end cover. Air flows down the center of the desiccant cartridge bolt, through a cross-drilled passage and exits the air dryer delivery port through the delivery check valve.

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 cut-out 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 Cut-off 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.

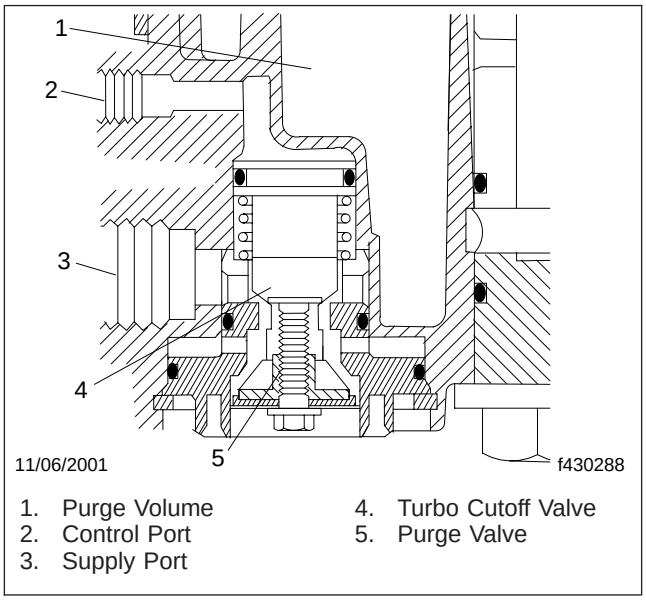
NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to **Group 42** of the *S2 Chassis Maintenance Manual* for intervals and procedures.

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.

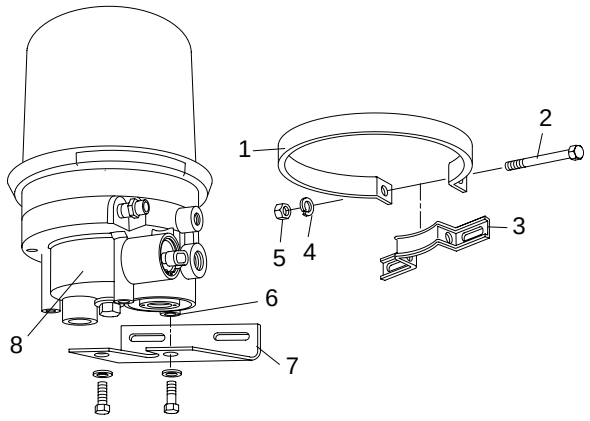
  Make sure that when replacing tubing or hose, all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.

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 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.
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 *S2 Chassis 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

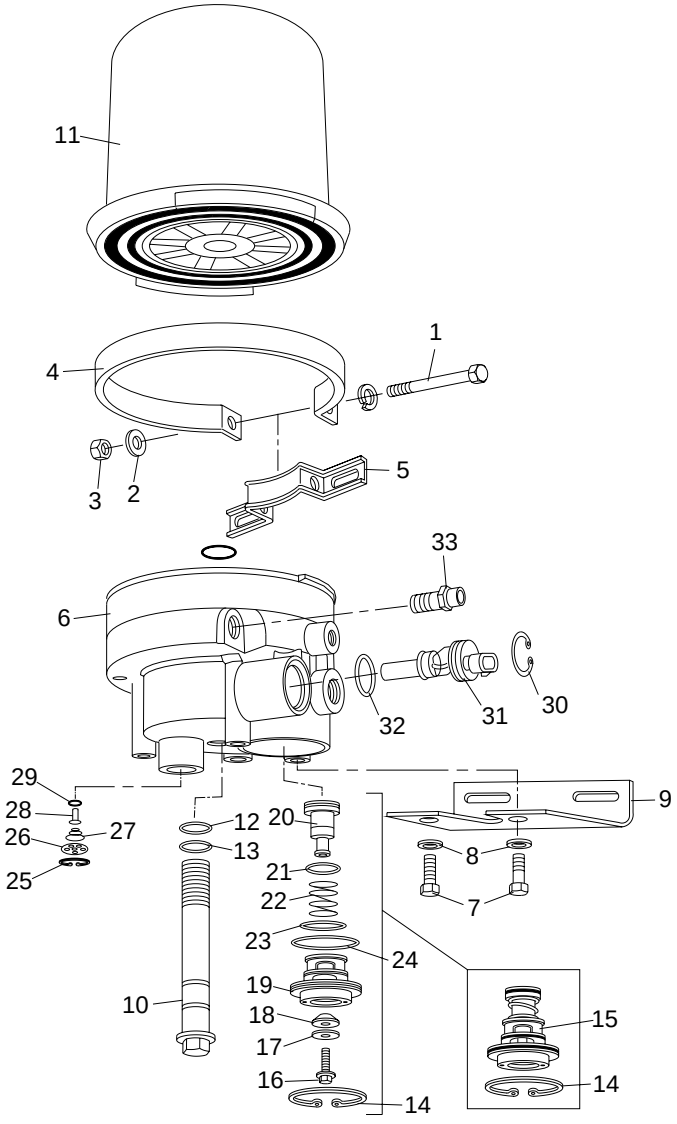
1. Wash all metal parts thoroughly, using a quality commercial solvent, such as mineral spirits.

NOTE: Don't 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



06/07/2004 f430283

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)

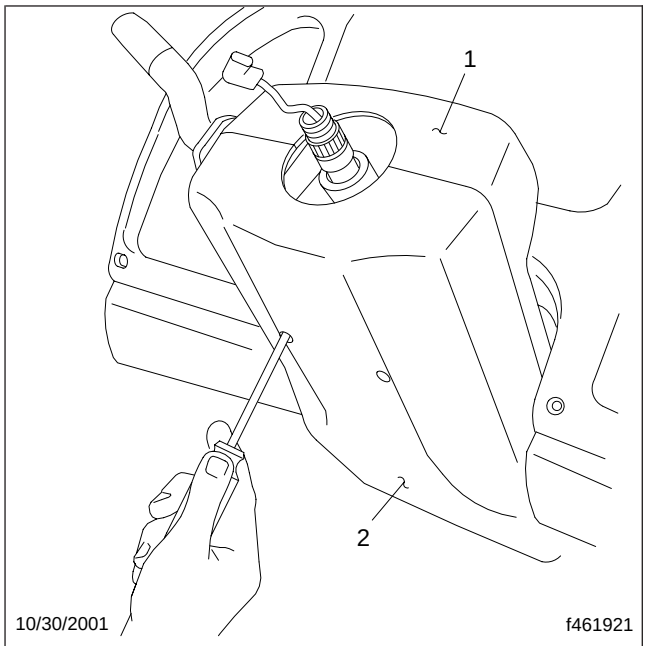
Problem—Constant Air Seepage at the Purge Valve (Non-Charging Mode)	
Possible Cause	**Remedy**
Air compressor inlet is pressurized by the engine turbocharger.	Some pressure leakage past the metal seat of the turbocharger cutoff feature of the AD-9 air dryer is normal, and may be heard. This slight loss 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.

Replacement

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 the capscrews that attach the lower steering column cover to the steering column. Remove the lower and upper steering column covers. See **Fig. 1**.



1. Upper Steering Column Cover
2. Lower Steering Column Cover

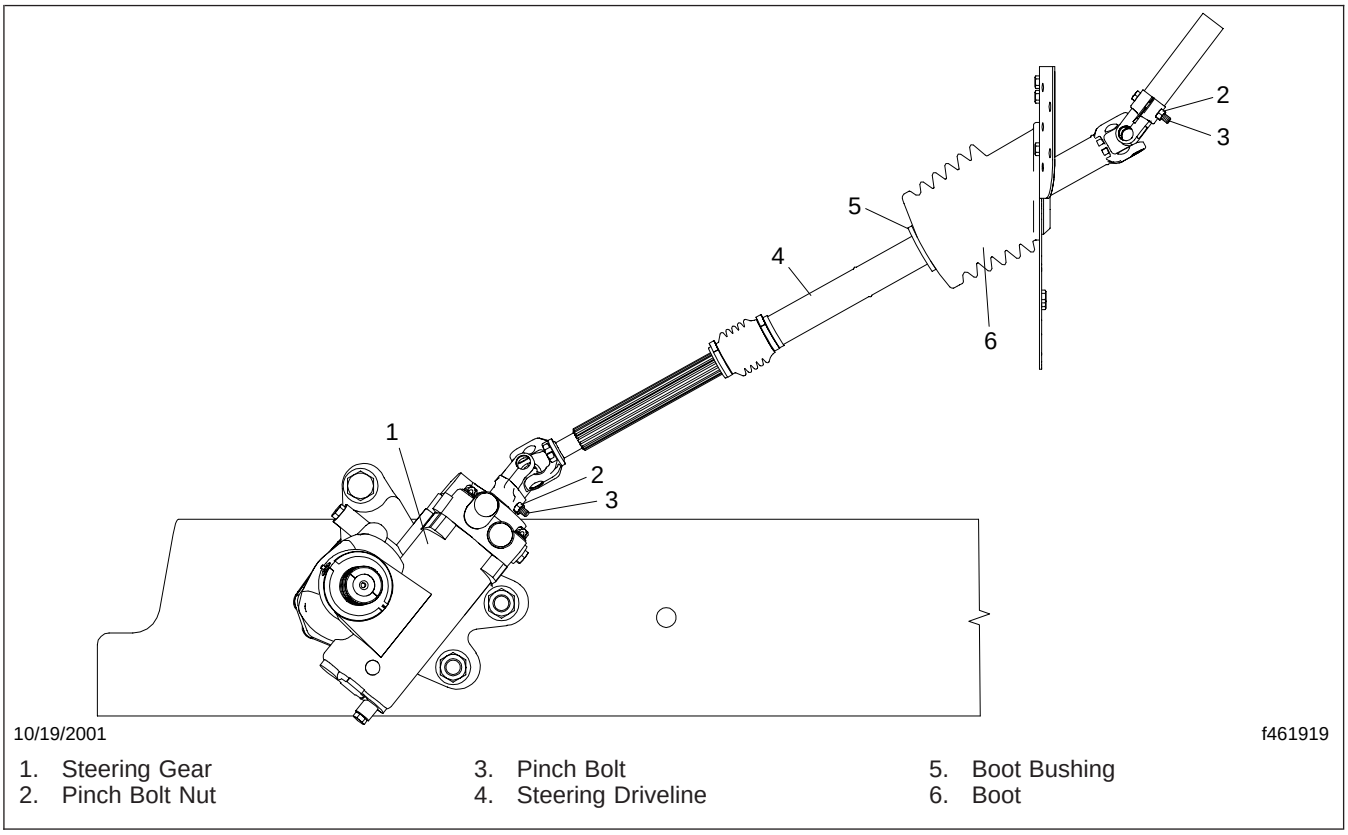
Fig. 1, Steering Column Covers

4. Remove and discard the pinch bolt and nut that attach the steering column to the steering driveline.
5. Remove the boot bushing. See **Fig. 2**.
6. Remove and discard the pinch bolt and nut that attach the steering driveline to the steering gear. Then remove the steering driveline.
7. Place a new steering driveline through the boot and the frontwall.
8. Using a new pinch bolt and nut, attach the steering driveline to the steering gear input shaft. Torque the bolt 35 to 40 lbf·ft (47 to 54 N·m).

   Apply torque seal OGP F900WHITE to the exposed threads of the pinch bolt.
9. Install the boot clamp on the steering driveline.
10. Using a new pinch bolt and nut, attach the steering driveline to the steering column. Torque the bolt 35 to 40 lbf·ft (47 to 54 N·m).

    Apply torque seal OGP F900WHITE to the exposed threads of the pinch bolt.
11. Using capscrews, attach the upper and lower steering column covers to the steering column.
12. Lower the hood and remove the chocks from the tires.

Steering Driveline Replacement



1. Steering Gear
2. Pinch Bolt Nut
3. Pinch Bolt
4. Steering Driveline
5. Boot Bushing
6. Boot

Fig. 2, Steering Driveline Installation

Drag Link Replacement

Replacement

1. Position the tires straight ahead. If possible, drive the vehicle in a straight line for a short distance stopping at the spot where service operations are to be performed. **Do not** turn the steering wheel at any time while the drag link is still attached to both the pitman arm and the axle steering arm. If the steering wheel is turned, the front tires will not be straight ahead.
2. Shut down the engine, apply the parking brakes, chock the rear tires, and open the hood.
3. Remove the cotter pin and castle nut that attach the drag link to the pitman arm.
4. Remove the cotter pin and castle nut that attach the drag link to the steering arm.
5. Remove the drag link.
6. Install a new drag link on the pitman arm and steering arm.
7. Using castle nuts, secure the drag link to the pitman arm and the steering arm. Torque the castle nuts 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)
8. If required, continue to tighten each nut until a slot on the nut aligns with the hole in the ball stud. **Do not** back off the nut when locating the cotter pin hole.
9. Install new cotter pins in the ball studs and nuts. Lock the cotter pins in place.

⚠ WARNING

Failure to install or lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control.

10. Clean the grease fittings and apply chassis grease to the fittings until all the old grease is forced out.
11. Make sure that the steering wheel spokes are within 10 degrees of the 3 o'clock and 9 o'clock positions. See **Fig. 1**.
12. Lower the hood and remove the chocks from the tires.

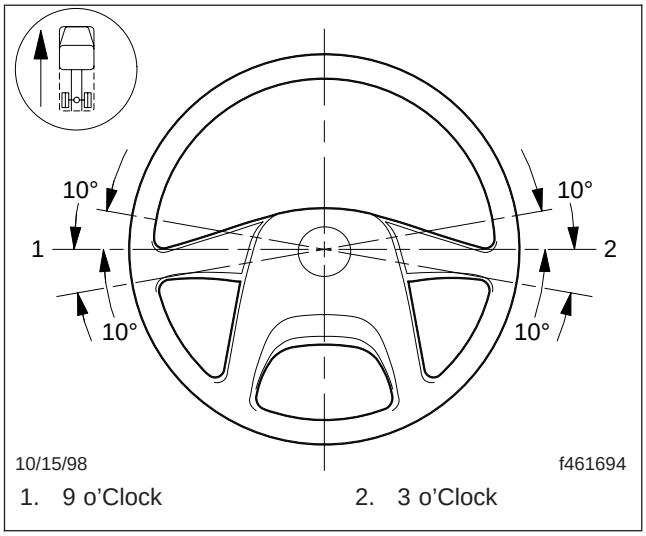


Fig. 1, Centering the Steering Wheel

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. Have someone gently turn the steering wheel back and forth. Check for looseness between the ball stud end and the pitman arm, and between the ball stud end and the steering arm. If the ball stud end is loose, replace the drag link. For instructions, see **Subject 100**.
2. Check for looseness of the ball stud nut. If the ball stud nut is loose, replace the nut and the cotter pin. Tighten the ball stud 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)
3. Grasp the drag link near the pitman arm and move the drag link back and forth to check for axial movement in the ball stud end. If there is movement, replace the drag link. For instructions, see **Subject 100**. If there is movement of 1/8 inch (3 mm) or more, do not drive the vehicle until the drag link is replaced.
4. Grasp the drag link near the steering arm and move the drag link back and forth to check for axial movement in the ball stud end. If there is movement of 1/8 inch (3 mm) or more, replace the drag link. For instructions, see **Subject 100**.
5. Apply grease to the drag link until all the old grease is purged.

Removal

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping at the place where the work will be done. Don't turn the steering wheel at any time during the removal procedure.
2. Shut down the engine, apply the parking brakes, and chock the tires.
3. Disconnect the batteries.
4. Using a small screwdriver, carefully pry out the horn button assembly and disconnect the two wires.
5. Using a deep socket to avoid damaging the wires, remove the steering wheel nut.
6. Place a timing mark on the top of the steering shaft in line with the existing timing mark on the steering wheel.
7. Using a steering wheel puller, remove the steering wheel from the steering column.

Installation

1. Make sure the front tires are pointed straight ahead and the steering gear is centered.
2. Pull the wiring harness through the steering wheel center hole.
3. Put the steering wheel on the steering column matching the timing mark on the steering wheel with the timing mark on the steering shaft. Make sure that the steering wheel spokes are within 10 degrees of the 3 o'clock and 9 o'clock positions. See **Fig. 1**.
4. Using a nut, install the steering wheel on the steering column and torque the nut 33 to 41 lbf·ft (45 to 55 N·m).
5. Connect the wiring harness to the horn button.
6. Apply a small amount of soap and water solution around the hole in the steering wheel to ease the installation of the horn button assembly on the steering wheel. Align the logo on the horn button assembly so that it is horizontal. Then press the horn button assembly into the steering wheel.
7. Connect the batteries.
8. Remove the chocks from the tires.

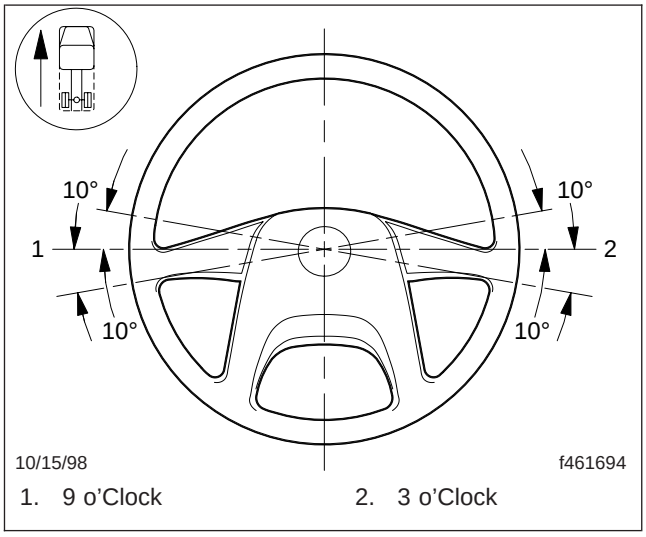
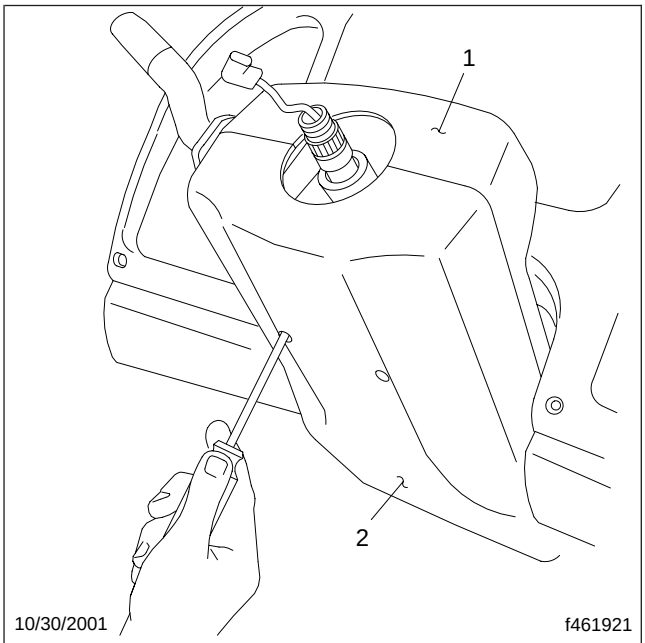


Fig. 1, Centered Steering Wheel

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 steering column is removed.
2. Shut down the engine, apply the parking brakes, and chock the tires.
3. Disconnect the batteries.
4. Remove the steering wheel. For instructions, see **Subject 100**.
5. On a vehicle with a fixed steering column, remove the screws that attach the lower and upper clamshell covers to the steering column and remove the covers. See **Fig. 1**.

   On a vehicle with an adjustable steering column, remove the screws that attach the lower and upper clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers. See **Fig. 2**.



1. Upper Clamshell Cover
2. Lower Clamshell Cover

Fig. 1, Fixed-Steering-Column Covers

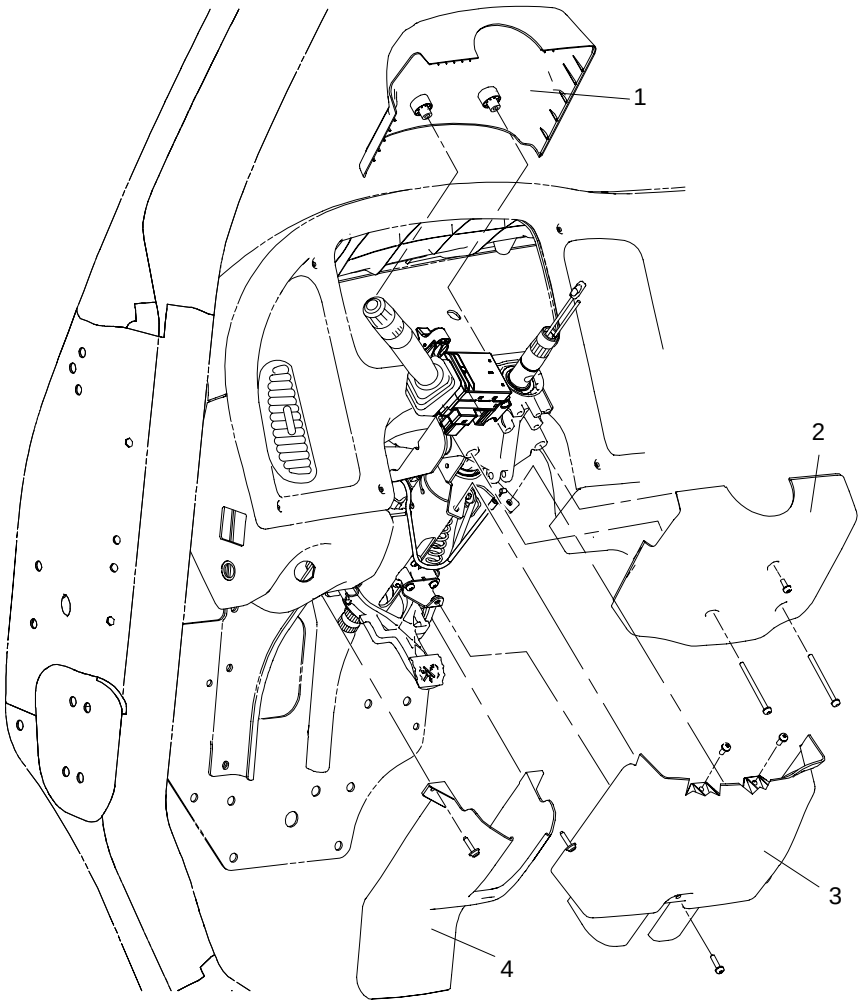
6. Remove the self-canceling turn signal cam from the steering column.
7. Remove the turn signal lever.
   - 7.1 Disconnect the horn wire from the turn signal wiring harness.
   - 7.2 Remove the capscrews that attach the turn signal lever to the steering column.
8. Make a timing mark on the steering driveline yoke and the steering column spline.
9. Remove and discard the pinch bolt and nut from the steering driveline yoke. See **Fig. 3**.
10. If the vehicle is equipped with a steering-column-mounted shift lever, disconnect the shift cable at the steering column.
11. Remove the capscrews that attach the steering column to the mounting bracket.
12. Remove the steering column from the steering driveline yoke.

Installation

1. Using a new pinch bolt and nut, attach the steering column to the steering driveline yoke. Torque the bolt 35 to 40 lbf·ft (47 to 54 N·m).

   Apply torque seal OGP F900WHITE to the exposed threads of the pinch bolt.
2. Using capscrews, attach the steering column to the mounting bracket. Torque the capscrews 24 to 30 lbf·ft (32 to 40 N·m).
3. If the vehicle is equipped with a steering-column-mounted shift lever, use a new cotter pin to attach the shift cable to the steering column. Check for proper operation and adjustment of the shift lever.
4. Install the self-canceling turn signal cam on the steering column.
5. Using capscrews, attach the turn signal lever to the steering column.
6. Attach the horn wire to the turn signal wiring harness.
7. On a vehicle with an adjustable steering column, use screws to attach the lower and center steering column covers to the steering column.

Steering Column Removal and Installation

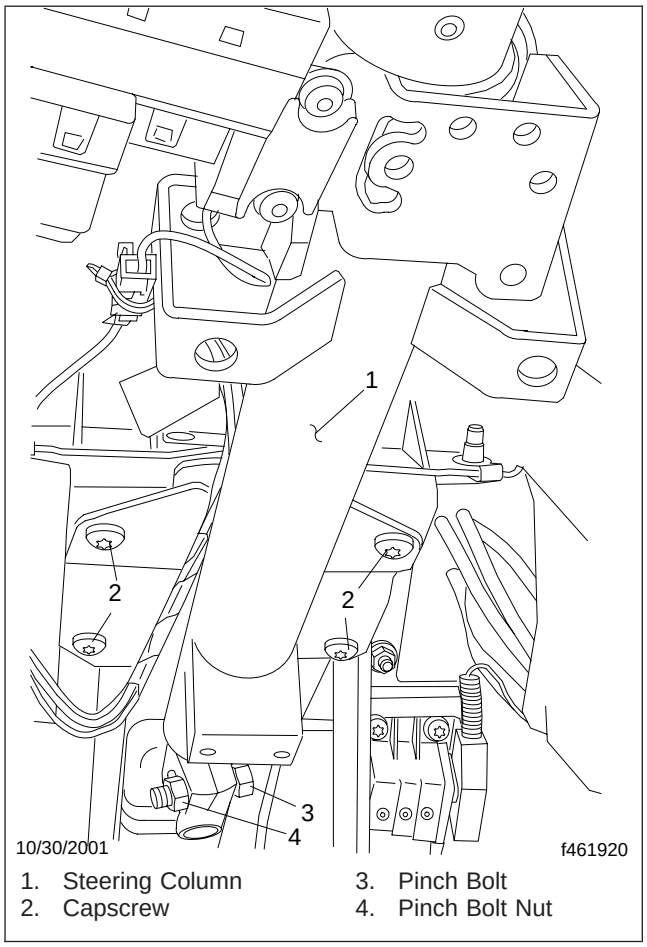


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1. Upper Clamshell Cover
2. Lower Clamshell Cover
3. Center Cover
4. Lower Cover

Fig. 2, Adjustable-Steering-Column Covers

8. Using screws, attach the upper and lower clamshell covers to the steering column.
9. Install the steering wheel. For instructions, see **Subject 100**.
10. Connect the batteries.
11. Remove the chocks from the tires.

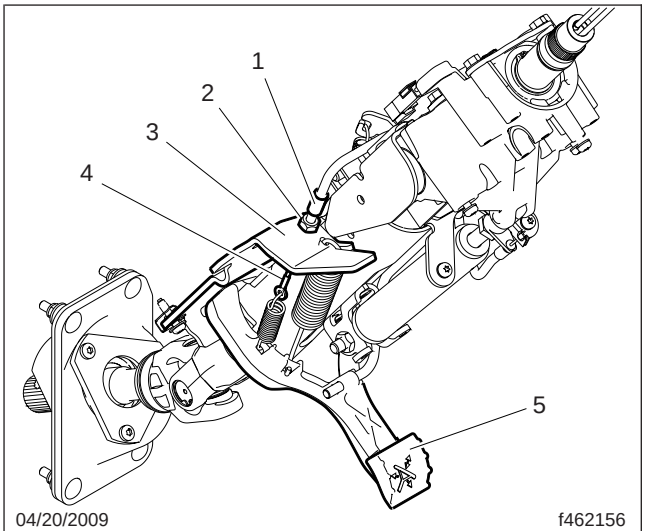


1. Steering Column
2. Capscrew
3. Pinch Bolt
4. Pinch Bolt Nut

Fig. 3, Fixed Steering Column

Tilt Lock Adjustment

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work will take place.
2. Shut down the engine, apply the parking brake, and chock the tires.
3. Remove the screws that attach the upper and lower clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers.
4. Loosen the cable jam nut located on the top side of the mounting bracket flange, see **Fig. 1**.



1. Cable Adjuster
2. Cable Jam Nut
3. Mounting Bracket Flange
4. Cable Slack
5. Steering Column Release Pedal

Fig. 1, Steering Column Tilt Lock Adjustment

5. Use the cable adjuster to remove all slack from the steering column release pedal.

NOTE: Removing too much cable slack can prevent the tilt lock mechanism from locking, regardless of the steering column release pedal position. Adding too much cable slack can prevent the tilt lock mechanism from unlocking when the pedal is fully depressed.

6. Test to verify proper steering column tilt function.
   - 6.1 Fully depress the steering column release pedal. The tilt mechanism should unlock.
   - 6.2 Release the pedal and let it revert to the standard position. The tilt mechanism should lock.
7. Readjust the cable slack if necessary.
8. Tighten the cable jam nut 25 to 30 lbf·in (282 to 340 N·cm).
9. Attach the lower and center steering column covers to the steering column first, then install the upper and lower clamshell covers.

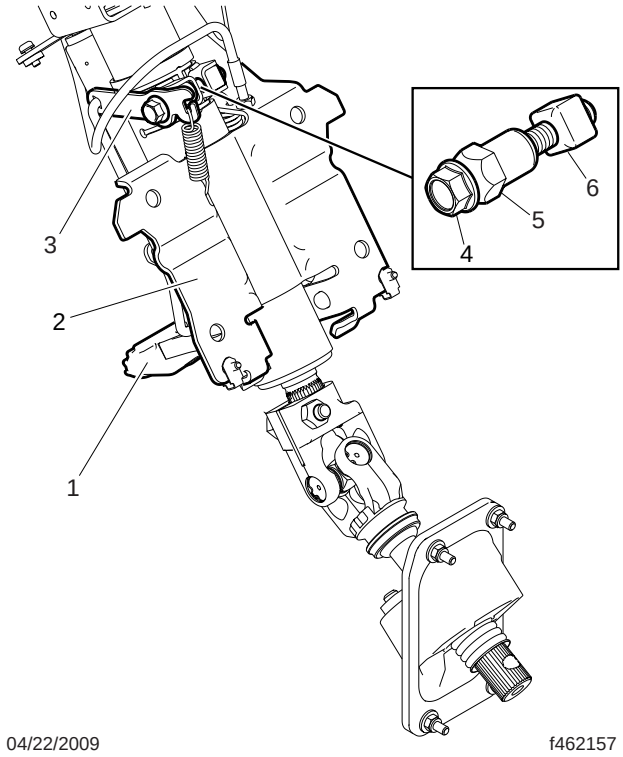
Telescope Lock Adjustment

1. Put the front wheels in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping where the work will take place.
2. Shut down the engine, apply the parking brake, and chock the tires.
3. Remove the screws that attach the upper and lower clamshell covers to the steering column and remove the covers. Remove the screws that attach the center and lower covers to the steering column and remove the covers.
4. Loosen the telescope lock bolt, see **Fig. 2**.
5. While holding the telescope lock rod in place, rotate the telescope lock lever to adjust the telescope lock. Counterclockwise rotation will tighten the telescope lock, while clockwise rotation will loosen the telescope lock. The lever can be easily rotated by moving the steering column release pedal up or down.

NOTE: Rotating the lever too much can prevent the telescope lock mechanism from unlocking with the steering column release pedal depressed, or locking when the steering column release pedal is released.

6. Continue holding the telescope lock rod in place and tighten the lock bolt.
7. Test to verify proper steering column telescope function.

Adjustable Steering Column Lock Adjustments



1. Steering Column Release Pedal
2. Mounting Bracket
3. Telescope Lock Lever
4. Telescope Lock Bolt
5. Telescope Lock Rod
6. Telescope Lock Rod Nut

Fig. 2, Steering Column Telescope Lock Adjustment

7.1 Fully depress the steering column release pedal. The telescoping mechanism should unlock.

7.2 Release the pedal and let it revert to the standard position. The telescoping mechanism should lock.

8. Readjust the telescope lock lever if necessary. Once the telescope lock has been properly adjusted, tighten the lock bolt 145 to 150 lbf·in (1638 to 1695 N·cm).

9. Attach the lower and center steering column covers to the steering column first, then install the upper and lower clamshell covers.

General Information[1]

NOTE: Procedures contained in this section have been slightly modified from the original component manufacturer's service manual. If you are not clear on how to perform an operation, consult the component manufacturer's service literature before continuing a specific procedure.

The TRW THP/PCF 45 and 60 series power steering gears are integral hydraulic power steering gears. Integral hydraulic power steering gears contain a manual steering mechanism, a hydraulic control valve, and a hydraulic power cylinder.

The hydraulic (rotary) control valve controls the flow of hydraulic fluid through the steering gear. The speed at which the driver can turn the steering wheel with power assist is dependent on the pump flow directed to a cylinder cavity.

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 (and in the auxiliary cylinder if it is a dual steering system) at the proper flow rate and pressure.

The higher pressure a steering gear can withstand, the more work it can perform. The maximum operating pressure for all THP/PCF gears is 2685 psi (18 512 kPa). The maximum flow rate for all THP/PCF gears is 8 gpm (30.3 L/min).

The THP/PCF series gears can steer a vehicle within its front axle weight rating through a turn at low speed and engine idle. As the steering wheel is turned faster or slower, more or less fluid will be required by the gear.

The THP45 power steering gear is used for front axle capacities up to 9000 lb (4100 kg). The THP/PCF60 power steering gear is used for front axle capacities up to 14,300 lb (6500 kg).

The recommended minimum flow at 1.5 steering wheel turns per second is 2.2 gpm (8.3 L/min) for the THP45 steering gear and 2.6 gpm (9.8 L/min) for the THP/PCF60 steering 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.

Maximum internal leakage for all THP/PCF gears is 1.2 gpm (4.5 L/min).

Principles of Operation

When the steering wheel is turned, force is transmitted 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, the worm shaft, acting through the recirculating ball mechanism, tries to move the rack piston on or along the axis through the gear housing cylinder bore.

The rack piston's axial movement is resisted by its engagement to the sector shaft, which is connected by linkage to the steered wheels. Because of this resistance, the torsion bar is twisted by the input shaft, thereby actuating the control valve. Pressurized fluid, directed by the control valve, assists in moving the rack piston on or along the axis through the cylinder bore. The rack piston then turns the sector shaft to steer the vehicle.

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 high-pressure 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 THP/PCF steering gears are equipped with two poppet (unloading) valves, one at each end of the rack piston. One valve or the other, depending on the direction of the turn, will trip as the steered wheels approach the axle stops, which must be set to the manufacturer's specifications. The tripped valve reduces pressure in the gear and helps to reduce heat generated by the pump. At the same time, the valves also reduce forces on the steering linkage. These valves are automatically set to axle stops after installation in the vehicle at first full right and first full left turns.

Some THP/PCF steering gears with or without poppets are supplied with a relief valve. The relief valve

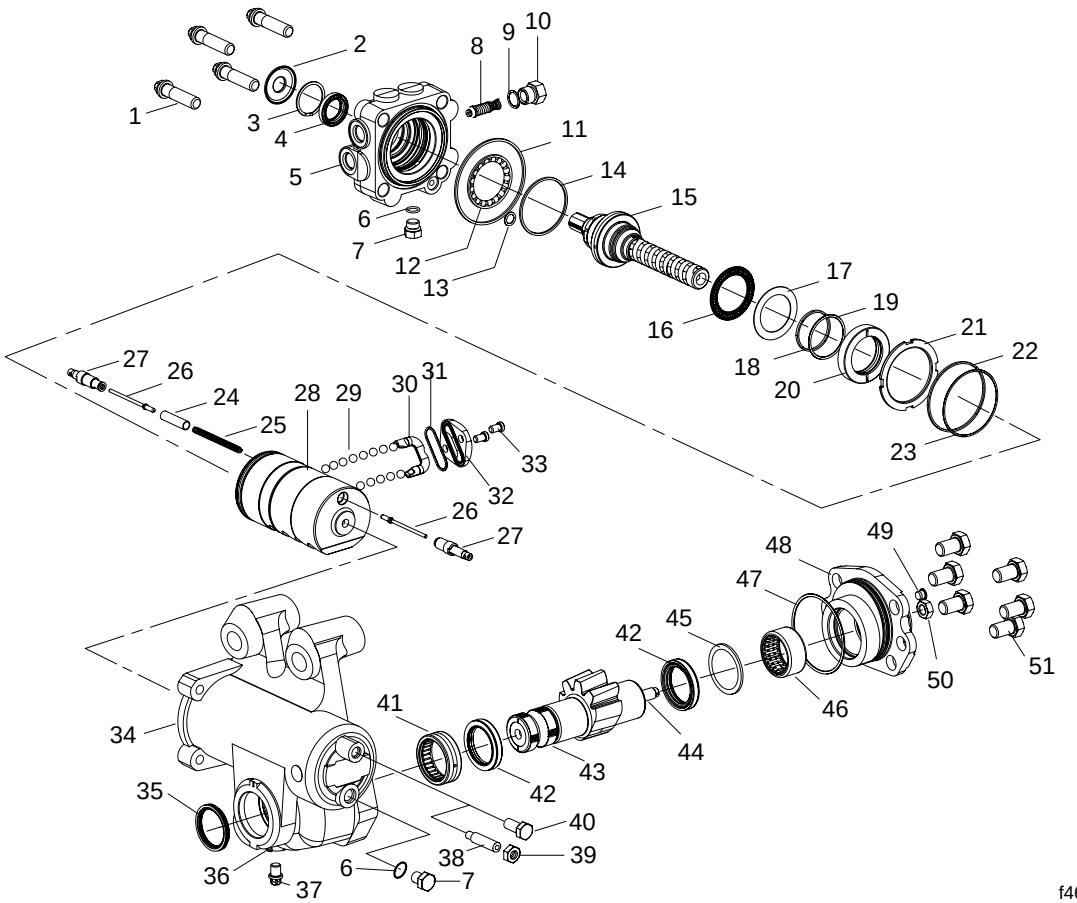
[1] The illustrations in this section are provided by TRW Commercial Steering Systems and are used with permission.

General Information

limits maximum supply pressure to protect the power steering gear, but it does not reduce pressure as the steered wheels approach the axle stops.

Some THP/PCF steering gears that are mounted with the output shaft above the rack piston bore are equipped with either an automatic bleed system or a manual bleed screw.

See **Fig. 1** for an exploded view of the THP/PCF steering gear.



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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, THP/PCF Steering Gear

Removal

1. Verify that the axle stops are adjusted to the specifications in **Section 33.00, Subject 110**. Ensuring correct axle stop adjustment now will eliminate the possibility of resetting the steering gear poppets after the steering gear is replaced.
2. Place the front tires in the straight ahead position. If possible, drive the vehicle in a straight line for a short distance, stopping at the spot where the work is to be done.
3. Turn off the engine, apply the parking brakes, chock the tires, disconnect the batteries, and open the hood.
4. Clean all the fittings and hose connections on the steering gear until they are free of dirt.
5. 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.

⚠ CAUTION

Do not pound the U-joint or lower end yoke on or off the steering gear input shaft. Internal damage to the steering gear can result.

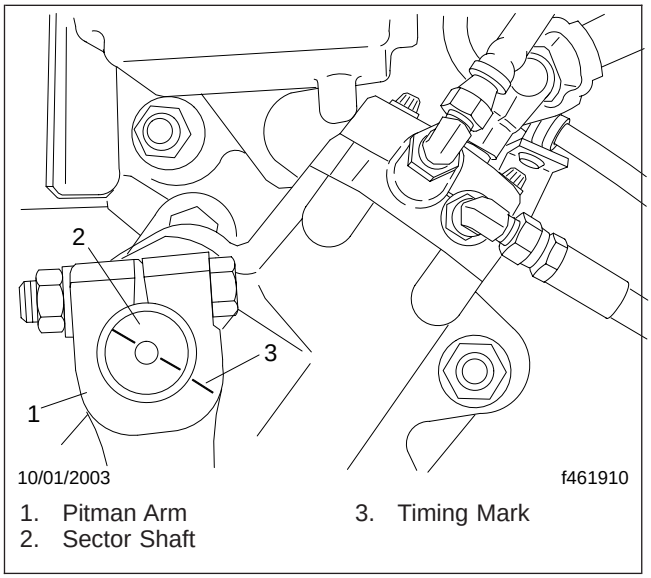
6. Remove and discard the pinch bolt and nut that attach the steering driveline to the steering gear. Remove the lower end yoke from the steering gear.
7. Remove and discard the pinch bolt and nut that attach the pitman arm to the steering gear. Remove the pitman arm from the steering gear.

NOTE: The steering gear is heavy. Use care when removing, lifting, and carrying the steering gear to avoid injury.

8. Remove the bolts, nuts, and washers that attach the steering gear to the mounting bracket. Remove the steering gear.

Installation

1. Using bolts, nuts, and washers, attach the steering gear to the mounting bracket. Torque the bolts 342 to 434 lbf·ft (464 to 588 N·m).
2. Match the timing mark on the pitman arm to the timing mark on the steering gear sector shaft and attach the pitman arm to the steering gear. Using a new pinch bolt and nut, secure the pitman arm to the steering gear. See **Fig. 1**.
   - For a 5/8–18 pinch bolt, torque the bolt 130 to 155 lbf·ft (176 to 210 N·m).
   - For a 3/4–16 pinch bolt, torque the bolt 200 to 230 lbf·ft (271 to 312 N·m).



1. Pitman Arm
2. Sector Shaft
3. Timing Mark

Fig. 1, Pitman Arm Timing Mark

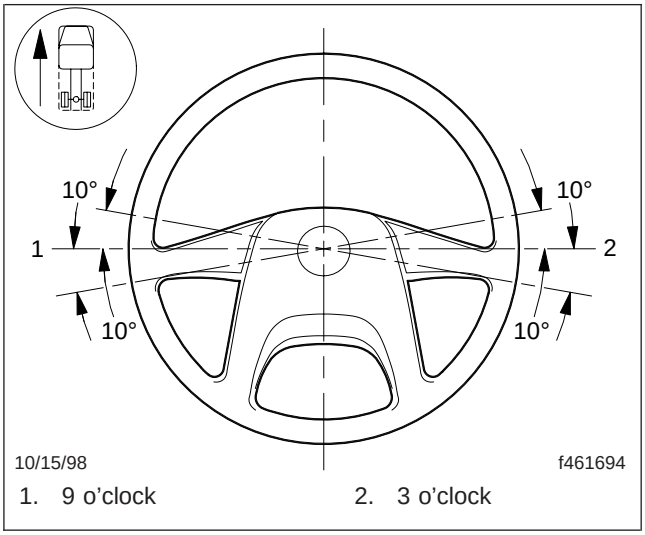
3. Match the hole in the end yoke to the groove on the input shaft and attach the end yoke to the steering gear Using a new pinch bolt and nut, secure the lower end yoke to the input shaft. Torque the pinch bolt 55 to 65 lbf·ft (75 to 88 N·m).
4. Unplug the hydraulic lines and fittings and connect the lines.
5. Connect the batteries.
6. Fill the power steering reservoir to between teh MAX HOT and MIN COLD lines. For approved power steering fluids, see **Specifications 400**.
7. Start the engine and turn the steering wheel from full right to full left two or three times to remove air from the lines.
8. Check the power steering reservoir again and add fluid, if needed.
9. Check the hydraulic lines for leaks.

Power Steering Gear Removal and Installation

10. Remove the chocks from the tires and close the hood.
11. Test drive the vehicle.

    With the front tires pointing straight ahead, check the position of the steering wheel spokes. If the steering wheel is not in the correct position, remove the steering wheel and install it in the correct position. For instructions refer to the applicable section in this group.

    The center spokes should be within ±10 degrees of the 3 o'clock and 9 o'clock positions. See **Fig. 2**.



1. 9 o'clock
2. 3 o'clock

Fig. 2, Steering Wheel Centered

Filling and 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 160**.

1. Fill the power steering reservoir nearly full. Do not steer.
2. Start the engine and run it for 10 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.

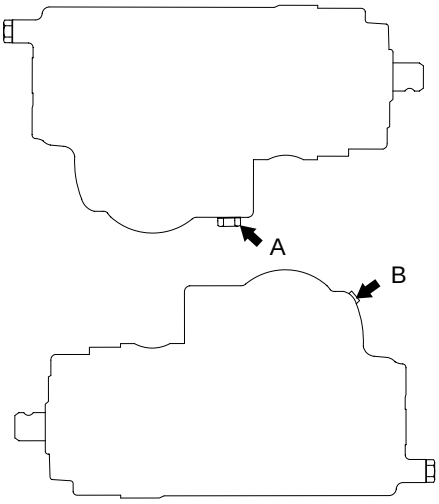
3. Start the engine and let it idle for two minutes. Do not steer. Shut off the engine and check the fluid level in the reservoir. If needed, add more fluid.
4. Start the engine again. Turn the steering wheel from full left to full right several times. If needed, add fluid to the reservoir.

   Automatic bleed systems should now be free of trapped air. If the vehicle has a manual bleed system, proceed to the next step. See **Fig. 1**.

IMPORTANT: Do not turn the steering wheel while the bleed screw is loosened.

5. With the engine idling, turn the steering wheel from full left to full right several times. Stop steering and loosen the manual bleed screw about one turn. 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 the air is out of the system. Torque the bleed screw 40 to 50 lbf·in (450 to 560 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

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 brakes, 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, item 2 in **Fig. 1**, from the steering gear. Save this seal to determine the correct size of the new seal.
5. Using a clean cloth, remove the grease from around the input shaft.
6. Using a screwdriver inserted into the notch formed in the end of the retaining ring, item 3 in **Fig. 1**, 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, and a loss of steering assist, which could result in serious personal injury or death.

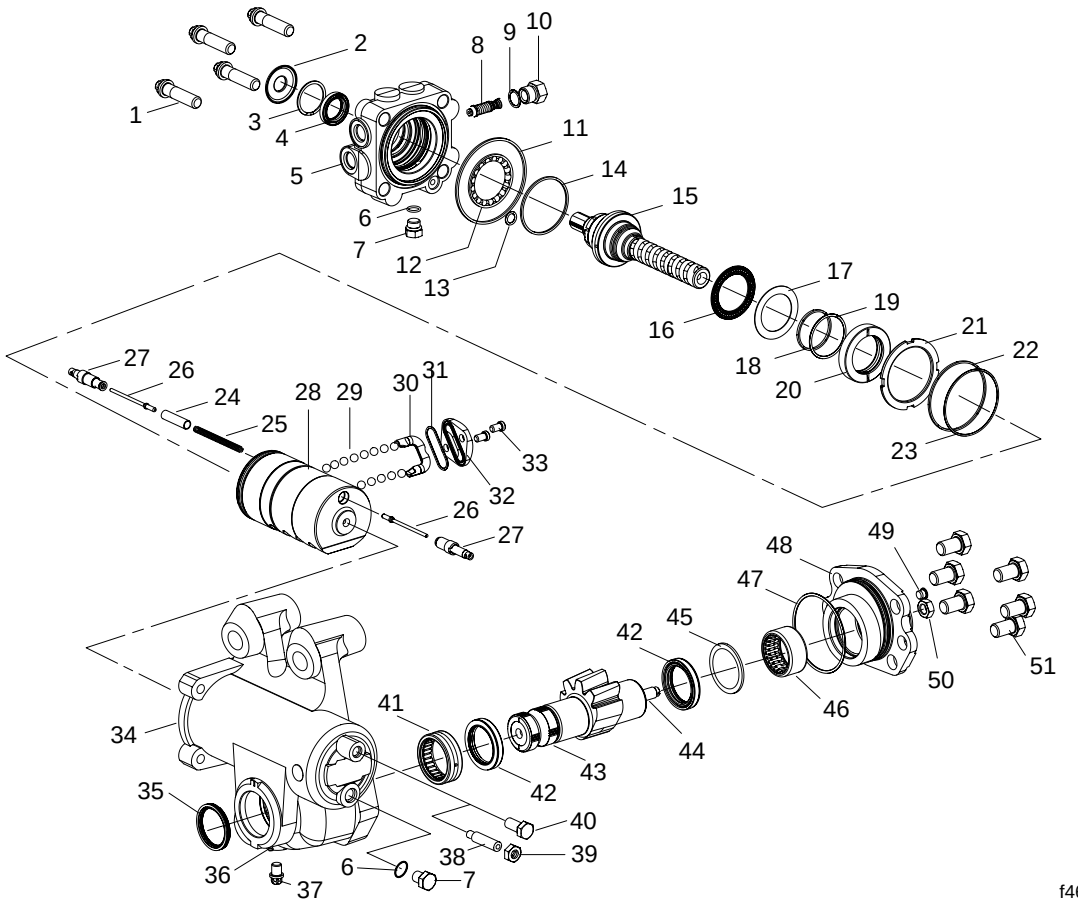
9. If needed, add hydraulic fluid to the steering reservoir to the line between the MIN COLD and MAX HOT lines. Do not mix fluid types. See **Specifications 400** for a list of approved hydraulic fluids.
10. With the vehicle in neutral, momentarily turn the starter; if the engine starts, quickly turn 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, item 4 in **Fig. 1**.
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 which could result in serious personal injury or death.

14. Install a new input shaft seal, as follows.
    - 14.1 Using Exxon Polyrex® EP2 grease (PN 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 (PN 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 (PN 045422), pack the end of the valve housing bore.
17. Install a new dirt and water seal, as follows.
    - 17.1 Choose the correct size dirt and water seal by comparing the replacement seals to the old seal, or by measuring 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 (PN 045422) 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 35 to 40 lbf·ft (47 to 54 N·m).
19. Attach the return line to the steering gear return port.

Input Shaft Seal Replacement



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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
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, THP/PCF Steering Gear

Major Serration Diameters and Corresponding Seal Part Numbers		
Major Serration Diameter: inch (mm)	**Serration Size**	**Part Number**
0.807/0.799 (20)	13/16 inch (21 mm) x 36	478044
0.866/0.857 (22)	7/8 inch (22 mm) x 36	478060
0.987/0.977 (25)	1 inch (25 mm) x 36	478050
1.008/1.000 (25)	1 inch (25 mm) x 79	478050

Table 1, Major Serration Diameters and Corresponding Seal Part Numbers

20. Bleed the air from the system. For instructions, see **Subject 110**.
21. Remove the chocks from the tires.

Sector Shaft Adjustment

The sector shaft adjustment can only be completed if the adjusting screw jam nut is accessible when the steering gear is attached to the frame rail. The jam nut is located on the side cover. If the jam nut is not accessible, the adjustment can be made by removing the steering gear and placing it in a vise. See **Subject 100** for removal instructions.

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 from 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.

NOTE: If the steering gear is removed from the frame rail to correct the lash, leave the pitman arm attached to the steering gear and follow the instructions under the "Final Adjustments" heading in **Subject 150**.

6. If no lash is detected, use a screwdriver to turn the shaft adjusting screw counterclockwise until you feel lash at the sector shaft.
7. 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).

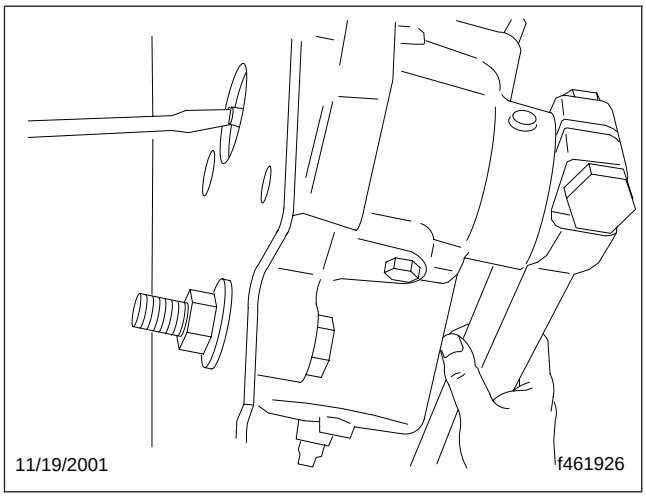


Fig. 1, Adjusting the Sector Shaft

8. Turn the steering wheel one-quarter 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.
9. If the steering gear was removed from the frame rail, install the steering gear on the frame rail. For instructions, see **Subject 100**.
10. Using a castle nut, attach the drag link to the pitman arm. Torque 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)
11. If required, continue to tighten the castle nut until a slot on the nut aligns with the hole in the ball stud. Do **not** back off the nut when locating the cotter pin hole. Install a new cotter pin in the ball stud and nut and lock the cotter pin in place.

WARNING

Failure to install or lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control.

CAUTION

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.

Sector Shaft Adjustment

12. 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.
13. Remove the chocks from the tires.

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 using the "Poppet Component Replacement" procedure in **Subject 160**.

1. Check that the axle stops are adjusted to the specifications in **Section 33.00, Subject 110**.
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, items 38 and 39 in **Fig. 1**, are being used, turn the screw into the nonsealing 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.
6. If equipped with a poppet fixed stop screw and washer, remove and discard both items from the lower end of the housing.

   If equipped with a poppet adjusting screw and nut that need to be replaced, remove and discard both items.
7. Using a 7/32-inch Allen wrench (THP/PCF60) or a 6 mm Allen wrench (THP45), 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.

CAUTION

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.

WARNING

Do not mix hydraulic fluid types or use unapproved fluids. Doing so could cause seal deterioration, leaks, and a loss of steering assist, which could result in serious personal injury or death.

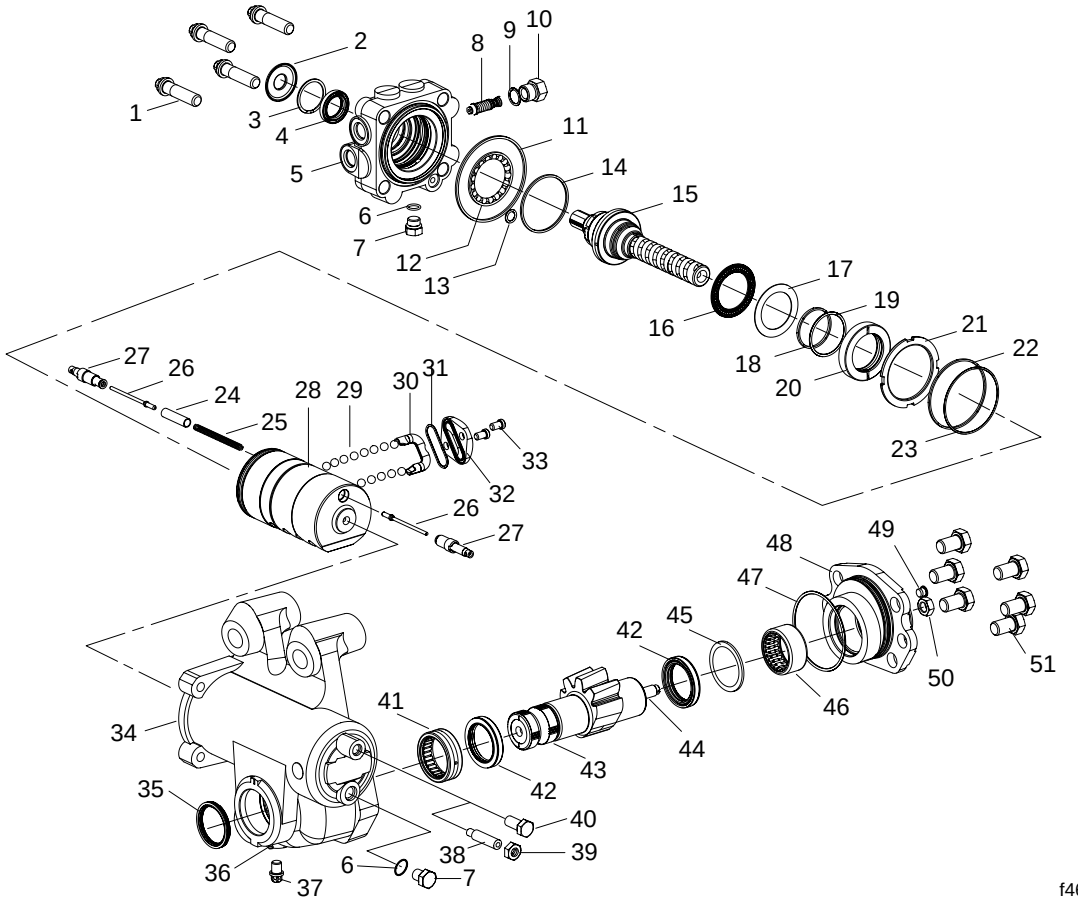
8. Fill the power steering reservoir to between the MAX HOT and MIN COLD lines. For approved hydraulic fluids, see **Specifications 400**.
9. Place a jack under the center of the front axle and jack up the front of the vehicle so the steer axle tires are off the ground.

CAUTION

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.

10. Push the upper poppet out to prepare it for setting, as follows.
    - 10.1 Start the engine and let it run at idle speed.
    - 10.2 Note which sector shaft timing mark is nearest the housing piston bore.
    - 10.3 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.
    - 10.4 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel after the axle stop is contacted.
11. Set the upper poppet, as follows.
    - 11.1 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.
    - 11.2 Pull hard on the steering wheel. Put up to 40 lbf (178 N) pull on a 20-inch diameter steering wheel.
    - 11.3 Release the steering wheel and shut off the engine.

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
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, THP/PCF Steering Gear

12. 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.

⚠ CAUTION

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.

13. Set the lower poppet, as follows.
    - 13.1 Start the engine and let it idle.
    - 13.2 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.
    - 13.3 Hold the steering wheel in this position with up to 40 lbf (178 N) pull for 10 seconds, then release. Repeat this hold-and-release process as many times as necessary while completing the next step.
14. Position the adjusting screw, as follows.
    - 14.1 With the steering wheel held tightly at full turn, loosen the nut and hold it in place with a wrench.
    - 14.2 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.

    IMPORTANT: The length of the adjusting screw beyond the nut must not be more than 1-1/16 inch (27 mm) for proper thread engagement.

    NOTE: The length of the adjusting screw beyond the nut may be different for each vehicle.

    - 14.3 Back off the adjusting screw 3-1/4 turns and tighten the nut 35 lbf·ft (47 N·m).
15. The poppets have now been completely reset. Check the power steering reservoir and fill if necessary.
16. Lower the vehicle and remove the chocks from the tires.

Disassembly, Inspection, Assembly, and Final Adjustments

Disassembly

NOTE: Replace all seals, seal rings, and gaskets each time the gear is disassembled.

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.

1. Remove the power steering gear. For instructions, see **Subject 100**.

⚠ CAUTION

Never steam clean or high-pressure wash hydraulic steering components. Do not force or abuse closely fitted parts. Use care that the bearing and sealing surfaces are not damaged by the disassembly and assembly procedures. Failure to follow these precautions could result in damage to the components.

2. Clean and dry the steering gear before beginning to disassemble it.
3. As you disassemble the gear, clean all parts in clean, OSHA-approved solvent and use only air to blow dry the parts.
4. With the input shaft horizontal and the side cover and valve housing accessible, put the steering gear in a vise with the clamps firmly against the housing mounting flange or boss.

IMPORTANT: Do not clamp against the body of the housing. If the mounting boss or flange is not accessible, fabricate and attach a mounting plate to the housing mounting bosses.

5. Place a drain pan under the gear and remove the plugs from the hydraulic ports.
6. Rotate the input shaft until the timing mark on the end of the sector shaft is in line with the timing mark on the end of the housing. The sector shaft is now positioned for removal.
7. Remove any paint or corrosion from the exposed area of the sector shaft.
8. Tape the serrations and bolt groove of the sector shaft with one layer of masking tape. The tape should not extend on to the sector shaft bearing diameter.
9. Remove the adjusting screw jam nut, item 50 in **Fig. 1**.
10. Remove the capscrews that attach the side cover to the housing.
11. Remove the side cover and sector shaft assembly from the gear. Start the cover and sector shaft assembly removal by lightly tapping the end of the shaft with a soft mallet.
12. Remove and discard the vent plug, item 49 in **Fig. 1**
13. Remove and discard the side cover O-ring, item 47 in **Fig. 1**.
14. Turn the sector shaft adjusting screw, item 44 in **Fig. 1**, clockwise through the side cover and pull the sector shaft out of the side cover.

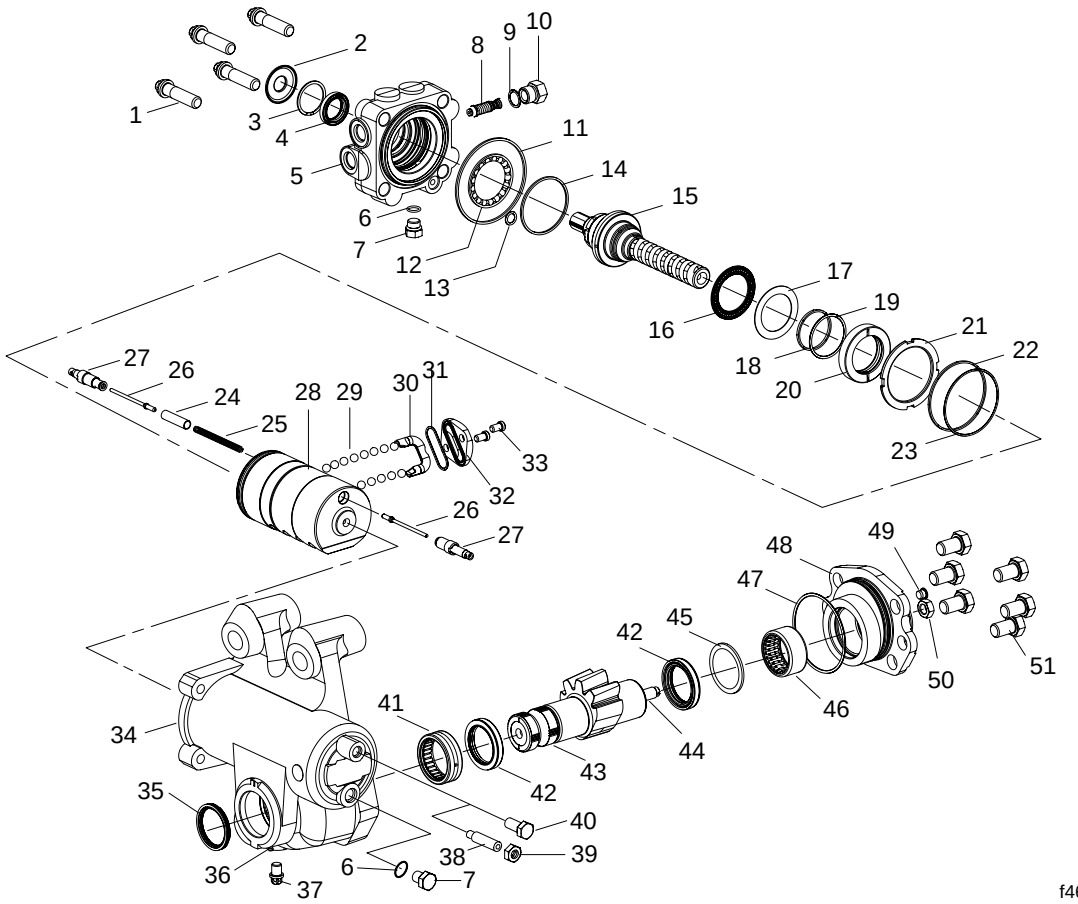
IMPORTANT: Take care not to damage the bore or bearing when removing the output seal.

15. Clamp the side cover in a vise. Place a 3/8-inch drive socket in the center of the side cover. Using the socket for support, pry out the output seal with a rolling head pry bar. Discard the seal and remove the socket. Remove the washer.
16. Inspect the sector shaft assembly for damaged adjusting screw threads. The retainer must be securely staked in place. The adjusting screw must rotate by hand with no perceptible end play.
17. If equipped with a relief valve, remove the relief valve cap, the O-ring, and the relief valve from the valve housing. Discard the O-ring.
18. Remove the dirt and water seal, item 2 in **Fig. 1**, from the input shaft assembly. Save this seal to determine the correct size of the new seal.
19. Clean any paint or corrosion from the exposed area of the input shaft
20. Remove the four valve housing capscrews and remove the rack piston. Place the rack piston on a clean cloth.

IMPORTANT: The set position of the poppet seat and sleeve assembly must not be disturbed if the poppets are not going to be replaced or reset during disassembly.

21. Remove and discard the O-ring and the valve housing O-ring, items 13 and 11 in **Fig. 1**.

Disassembly, Inspection, Assembly, and Final Adjustments



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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
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, THP/PCF Steering Gear

⚠ CAUTION

Do not remove the input shaft assembly or the balls from the rack piston until the ball return guides are removed. If this precaution is not followed, the ball return guides will be damaged.

22. Remove and discard the two Torx® capscrews, item 33 in **Fig. 1**. Remove the ball return guide cap and the cap seal. Discard the cap seal.
23. Remove the ball return guide by carefully inserting a screwdriver between the rack piston and guide.

NOTE: Left-hand ball return guide halves are plated with copper or zinc chromate for identification. Right-hand guide halves are not plated.

24. Remove the balls from the rack piston by rotating the input shaft assembly until the balls fall out. Place the balls and return guide in a container. Count the balls and make sure all have been removed. There are 29 balls in the THP45 model and 31 balls in the THP/PCF60 model.

IMPORTANT: The balls are a matched set. If any are lost, the set must be replaced.

25. Remove the valve housing and input shaft assembly from the rack piston.
26. Cut and remove the seal ring and O-ring, items 23 and 22 in **Fig. 1**, from the rack piston.

Inspection

⚠ WARNING

If one of the conditions in Table 1 is found in one component of the steering gear, inspect all components carefully for signs of impact damage. Replace the components if you suspect impact damage. Failure to replace all damaged components could result in a serious vehicle accident.

1. Inspect the poppet seat and sleeve assembly, as follows.
   - 1.1 Push on the poppet stem; it should spring back.
   - 1.2 Push on the poppet seat; it should not move by hand.
   - 1.3 If the components are bent or broken, if the poppet stems don't spring back, or if the poppet seat moves by hand, replace the poppet seat and sleeve assembly. For instructions, see **Subject 160**.

Conditions in the Steering Gear That Indicate Impact Damage	
Condition	**Area**
Brinelling	Ball track grooves of rack piston
	Ball track grooves of worm screw
	Bearing area of sector shaft
	Thrust washer and bearing in valve housing
	Ball cup and bearing in valve housing
Cracks or Breaks	Bearing area of sector shaft
	Sector shaft teeth
	Rack piston teeth
	Housing
	Thrust washer and bearing in valve housing
	Worm screw
	Ball cup and bearing in valve housing
Twisted Serrations	Output shaft serrations

Table 1, Conditions in the Steering Gear That Indicate Impact Damage

NOTE: TRW recommends that the poppet seat and sleeve assemblies not be removed unless replacement of the poppet is required.

2. Inspect the valve housing and input shaft assembly for heat damage or bearing roughness. If these conditions are present, if there is excessive internal leakage, or if preload adjustment is required, see the instructions in **Subject 170**.
3. Remove and discard the dirt and water seal, item 35 in **Fig. 1**.
4. Insert a screwdriver through the trunnion opening and carefully push the output seal out without damaging the sealing area of the bore. Discard the output seal.

NOTE: A special hook groove has been machined into the bore to hold the seal in position.

Disassembly, Inspection, Assembly, and Final Adjustments

Clean out the rubber from the groove prior to installing a new seal.

5. Inspect the roller bearing for brinelling or spalling. If the roller bearing needs to be replaced, see the instructions in **Subject 180**.
6. Inspect the following components for damage. If they are damaged, see the instructions in **Subject 190**.
    - poppet fixed stop screw
    - poppet adjusting screw and nut
    - automatic bleed plug
    - manual bleed screw
    - auxiliary port plug and O-ring
7. Make sure all sealing surfaces and seal cavities are free of nicks and corrosion. Any nicked or corroded surface requires part replacement to ensure proper sealing.
8. Inspect the rack piston teeth for cracks or damage. If teeth are damaged, replace the rack piston, the sector shaft, and the set of balls.
9. Inspect the rack piston ball track grooves for brinelling or spalling. If either condition exists, replace the input shaft assembly, the valve housing, the rack piston, and the balls.
10. Inspect the sealing area of the input shaft assembly for nicks and damage. Inspect for discoloration from excess heat. Inspect the input shaft ball track grooves for brinelling or spalling. If any of these conditions exist, replace the:
    - input shaft
    - worm/valve assembly
    - valve housing
    - balls
    - rack piston
11. Inspect the gear housing cylinder bore. Some scoring marks are normal. If there was internal leakage greater than 1.2 gpm (4.5 L/min), make sure there are no damaged seals before replacing the housing.
12. Inspect the valve housing mating surface for nicks that would prevent proper sealing. Replace the gear housing if these nicks are present and cannot be easily removed with a fine-tooth flat file without changing the dimensional characteristics.
13. Inspect the roller bearing in the side cover assembly for brinelling or spalling. If either condition exists, replace the side cover assembly.
14. Inspect the sector shaft bearing and sealing areas and sector teeth contact surfaces for brinelling, spalling, or cracks. Run the end of your fingernail across these areas to detect steps. Remove the masking tape from the shaft and inspect the shaft for twisted or damaged serrations. If any of these conditions exist, replace the sector shaft.

NOTE: A replacement sector shaft comes with the adjusting screw and retainer.

Assembly

NOTE: Use the bearing and seal tool (PN J37705 for THP45, PN J37071 for THP/PCF60) in the following two steps.

1. Install a new output seal on the short end of the bearing and seal tool so that the lip with the garter spring is toward the shoulder of the tool. Working from the side cover side of the housing, pilot the bearing and seal tool into the washer and bearing, and press, with 100 to 800 lbf·ft (445 to 3560 N·m) until the seal is seated firmly.
2. Using the long end of the bearing and seal tool, install the dirt and water seal, item 35 in **Fig. 1**, making sure it is not distorted or twisted.

IMPORTANT: Press the seal only until it seats against the bearing; do not press it in farther.

3. Pack the roller bearing seal, the output seal, and the dirt and water seal liberally with clean, high-temperature industrial grease, Exxon Polyrex® EP2 grease (PN 045422).
4. Lightly oil the valve housing O-ring, item 11 in **Fig. 1**, and install the O-ring in the mounting face groove of the valve housing.
5. Lightly oil a new seal ring, item 14 in **Fig. 1**, and install the seal ring in the valve housing mounting face groove.
6. Install a new O-ring, item 22 in **Fig. 1**, and then a seal ring, item 23, on the rack piston. Do not

overstretch the rings as they're being installed. Do not allow the seal ring to become twisted.

7. Apply clean oil to the gear housing cylinder bore. Place the rack piston in the housing with the ball return guide holes up.
8. Install the input shaft assembly in the rack piston close to maximum depth without the valve housing making contact with the poppet stem. Insert two 14 mm x 2.0 mm All Threads through the lower valve housing mounting holes and tighten them to support the worm and valve assembly. Line up the rack piston ball guide holes with the worm ball track grooves by rotating the input shaft.
9. Install the ball return guide in the rack piston until seated. Rotate the input shaft slightly if necessary.

⚠ WARNING

Do not seat the ball return guide with a hammer. Damage to the guide can result in subsequent lockup or loss of steering, resulting in personal injury or property damage.

IMPORTANT: If a new rack piston, input shaft, or input shaft assembly is being installed, the balls must be replaced. The balls in a service ball kit are sized to function in the ball track guide path as altered by component replacement.

When using a service ball kit, use the correct quantity of balls, 29 balls for the THP45 model and 31 balls for the THP/PCF60 model.

NOTE: Hold the ball return guide firmly in place while performing the following step.

10. Insert as many balls as you can through the hole in the top of the ball return guide. Rotate the input shaft to pull the balls down and around the ball track guide path. Continue until the correct number of balls is in the ball track guide path.

    If the ball guide becomes unseated (raised) at any time, start the procedure again beginning with the previous step.

⚠ WARNING

Hold down the ball return guide until the ball return guide cap is installed. Failure to hold the guide will result in a trapped ball or balls, which could cause a vehicle accident resulting in personal injury or property damage.

⚠ CAUTION

Do not allow the valve housing to contact the poppet stem or move more than 2.5 inches (64 mm) from the upper end of the rack piston during these procedures. This could incorrectly reset the poppet or back out the input shaft assembly beyond the closed ball loop, trapping the balls.

⚠ CAUTION

Remove any fluid present in the two screw holes. Fluid in these holes could cause improper clamp load when torquing the ball return guide cap.

11. Install a new cap seal in the groove of the ball return guide cap. Make sure the seal makes full contact with the rack piston surface. Install two new Torx capscrews and torque each capscrew alternately until a final torque of 18 lbf·ft (24 N·m) is reached.

IMPORTANT: The cap seal is greased to hold the seal in the groove while it is assembled. Be sure not to trap the seal outside of the groove during assembly.

12. Rotate the input shaft from one end of travel to the other without contacting the poppet stem to the valve housing and without moving the valve housing face more than 2.5 inches (64 mm) from the input end (upper end) of the rack piston. If you cannot rotate the input shaft, remove the balls and install them again.

⚠ WARNING

If a gear is installed on a vehicle when the input shaft is not able to be rotated, the gear will not function correctly. Steering and gear failure may result, possibly causing personal injury or property damage.

13. Apply clean oil to the seal ring, item 23 in **Fig. 1**, on the rack piston. Make sure there is a space of

Disassembly, Inspection, Assembly, and Final Adjustments

3/8 to 1/2 inch (10 to 13 mm) between the valve housing and the poppet stem to prevent poppet contact at either end. Remove the All Threads and push the rack piston into the housing with the rack piston teeth toward the sector shaft cavity. Line up the valve housing cylinder feed hole with the gear housing feed hole. Make sure both O-rings in the valve housing remain in position.

IMPORTANT: Do not damage the seal ring while installing the rack piston in the housing.

IMPORTANT: The poppet seat and sleeve assembly must not bottom against the internal poppet stops in the steering gear until the gear is installed on the vehicle and the poppet adjustment procedures are performed.

14. Lubricate and install the four valve housing capscrews in the housing. Torque the capscrews 118 to 138 lbf·ft (160 to 187 N·m).
15. If the gear is equipped with a relief valve, install a new O-ring on the relief valve cap. Install the small end of the tapered spring on the pin on the relief valve cartridge and install the relief valve with the large end of the tapered spring end first in the relief valve cap cavity. Turn the relief valve cap into the valve housing and torque 30 lbf·ft (41 N·m).

CAUTION

The caged bearing assembly is sealed and will not receive lubrication from the hydraulic fluid in the gear. Failure to use the proper grease could result in premature bearing wear.

16. Apply a generous amount of Exxon Polyrex EP2 grease (PN 045422), and **only** this type of grease, to the caged bearing assembly in the side cover. Then install the washer, item 45 in **Fig. 1**, on top of the bearing.

NOTE: Use bearing and seal tool PN J37705 on a THP45 steering gear. Use bearing and seal tool PN J37071 on a THP/PCF60 steering gear.

17. Grease and install a new output seal on the installation tool so that the side with the garter spring is against the shoulder of the tool. Pilot the tool into the side cover with a force of 100 to 800 lbf·ft (445 to 3560 N·m) until it is seated against the bearing or bushing.

IMPORTANT: Make sure the outside diameter of the seal and the inside diameter of the bore are free from grease and dust for proper engagement of the seal.

18. Apply a generous amount of Exxon Polyrex EP2 grease (PN 045422) to the short bearing area of the sector shaft.
19. Install the sector shaft in the side cover and turn the sector shaft adjusting screw counterclockwise until the screw reaches solid height.

    Rotate the adjusting screw clockwise one-half turn so that the side cover will rotate freely on the sector shaft.
20. Install the sector shaft adjusting screw jam nut, item 50 in **Fig. 1**, on the sector shaft adjusting screw a few threads. Final adjustment will be made later.
21. Press the new vent plug into the hole provided in the side cover until the plug has bottomed.

WARNING

Do not weld or otherwise plug this hole in a permanent manner. This is a safety vent that functions only if the side cover fails. If the seal fails and the plug cannot vent, the steering gear may lockup or malfunction possibly resulting in personal injury or property damage.

22. Apply clean oil to the new side cover O-ring, item 47 in **Fig. 1**, and install it on the side cover.

WARNING

If the rack piston is not centered when the sector shaft is installed, gear travel will be severely limited in one direction. This could cause an accident possibly resulting in personal injury or property damage.

23. There are four teeth on the rack piston. Rotate the input shaft to position the rack piston so that the space between the second and third tooth is in the center of the sector shaft opening. This will center the rack piston for installation of the sector shaft.

⚠ CAUTION

If the serrations are not properly taped, they will damage the output seal in the housing and cause the seal to leak.

24. Remove all tape on the serrations. Apply one layer of masking tape on the serrations and bolt groove of the sector shaft. Install the sector shaft in the housing. The center tooth of the sector shaft must engage the center space (between the second and third tooth) of the rack piston. Lightly tap on the side cover with a rubber mallet to seat the cover against the housing face.
25. Lubricate the capscrews. By hand, install the capscrews in positions 3 and 4 on the side cover by hand. Then install the remaining capscrews in the side cover and tighten them in the sequence shown in **Fig. 2**, and torque 180 to 220 lbf·ft (244 to 298 N·m).

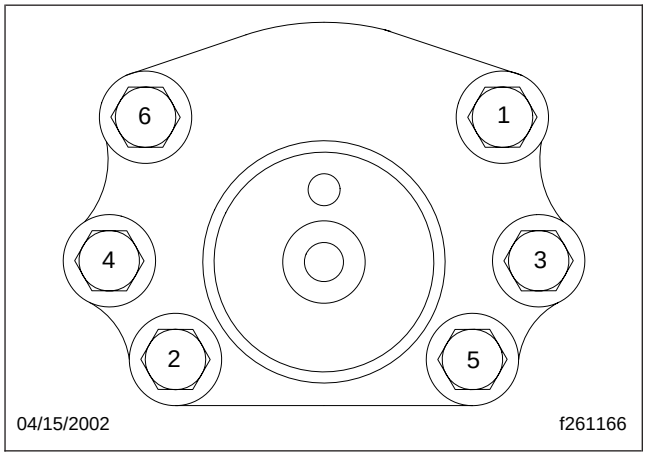


Fig. 2, Capscrew Tightening Sequence

IMPORTANT: If the capscrews must be replaced, use capscrews of the same design, type, and length as those removed.

26. Remove the tape from the sector shaft.
27. Pack the end of the valve housing bore with Exxon Polyrex EP2 grease (PN 045422). Apply more grease to the inside of a new dirt and water seal and install it on the input shaft. Seat the seal in the groove behind the serrations and against the valve housing.

NOTE: This step may have already been completed if the valve housing and input shaft assembly were disassembled for repair.

Final Adjustments

Before installing the steering gear on the vehicle, make the following adjustments.

NOTE: Worm shaft preload adjustment was done when the input shaft was installed in the valve housing during the assembly procedure.

IMPORTANT: When the steering gear is not connected to the steering system, don't turn the input shaft more than 1-1/2 turns from the center position or the automatic poppets could become inoperative when the steering gear is installed on the vehicle. This would require disassembling the gear to position the poppet seat and sleeve assemblies.

1. Using a 3/4- or 11/16-inch socket or box end wrench, center the steering gear by rotating the input shaft until the timing mark on the end of the sector shaft is in line with the timing mark on the end of the housing trunnion.

NOTE: If new or reset poppets are in the gear, they will be moved when the input shaft is turned less than one rotation in either direction from the center position. This will not affect the function of the poppets.

2. With the adjusting screw jam nut loose, turn the sector shaft adjusting screw clockwise to provide 45 to 50 lbf·in (450 to 560 N·cm) of torque to rotate the input shaft through one-half turn each side of center.

NOTE: This step will properly mesh and seat the rack piston and sector shaft for final adjustments.

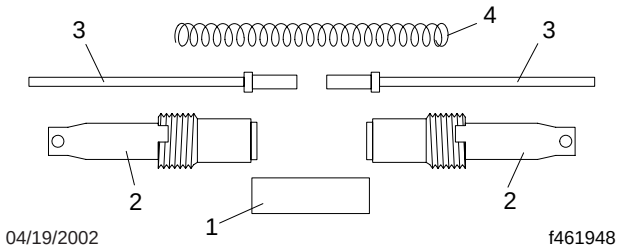
3. Turn the sector shaft adjusting screw counterclockwise one-half turn and note the maximum torque required to rotate the input shaft through one-half turn each side of center.
4. Turn the sector shaft adjusting screw clockwise to increase the maximum torque noted in the previous step by 7 lbf·in (79 N·cm). Tighten the jam nut firmly against the side cover while holding the adjusting screw in position.

Disassembly, Inspection, Assembly, and Final Adjustments

5. Torque the jam nut 43 lbf·ft (58 N·m) and check the input shaft torque again. Adjust the sector shaft adjusting screw if the input shaft torque exceeds 40 lbf·in (452 N·cm).
6. Install the steering gear on the vehicle. For instructions, see **Subject 100**.
7. Remove the chocks from the tires.

Replacement

1. Remove the rack piston from the steering gear. For instructions, see **Subject 150**.
2. Place the rack piston in a soft-jawed vise.
3. Place special tool, PN J36452-A, over the seat of the poppet seat and sleeve assembly and engage the special tool in the slots of the threaded sleeve. Hit the end of the tool firmly four or five times with a two-pound sledge hammer to loosen the Loctite®.
4. Place a ratchet on the special tool and remove the seat and sleeve assembly from the rack piston. If the ratchet does not turn easily, strike the special tool again with a hammer. If the engaging tangs won't stay in place while torquing, it may be necessary to hold the tool in place with an arbor press while applying loosening torque.
5. Discard the poppet seat and sleeve assembly. See **Fig. 1**.



1. Push Tube
2. Poppet Seat and Sleeve Assembly
3. Poppet
4. Spring

Fig. 1, Poppets Components

6. Remove the two poppets, the spring, and the push tube. See **Fig. 1**.
7. If necessary, remove and discard the second poppet seat and valve assembly.

NOTE: It is possible to reset one poppet seat and sleeve assembly for automatic poppet adjustment while it is in the rack piston if one poppet seat and sleeve assembly and the poppets, spring, spacer rod, and push tube are removed.

8. To reset the automatic poppet adjustment when one poppet seat and sleeve assembly has been left in the rack piston, insert a 3/8-inch (9.5-mm) diameter x 6-inch (152-mm) drill rod down through the poppet seat hole at the opposite end of the rack piston and against the adjuster seat to press the seat in until it bottoms against the adjuster sleeve.

CAUTION

Do not allow Loctite or Locquic to get on the adjuster seat component of the poppet seat and sleeve assembly. Failure to follow this precaution, will prevent the poppets from functioning properly.

9. Carefully apply Locquic® T primer to the threads in the poppet holes and to the threads on the new seat and sleeve assemblies. Allow the primer to dry for ten minutes, then carefully apply Loctite RC680 to the same threads.

WARNING

Wear eye protection when assembling the poppets since the spring loaded poppets could eject and cause personal injury.

10. Place the rack piston in a soft-jawed vise. If the second poppet seat and valve assembly was removed, install a new poppet seat and sleeve assembly, with the slotted end out, into the poppet hole in one end of the rack piston.
11. From the other end of the poppet hole in the rack piston, install one poppet, the poppet spring, push tube, the other poppet, and a new poppet seat and valve assembly. The new components will stack up as shown in **Fig. 2**.

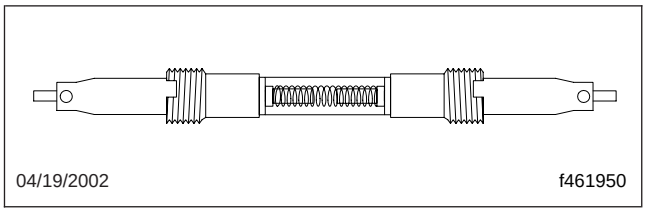


Fig. 2, Poppet Components Assembled

12. Torque the poppet seat and valve assemblies 18 lbf·ft (24 N·m).
13. Install the rack piston in the steering gear. For instructions, see **Subject 150**.

Valve Housing/Input Shaft Disassembly, Inspection, and Assembly

Disassembly

1. Remove the valve housing and the input shaft assembly from the steering gear. For instructions, see **Subject 150**.
2. Place the valve housing, with the input shaft in the upright position, in a soft-jawed vise.
3. Unstake the valve housing where the material was moved into the adjuster locknut slot.
4. Using a roll pin punch and hammer, unstake the adjuster locknut from the bearing adjuster. See **Fig. 1**.
5. Using the adjuster locknut tool (PN J37464), remove the adjuster locknut from the valve housing.
6. Using the bearing adjuster tool (PN J37070), remove the bearing adjuster from the valve housing.
7. Remove and discard the seal ring and O-ring, items 18 and 19 in **Fig. 1**, from the bearing adjuster.
8. Remove the input shaft from the valve housing.
9. Remove the thrust washer and thrust bearing, items 17 and 16 in **Fig. 1**, from the input shaft.

CAUTION

The input shaft assembly must not be disassembled any further. The components are a select fit at assembly and are available only as part of this subassembly. If disassembled further, the subassembly must be replaced.

10. Remove the bearing assembly, item 12 in **Fig. 1**, from the valve housing.

IMPORTANT: Do not remove the ball cup that the bearing assembly rides on. Do not remove the special spacer seal behind the ball cup.

11. Remove and discard the seal ring, item 14 in **Fig. 1**, from the valve housing.
12. Remove the valve housing from the vise. Turn the valve housing over and remove the retaining ring, item 3 in **Fig. 1**.

CAUTION

Be careful when removing the input shaft seal to prevent damage to the valve housing seal bore.

13. Using a 1-1/8-inch socket and hammer, remove the input shaft seal, item 4 in **Fig. 1**, from the valve housing. Discard the input shaft seal.

NOTE: The valve housing also utilizes a ball plug for manufacturing purposes that must not be removed.

Inspection

1. Inspect the sealing areas of the input shaft and valve housing for nicks. Run the edge of your fingernail over the sealing surfaces to detect steps. Inspect for discoloration from excess heat. Inspect the input shaft ball track grooves for brinelling or spalling. If any of these conditions exist, the input shaft assembly, valve housing, and balls must be replaced. Replace the rack piston if brinelling or spalling is found.
2. Inspect the rollers in the thrust bearing and the bearing assembly for deterioration. Inspect the thrust washer and ball bearing race in the valve housing for brinelling, spalling, or cracks. Replace all parts that exhibit these conditions.

Assembly

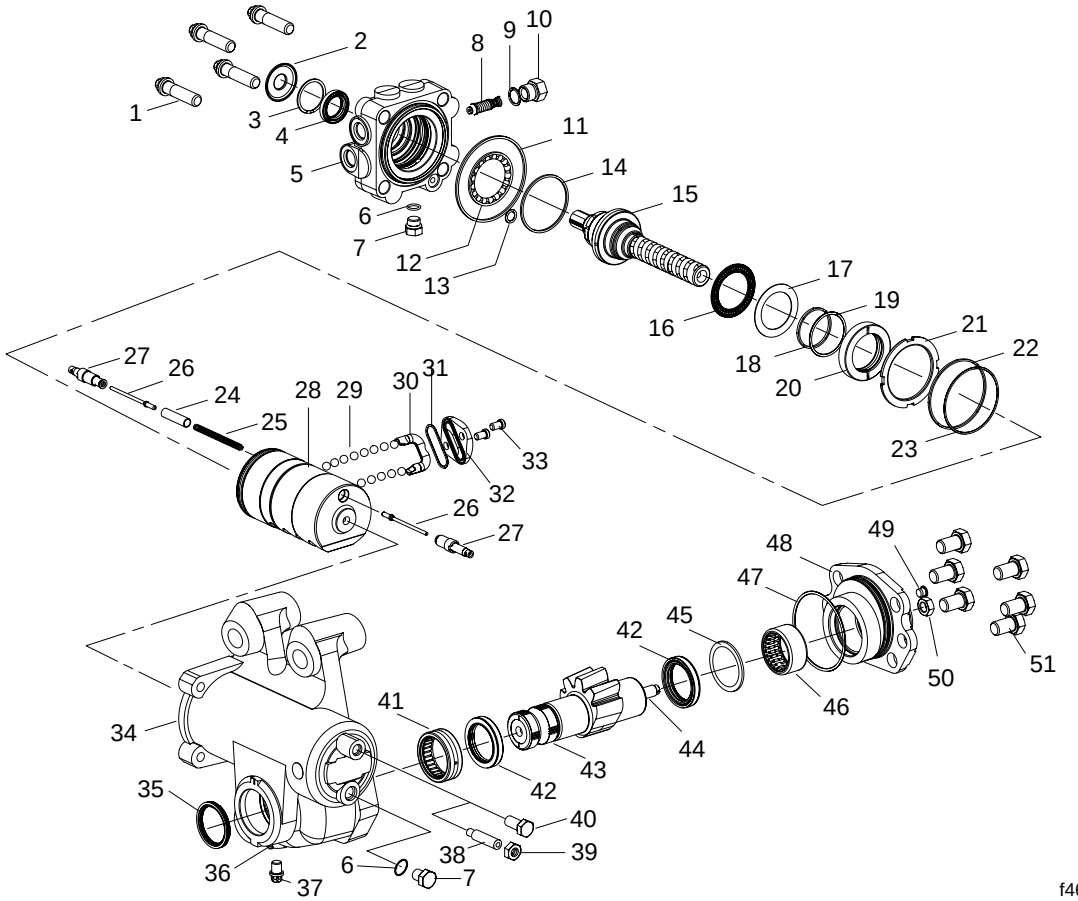
IMPORTANT: Do not clamp the valve housing against the threaded port hole or relief valve hole sealing faces when placing the valve in the vise.

1. Place the valve housing in a vise so the input shaft can be assembled with the worm screw up.
2. Lightly oil a new seal ring and install the seal ring in the large diameter groove in the valve housing. It may be necessary to bend and work the seal ring into the groove. Smooth out the seal ring.

IMPORTANT: The seal ring must be smoothed out to prevent it from damage when the worm screw is installed.

3. Install the bearing assembly in the valve housing. See **Fig. 2** for correct orientation of the bearing assembly.

Valve Housing/Input Shaft Disassembly, Inspection, and Assembly

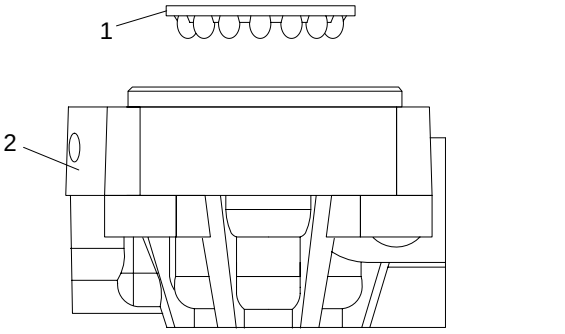


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1. Valve Housing Capscrew
2. Dirt and Water Seal
3. Retaining Ring
4. Input Shaft Seal
5. Valve Housing
6. Auxiliary Port O-Ring (2)
7. Auxiliary Port Plug (2)
8. Relief Valve
9. O-Ring
10. Relief Valve Cap
11. Valve Housing O-Ring
12. Bearing Assembly
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, THP/PCF Steering Gear

Valve Housing/Input Shaft Disassembly, Inspection, and Assembly



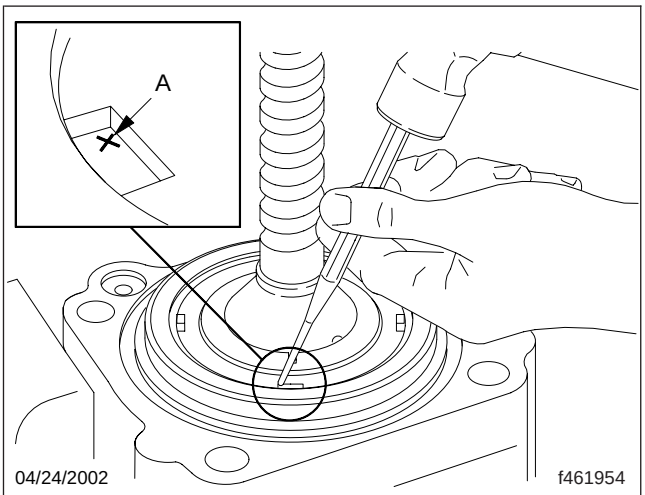
1. Bearing Assembly 2. Valve Housing

Fig. 2, Correct Orientation of Bearing Assembly

4. Dip the input end of the input shaft assembly in oil up to the worm lead. Install the input shaft end of the assembly in the valve housing until it is firmly seated.
5. Apply oil to the thrust bearing and thrust washer, then install the bearing and washer over the ball groove end of the worm screw and seat them against the shoulder of the input shaft assembly.
6. Lightly oil a new O-ring and install it in the bearing adjuster seal groove. Lightly oil a new seal ring and install it in the same bearing adjuster seal groove. Smooth out the seal ring.

NOTE: Be sure the valve housing, the adjuster locknut, and the bearing adjuster threads are clean and free of any staking burrs that would impede the locknut from turning freely in the valve housing.

7. Lightly oil a new bearing adjuster and install it in the valve housing. Using a torque wrench inserted in the bearing adjuster tool (PN J37070), torque the bearing adjuster 13 lbf·ft (18 N·m). This will seat the components. Back off the adjuster one-quarter to one-half of a turn.
8. Lightly oil a new adjuster locknut and install it on the bearing adjuster with the slightly rounded side down. Tighten slightly to keep the bearing adjuster in place.
9. Reverse the valve housing in the vise so that the worm screw is down. With a pound-force-per-inch torque wrench on the input shaft, note the torque required to rotate the input shaft 360 degrees in each direction. Tighten the bearing adjuster to increase the maximum torque at the input shaft 5 to 10 lbf·in (50 to 110 N·cm) over that which was previously noted.
10. Reverse the valve housing in the vise so that the worm screw is up. Torque the adjuster locknut while holding the bearing adjuster in the position established in the previous step with the adjuster locknut tool (PN J37464). When using a torque wrench in the adjuster locknut tool, the torque wrench reading should be 112 lbf·ft (152 N·m).
11. Check the input shaft torque. It should match the torque measured previously. If the torque specs do not match, repeat the previous two steps.
12. Stake the valve housing in the clockwise-most corner of two opposing slots in the adjuster locknut. See **Fig. 3**. Stake the locknut into the bearing adjuster in two places, 180 degrees apart, at the threaded area. Choose areas that have not been previously staked.



A. Stake the valve housing in the clockwise-most corner of the slot in the adjuster locknut.

Fig. 3, Staking the Valve Housing

13. After staking, the torque required to rotate the input shaft must be from 5 to 10 lbf·in (56 to 113 N·cm) greater than the torque noted previously. The torque value must not exceed 22 lbf·in (249 N·cm). If necessary, unstake and readjust.
14. Place the valve housing/worm screw assembly in the vise so that the worm screw is down.

Valve Housing/Input Shaft Disassembly, Inspection, and Assembly

IMPORTANT: Remove any seal material that may have sheared off and is in the seal bore and retaining groove ring.

15. Apply Exxon Polyrex® EP2 grease (PN 045422) to the outside and inside diameters (fill cavity between the lips) of the new input shaft seal and install it, garter spring side first, on the input shaft. Align the seal in the valve housing seal bore.

IMPORTANT: The input shaft seal must be square in the seal bore and installed to the correct depth.

16. Place the seal driver tool (PN J37073) with the smaller end first, on the input shaft and against the seal. Tap the seal installer tool until the tool shoulder is squarely against the valve housing. This will correctly position the seal in the housing bore just beyond the retaining ring groove.
17. Insert the new retaining ring, item 3 in **Fig. 1**, into the retaining ring groove in the valve housing.
18. Pack the end of the valve housing bore around the input shaft with Exxon Polyrex EP2 grease (PN 045422). Apply more of the grease to the inside of a new dirt and water seal and install it on the input shaft. Seat the seal in the groove behind the serrations and against the valve housing.
19. Install the valve housing/input shaft assembly in the steering gear. For instructions, see **Subject 150**.

Replacement

1. Remove the roller bearing, item 41 in **Fig. 1**, from the gear housing. For instructions, see **Subject 150**.
2. Place the long end of the bearing and seal tool (PN J37705 for THP45, PN J37071–A for THP/PCF60) against the trunnion end of the bearing and press it out of the side-cover end of the bearing bore. Discard the roller bearing.

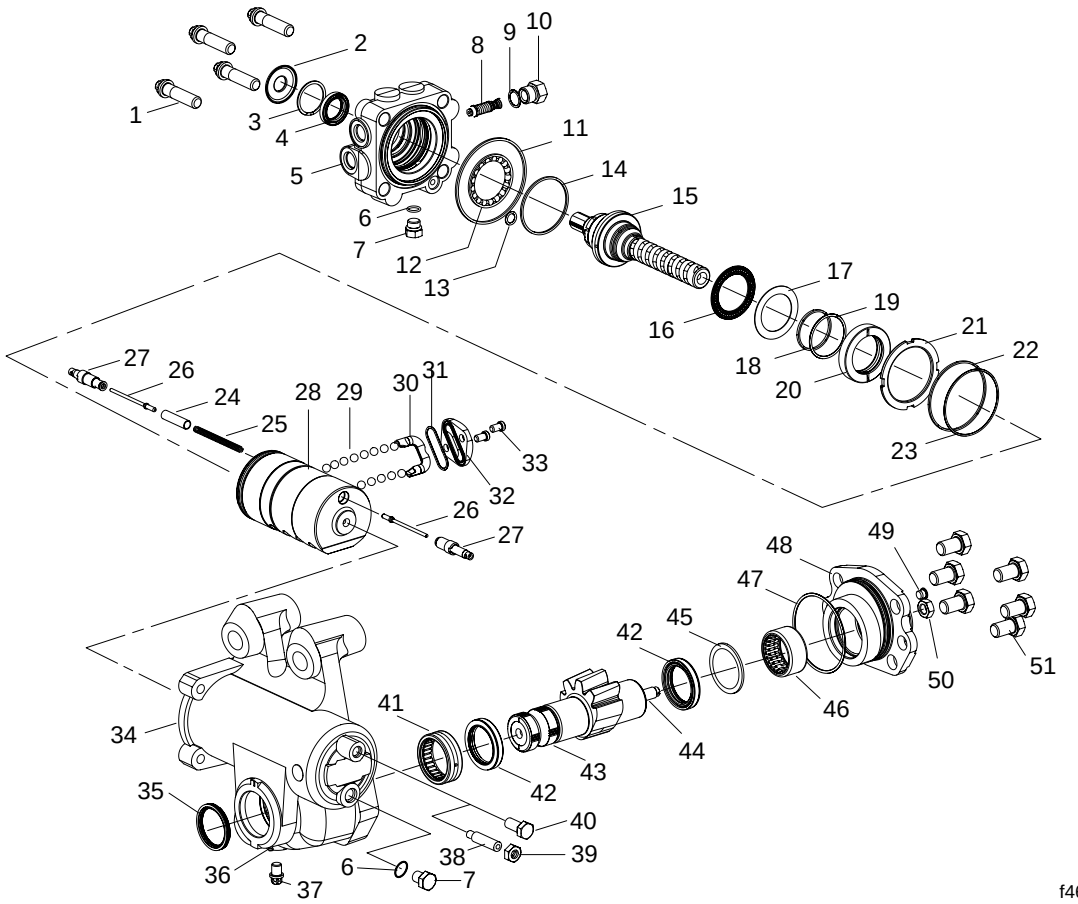
⚠ CAUTION

Use the short end of the bearing and seal tool to press in the roller bearing. If the long end of the bearing and seal tool is used to press in the bearing, the cage on the roller bearing may be damaged.

NOTE: If the unmachined trunnion face is not square, use shims to square it before pressing in the bearing.

3. Using the short end of the bearing and seal tool, press the new roller bearing into the gear housing from the side-cover end of the bearing bore until it is seated against the step bore. Be sure the housing is square with the press base and the bearing is not cocked.
4. Install the side cover on the gear housing. For instructions, see **Subject 150**.

Roller Bearing Replacement



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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, THP/PCF Steering Gear

Poppet Fixed Stop Screw Replacement

1. If damaged, remove the poppet fixed stop screw, item 40 in **Fig. 1**, and the washer. Discard the washer.
2. Install a new poppet fixed stop screw and torque it 48 lbf·ft (65 N·m).

Poppet Adjusting Screw Replacement

1. If damaged, remove the poppet adjusting screw and poppet adjusting screw nut, items 38 and 39 in **Fig. 1**, without allowing the nut to change its position on the screw.
2. Install a new nut on the new poppet adjusting screw matching its position to the nut and screw removed. Torque the nut 35 lbf·ft (48 N·m).

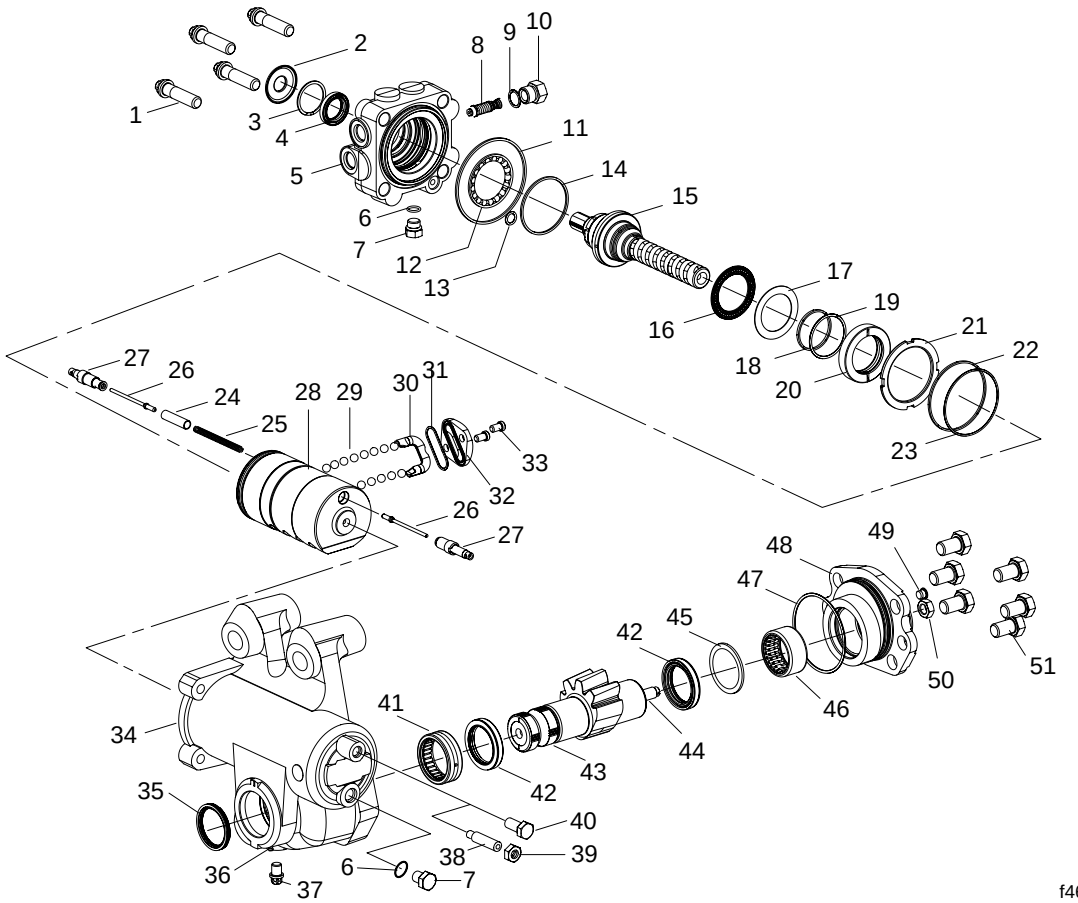
Automatic Bleed Plug and Auxiliary Port Plug Replacement

1. If damaged, remove the automatic bleed plug, item 37 in **Fig. 1**.
2. Install a new automatic bleed plug and torque the plug 48 lbf·ft (65 N·m).
3. If damaged, remove the auxiliary port plug and the auxiliary port O-ring, items 7 and 6 in **Fig. 1**.
4. Install a new auxiliary port plug and auxiliary port O-ring in the gear housing or valve housing and torque the plug 30 lbf·ft (41 N·m).

Manual Bleed Screw Replacement

1. If damaged, remove the manual bleed screw. For possible manual bleed screw locations, see **Fig. 2**.
2. Install a new manual bleed screw and torque the screw 45 lbf·in (508 N·cm).

Housing Port Plugs, Screws, and Fittings Replacement



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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, THP/PCF Steering Gear

Housing Port Plugs, Screws, and Fittings Replacement

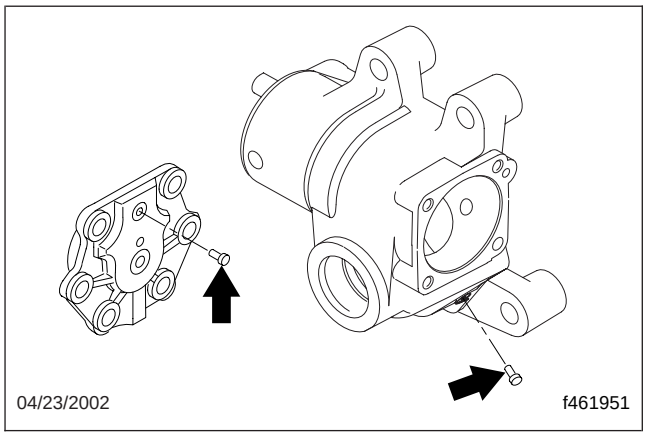


Fig. 2, Possible Manual Bleed Screw Locations

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 a loss of hydraulic assist, 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 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, a sign 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 using the instructions in **Group 46** of the *S2 Chassis Maintenance Manual*.
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) clearance between the tires and any fixed components that are attached to the vehicle. Clearance between moving components should be 3/4 inch (19 mm). If clearance is less than the above, reset the axle stops.
4. Check that the poppets are set correctly. If needed, adjust them. For instructions, refer to **Subject 140**.
5. If there are still problems with the power steering system, see **Section 46.06, Subject 300** and perform the steering system hydraulic tests as instructed; otherwise, go to the next step.
6. Test drive the vehicle or take a ride with the driver. 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 or remove the steering wheel and reposition it.

Specifications

⚠ WARNING

Do not mix hydraulic fluid types or use unapproved fluids. Doing so could cause seal deterioration, leaks, and a loss of steering assist, which could result in serious personal injury or death.

The following hydraulic fluids are approved for use in the steering system:

- Automatic Transmission Fluid (ATF), Dexron® II
- Automatic Transmission Fluid (ATF), Dexron® VI

The following type of grease is approved for use on the steering gear components:

- Exxon Polyrex® EP2 (PN 045422)

Special tools can be ordered from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092
1-800-328-6657

SPX Kent-Moore Tools		
SPX Kent-Moore Part Number		Description
THP45	THP/PCF60	
J37705	J37071 and J37071–A	Bearing and Seal Tool
J36452–A		Special Tool
J37070		Bearing Adjuster Tool
J37073		Seal Driver Tool
J37464		Adjuster Locknut Tool

Table 1, SPX Kent-Moore Tools

Removal

1. Apply the parking brakes, chock the tires, disconnect the batteries at the negative terminals, and open the hood.
2. Clean all the fittings and hose connections on the power steering reservoir, the power steering pump, and the pressure line on the power steering gear until they are free of dirt. See **Fig. 1**.

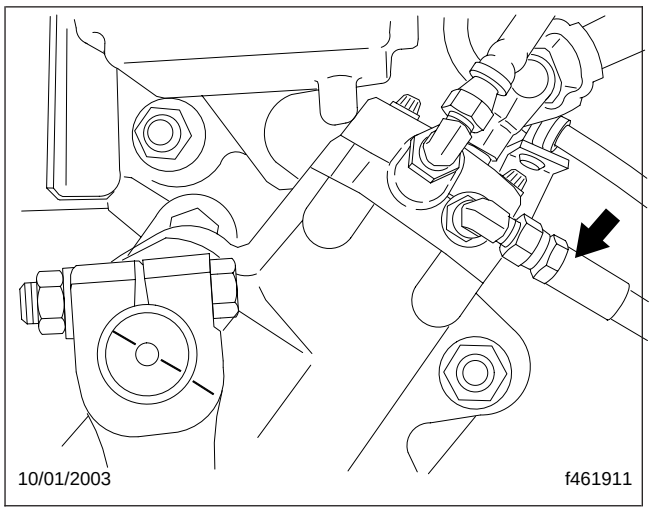


Fig. 1, Pressure Line on the Power Steering Gear

3. Drain the fluid from the power steering system. Disconnect the supply line from the power steering reservoir, marking the lines for later reference. Plug the lines and the fittings to keep out dirt.
4. Remove the pressure line at the power steering gear, and plug the line.
5. Remove the power steering pump, and discard the gasket or O-ring.
6. If a new power steering pump is being installed, remove the lines and fittings attached to the steering pump, and install them on the new steering pump.

Installation

1. Install a new gasket on the power steering pump. If a new power steering pump is being installed, make sure the O-ring is in place on the power steering pump. If the original power steering pump is being installed, replace the O-ring.
2. Using capscrews, attach the power steering pump to the engine or the air compressor. Tighten the capscrews 32 to 37 lbf·ft (43 to 50 N·m).
3. Unplug the pressure line and attach it to the steering gear.
4. Unplug the remaining hydraulic lines and fittings and connect the lines.
5. Using bolts, nuts, and washers, attach the power steering reservoir to the mounting bracket.
6. Connect the batteries.
7. Fill the power steering reservoir to between the MAX HOT and MIN COLD lines. For approved power steering fluids, see **Specifications 400**.
8. Start the engine and turn the steering wheel from full right to full left two or three times to remove air from the lines.
9. Check the power steering reservoir again and add fluid if needed.
10. Check the hydraulic lines for leaks.
11. Close the hood and remove the chocks from the tires.

Specifications

Automatic Transmission Fluid (ATF) is the only approved power steering fluid: use, Dexron® II, Dexron VI, or (Allison) TES-389 licensed products.

Pitman Arm Removal and Installation

Removal

1. Identify the timing marks on the pitman arm and the steering gear sector shaft.
2. Remove and discard the pinch bolt and nut that attach the pitman arm to the steering gear.
3. Remove and discard the cotter pin from the castle nut that attaches the pitman arm to the drag link. Remove the castle nut.
4. Remove the pitman arm.

Installation

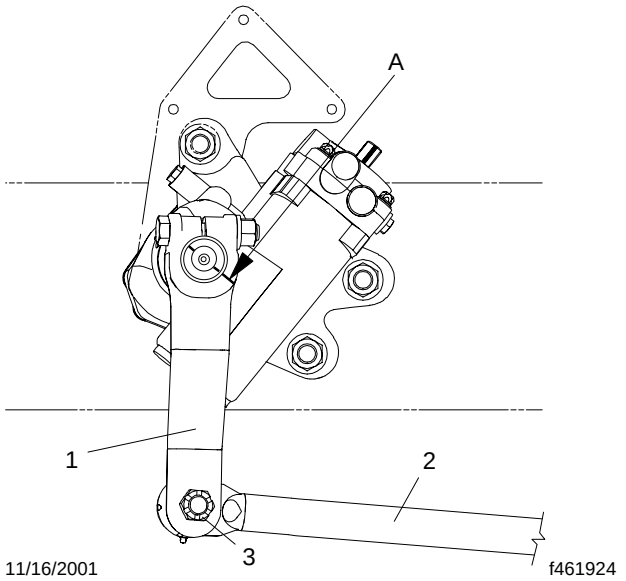
1. Install the pitman arm on the steering gear, aligning the timing marks on the pitman arm with the timing marks on the sector shaft. See **Fig. 1**.

   The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the pitman arm. To wedge the slot open, clamp the pitman arm in a vise with the slot at the top. Use a ball peen hammer to drive a chisel into the slot. Hold the chisel in place, remove the pitman arm from the vise, and install the pitman arm on the sector shaft. Remove the chisel from the slot.

⚠ 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.

2. Using a new pinch bolt and nut, attach the pitman arm to the steering gear. Torque the nut 130 to 155 lbf·ft (177 to 211 N·m).
3. Using a castle nut, attach the drag link to the pitman arm. Torque the castle nut 90 to 170 lbf·ft (122 to 230 N·m). If necessary, continue tightening the castle nut until a slot on the nut aligns with a hole in the ball stud. **Do not** back off the nut.
4. Install a new cotter pin through the ball stud and the castle nut and lock the cotter pin in place.



A. The timing mark on the pitman arm must line up with the timing mark on the sector shaft.

1. Pitman Arm
2. Drag Link
3. Castle Nut

Fig. 1, Pitman Arm

⚠ WARNING

Failure to install or lock a new cotter pin in the ball stud and nut could result in disengagement of the parts and loss of steering control.

5. Wipe the grease fittings clean at both ball stud sockets. Using a pressure gun, fill the sockets with chassis grease.

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.

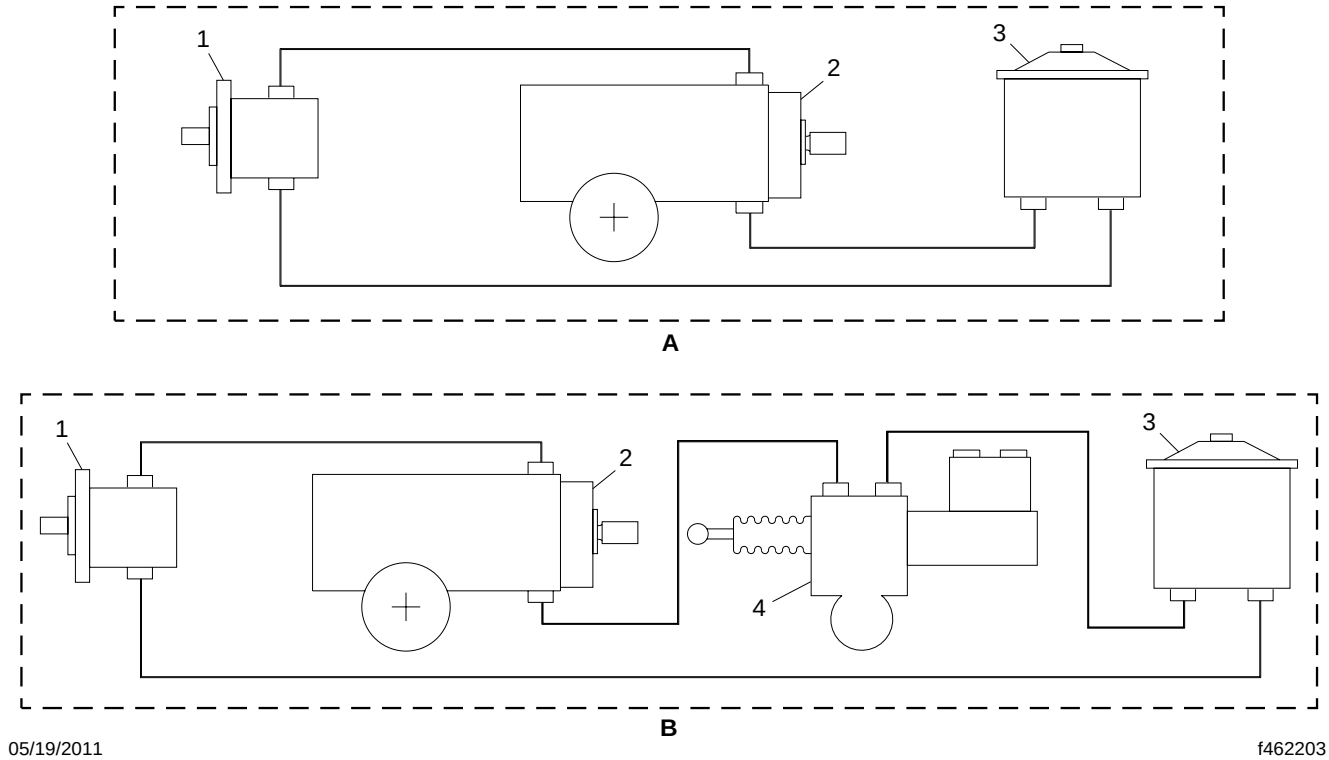
  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

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.

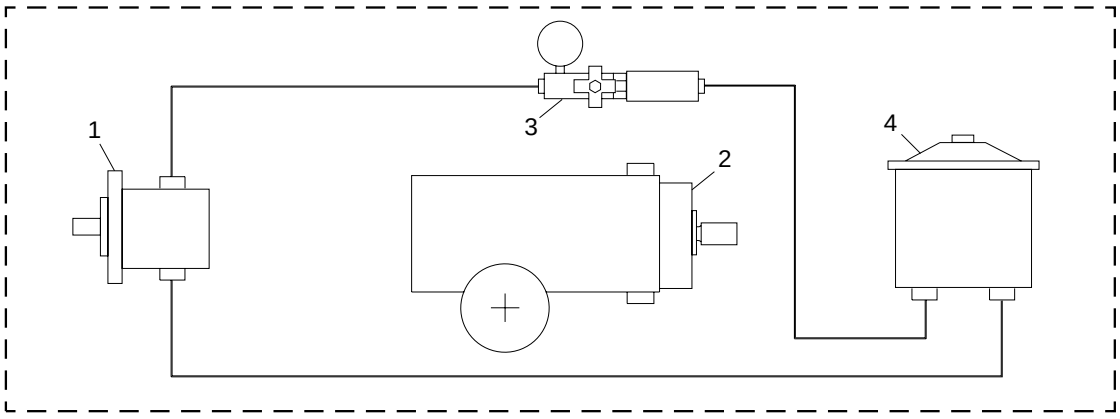
  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

- 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.

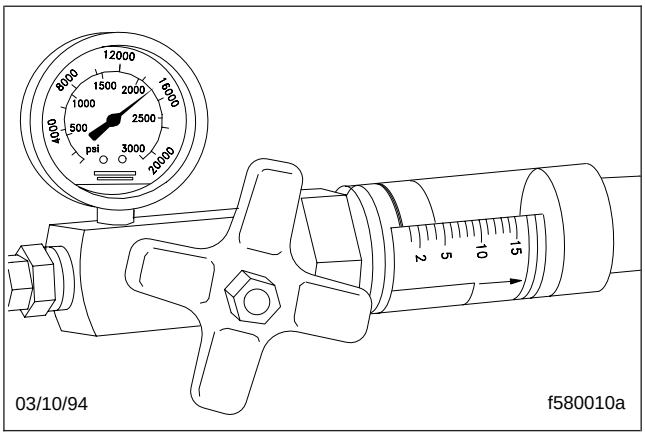


Fig. 3, Power Steering System Analyzer

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.

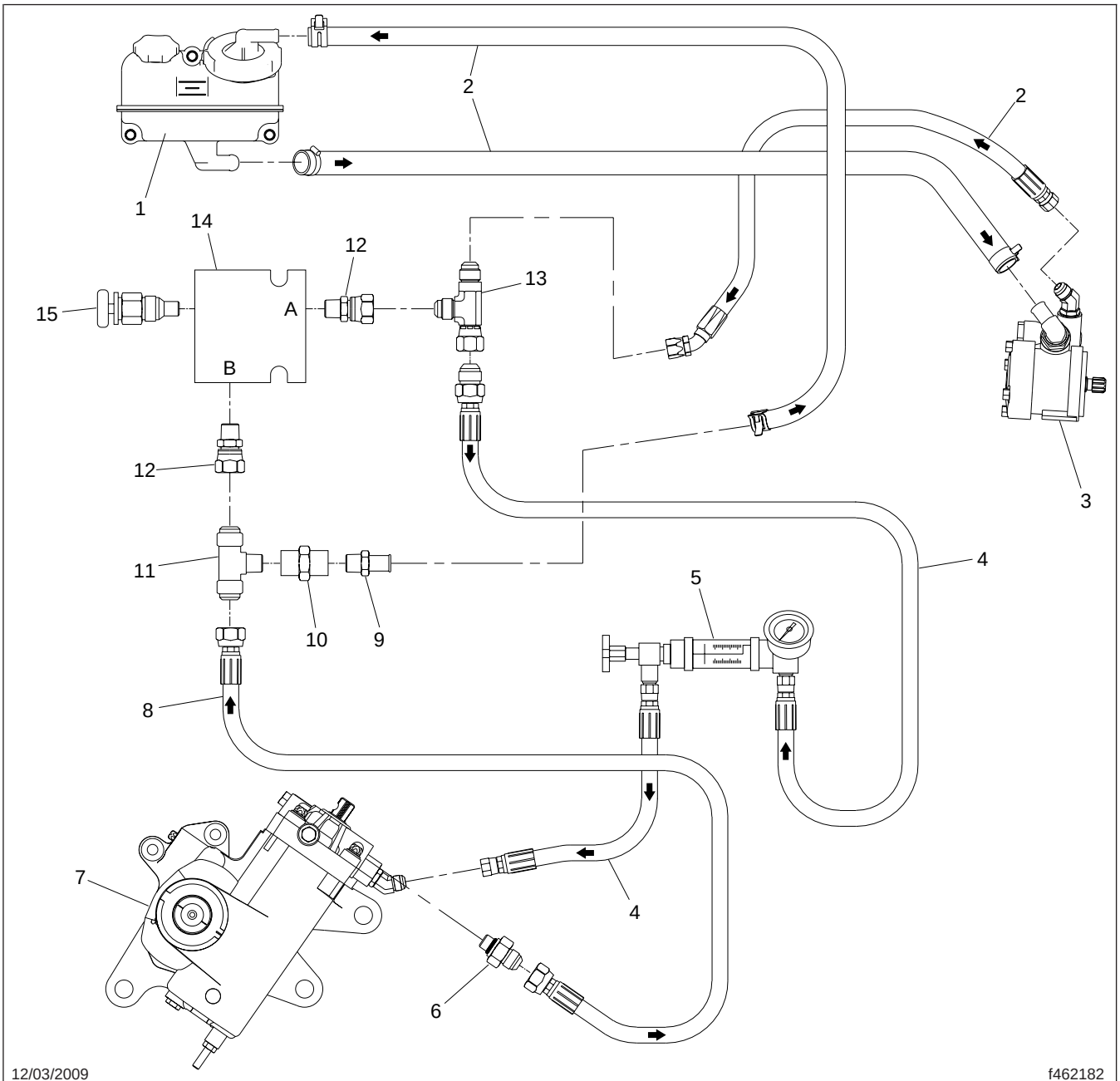
8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal 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



12/03/2009 f462182

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 Information

The fuel system delivers fuel from the fuel tank to the engine. It consists of the engine fuel system components, the fuel tank and tank mounting components, and the fuel lines and (if so equipped) shutoff valve.

The engine fuel system components include fuel filters, injectors, fuel transfer pumps, and a fuel governor. For service and maintenance procedures, see the applicable engine manufacturer's service and maintenance manuals.

The fuel tank, which provides a clean storage area for fuel, is held in place by metal straps that transfer the weight load to the vehicle frame. It is normally mounted between the frame rails. When it is mounted outside the frame rails, it is enclosed in a tube steel cage assembly.

Fuel suction and return lines made of polyester-braid-reinforced nylon tubing bring fuel from the tank to the engine, and return surplus fuel from the engine to the tank.

Standard equipment includes a fuel level gauge sender in the tank, with an electric fuel level gauge mounted in the dash instrument panel.

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation

Removal

If there is any damage to the fuel tank, *replace* it. *Do not repair* fuel tanks. See **Fig. 1** and **Fig. 2**.

⚠ WARNING

Damaged fuel tanks must be replaced. A repaired fuel tank will not meet the strength, leakage, and venting standards required by U.S. Federal regulations for original and replacement fuel tanks. A repaired fuel tank may be more likely to spill fuel or be ruptured in a vehicle accident, which could lead to serious personal injury or property damage.

Damaged fuel tank cages must be replaced. Also, replace the mounting fasteners with those of the specified grade. Failure to do so could compromise the ability of the cage to meet the performance requirements of U.S. Federal crashworthiness standards. A repaired fuel tank cage may increase the risk of serious personal injury or death in an accident.

1. Park the vehicle on a level surface. Shut down the engine. Set the vehicle parking brake and chock the front and rear tires.

⚠ WARNING

Do not drain fuel near, or expose fuel vapor to, open flame or intense heat. To do so might cause a fire, which could lead to serious personal injury or property damage.

2. Remove the drain plug.

   If the fuel is to be re-used, store it in a clean container, and protect it from contaminants.

3. Access the fuel return and suction lines through a covered hole in the floor of the vehicle body. Then, disconnect and cap the lines.
4. Unplug the connector to the chassis harness from the fuel level gauge sender.
5. Remove the fuel tank and the fuel tank cage or guard assembly, as follows.

   5.1 On vehicles with a side-mounted fuel tank and fuel tank cage assembly, support the assembly with a forklift. See **Fig. 1**. Remove the 16 locknuts, hardened washers, and bolts that attach the fuel tank cage to the frame rail. Use the forklift to lower and then remove the fuel tank and fuel tank cage assembly from underneath the vehicle.

   5.2 On vehicles with a fuel tank and fuel tank guard assembly mounted between the frame rails, remove the hexnuts, the hardened washers, and the bolts that attach the forward and aft lower crossmembers to the side channels at the bottom of the fuel tank guard assembly. See **Fig. 2**. Then, support the assembly with a jack or other suitable support device. Remove the center lower crossmembers (the number of lower crossmembers depends on the size of the fuel tank). Lower the fuel tank and fuel tank guard assembly from underneath the vehicle.

6. Remove the tank straps. Remove the nuts and washers from the tank strap T-bolts. Remove the tank straps and the isolators.
7. If it is necessary to remove the fuel tank from the fuel tank cage or guard, use the lifting eye tabs on the tank.
8. Inspect the tank straps and isolators for wear and damage. Replace worn or damaged tank straps and isolators.

⚠ WARNING

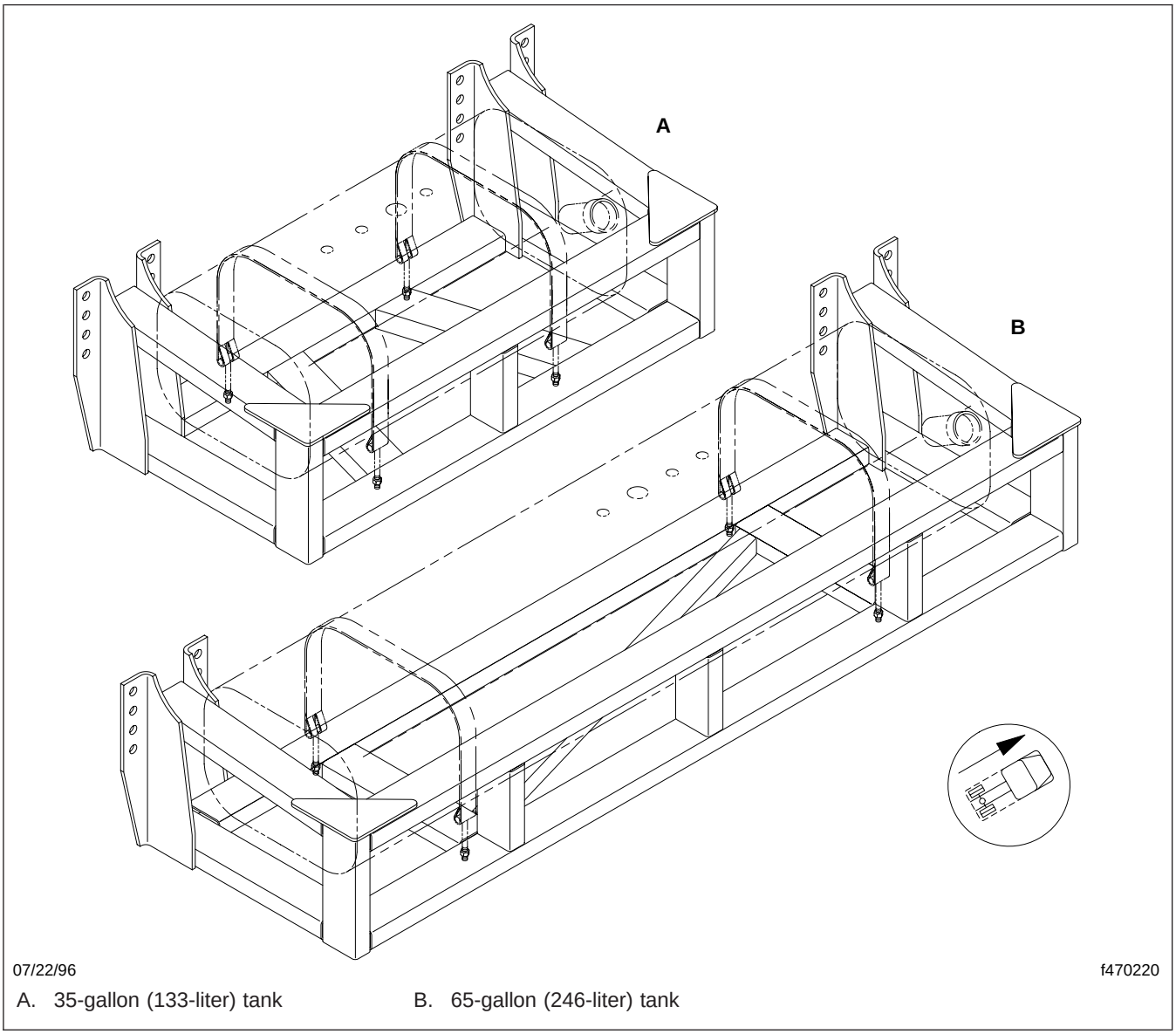
Replace worn or damaged components, such as straps or isolators, used to attach the fuel tank to the fuel tank cage or guard assembly. Failure to do so could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

9. If a fuel tank is being replaced, inspect the fuel tank system components for wear or damage. Replace all worn or damaged components. Undamaged components may be removed from the old fuel tank and installed on the new tank.

   9.1 Remove and clean all pipe plugs and fittings, and transfer them to the new tank. Coat all tapered (pipe plug and fitting) threads with Loctite® 592, or an equivalent.

   9.2 Inspect the vent line for wear or damage. Replace the line if it is worn or damaged. Clean a plugged vent line by directing

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation



A. 35-gallon (133-liter) tank B. 65-gallon (246-liter) tank

Fig. 1, Side-Mounted Fuel Tanks and Fuel Tank Cages

shop air through the line. An undamaged vent line may be transferred from the old tank to the new tank.

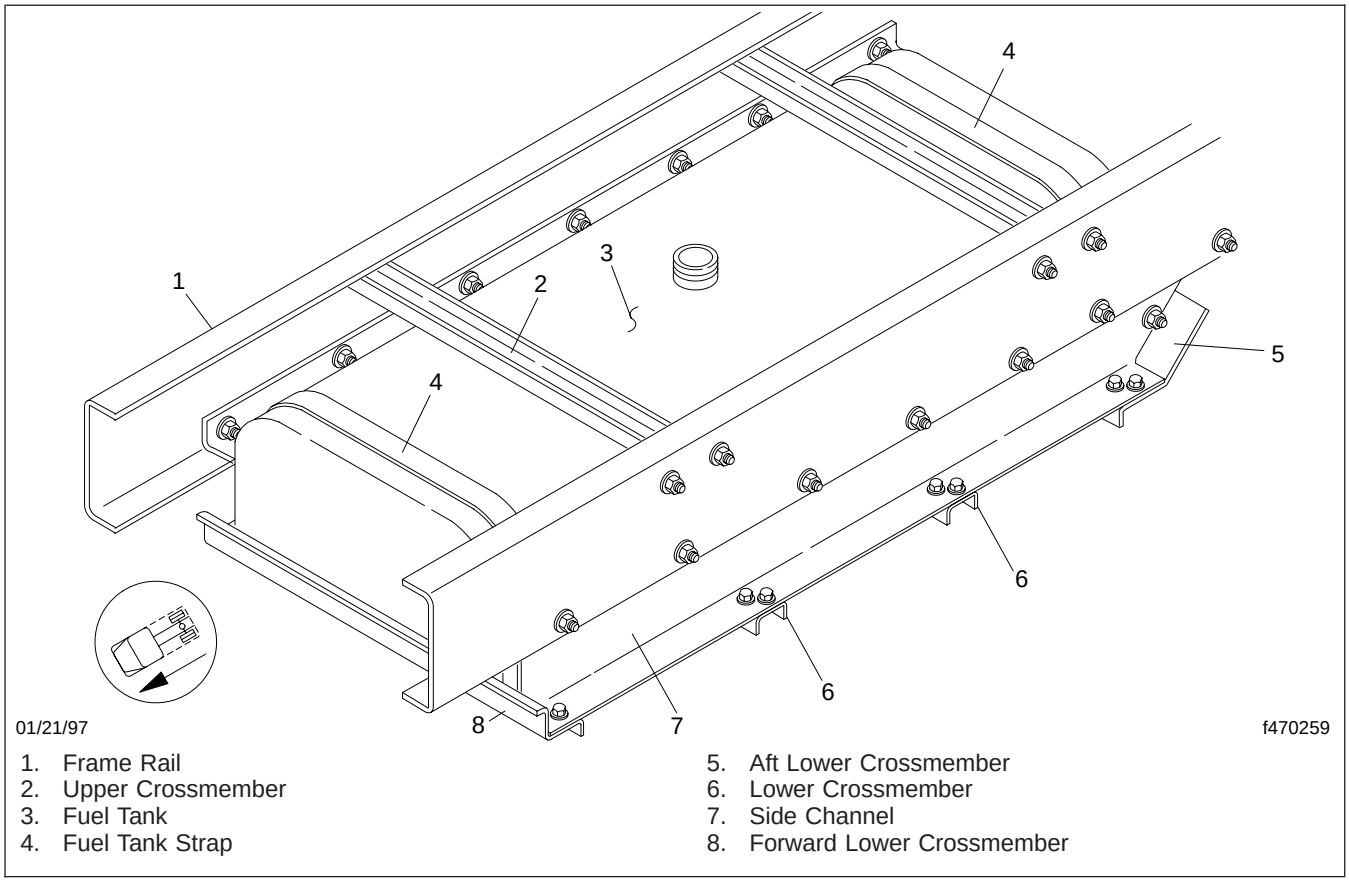
9.3 Transfer the fuel level gauge sender and gasket to the new tank. See **Fig. 3**. Securely and evenly tighten the machine screws.

Installation

1. If the fuel tank has been removed, place the fuel tank in its approximate installed position in the fuel tank cage or mount it to the fuel tank guard assembly.

   Make sure the fuel filler neck is properly positioned.

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation



1. Frame Rail
2. Upper Crossmember
3. Fuel Tank
4. Fuel Tank Strap
5. Aft Lower Crossmember
6. Lower Crossmember
7. Side Channel
8. Forward Lower Crossmember

Fig. 2, Between the Frame Rail-Mounted Fuel Tank and Fuel Tank Guard Assembly

2. Install the isolators and the tank straps, as follows.

⚠ WARNING

Do not overtighten the fuel tank straps. Torque to the recommended specifications. Overtightening the straps could cause damage to the tanks, which could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

2.1 Install a bearing washer and two nuts on each tank strap T-bolt. Tighten the first nuts 15 lbf·ft (20 N·m).

2.2 While holding the first nut stationary with a wrench, tighten each jam nut 30 lbf·ft (41 N·m).

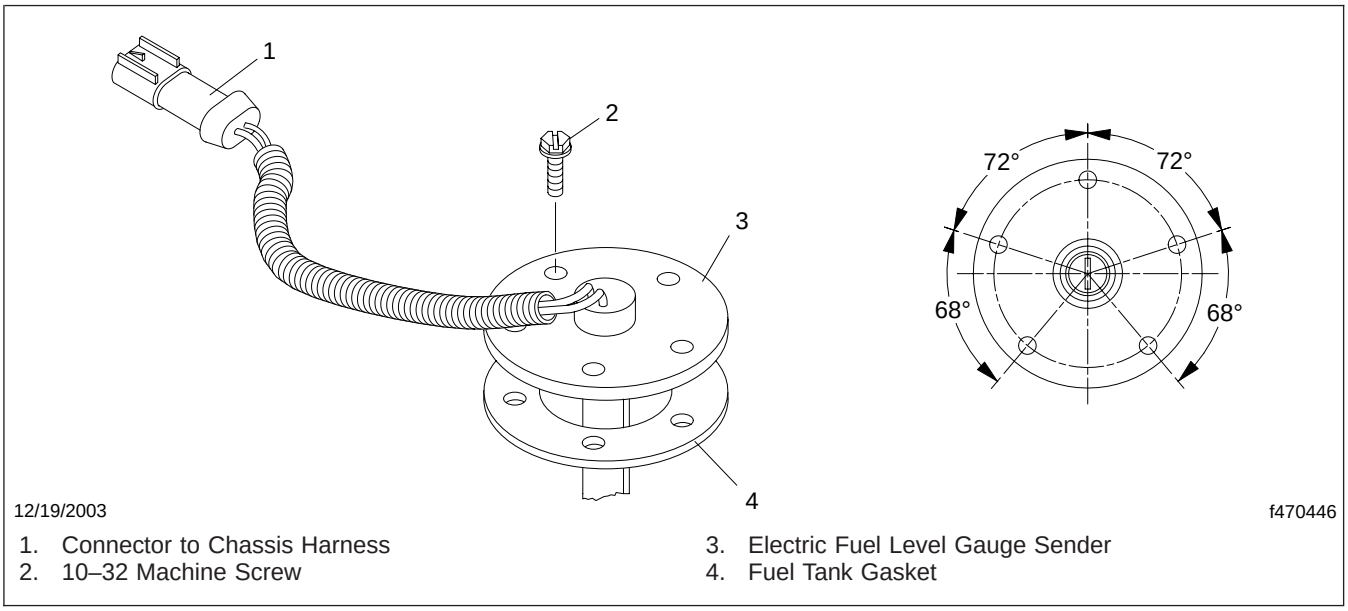
3. Attach the fuel tank and fuel tank cage or guard assembly to the frame, as follows.

3.1 On vehicles with side-mounted fuel tanks, using a forklift, position the fuel tank and fuel tank cage assembly underneath the vehicle. Use the forklift to support the assembly during installation. From inside the frame rail, install the two upper bolts and hardened washers. Position the new tank bracket on the bolts, then install the two upper hardened washers and locknuts, finger-tight. Then, install the two lower sets of fasteners. Tighten all of the locknuts 68 lbf·ft (92 N·m).

⚠ WARNING

Install the bolts used to attach the fuel cage brackets onto the inboard flanges of the brackets with their heads on the outside of the frame rail. This will help to prevent these bolts from possibly puncturing the fuel tank. Puncturing the fuel

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation



1. Connector to Chassis Harness
2. 10–32 Machine Screw
3. Electric Fuel Level Gauge Sender
4. Fuel Tank Gasket

Fig. 3, Fuel Level Gauge Sender Installation

tank could result in the spillage of fuel or the loss of a fuel tank, which could cause serious personal injury or property damage.

3.2 On vehicles with a fuel tank and fuel tank guard assembly mounted between the frame rails, position the assembly underneath the vehicle. Using a jack or other suitable support device, support the assembly. Raise and position the assembly to the frame rails, then install the center lower crossmembers. Install the forward and aft lower crossmembers on the side channels at the bottom of the fuel tank guard assembly. Tighten all of the hexnuts 68 lbf·ft (92 N·m).

4. Working through the hole in the vehicle floor, attach the wires to the fuel level gauge sender. Securely tighten the machine screw and hexnut.
5. Make certain the fuel lines are clean, then install them on their fittings on the fuel tank; see **Subject 120** for general guidelines. Coat all tapered (pipe plug and fitting) threads with Loctite 592, or an equivalent. Install pipe plugs in any remaining open threaded holes.
6. Add clean fuel to the fuel tank.
7. Prime the engine fuel pump; see **Subject 130.**
8. Remove the tire chocks.

Replacement

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the front and rear tires.
2. Remove the nuts and washers from the fuel tank strap T-bolts that hold the fuel tank inside the fuel tank cage. See **Fig. 1**.
3. Remove the straps from around the fuel tank.
4. Remove the rubber isolators from the straps.
5. Inspect the isolators for wear or damage; replace if needed.

⚠ WARNING

Replace worn or damaged parts. Failure to do so could result in loss of a fuel tank and spilling of fuel, which could cause personal injury or property damage.

6. Install the rubber isolators and the new tank straps onto the fuel tank, as follows.

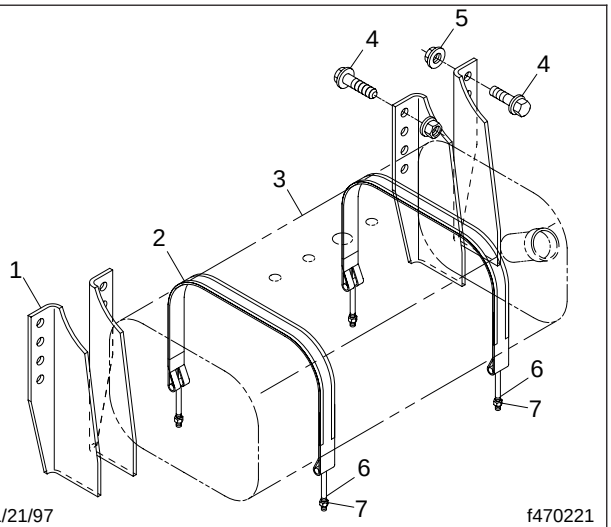
   IMPORTANT: Fuel tanks can be damaged by overtightening the fuel tank straps.

   6.1 Install each strap end evenly so that the amount of each bolt length is approximately the same.

   6.2 Install a bearing washer and two nuts on the tank strap T-bolt. Tighten the first nut 15 lbf·ft (20 N·m).

   6.3 While holding the first nut stationary with a wrench, tighten the jam nut 30 lbf·ft (41 N·m).

7. Remove the chocks from the tires.



1. Fuel Tank Cage Bracket
2. Fuel Tank Strap and Rubber Isolators
3. Fuel Tank
4. Hexhead Bolt
5. Hexnut
6. Washer
7. Hexnut

Fig. 1, Fuel Tank (35-gallon shown)

Fuel Line Routing

General Guidelines

If diesel fuel lines are worn, damaged, or deteriorated, replace them. Use the following guidelines for installing and routing them.

NOTE: For fuel line repairs, only fuel tubing, hoses, fittings, and valves used in production are approved for use.

Fuel lines must be free of droops, sharp bends, and kinks in the lines.

Fuel lines must not extend more than 2 inches (5 cm) below the fuel tank unless they are completely enclosed in a protective housing.

Fuel lines must be secured to prevent chafing, kinking, and other causes of damage.

Fuel lines must be long enough to allow movement of the parts to which they are attached.

Coat all pipe threads (tapered threads) with Loctite® 592, or an equivalent.

Fuel lines and fittings must be free of leaks, to prevent fuel loss or entry of air into the line, which may result in a loss of prime by the engine fuel system.

Fuel suction and return line hoses must be made of reinforced flexible hose assemblies that meet or exceed SAE specification J1402.

NOTE: For fuel line hose selection, it is the inside diameter (ID) that matters. When changing from one hose type to another, make sure the hose you are changing to has the same or larger ID as the one being replaced.

Drains or other bottom fittings must not extend more than 3/4 inch (19 mm) below the lowest part of the fuel tank or sump.

Priming

Before priming the system, make sure there is enough fuel in the tank. Don't fill the tank to more than 95 percent of capacity.

⚠ WARNING

Federal regulations prohibit filling a fuel tank to more than 95 percent of its capacity. A tank with air space is much less likely to rupture in an accident than one that has little or no air space. Fuel tank rupture could result in fuel spillage and a hazardous condition.

⚠ CAUTION

Do not crank the starter more than 30 seconds at a time during any of the following procedures; wait 2 minutes after each try to allow the starter to cool, or starter damage may occur.

1. If the engine is equipped with a priming pump, use it to prime the fuel transfer pump.
   - 1.1 Operate the priming pump plunger until there is resistance.
   - 1.2 Push the plunger in and tighten it by hand.
   - 1.3 Start the engine; if it doesn't start, more priming is needed. Once the engine has started, it may run rough; if so, run the engine at low idle until it runs smoothly.
2. If the engine isn't equipped with a priming pump, pressurize the fuel in the fuel tank, to prime the fuel transfer pump.
   - 2.1 Remove the fuel tank cap from the primary tank.
   - 2.2 Loosen the fuel supply line at the fuel transfer pump.
   - 2.3 While someone else looks for a constant fuel flow at the loosened fuel supply line, partially block the fuel tank opening with a clean rag, and use an air hose to apply no more than 5 psi (35 kPa) air pressure to the fuel tank.
   - 2.4 When the fuel flow is constant, remove the air hose and rag, and tighten the fuel supply line.

IMPORTANT: To prevent fuel loss or entry of air into a fuel line, make sure that all fuel line connections are tight.

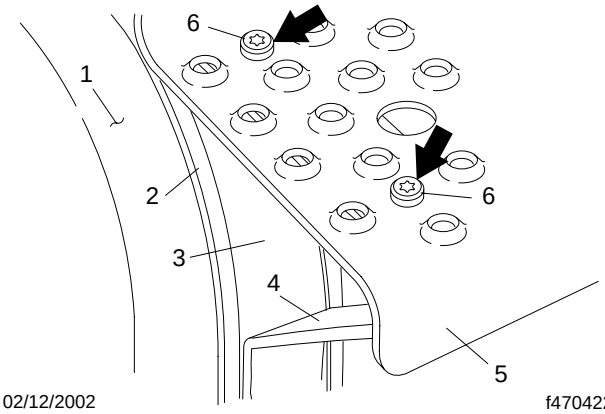
- 2.5 Start the engine. Once the engine has started, it may run rough. If this occurs, run the engine at low idle until it runs smoothly.

Tank-Mounted Step Assembly Removal and Installation

Removal

NOTE: The procedure below describes a two-step installation. To remove a single step, follow the procedure for the bottom step of the two-step installation.

1. Remove the Torx screws and washers that attach the top step to the braces welded to the fuel tank bands. See **Fig. 1**.



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Welded Brace (on band)
5. Top Step
6. Torx Screw, 1/4–20

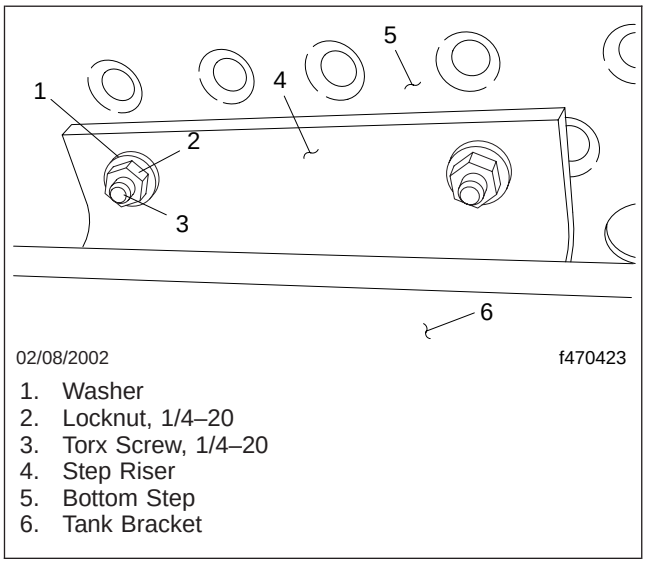
Fig. 1, Top Step Removal and Installation

IMPORTANT: Removing the bottom step from the riser is necessary only when the step itself needs replacement. If replacing the fuel tank, remove the step and risers as an assembly.

2. Remove the Torx screws, locknuts, and washers that attach the bottom step to the risers. See **Fig. 2**.
3. Remove the 3/8–16 mounting bolts, locknuts, and washers that attach a step riser to each tank bracket. See **Fig. 3**.
4. Remove the step from the vehicle.

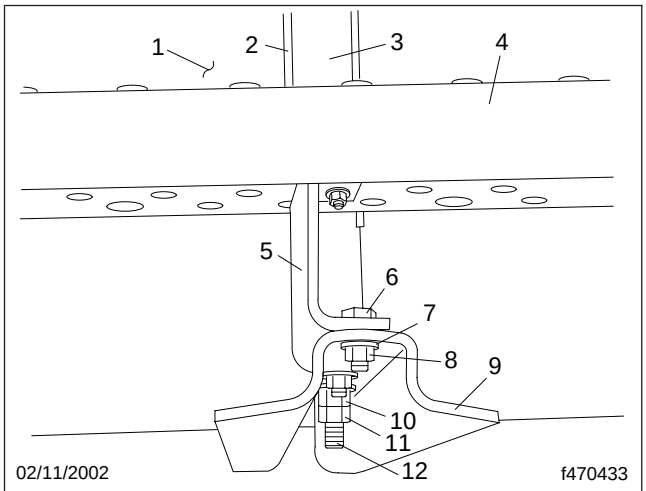
Installation

NOTE: The procedure below describes a two-step installation. To install a single step, follow



1. Washer
2. Locknut, 1/4–20
3. Torx Screw, 1/4–20
4. Step Riser
5. Bottom Step
6. Tank Bracket

Fig. 2, Bottom Step Removal and Installation



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Bottom Step
5. Step Riser
6. Riser Mounting Bolt, 3/8–16
7. Washer
8. Riser Locknut, 3/8–16
9. Tank Bracket
10. Mounting Nut, 1/2–13
11. Jam Nut, 1/2–13
12. T-Bolt

Fig. 3, Step Riser Removal and Installation

Tank-Mounted Step Assembly Removal and Installation

the procedure for the bottom step of the two-step installation.

1. Install a step riser on each tank bracket.
   - 1.1 Position a riser on each bracket, as shown in **Fig. 3**.
   - 1.2 Install the 3/8–16 mounting bolts, locknuts, and washers, as removed. Leave the fasteners finger-tight.
   - 1.3 When all the risers have been installed, tighten the locknuts 28 lbf·ft (38 N·m).
2. Install the bottom step on the risers, if removed.
   - 2.1 Position the bottom step on the risers, as shown in **Fig. 2**.
   - 2.2 Install the 1/4–20 Torx screws, locknuts, and washers on the step, as removed. Leave the fasteners loose.
3. Install the top step on the fuel tank.
   - 3.1 Position the top step on the braces welded to the fuel tank bands, as shown in **Fig. 1**.
   - 3.2 Install the 1/4–20 Torx screws, locknuts, and washers on the step, as removed. Leave the fasteners loose.
4. Tighten the step locknuts 72 lbf·in (800 N·cm).

Fuel Tank and Mounted Step Removal and Installation

Removal

WARNING

Damaged fuel tanks must be replaced. A repaired fuel tank may not meet U.S. Federal strength, leakage, and venting standards required for all fuel tanks. A repaired fuel tank may be more likely to spill fuel or be ruptured in a vehicle accident, which could lead to personal injury or property damage.

If a tank is damaged, use the following procedure:

1. Park the vehicle on level ground. Apply the parking brakes and chock all the tires.
2. Remove the cab-access step(s). For instructions, see **Subject 100**.

WARNING

Do not drain fuel near, or allow fuel vapor near, open flame or intense heat. Doing so is a dangerous practice, and creates a severe fire hazard. This could lead to personal injury, or property damage.

3. Remove the fuel from the tank, as follows.
   - 3.1 Place a suitable container under the fuel tank.
   - 3.2 On a dual-tank installation, close the fuel shutoff valve (if equipped) located on the primary fuel tank.
   - 3.3 Remove the drain plug. See **Fig. 1**.

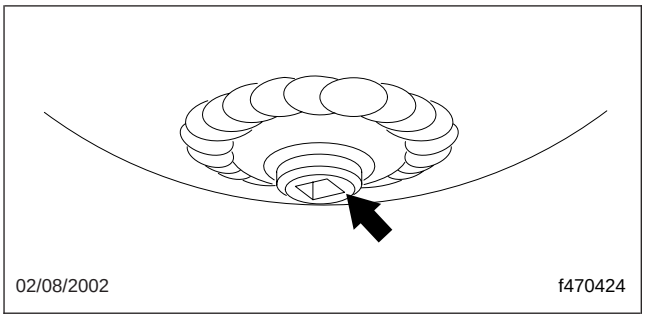
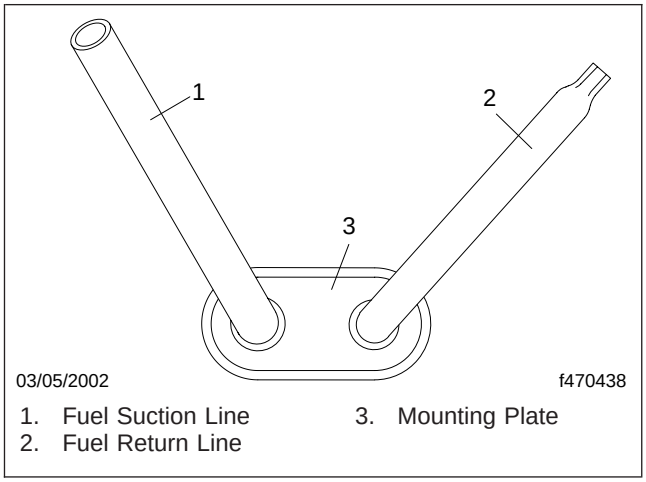


Fig. 1, Fuel Drain Plug

   - 3.4 Protect the fuel from contaminants. Store it in a clean container for later re-use.
4. Disconnect the fuel return and suction lines from the tank. Cap the lines to prevent fuel spillage. See **Fig. 2**.

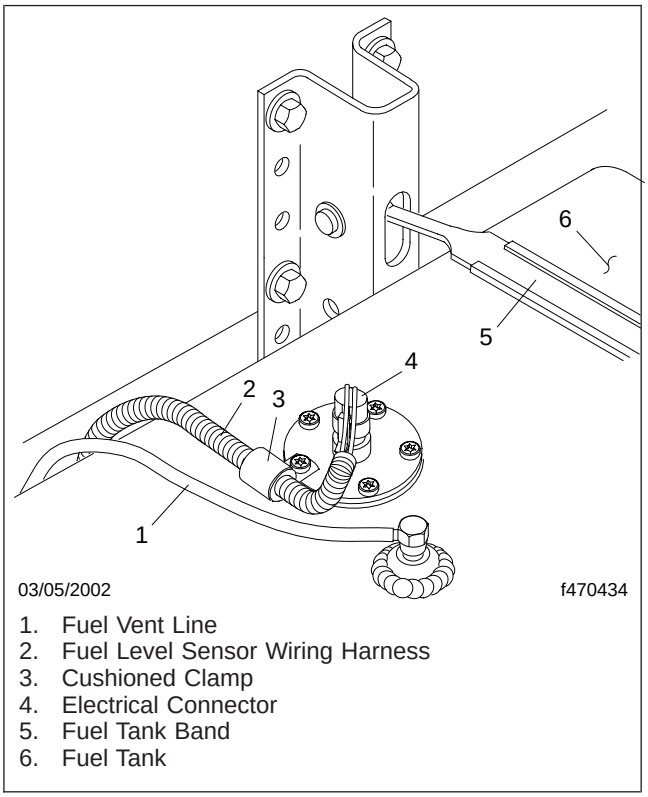


1. Fuel Suction Line
2. Fuel Return Line
3. Mounting Plate

Fig. 2, Fuel Lines

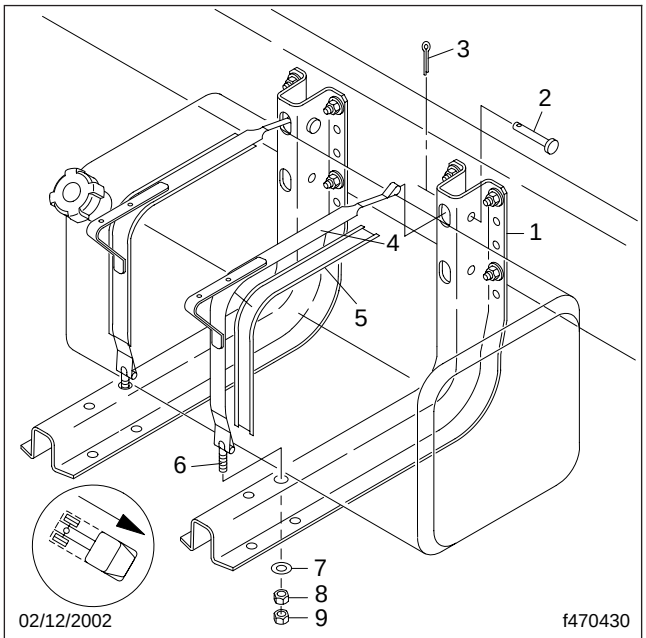
5. Disconnect the electrical connector from the fuel level sensor harness and remove the cushioned clamp from the flange of the fuel level sensor. See **Fig. 3**.
6. Remove the fuel tank bands and isolators, as follows. See **Fig. 4**. For detailed procedures, see **Subject 110**. Follow the procedure in **Subject 100** before removing the tank.
   - 6.1 Remove the nuts and washers from the T-bolt at the lower (outboard) end of each tank bracket.
   - 6.2 Remove the cotter pins and clevis pin from the upper (inboard) end of each tank bracket.
   - 6.3 Remove the band and isolators from each tank bracket.
7. Using a fork lift, remove the fuel tank. Remove the tank bracket isolator from the fuel tank, if it adheres to the tank.
8. Inspect the bands, isolators, and brackets for wear and damage. Replace worn or damaged parts with new parts.

Fuel Tank and Mounted Step Removal and Installation



1. Fuel Vent Line
2. Fuel Level Sensor Wiring Harness
3. Cushioned Clamp
4. Electrical Connector
5. Fuel Tank Band
6. Fuel Tank

Fig. 3, Electrical Connector, Fuel Level Sensor



1. Tank Bracket
2. Clevis Pin
3. Cotter Pin
4. Fuel Tank Band
5. Band Isolator
6. T-Bolt
7. Washer
8. Mounting Nut, 1/2–13
9. Jam Nut, 1/2–13

Fig. 4, Fuel Tank

⚠ WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause property damage or personal injury.

9. If installing a new tank, remove all parts necessary to install the new fuel tank. Inspect the parts, and replace them as needed.

    9.1 Remove and clean the pipe plugs and fittings for the fuel return and suction lines. Transfer them to the new fuel tank.

    9.2 Remove and clean the fuel vent line, pipe plug, and fitting. Transfer it as a unit to the new fuel tank.

    9.3 Transfer the fuel level sensor and gasket to the new fuel tank.

Installation

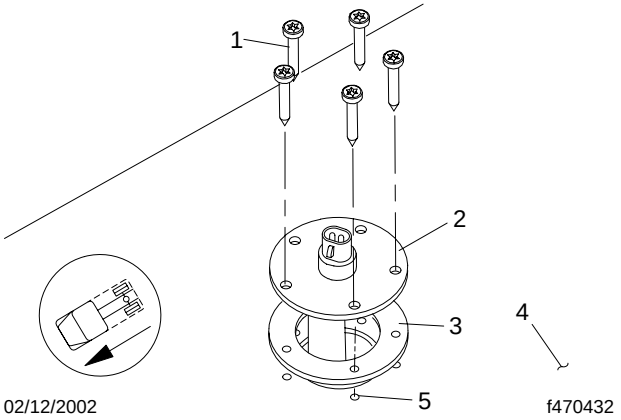
1. If installing a new tank, install all necessary components on the new fuel tank before installation of the tank on the vehicle. See **Fig. 5** for fuel level sensor installation.

    1.1 If removed, install the fuel level sensor and gasket in the fuel tank. Install the self-tapping screws until contact is made with the sensor unit. Do not tighten the screws yet.

    1.2 Install all removed pipe plugs and fittings. Coat all tapered pipe plug and fitting threads with Loctite® 592, or an equivalent sealer. Install the vent line as a unit along with its pipe plug and fitting.

2. Make sure the tank bracket isolator is correctly positioned on the tank bracket.

Fuel Tank and Mounted Step Removal and Installation



1. Self-Tapping Screw, 10–24
2. Fuel Level Sensor
3. Gasket
4. Fuel Tank
5. Mounting Hole in Tank

Fig. 5, Fuel Level Sensor

3. Using a fork lift, or other approved lifting device, place the fuel tank in its approximate installed position. Make sure the fuel filler neck is outboard.
4. Install the fuel tank bands and isolators.
   - 4.1 Position the closed (non-slotted) loop of a fuel tank band through the slot in the upper (inboard) end of each tank bracket.
   - 4.2 Install the clevis pin through the upper (inboard) end of each tank bracket and the loop of the fuel tank band. Install new cotter pins and bend back the ends to lock in the clevis pins.

CAUTION

Do not overtighten the fuel tank bands. To do so could damage the fuel tanks.

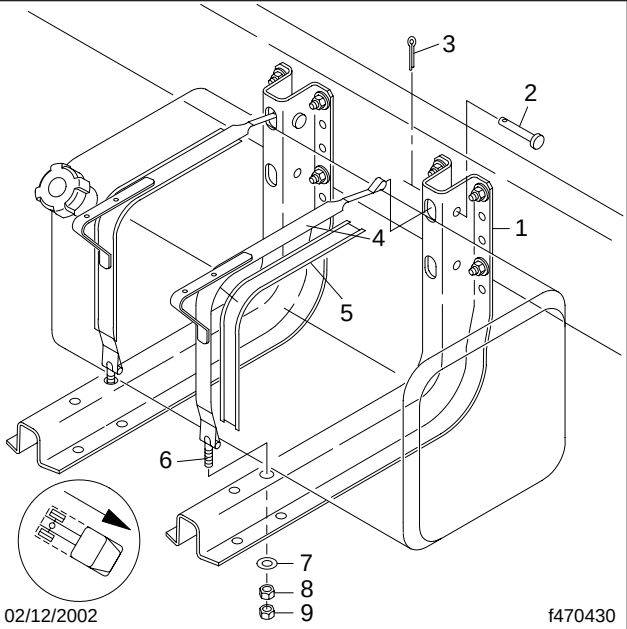
   - 4.3 Insert the T-bolt at the lower (slotted) end of each band into the tank bracket.
   - 4.4 Install a washer and two nuts on each T-bolt. Tighten the mounting nuts 15 lbf·ft (20 N·m).
   - 4.5 While holding the first nut stationary with a wrench, tighten each jam nut an additional 15 lbf·ft (20 N·m).
5. Attach the electrical connector to the fuel level sensor wiring harness. Attach the cushioned clamp to the flange of the sensor unit. Using a star pattern to distribute the torque evenly around the sensor unit, tighten the screws 15 to 30 lbf·in (160 to 340 N·cm).
6. Make certain the fuel lines are clean and install them on their fittings on the fuel tank. See **Subject 120** for general guidelines.

IMPORTANT: Install pipe plugs in any remaining open threaded holes. Coat all remaining tapered pipe plug and fitting threads with Loctite 592, or an equivalent sealer.

7. Install the cab-access step(s). For instructions, see **Subject 140**.
8. Add clean fuel to the fuel tank.
9. Prime the engine fuel system. For instructions, see **Subject 130**.
10. Remove the chocks from the tires.

Replacement

1. Apply the parking brakes and chock all the tires.
2. Remove the cab-access step(s). For instructions, see **Subject 140**.
3. Remove the fuel tank band and isolator. See **Fig. 1**.



1. Tank Bracket
2. Clevis
3. Cotter Pin
4. Fuel Tank Band
5. Band Isolator
6. T-Bolt
7. Washer
8. Mounting Nut, 1/2–13
9. Jam Nut, 1/2–13

Fig. 1, Fuel Tank Band Removal

3.1 Remove the two nuts and one washer from the T-bolt at the lower (outboard) end of the tank bracket.

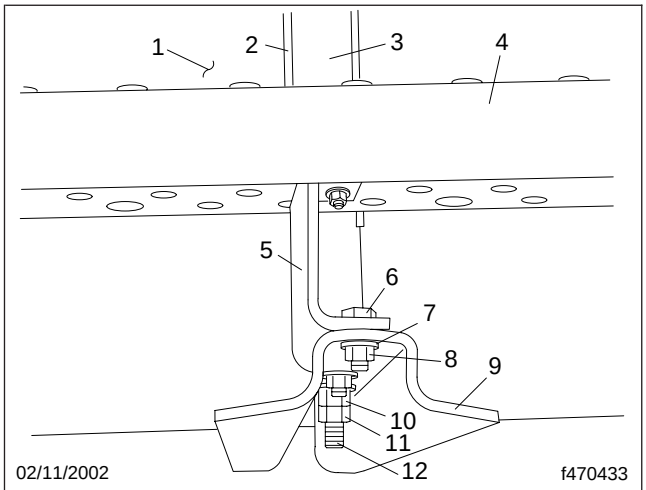
3.2 Remove the cotter pin and clevis pin from the eye at the upper (inboard) end of the tank bracket.

4. Inspect the isolator and clevis pin for wear or damage; replace if needed.

⚠ WARNING

Failure to replace worn or damaged parts could result in loss of a fuel tank and spilling of fuel, which could cause personal injury or property damage.

5. Install the isolator and the new tank band on the tank. See **Fig. 2**.



1. Fuel Tank
2. Band Isolator
3. Fuel Tank Band
4. Bottom Step
5. Step Riser
6. Riser Mounting Bolt, 3/8–16
7. Washer
8. Riser Locknut, 3/8–16
9. Tank Bracket
10. Mounting Nut, 1/2–13
11. Jam Nut, 1/2–13
12. T-Bolt

Fig. 2, Fuel Tank Band Installation

5.1 Install the clevis pin through the inboard end of the tank bracket and tank strap. Install and lock a new cotter pin in the clevis pin.

IMPORTANT: Fuel tanks can be damaged by overtightening the fuel tank straps.

5.2 Install a washer and two nuts on the tank strap T-bolt. Tighten the mounting nut 15 lbf·ft (20 N·m).

5.3 While holding the mounting nut stationary with a wrench, tighten the jam nut 15 lbf·ft (20 N·m).

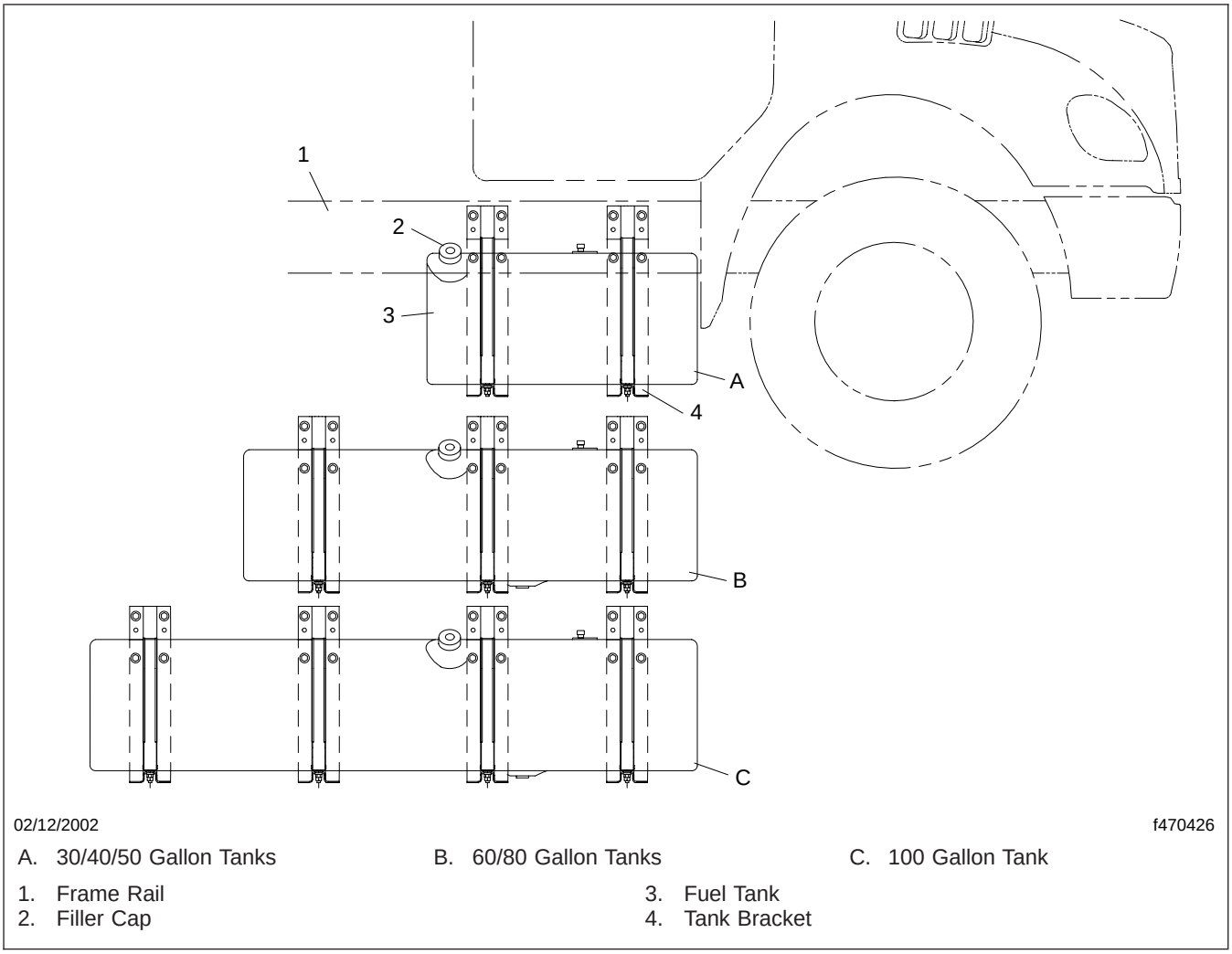
Fuel Tank Band Replacement

6. Install the cab-access step(s). For instructions, see **Subject 140**.
7. Remove the chocks from the tires.

Fuel Tank Bracket Replacement

Replacement

1. Remove the fuel tank. For instructions, see **Subject 150**.
2. Remove the locknut, washers, spacer (if installed), and capscrew that attach each bracket to the frame rail. See **Fig. 1** for bracket installation on different size fuel tanks and **Fig. 2** for fasteners.
3. Remove the tank bracket from the vehicle.
4. From outside the frame rail, install the two upper capscrews and hardened washers. If so equipped, install the fuel tank bracket spacers onto the outboard ends of the capscrews. Position the new tank bracket on the capscrews, then install the two upper hardened washers and locknuts, finger-tight.
5. Install the two lower sets of fasteners. Tighten all of the 5/8–11 locknuts 136 lbf·ft (184 N·m).
6. Install the fuel tank. For instructions, see **Subject 150**.



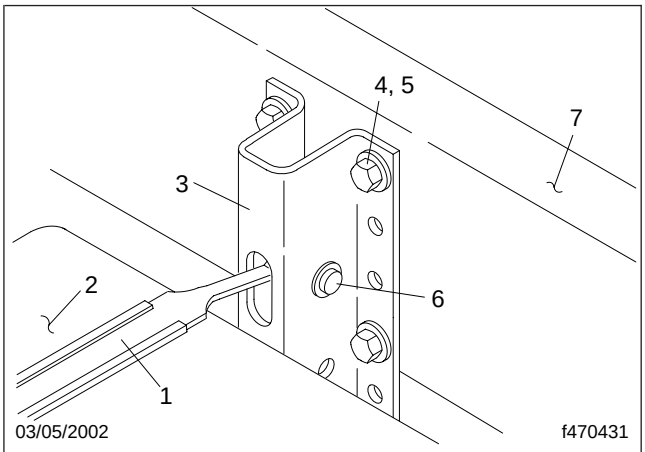
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A. 30/40/50 Gallon Tanks
B. 60/80 Gallon Tanks
C. 100 Gallon Tank

1. Frame Rail
2. Filler Cap
3. Fuel Tank
4. Tank Bracket

Fig. 1, Fuel Tank Sizes

Fuel Tank Bracket Replacement



1. Fuel Tank Band
2. Fuel Tank
3. Tank Bracket
4. Bracket Mounting Bolt, 5/8–11
5. Washer
6. Head of Clevis Pin
7. Frame Rail

Fig. 2, Fuel Tank Bracket

Specifications

Fastener Torque Values				
Fuel Tank Option	**Description**	**Size**	**Grade**	**Torque: lbf·ft (N·m)**
Side Mounted (Aluminum) Fuel Tank with Step	Fuel Tank Strap T-Bolt: Hexnut/Jam Nut	1/2–13	B	15 (20)
	Fuel Tank Bracket Mounting Locknut	1/2–13	C	112 (152)
Side Mounted Fuel Tank with Cage	Fuel Tank Strap T-Bolt: Hexnut Jam Nut	5/8–11 5/8–11	C C	15 (20) 30 (41)
	Fuel Tank Cage Locknut	3/4–10	C	198 (268)
Between the Frame Rail Mounted Fuel Tank and Guard Assembly	Fuel Tank Strap T-Bolt: Hexnut Jam Nut	1/2–20 1/2–20	C C	15 (20) 30 (41)
	Upper Crossmember Locknut	1/2–13	C	56 (76)
	Side Channel Locknut	5/8–11	C	112 (152)
	Lower Crossmember Locknut	1/2–13	C	56 (76)
	Forward Lower Crossmember Locknut	1/2–13	C	56 (76)
	Aft Lower Crossmember Locknut	1/2–13	C	56 (76)

Table 1, Fastener Torque Values

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:

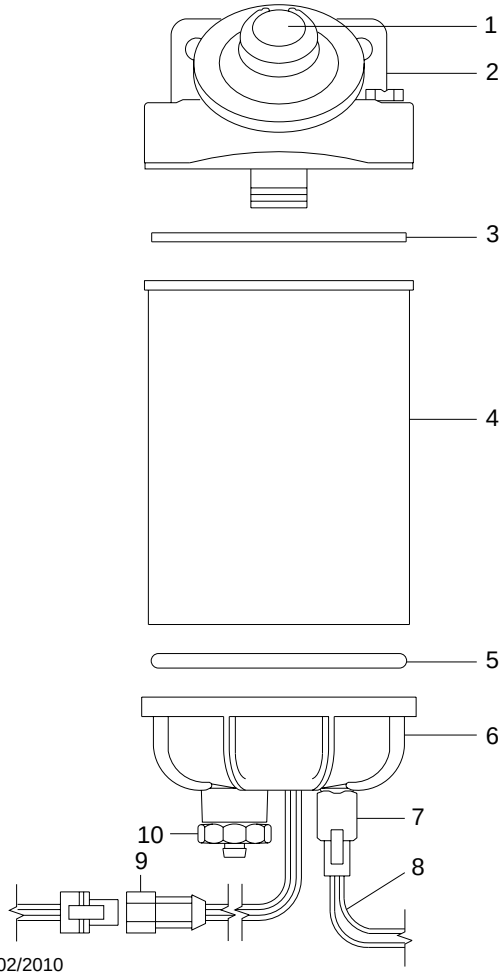
- Ignition-controlled heater to melt ice and wax in the fuel
- Water sensor probe to alert the operator to drain the sight bowl
- Manual priming pump to easily prime the fuel/water separator

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, if equipped, 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. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

Removal

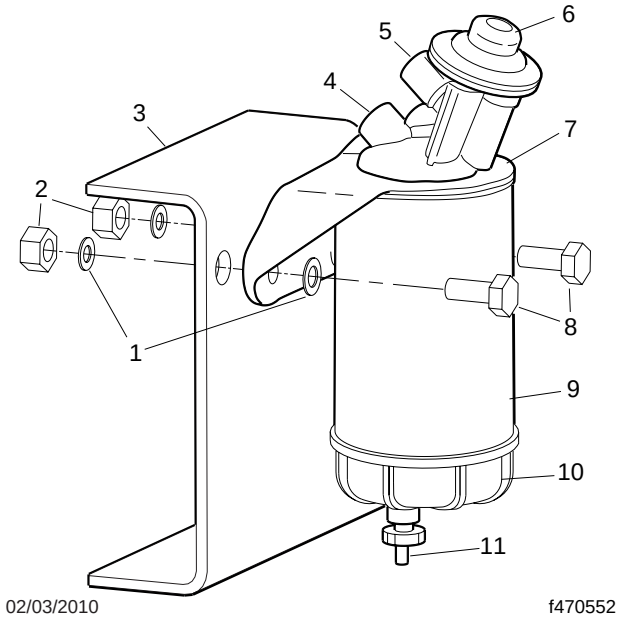
1. Shut down the engine, apply the parking brake, and chock the tires.

   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. If equipped, 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 112 lbf·ft (152 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. If equipped, connect the wiring harnesses to the water sensor probe and the heater.
7. Connect the fuel lines to the fuel/water separator. Tighten all fittings finger-tight plus 1/4 turn.
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.

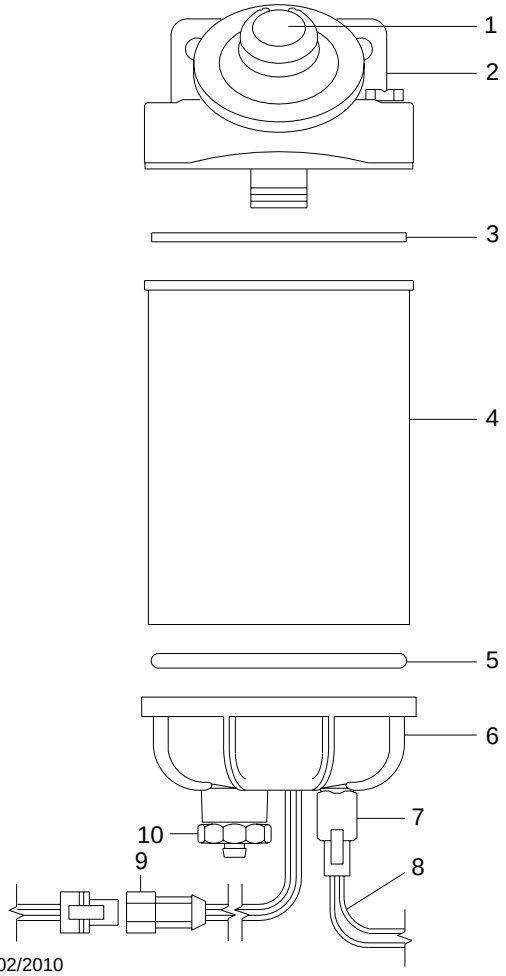
3. Turn the drain plug counterclockwise to open it. If equipped, operate the pump.
4. When the fuel/water separator is completely drained, turn the drain plug clockwise to close it.

⚠ 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. If equipped, 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, if equipped.
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. Priming Pump
2. Mounting Head
3. Gasket
4. Filter Element
5. O-Ring
6. Sight Bowl
7. Water Sensor Probe
8. Water Sensor Probe Wiring Harness
9. Heater Wiring Harness
10. Drain Plug

Fig. 1, Fuel/Water Separator Assembly

   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.

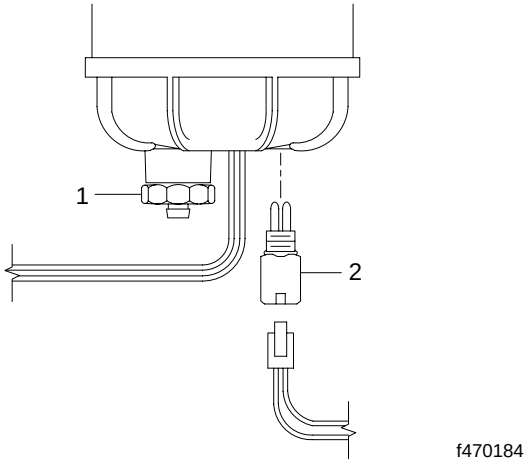
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

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.

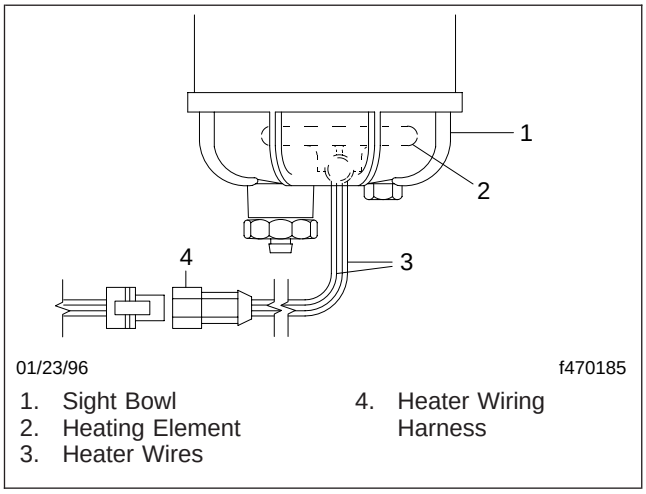
5. If equipped, disconnect the wiring harness from the water sensor probe. See **Fig. 1**.



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.

    If equipped, 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.

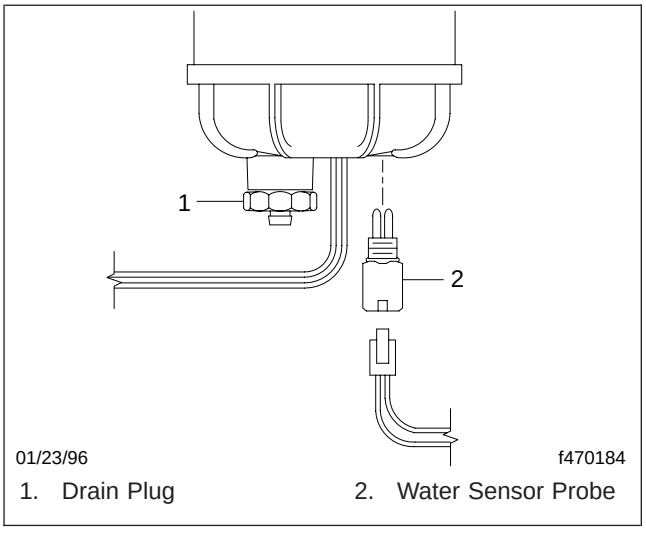
IMPORTANT: When draining fluid from a fuel/water separator, drain the fluid into an appropriate container, and dispose of it properly. Many states now issue fines for draining fuel/water separators onto the ground.

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

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 impurities.

At the fuel/water separator inlet port, a check valve (**Fig. 1**, Item 8) prevents the fuel from draining back to the fuel tank. Large pieces of dirt and water separate from the fuel in the lower housing, and collect in the bottom to be drained out when the drain valve (**Fig. 1**, Item 13) is opened. From the lower housing, the fuel level rises into the clear cover, which contains the replaceable filter. In the clear cover, the fuel passes through the filter element into the center of the filter, and to the outlet port.

When the filter is new, the 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 order to pass through the filter. This process continues until the filter element is clogged all the way to the top.

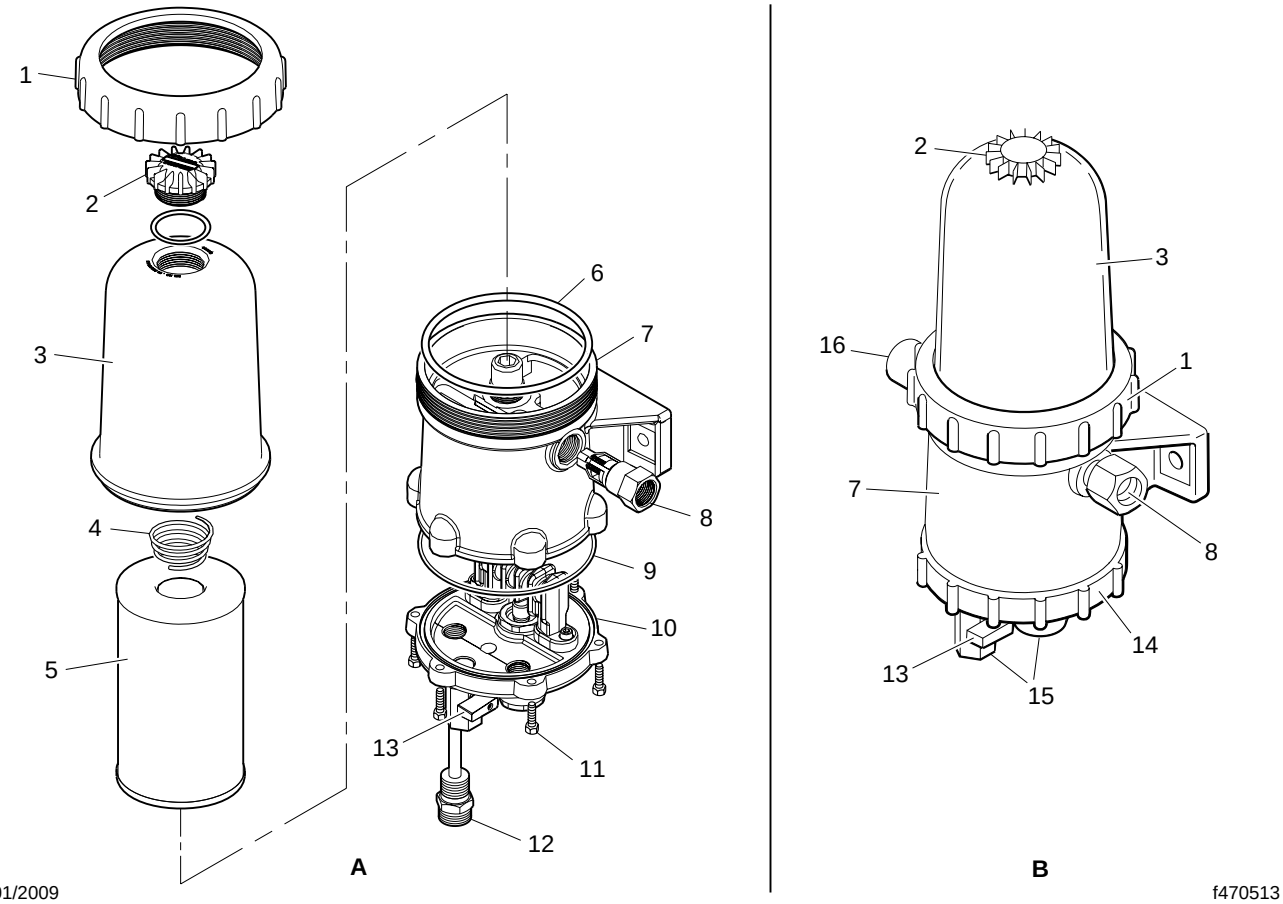
For efficiency, the filter should be changed only when the fuel level has reached the top of the filter element. There is no significant restriction to fuel flow until the element is completely clogged.

DAVCO fuel/water separators come in a number of different configurations. The lower housing may be screw-assembled (**Fig. 1**, Ref. A) or locking-collar-assembled (**Fig. 1**, Ref. B). There may be an electric heating element (**Fig. 1**, Item 12) installed in the lower housing or there may be fluid heating in the lower housing (**Fig. 1**, Item 15).

If there is fluid heat, the warming fluid may be fuel returning from the engine or engine coolant. **Fig. 2** 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.

General Information

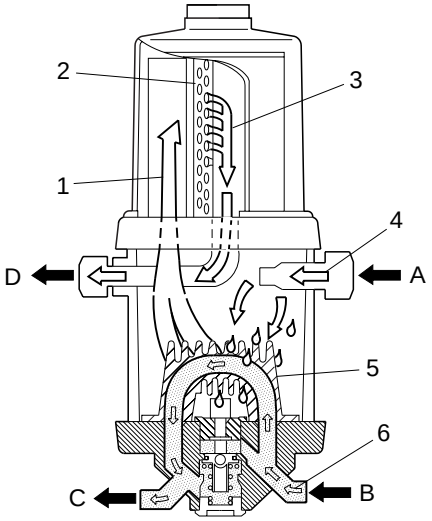


A. Configuration and components with screw-assembled lower housing and electric fuel heater

B. Configuration and components with locking-collar-assembled lower housing and fluid fuel heater

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Lower Housing
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Electric Heating Element
13. Drain Valve
14. Lower Collar
15. Fluid Heater Ports
16. Outlet Port

Fig. 1, DAVCO Fuel Pro and Diesel Pro Configurations



02/20/2009 f470413

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. 2, DAVCO Fluid Circulation, Fluid-Heated Units

Removal

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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.
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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 2) and open the drain valve (**Fig. 1**, Item 12) 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, including the locking collars, 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 inlet fuel line before mounting the fuel/water separator on the frame rail.

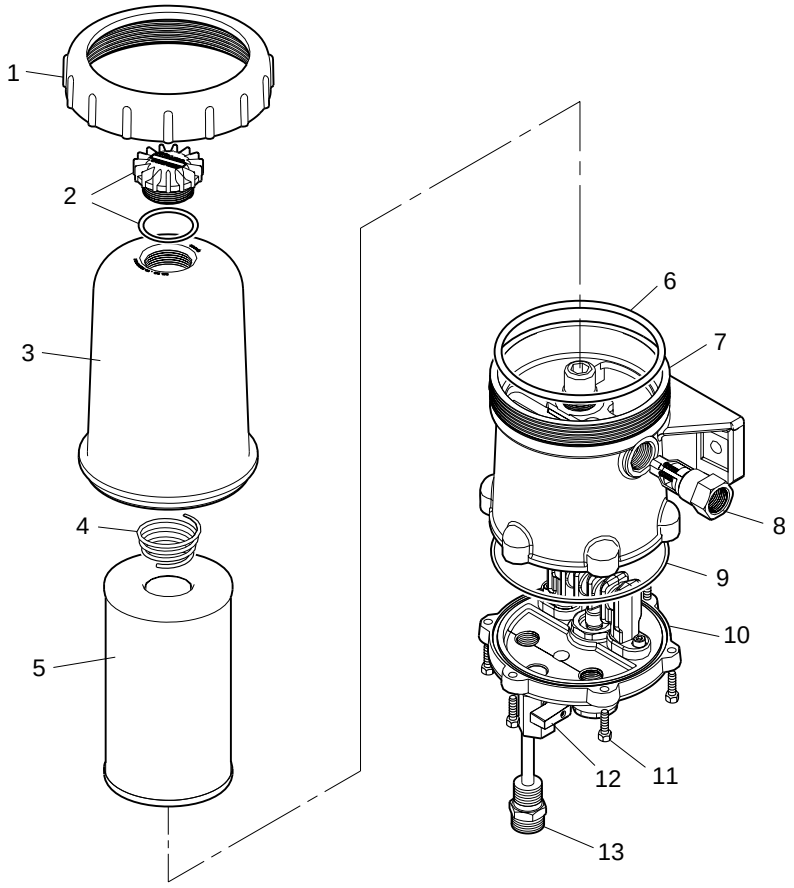
   To minimize restrictions, keep fuel line routing as smooth as possible, with no low-hanging loops that could trap water. If the fuel line is being made to length on the job, be sure that the inner liner of the hose is not cut by the fitting. Be certain the interior of all fuel lines is clean and free 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 the fuel outlet line. Tighten the fitting 25 to 40 lbf·ft (34 to 54 N·m).
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.
   - 6.2 Remove the vent cap from the cover, and fill the housing to the top with clean diesel fuel.

Removal and Installation



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1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Housing Collar Threads
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Drain Valve
13. Electric Heating Element

Fig. 1, Fuel/Water Separator With Electric Fuel Heater

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 Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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.

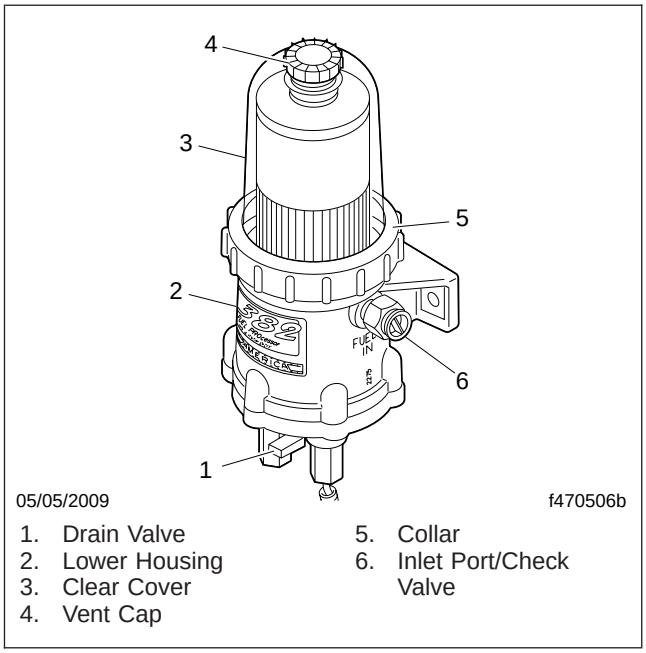
If returning fuel is released into the atmosphere, its vapors can ignite in the presence of any ignition source. Do not expose the fuel to, or work with the fuel system near, open flame or intense heat. To do so could cause fire, possibly resulting in serious personal injury or property damage.

1. Shut down the engine, apply the parking brake, and chock the tires.
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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) 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, cover O-ring, and vent cap O-ring (see **Fig. 3**). Dispose of them 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. Install the grommet on the bottom of the new filter.



1. Drain Valve
2. Lower Housing
3. Clear Cover
4. Vent Cap
5. Collar
6. Inlet Port/Check Valve

Fig. 1, DAVCO Fuel/Water Separator (Fuel Pro 382 shown)

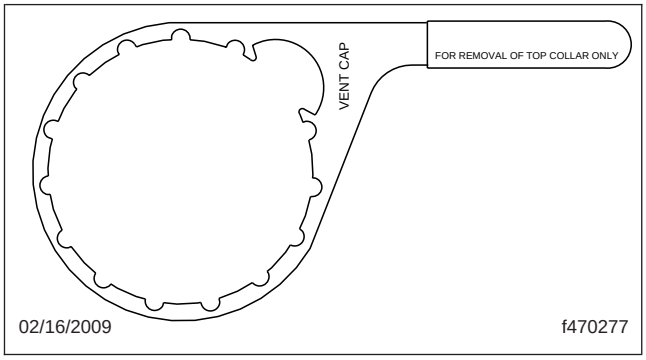
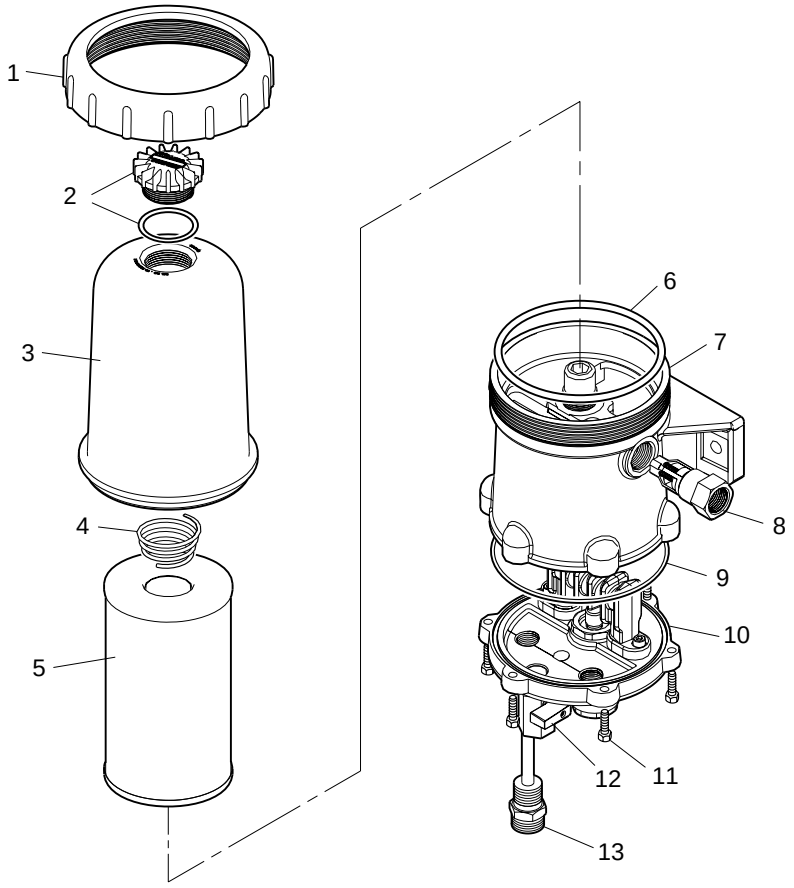


Fig. 2, DAVCO Collar Wrench

8. Install the new filter and grommet assembly and cover O-ring on the housing.
9. Install the clear cover and the collar. Hand-tighten the collar.
10. Prime the system
    - 10.1 Ensure that the drain valve is closed.
    - 10.2 Fill the housing to the top with clean diesel fuel.
    - 10.3 Install and hand-tighten the vent cap O-ring and vent cap.

Filter and Check Valve Replacement



04/30/2007 f470505

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Housing Collar Threads
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screw
12. Drain Valve
13. Electric Heating Element

Fig. 3, Fuel/Water Separator With Electric Fuel Heater

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.

Emergency Temporary Filter Replacement

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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.
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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) 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

⚠ WARNING

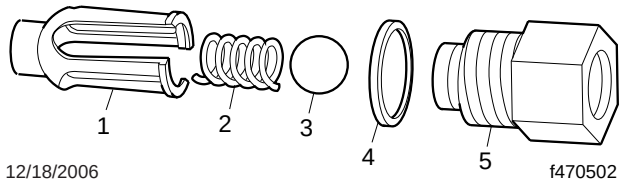
Fluid circulated through the fuel/water separator to heat the fuel may be diesel fuel returned from the engine, or engine coolant. Drain the fuel/water separator only when the engine and fluids have cooled. Draining it when the engine is hot could cause severe personal injury due to scalding.

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.
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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
3. Remove the vent cap (**Fig. 1**, Item 4) 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 (**Fig. 3**, Item 8) 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. 4**.
7. Carefully clean the threads on the check valve body. Install the new check ball, spring, and plastic retainer on the check valve body.

Filter and Check Valve Replacement



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 4, Check Valve Assembly

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. 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.
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.

Electric Pre-Heater, Thermoswitch, and Fluid Heat 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:

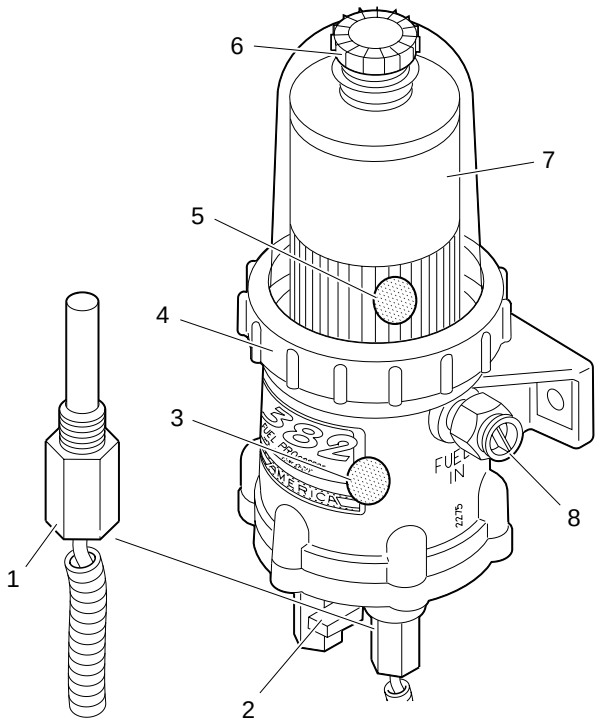
- Electric Heater
- 12 VDC Thermoswitch
- Combination Heater Thermoswitch
- Fluid Heat

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 Test

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the heater from the wiring harness, see **Fig. 1**.
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.



1. Electric Heating Element
2. Drain Valve
3. Housing
4. Collar
5. Filter Element
6. Vent Cap
7. Clear Cover
8. Inlet Port/Check Valve

Fig. 1, Fuel Pro 382 With Electric Heating Element

Electric Heater Test Paramaters		
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 Test

1. Shut down the engine, apply the parking brake, and chock the tires.

Electric Pre-Heater, Thermoswitch, and Fluid Heat Tests

WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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. 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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

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. 2**. Remove the thermoswitch from the fuel/water separator.

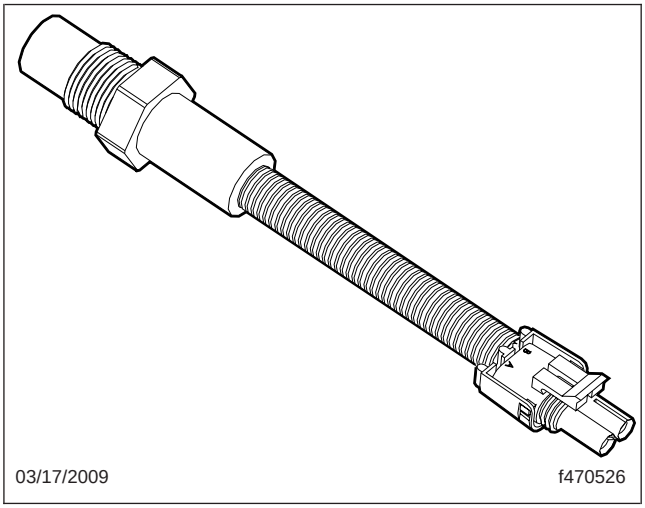


Fig. 2, 12 VDC Thermoswitch

5. Connect the ohmmeter leads to the pins of the 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 Test

1. Shut down the engine, apply the parking brake, and chock the tires.

WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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. 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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

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. 3**.

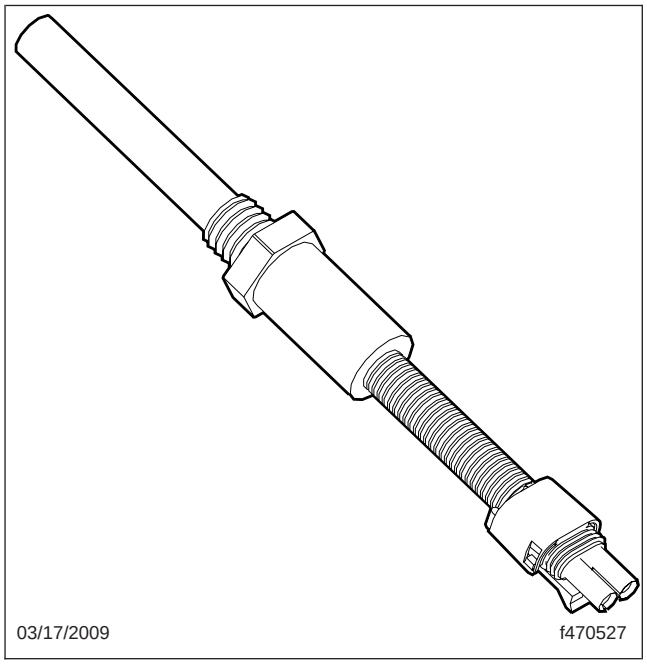


Fig. 3, Combination Heater Thermoswitch

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

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 Heater Test

1. Shut down the engine, apply the parking brake, and chock the tires.

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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.

Electric Pre-Heater, Thermoswitch, and Fluid Heat Tests

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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

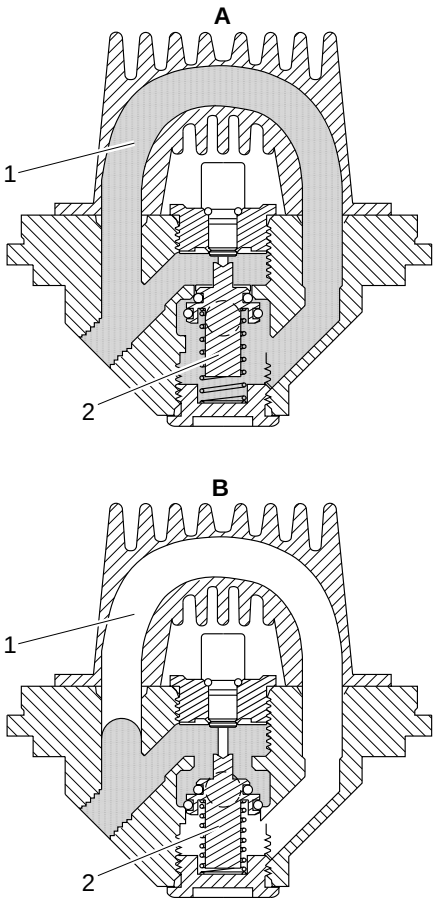
3. Remove the vent cap and open the drain valve to drain the fuel to just below the collar level, then close the drain valve.
4. Disconnect the heating fluid lines from the bottom plate. These will be either engine coolant lines or return fuel lines. Plug engine coolant lines after removing them from 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. 4**.

   While looking into the fluid port of the bottom plate (**Fig. 5**), 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.

7. Replace the lower housing O-ring, and install the bottom plate on the fuel/water separator. There are two types of bottom plates: locking-collar-assembled and screw-assembled.
   - Locking-collar-assembled: Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
   - Screw-assembled: 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

   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.



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A. Fuel is Cold, Thermovalve Is Up
B. Fuel is Warm, Thermovalve is Down

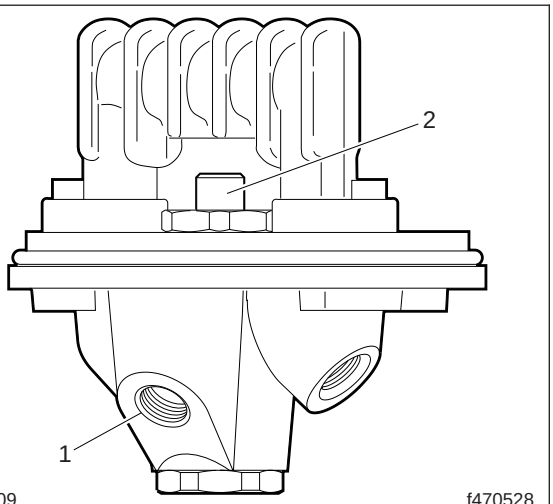
1. Heater Loop 2. Thermovalve

Fig. 4, Heat Exchanger Fluid Flow

   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.



1. Fluid Port
2. Top of Thermovalve Spool

Fig. 5, Fluid Heater Thermovalve Test

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.

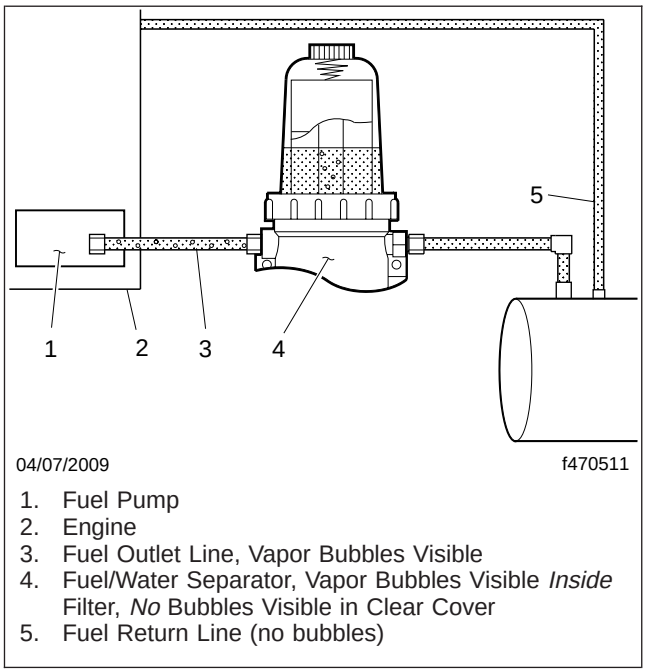
Identifying Bubble Types

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.

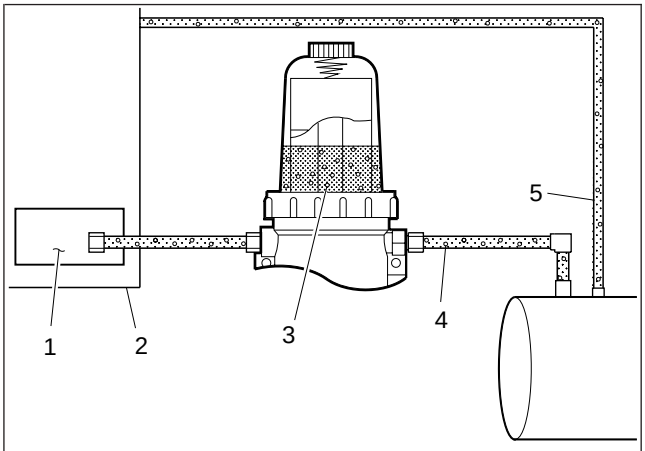
Air bubbles visible in the clear cover of a DAVCO fuel/water separator may indicate an air leak in the fuel system upstream of the bubbles, or in the fuel/water separator; see **Fig. 2**. If there are no bubbles visible in the clear cover but the engine runs rough, there may be an air leak at or between 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 to heat the fuel 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.
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.

   The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.
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 (**Fig. 3**, Item 16). 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. Some DAVCO fuel/water separators have locking collars on both the filter cover and the lower housing, as shown in **Fig. 3**. If a lower collar is present, it does not need to be removed for normal service. But if the lower collar is removed and the filter housing disassembled, a new lower housing O-ring (**Fig. 3**, Item 9) must be installed. Apply 2 to 3 drops of Loctite 406 to the bottom collar threads, then tighten 50 to 60 lbf·ft (68 to 81 N·m).
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.
10. If no bubbles appear, the air leak is not in the fuel/water separator.

Restriction Check

A DAVCO fuel/water separator, properly assembled with the rubber grommet in the bottom of the fuel filter, 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.

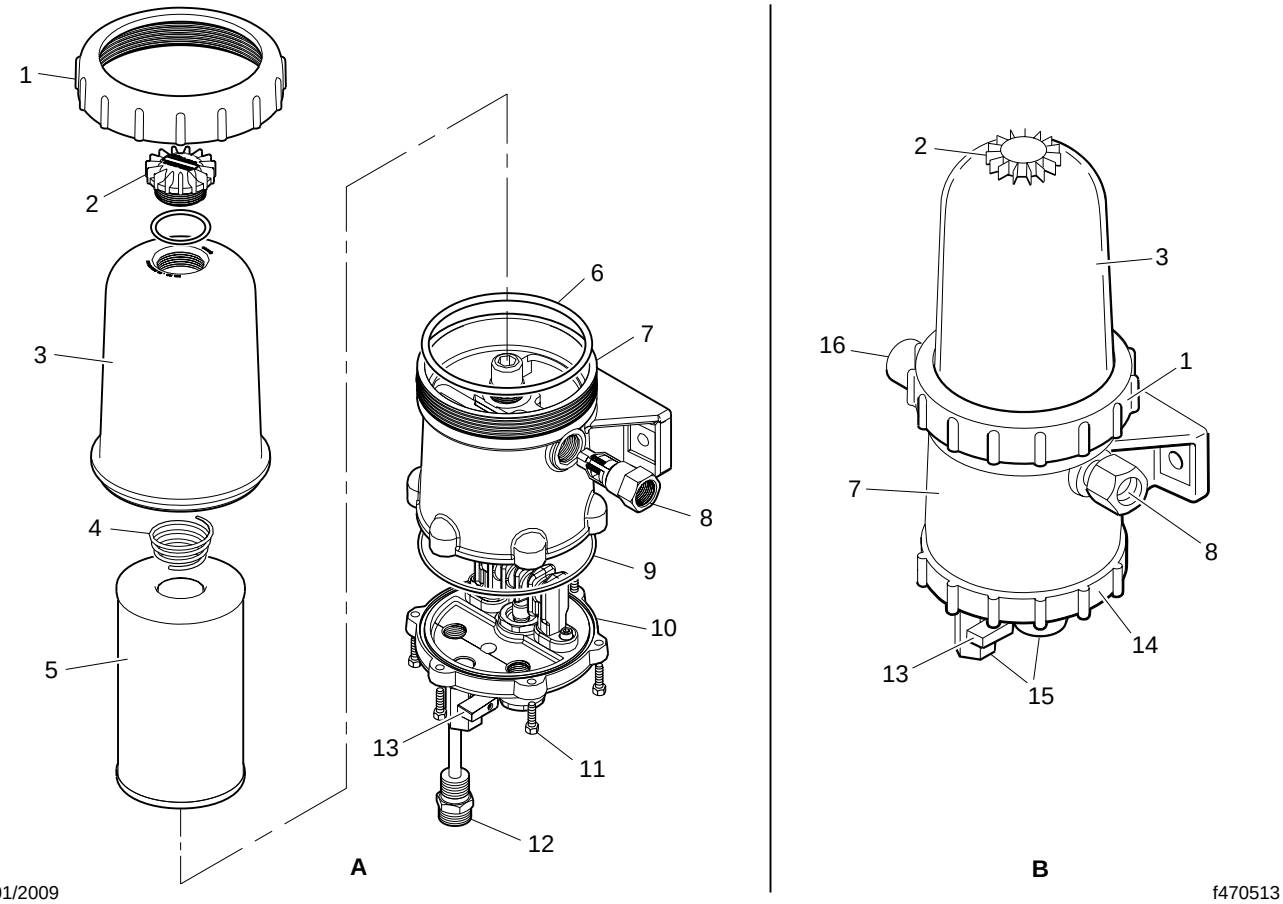
Check Valve Operation Test

When air is introduced into the fuel system, (e.g. when draining fluid or when replacing the fuel filter), the check valve (**Fig. 4**) works to keep the fuel system primed from the fuel tank to the fuel/water separator.

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.

1. Shut down the engine, apply the parking brake, and chock the tires.

Troubleshooting



A. Configuration and components with screw-assembled lower housing and electric fuel heater

B. Configuration and components with locking-collar-assembled lower housing and fluid fuel heater

1. Collar
2. Vent Cap with O-Ring
3. Clear Cover
4. Spring
5. Filter Element
6. Cover O-Ring
7. Lower Housing
8. Inlet Port/Check Valve
9. Lower Housing O-Ring
10. Housing O-Ring Groove
11. Housing Assembly Screws
12. Electric Heating Element
13. Drain Valve
14. Lower Collar
15. Fluid Heater Ports
16. Outlet Port

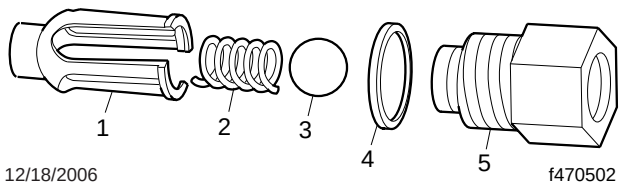
Fig. 3, DAVCO Fuel Pro and Diesel Pro Configurations

⚠ WARNING

Fluid circulated through the fuel/water separator to heat the fuel 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. 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.



1. Plastic Spring Retainer
2. Retaining Spring
3. Check Ball
4. Seal
5. Check Valve Body

Fig. 4, Check Valve Assembly

The drain valve on the Fuel Pro 382 has a 1/2-inch (12.7-mm) opening; use a hose with a 1/2-inch pipe thread to fit correctly.

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 (**Fig. 3**, Item 8) 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. 4**.
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 water separator 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.
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.

Troubleshooting

Conditions Visible Inside DAVCO Clear Filter Covers		
If You See:	**What to Do:**	**Comments:**
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 separtor 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 382		Diesel Pro 232/233	
	lbf·ft (N·m)	lbf·in (N·cm)	lbf·ft (N·m)	lbf·in (N·cm)
Inlet Port/Check Valve	44–60 (60–81)	—	25–40 (34–54)	—
Fuel Outlet Fitting	—	—	25–40 (34–54)	—
Water in Fuel Sensor	—	20–24 (226–271)	—	20–24 (226–271)
Electric Heating Element	15–30 (20–41)	—	15 (20)	—
Drain Valve	25 (34)	—	15 (20)	—
Housing Assembly Screws	8–10 (11–14)	—	—	—

Table 1, Torque Values

General Information

All S2 chassis built with pre-EPA07-compliant engines are equipped with a muffler. For exhaust pipe routing, see **Fig. 1** and **Fig. 2**.

Muffler Exhaust System

The exhaust system routes hot exhaust gas away from the cab, and reduces engine exhaust noise. S2 chassis have a horizontally mounted muffler on the right side of the vehicle and are available with a horizontal outlet.

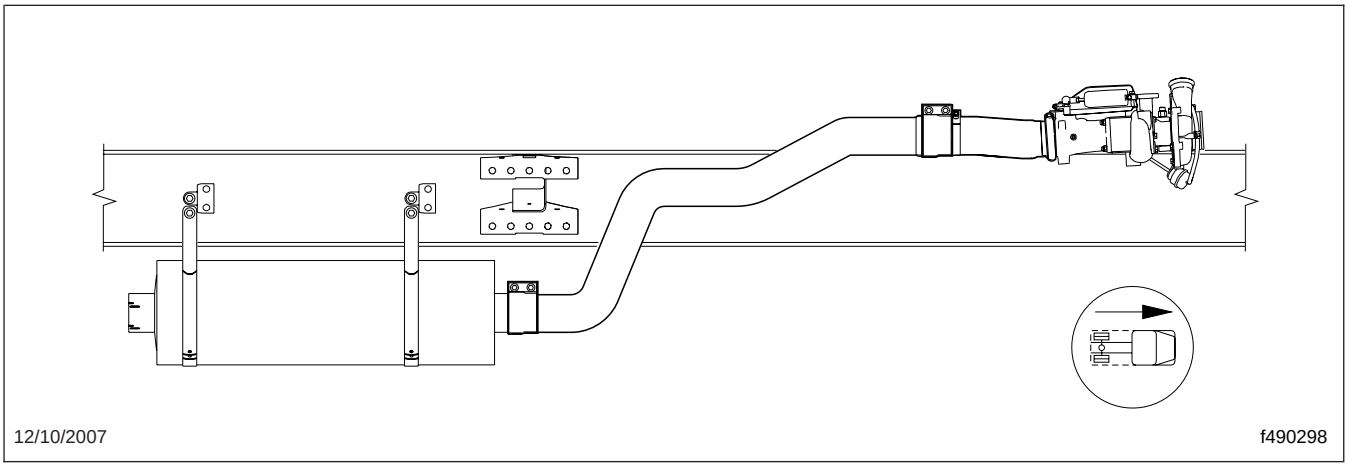


Fig. 1, Exhaust Pipe Routing, Engine to Muffler

System components include the engine outlet exhaust pipe, muffler, muffler mounting components, saddle clamps, wide-band exhaust clamps, tail pipe, and exhaust system heat shields.

Most exhaust installations consist of an engine exhaust pipe, sometimes called the turbo pipe, mounted to the rear of the turbocharger and secured with a V-clamp. Brackets, attached to the transmission, support the engine exhaust piping as it runs to the muffler. A wide-band clamp holds the exhaust pipe to the muffler.

The horizontal muffler hangs from brackets mounted inside the frame rail web. All exhaust components attach to either the engine or the chassis frame rails.

General Information

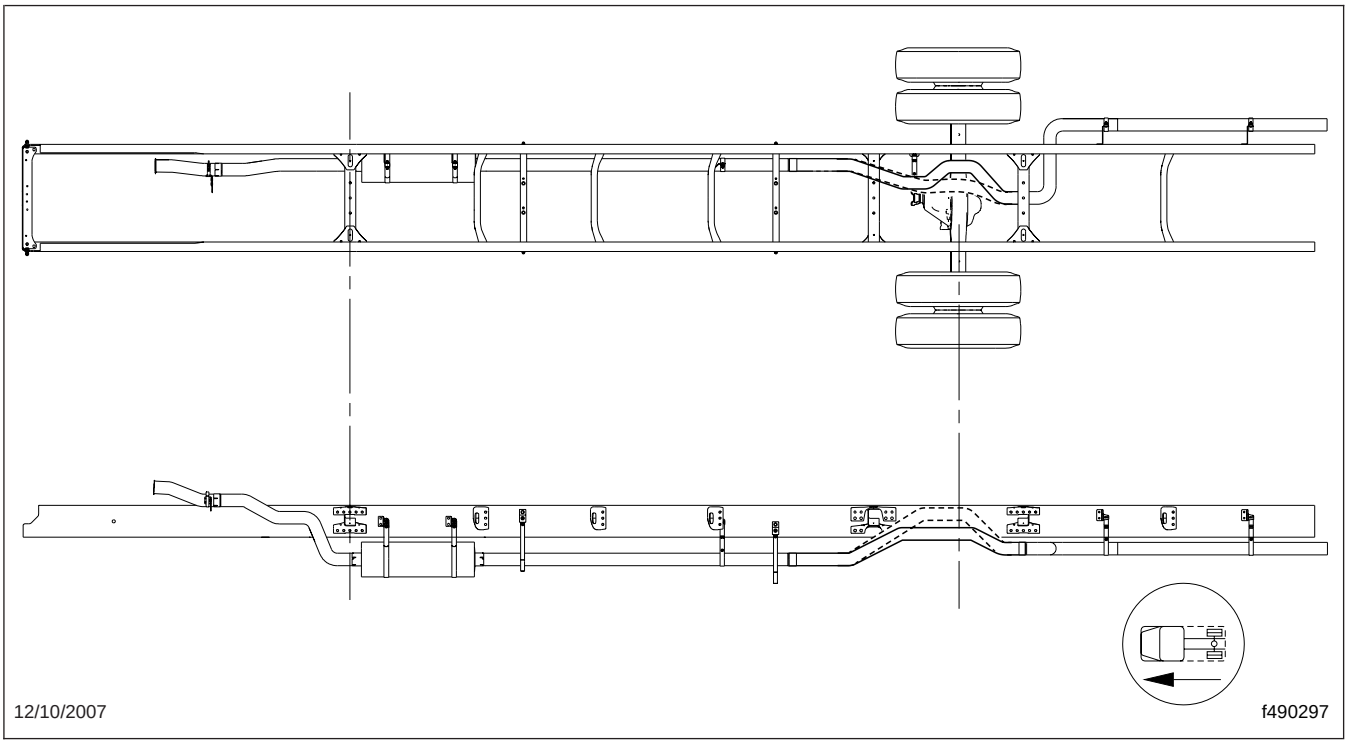
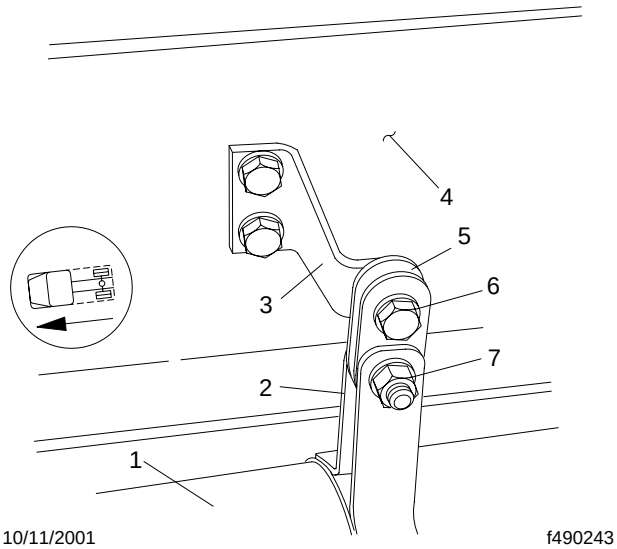


Fig. 2, Exhaust Pipe Routing, Muffler to Tail Pipe

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Loosen the clamp that attaches the muffler to the exhaust pipe.
3. Remove the fasteners that attach the muffler mounting bands and rubber isolators to the mounting brackets. See **Fig. 1**.



1. Muffler
2. Muffler Mounting Band
3. Mounting Bracket
4. Frame Rail
5. Rubber Isolator
6. Hexbolt and Washer
7. Hexnut and Washer

Fig. 1, Muffler Mounting Components

4. Remove the muffler and tailpipe from the vehicle.

Installation

1. If installing a new muffler, loosely install the muffler mounting bands on the muffler. The bands should be loose enough so you can rotate and slide them. See **Fig. 2**.
2. Position the muffler, aligning the ears of the muffler mounting bands with the rubber isolators.

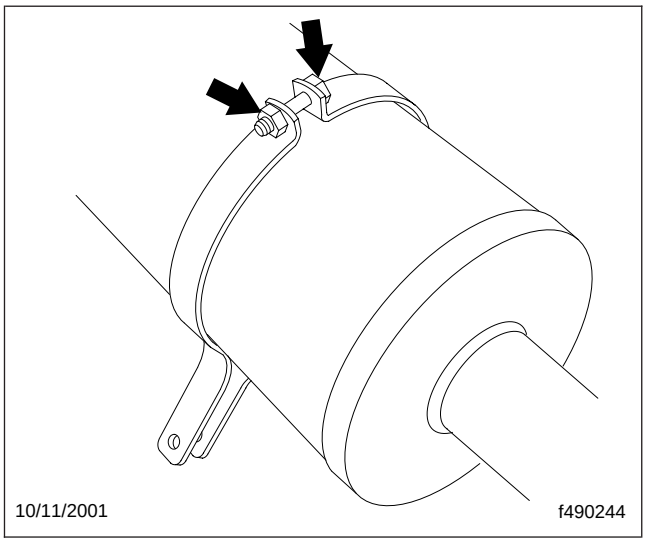


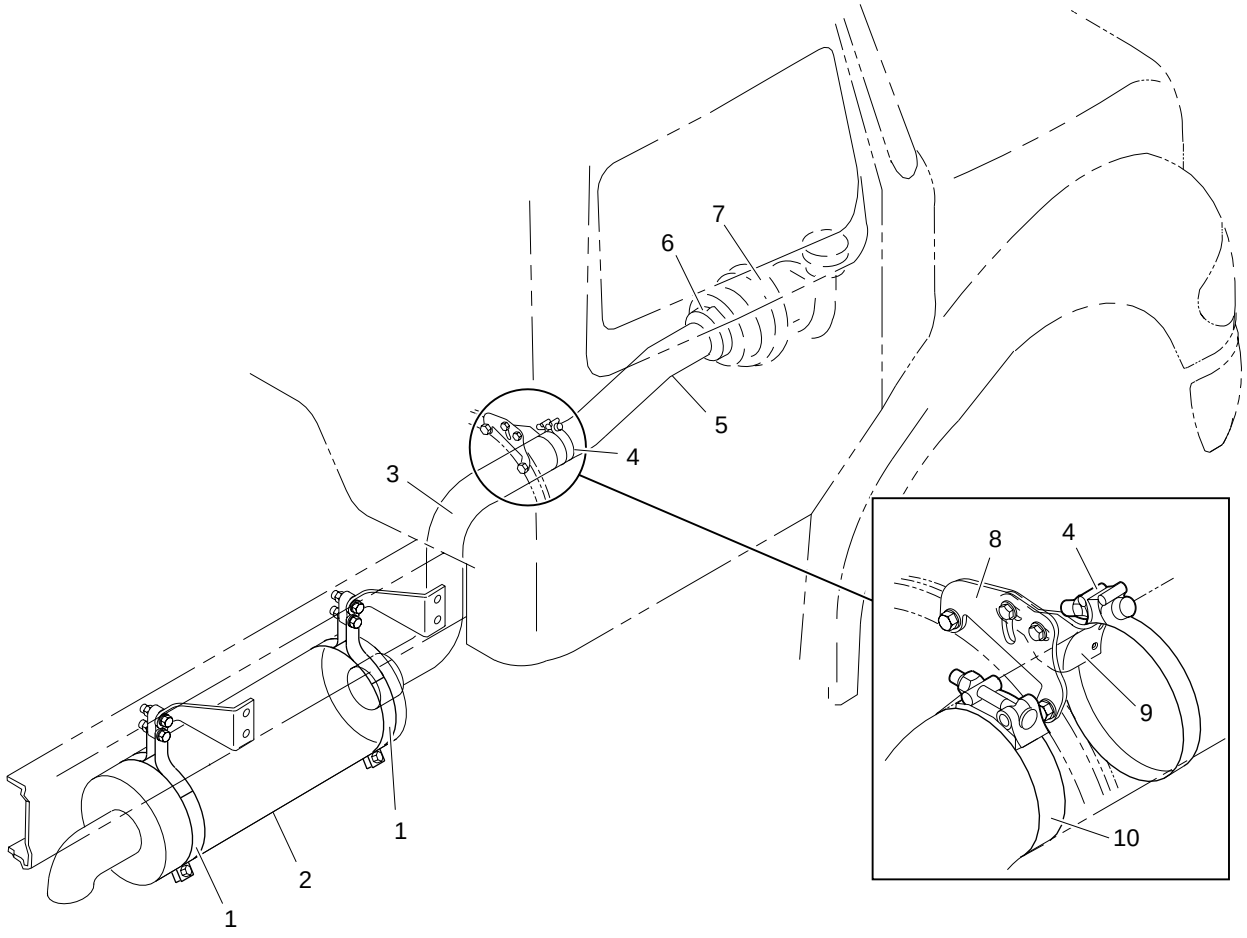
Fig. 2, Installing the Muffler Mounting Bands

3. Push the front of the muffler over the end of the exhaust pipe.
4. If needed, adjust the muffler mounting bands so the ears align with the frame-mounted mounting bracket.
5. Loosely attach the muffler bands to the isolators.
6. Make sure the muffler is pushed all the way onto the end of the exhaust pipe.
7. Install a narrow-band exhaust clamp on the end of the muffler. Tighten it firmly.
8. Tighten the fasteners that attach the bands to the frame-mounted mounting brackets and hold the isolators in place between the ears of the mounting bands.
9. If applicable, install the tail pipe to the end of the muffler, using a narrow-band exhaust clamp. Tighten 50 to 60 lbf·ft (68 to 81 N·m). firmly.
10. Start the engine and check for leaks. Tighten any fasteners as needed.
11. Remove the chocks from the tires.

Exhaust Piping Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the section of exhaust pipe between the muffer and the transmission (at the exhaust support plate), as follows. See **Fig. 1**.
   - 2.1 Loosen the narrow-band clamp that holds the front and rear sections of the exhaust piping together.
   - 2.2 Remove the fasteners that hold the muffler mounting bands to the rubber isolators. See **Fig. 2**.
   - 2.3 Remove the rear section of the exhaust pipe and the muffler together.

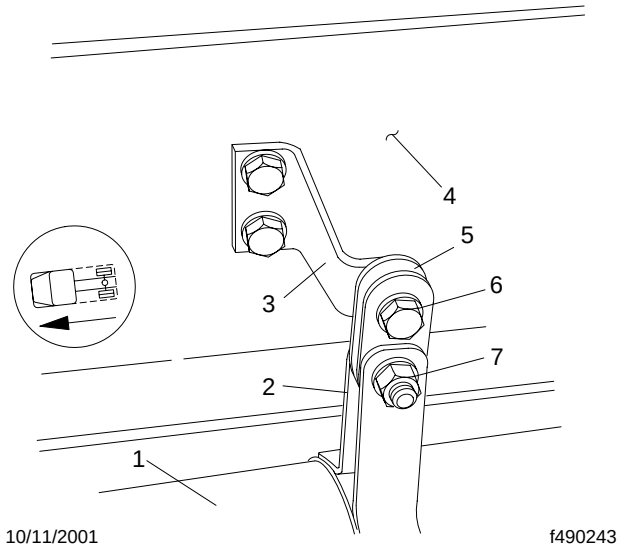


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1. Muffler Mounting Band
2. Muffler
3. Exhaust Mid-Pipe
4. Narrow-Band Exhaust Clamp
5. Engine Outlet Exhaust Pipe
6. V-Clamp
7. Turbocharger
8. Exhaust Support Plate (attached to transmission)
9. Bracket
10. T-Bolt Clamp

Fig. 1, Horizontal Exhaust Mounting, (typical installation)

Exhaust Piping Removal and Installation



1. Muffler
2. Muffler Mounting Band
3. Mounting Bracket
4. Frame Rail
5. Rubber Isolator
6. Hexbolt and Washer
7. Hexnut and Washer

Fig. 2, Muffler Mounting Components

2.4 Loosen the wide-band exhaust clamp that holds the exhaust pipe to the muffler and disconnect the pipe from the muffler.

3. Remove the forward section of the exhaust pipe, as follows.

   3.1 Loosen the V-clamp that holds the exhaust pipe to the turbocharger.

   3.2 Loosen the clamp that holds the exhaust pipe to the bracket on the transmission.

   3.3 Remove the exhaust pipe from the vehicle.

4. If applicable, remove the tailpipe. See **Fig. 3**.

Installation

1. Connect the forward section of the exhaust pipe to the turbocharger. Tighten the engine V-clamp just enough to hold it in place.
2. If it was removed, connect the muffler to the rear section of the exhaust pipe. Make sure the exhaust pipe is all the way inside the end of the muffler, then tighten the exhaust clamp snugly.
3. Place the rear section of the exhaust pipe and the muffler in position and push the rear exhaust pipe over the end of the front exhaust pipe.
4. Loosely connect the muffler mounting band to the frame- mounted muffler mounting brackets.
5. Install the narrow-band exhaust clamp. Tighten it 50 to 60 lbf·ft (68 to 81 N·m).
6. As needed, adjust the pipes so that they are in a straight line.
7. Fully tighten the two exhaust clamps and the muffler mounting fasteners.
8. Start the engine and check for leaks. Tighten any connections as needed.
9. Remove the chocks from the tires.

Exhaust Piping Removal and Installation

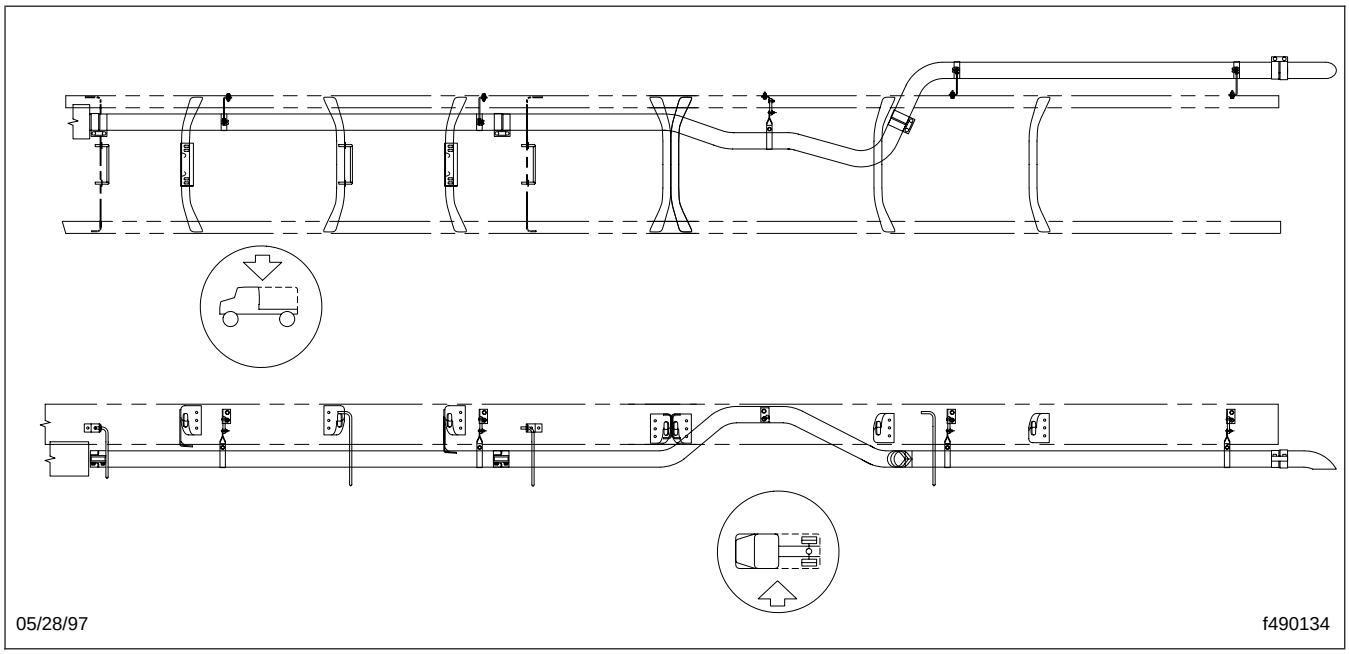


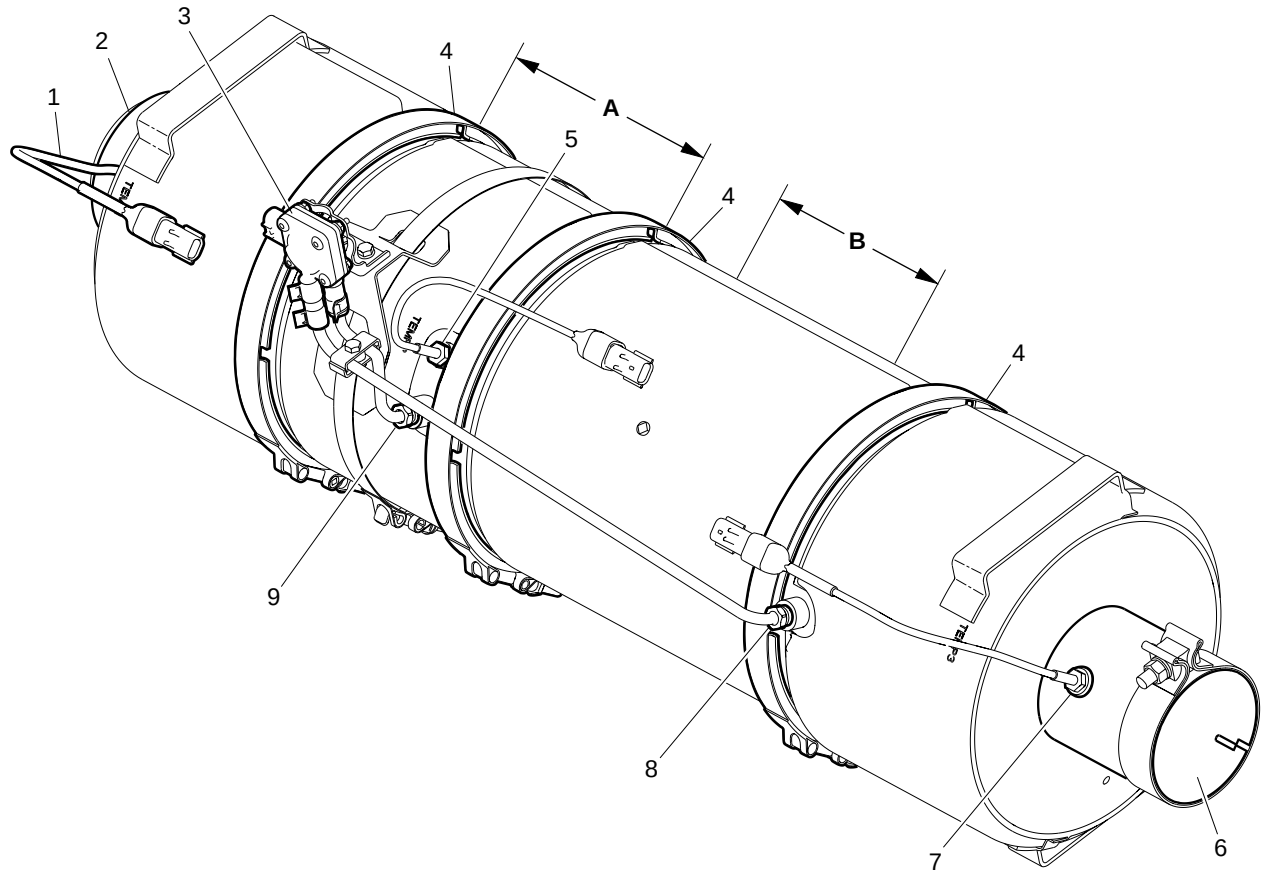
Fig. 3, Exhaust Pipe Routing, Muffler to Tail Pipe

General Information

The aftertreatment system (ATS) includes all the piping and equipment between the engine turbocharger outlet and the tip of the exhaust pipe. It corresponds to the exhaust system on pre-EPA07 vehicles, but includes an aftertreatment device (ATD) instead of a muffler and other equipment. See **Fig. 1**. Operation of the ATS is controlled by an electronic control module (ECM).

Engine manufacturers use different methods and equipment to reduce emissions from their engines, but an ATD is used on all of them. The ATD is available only in chassis-mounted configuration, and can be mounted either vertically or horizontally. ATS exhaust piping is stainless steel.

Inside the ATD, the exhaust emissions pass first through the diesel oxidation catalyst where they are chemically treated, then through the diesel particulate filter (DPF), where solid particles are trapped. The



01/22/2008 f490284a

A. DOC Area

1. Inlet Temperature Sensor
2. Marmon Fitting at Inlet from Turbocharger
3. Sensor Housing
4. DPF V-Band Mounting Clamps
5. Inlet Temperature Sensor

B. DPF Area

6. Exhaust Outlet to Diffuser
7. Outlet Temperature Sensor
8. DPF Outlet Pressure Sensor
9. DPF Intake Pressure Sensor

Fig. 1, Aftertreatment Components (typical)

General Information

remaining particulates are almost completely vaporized in the DPF, in a process called regeneration (regen).

Soot from additives in the engine oil cannot be vaporized, but it is burned to ash and held in the DPF. When the ash buildup is heavy enough to begin clogging the DPF, the DPF must be removed from the vehicle and physically cleaned in special processes specified by the engine manufacturers.

Using low-ash oil extends the time required for DPF cleaning, and **only low-ash oil should be used in EPA07 engines**.

EPA07 emissions regulations limit NOx to just over 1 gram per brake horsepower hour (g/bhp-hr) and particulate matter cannot exceed 0.01 g/bhp-hr. **EPA07 engines require ultralow-sulphur diesel (ULSD) fuel, for low emissions and long life of the ATD**.

EPA07 engines will run on higher sulfur fuel, but that reduces the efficiency of the ATS. Using non-ULSD fuel in an EPA07 engine will cause expensive damage to the ATD after a few tankfuls.

NOTE: FCCC documentation deals only with removal and installation of the ATD and other parts of the ATS. Refer to the engine manufacturers' service literature for all testing, disassembly, cleaning, and repair of the ATD and other components.

IMPORTANT: The ATS is part of an interrelated engine and emissions management system, controlled by the ECM. Follow the engine manufacturer's procedures, and use the correct equipment when diagnosing or working on any part of the ATS.

In Cummins and Mercedes-Benz engines, there is a diesel oxidation catalyst (DOC) inside the intake side of the ATD. The DOC chemically treats the exhaust, to reduce gas emissions before the exhaust reaches the DPF.

The DPF honeycomb tubes are closed at alternate ends, forcing the exhaust to move through its walls where it traps the soot.

There are two types of regen, passive and active.

Passive regen is ongoing, whenever vehicle operation creates an ATD temperature of 572°F (300°C) or higher. There is no indication to the driver that the process is happening, and exhaust gas temperature is no higher than normal. Under load and at highway speeds, passive regen may be all that is necessary to keep the DPF clear. But operating under light loads or at low speeds does not generate enough heat in the ATD for passive regen, and particulate matter builds up in the DPF.

As particulate matter builds up in the DPF, it blocks exhaust gas from passing through the honeycomb tube walls. Pressure sensors on the intake and exhaust sides of the DPF sense the increase in back pressure, and signal the ECM. The ECM also keeps track of engine hours and mileage, and other measurements, to calculate when active regen is necessary.

During active regen, the inside of the ATD is raised to very high temperatures. Exhaust gas temperature reaches over 1112°F (600°C), to reduce the trapped soot to ash. There are two types of active regen, at-speed and parked.

- At-speed regen is automatically initiated by the ECM. Exact conditions for its initiation vary, according to the engine manufacturer's design. Generally, it happens when the vehicle is travelling at least 7.5 mph (12 km/h), and stops when the vehicle slows to 5 mph (8 km/h) or below.
- Parked regen is initiated by the driver when the vehicle is safely parked, a specific sequence of procedures is followed, and the driver pushes the regen button on the dashboard. The parked regen sequence varies with vehicle configuration. Follow the exact sequence prescribed for a given vehicle, according to engine manufacturer's literature.

IMPORTANT: The ATS is an integrated system, and every component must be operating, in order for the ATS to work correctly.

Aftertreatment Device (ATD) Removal and Installation

Removal

It may be necessary to raise the vehicle or remove body panels to service the ATD, depending on vehicle configuration.

NOTICE

The ATD assembly weighs from 125 to 150 pounds (57 to 68 kg) and must be protected from impact or sharp jolts. Dropping the ATD, or subjecting it to jarring impact can crack the diesel particulate filter (DPF) inside, which is built on a ceramic substrate. If that happens, the DPF is ruined and must be replaced.

A secure support is necessary to remove and install the ATD safely. The ATD must be held securely to protect it from falling, or hitting hard against something else.

The horizontal ATD lifting device (TLZ00785) is designed for the job on a horizontal ATD.

The ATD is designed so that its exterior operating temperature is comparable to that of a standard muffler, but its interior and the outlet become extremely hot during regeneration events.

⚠ DANGER

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.

1. Set the parking brake, and chock the tires.

NOTE: Never attempt to start the vehicle with the ATD removed or with the ATD sensors disconnected, unless proper diagnostic tools are connected. See the engine manufacturer's literature for proper equipment and procedures.

2. Disconnect the connections at the sensor box and the diesel oxidation catalyst (DOC) inlet temperature sensor. See **Fig. 1**.
3. Using a suitable marker, mark the inlet and outlet joints and mounting bracket locations on the ATD, so that the ATD can be installed exactly as it was removed.

NOTE: There are positioning pins to guide placement of the ATD during vehicle manufacture, but they are designed to break off if they are highly stressed, to avoid damaging the ATD. If the positioning pins are gone, the locating marks serve the same purpose.

4. Move the ATD handling device into place against the ATD, so that it is in position to support the ATD securely and the ATD can not roll, tip, or fall.
5. The exhaust piping may require support, such as a rope sling, to support it when the ATD is removed. If such support is required, install it now.

NOTICE

Be careful not to stress or twist the bellows as the ATD is manipulated. The bellows are not designed to support weight or withstand undue stress and can easily be damaged, requiring expensive replacement.

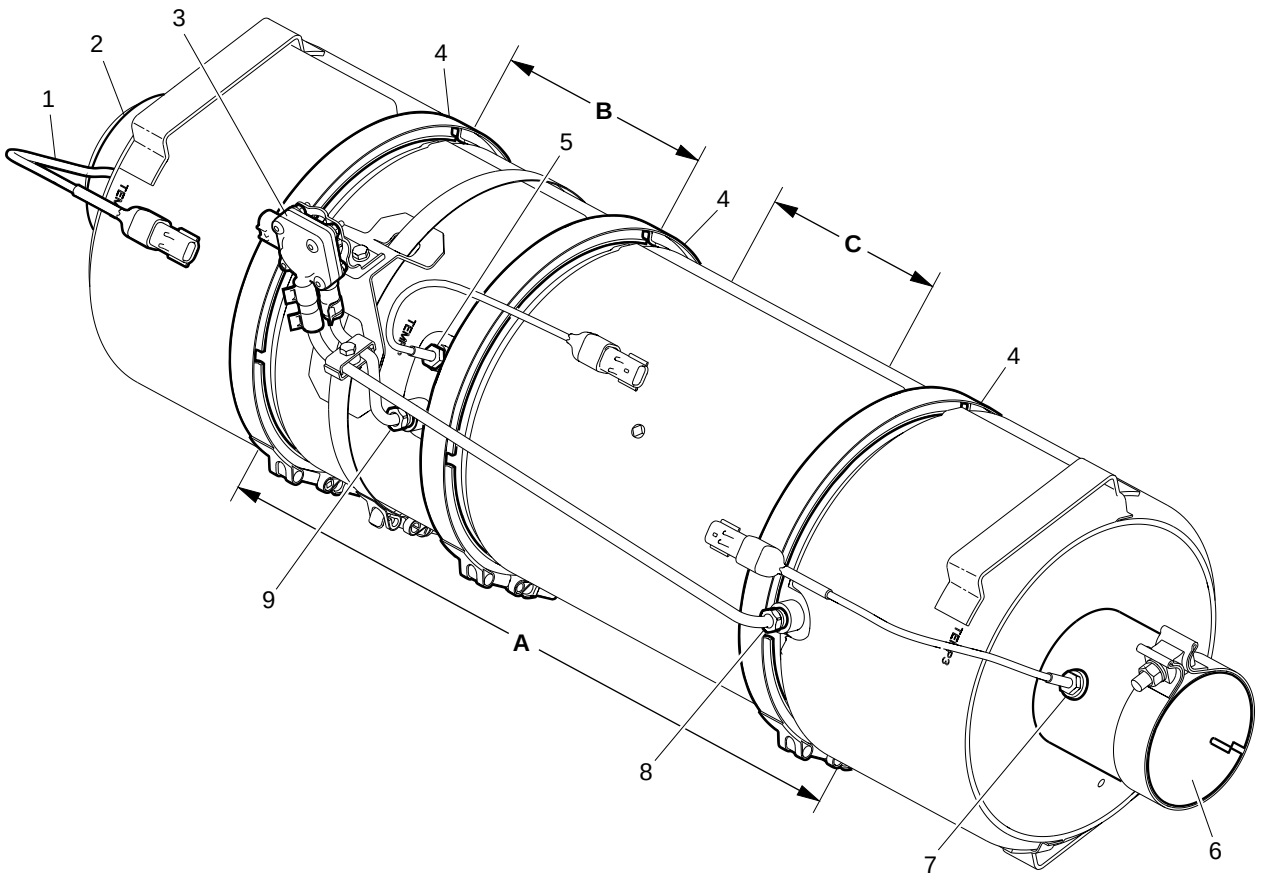
6. Remove the clamps from the Marmon fittings at the inlet and outlet of the ATD.
7. Remove the two mounting bands that hold the ATD to its mounting brackets, so that the ATD is held by the ATD handling device.
8. Move the ATD slightly, so that the ATD positioning pin clears its hole in the front mounting bracket, see **Fig. 2**. Carefully remove the ATD from the vehicle.

NOTE: ATD component service procedures, such as cleaning the diesel particulate filter or servicing the sensors, are documented in the engine manufacturer's service literature.

Installation

1. Using the ATD handling device, move the ATD into position so the inlet and exhaust align with the inlet and exhaust piping. Be sure the ATD

Aftertreatment Device (ATD) Removal and Installation



11/2/2006 f490284

A. Inspect this area of the canister for dents.
B. DOC Area
C. DPF Area

1. Inlet Temperature Sensor
2. Marmon Fitting at Inlet from Turbocharger
3. Sensor Housing
4. DPF V-Band Mounting Clamps
5. Inlet Temperature Sensor
6. Exhaust Outlet to Diffuser
7. Outlet Temperature Sensor
8. DPF Outlet Pressure Sensor
9. DPF Intake Pressure Sensor

Fig. 1, Aftertreatment Device (typical)

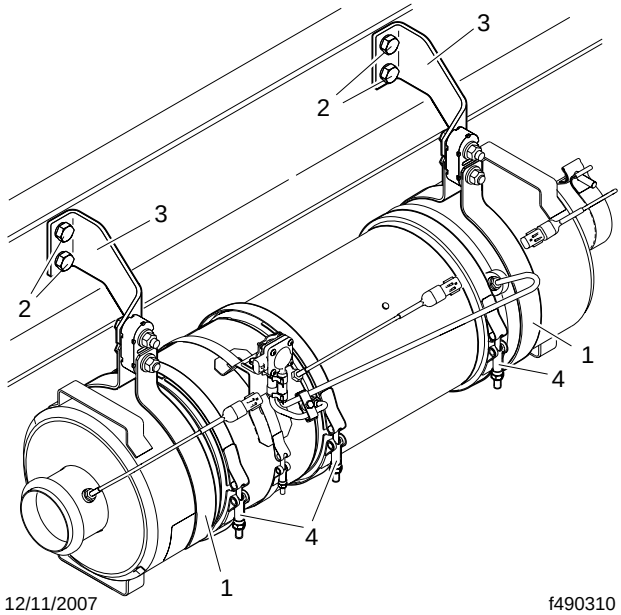
positioning pin engages its hole in the ATD mounting bracket.

2. Install the ATD mounting bands, but do not tighten them yet.

IMPORTANT: The exhaust flex bellows are easily damaged by improper handling or applying incorrect torque to the clamps.

3. Position the V-band clamps on the Marmon fittings and tighten them to the value shown in **Table 1**.
4. Tighten the ATD mounting bands to the value shown in **Table 1**. Do not overtighten, or the ATD could be deformed and the DPF may be ruined.
5. Connect the harness to the sensor housing and the front temperature sensor.

Aftertreatment Device (ATD) Removal and Installation



1. Mounting Bands
2. Mounting Bracket Fasteners
3. Mounting Brackets
4. V-Band Clamp Fasteners

Fig. 2, Aftertreatment Device Mounting

Aftertreatment Device Torque Values	
Fitting	**Torque: lbf·ft (N·m)**
Mounting Bands	Initial: 15 (20) Final: 30 (41)
Temperature Sensor Nuts	26–29 (35–39)
Pressure Line Tube Nuts	11–13 (15–18)
Pressure Sensor Jam Nuts	15–18 (20–24)
Marmon V-Band Clamps	12–13 (16–18)
Compression Fittings	15–18 (20–24)
Bellows Torco Clamps	Target: 41 (56) Range: 35–48 (47–65)

Table 1, Aftertreatment Device Torque Values

6. Remove the ATD handling device.
7. If a support was fastened around the exhaust pipe, remove it.
8. Remove the chocks from the tires.
9. Run an operational check on the vehicle and check for leaks.

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 DEF 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.

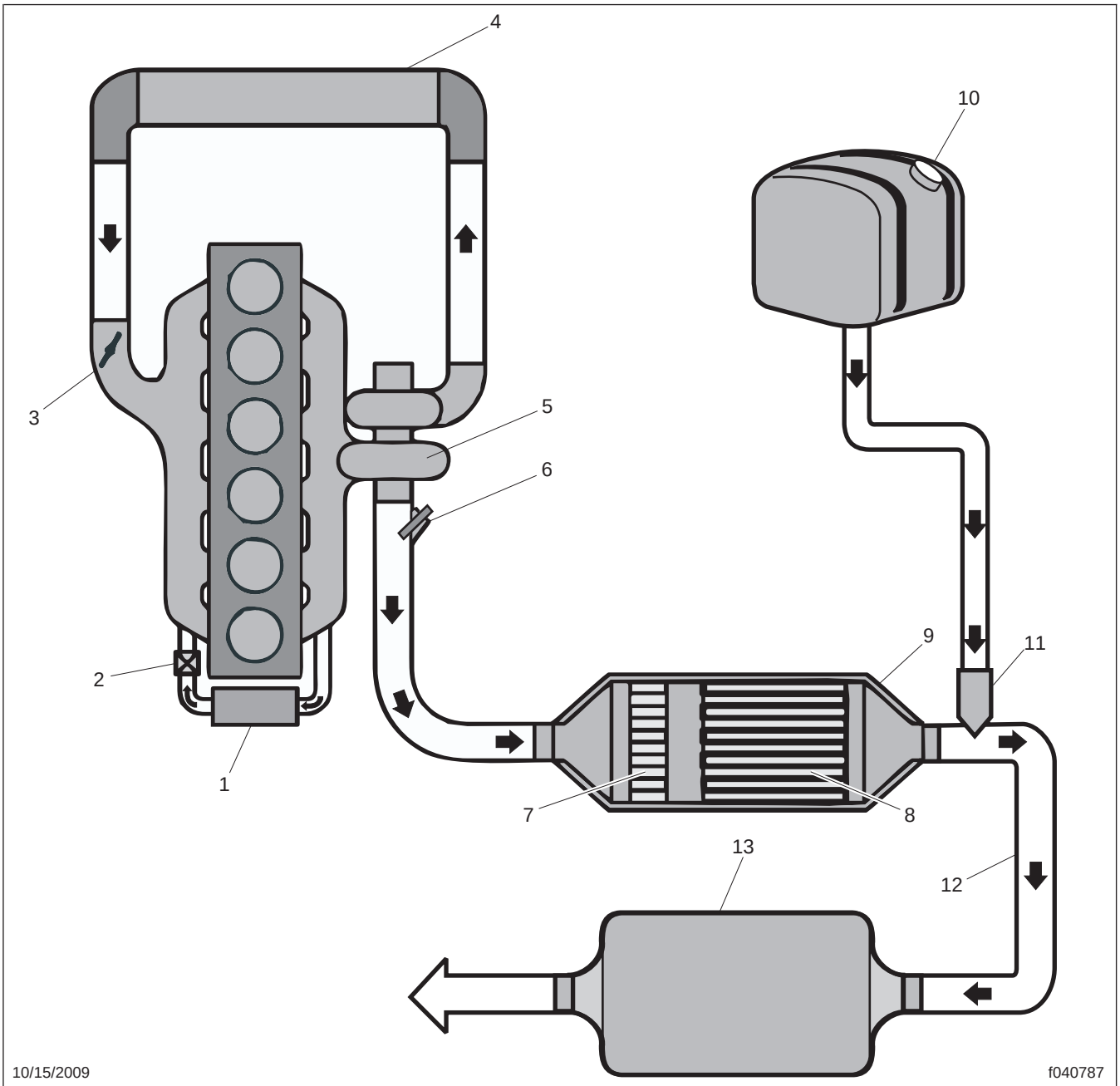
After exhaust gases leave the ATD, a controlled quantity of diesel exhaust fluid (DEF) is injected into the exhaust stream. DEF is colorless, non-toxic, and biodegradable. In the presence of heat, DEF is converted to ammonia gas, which reacts with NOx in the SCR chamber to yield nitrogen and water vapor, 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

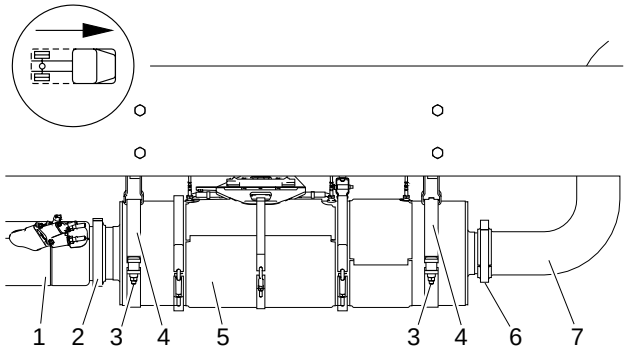


1. Exhaust Gas Recirculation (EGR) Cooler
2. EGR Valve
3. Intake Throttle Valve
4. Charge Air Cooler (CAC)
5. Turbocharger
6. Hydrocarbon Doser
7. Diesel Oxidation Catalyst (DOC)
8. Diesel Particulate Filter (DPF)
9. Aftertreatment Device (ATD)
10. Diesel Exhaust Fluid Tank
11. DEF Injector
12. Mixing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

Fig. 1, Aftertreatment System (typical)

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. Aftertreatment Device (ATD)
6. Spherical Clamp
7. ATD Inlet Pipe

Fig. 1, Cummins 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

NOTICE

Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

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.

Cummins 2HH ATD Removal and Installation

5. Connect the ATD to the ATD inlet pipe and install the new spherical clamp and gasket. Do not tighten at this time.
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) then 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 SCR catalyst.

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 Aftertreatment System (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 chassis wire harness from the NOx sensor.
5. Remove the NOx sensor module from the frame rail bracket and secure it to the SCR catalyst.
6. Disconnect the wire harness to the control module on the SCR catalyst.
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

NOTICE

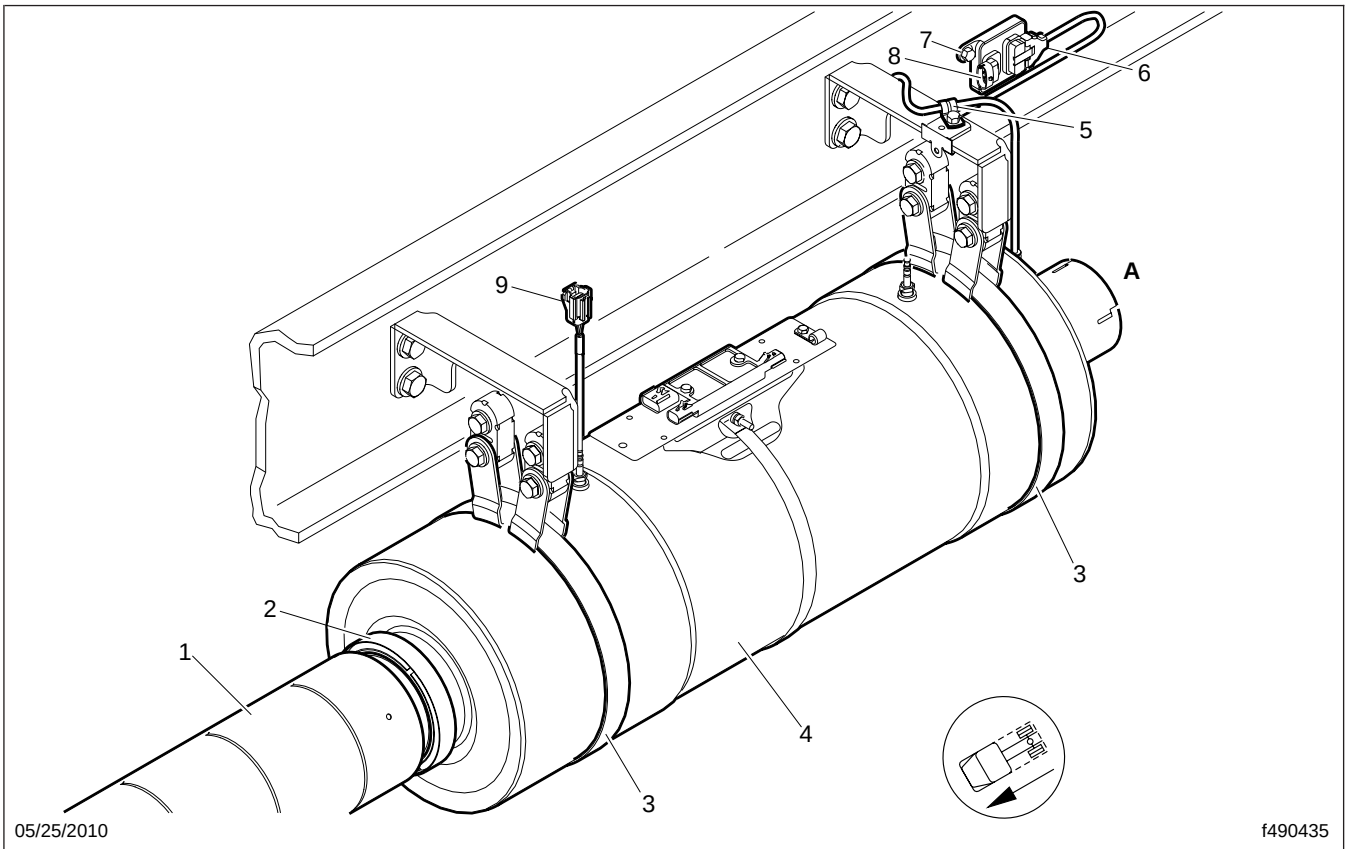
Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

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 120 lbf·in (1356 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.

Cummins 2HH SCR Catalyst Removal and Installation



A. To Exhaust Piping

1. Mixer Tube
2. Spherical Clamp
3. Mounting Strap
4. SCR Catalyst
5. Hose Clamp
6. NOx Sensor Module
7. 5/16–18 Bolt, Nut, Flatwasher
8. Chassis Harness Connector
9. Temperature Sensor

Fig. 1, SCR Catalyst Installation

11. Remove the jack and cradle.
12. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Bellows Replacement

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.

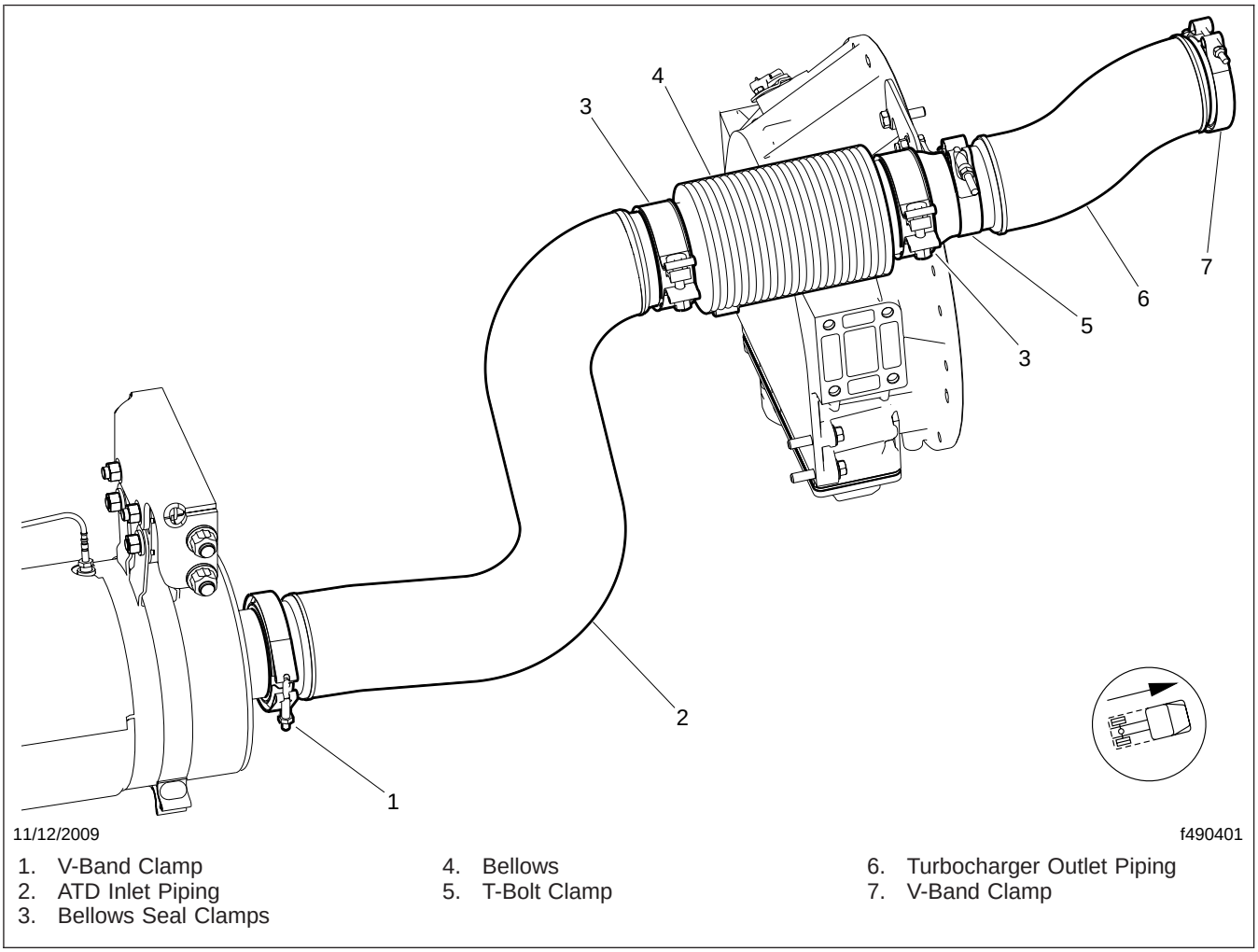
2. Allow the exhaust system to cool before working on it.
3. Make alignment marks on all of the components to be removed.
4. Remove the V-band clamp at the bellows outlet pipe. See **Fig. 1**. Discard the clamp.
5. Remove the V-band clamp at the turbocharger. Discard the clamp.
6. Remove the fasteners from the exhaust piping support bracket. See **Fig. 2**. Save the fasteners for reuse.
7. Remove the bellows and ATD exhaust piping as an assembly.
8. On a workbench, remove the exhaust bellows.
9. Slide the new exhaust bellows onto the exhaust piping, but do not tighten at this time.

NOTICE

Make sure that all exhaust outlet piping is installed or the DEF tank will be damaged.

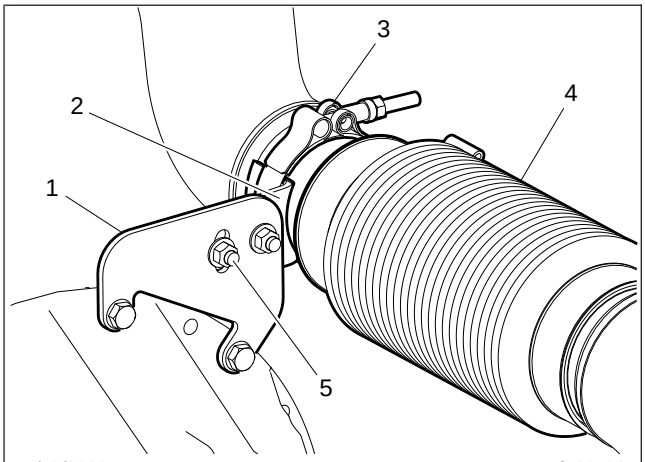
10. Position the bellows and exhaust piping on the chassis, and loosely install the support bracket fasteners.
11. Install a new V-band clamp on the exhaust bellows outlet. Do not tighten at this time.
12. Install a new V-band clamp at the bellows to the turbocharger outlet-pipe connection. Do not tighten at this time.
13. 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.
14. At each end of the bellows, tighten the seal clamp nuts 96 lbf·in (1085 N·cm).
15. Tighten the V-band clamp at the turbocharger outlet pipe connection 60 to 108 lbf·in (678 to 1220 N·cm).
16. Tighten the V-band clamp at the ATD inlet connection 48 to 60 lbf·in (542 to 678 N·cm).
17. Start the engine and check for leaks. Further tighten the clamps on any leaking connections as needed.

Bellows Replacement



1. V-Band Clamp
2. ATD Inlet Piping
3. Bellows Seal Clamps
4. Bellows
5. T-Bolt Clamp
6. Turbocharger Outlet Piping
7. V-Band Clamp

Fig. 1, Exhaust Piping, Engine to ATD



1. Exhaust Piping Support Plate
2. Exhaust Piping Support Bracket
3. T-Bolt Clamp
4. Bellows
5. 3/8–16 Bolt, Nut, Washer

Fig. 2, Exhaust Piping Support Bracket 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 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 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.

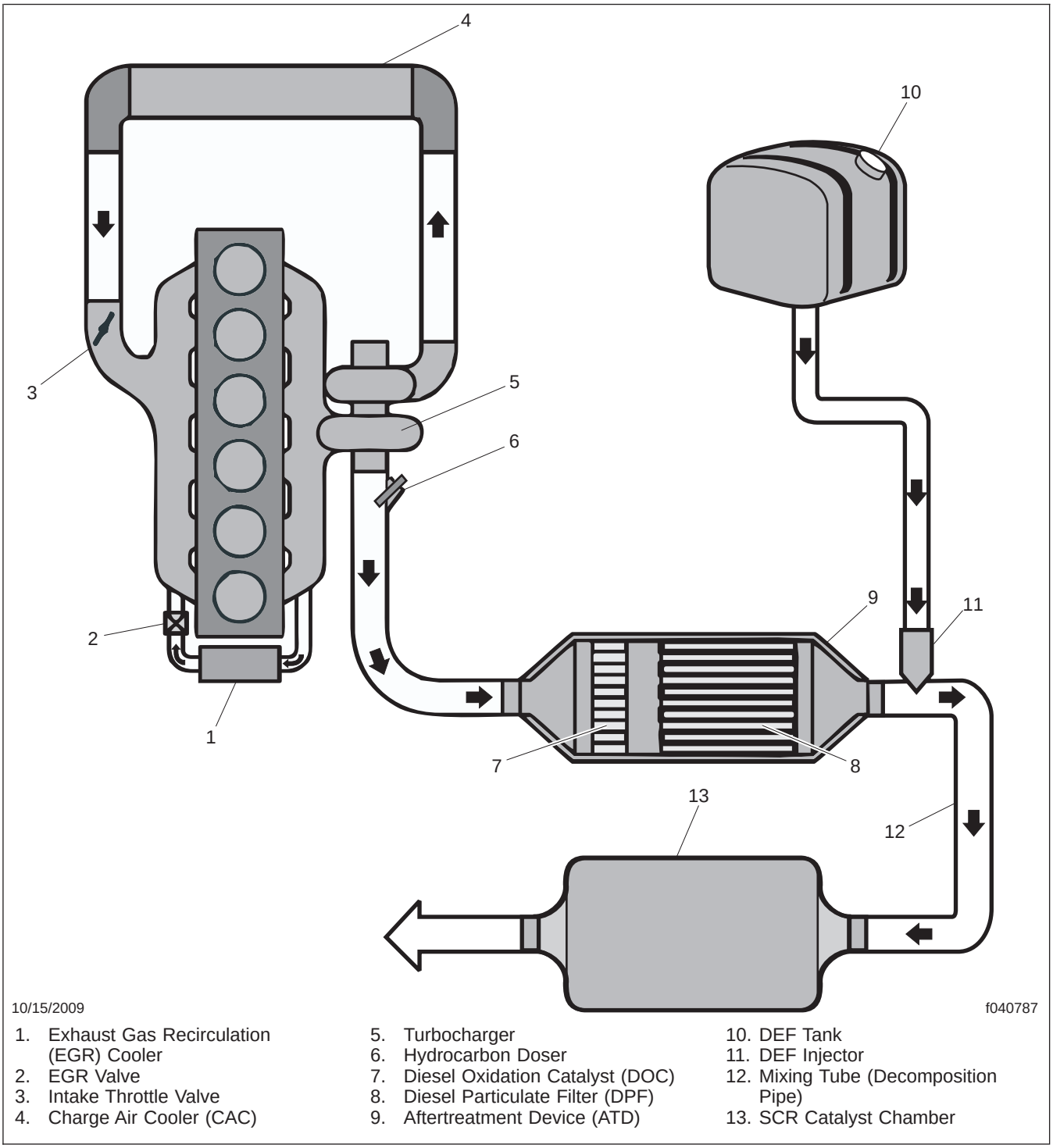
There are also safety controls that derate the engine if a contaminant has been introduced into the DEF tank. When a contaminant is detected, a minor engine derate will occur. When the vehicle has operated for 20 hours or 1000 miles with a contaminated tank, the vehicle will experience a major engine 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, DEF 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 *S2 Chassis Operator's and Maintenance Manual*.

For additional information on the ATS, see **Section 49.02**, Aftertreatment System, EPA10.

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 (Decomposition Pipe)
13. SCR Catalyst Chamber

Fig. 1, EPA10 Aftertreatment System

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.

10-Gallon Tank

Removal

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the coolant from the cooling system. For instructions, see **Group 20**.
3. Place a clean drain pan underneath the tank to catch draining DEF. Uncontaminated DEF may be reused.

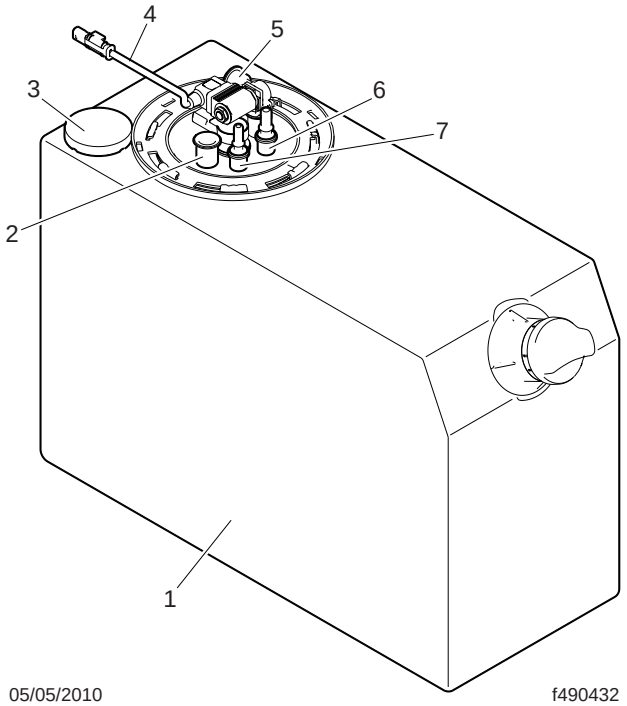
IMPORTANT: Wait at least five minutes after shutting down the engine to disconnect the DEF lines. Complete purging of the DEF lines requires approximately five minutes after the engine is shut down.

4. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank. See **Fig. 1**.

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 port.

5. Disconnect the DEF lines from the supply and return ports, and let the DEF drain into the drain pan.
6. Disconnect the wiring harness from the tank header unit.
7. Disconnect the coolant lines from the supply and return ports.



1. Tank
2. DEF Return
3. Vent
4. DEF Level and Temperature Sensor Wiring Harness
5. DEF Supply
6. Coolant Supply
7. Coolant Return

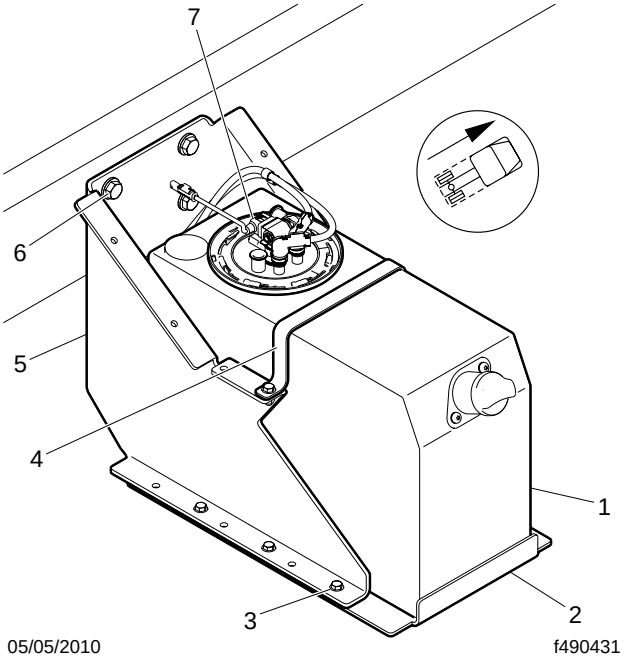
Fig. 1, 10-Gallon Tank Ports

8. Remove the fasteners and bolts that secure the tank in the mounting bracket assembly. See **Fig. 2**.
9. Remove the tank and mounting bracket assembly.

Installation

1. Install the tank and mounting bracket assembly.
2. Install the bolts and mounting fasteners, and tighten 23±3 lbf·ft (31±3 N·m).
3. Connect the coolant supply and return lines to the coolant ports on the top and back of the tank.
4. Remove any white DEF crystals from the DEF ports on the tank and the DEF line couplings.

Tank Removal and Installation



1. DEF Tank
2. Mounting Tray
3. 3/8–16 Bolt, Nut, Washer
4. Mounting Strap
5. Tank Mounting Bracket
6. 5/8–11 Bolt, Nut, Washer
7. Tank Header Unit

Fig. 2, DEF Tank Mounting

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 DEF ports on the back of the tank.
6. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
7. Connect the wiring harness to the tank header unit.
8. Fill the DEF tank.
9. Fill the cooling system. For instructions, see **Group 20**.

Tank Header Unit Replacement

The DEF header unit on vehicles with a 10-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.

The DEF temperature sensor detects when the temperature of the DEF in the tank is approaching its freezing point. As soon as the engine coolant reaches a temperature of 149°F (65°C), 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. The coolant then flows to the DEF pump, and is finally redirected back to the engine.

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.

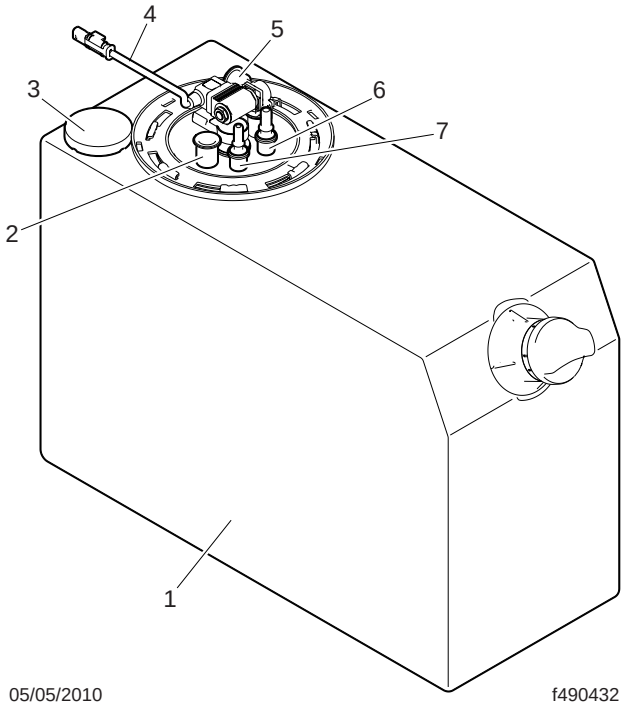
Replacement

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Drain the coolant from the cooling system. For instructions, see **Group 20**.
3. Place a drain pan underneath the DEF tank to catch any draining DEF or remaining coolant.
4. Disconnect the coolant valve and DEF level and temperature sensor wiring harnesses from the tank header unit. See **Fig. 1**.
5. 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.

6. Disconnect the DEF line heater wiring harnesses from the DEF lines at the tank.



1. Tank
2. DEF Return
3. Vent
4. DEF Level and Temperature Sensor Wiring Harness
5. DEF Supply
6. Coolant Supply
7. Coolant Return

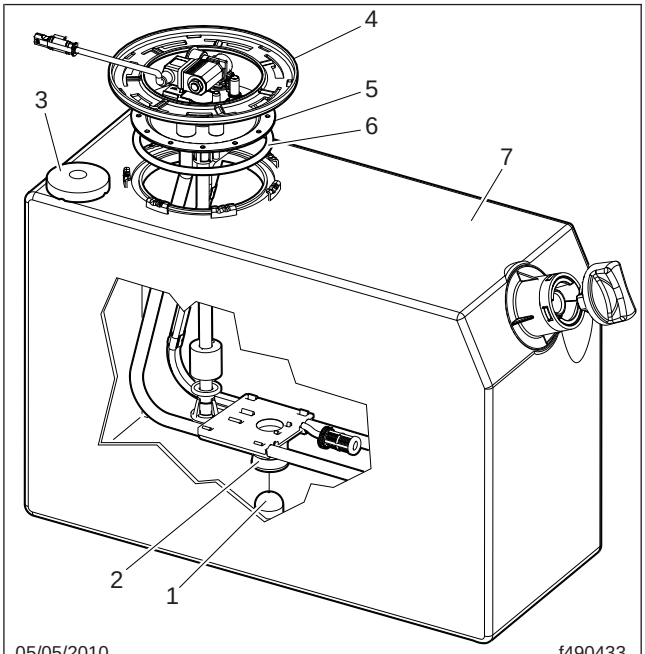
Fig. 1, 10–Gallon Tank Ports

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 port.

7. Disconnect the DEF lines from the tank header unit.
8. Rotate the header lockring counter-clockwise to loosen it, then remove the lockring. See **Fig. 2**.
9. 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;

Tank Header Unit Replacement



1. Locator Nub
2. Header Support Grommet
3. Vent
4. Lockring
5. Tank Header
6. Header O-Ring
7. Tank

Fig. 2, Header Unit Assembly

10. 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 header support grommet on the locator nub.
11. Install the header lockring and rotate it clockwise to secure it to the tank. Make sure the O-ring, between the lockring and the tank, is in the molded groove and is not pinched when the lock-ring is rotated in place.
12. Remove any white DEF crystals from the DEF ports on the header unit and the DEF line cou-plings.

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.

13. Connect the DEF supply and return lines to the DEF ports on the tank header unit.
14. Connect the DEF line heater wiring harnesses to the DEF lines at the tank.
15. Connect the coolant lines to the tank header unit.
16. Connect the coolant valve and DEF level and temperature sensor wiring harnesses to the tank header unit.
17. Fill the DEF tank.
18. Fill the cooling system. For instructions, see **Group 20**.

If a contaminant has been introduced into the system, use the instructions below to remove the contaminant from the diesel exhaust fluid (DEF) tank and components.

See the engine manufacturer's service literature for other component replacement instructions.

Flushing

If a contaminant has been introduced to the DEF tank, complete the following steps.

1. Apply the parking brake and chock the tires.
2. Place a suitable container underneath the DEF tank to catch draining DEF.

IMPORTANT: Discard contaminated DEF and coolant in accordance with EPA regulations.

3. Drain the DEF tank.

   Disconnect the DEF lines from the supply and return ports and let the DEF drain into the drain pan.
4. Remove the DEF dosing unit filter.
5. Thoroughly flush the DEF lines with distilled water, then reinstall the DEF lines.
6. Fill the DEF tank with distilled water.
7. Perform the INSITE™ electronic service tool "Diesel Exhaust Fluid Doser Pump Override Test." Repeat the test until the distilled water runs clear.
8. Drain the distilled water from the DEF tank and fill the tank with new DEF.
9. Install a new DEF dosing unit filter.
10. Test the performance and spray pattern of the DEF dosing valve by performing the INSITE™ electronic service tool "Diesel Exhaust Fluid Doser Pump Override Test."
11. Perform a parked regen. See **Chapter 8** of the *S2 Chassis Operator's Manual*.
12. Road test the vehicle for 30 minutes to verify system operation.

Introduction to Multiplexing

The term "multiplexing" describes how the vehicle's electrical system works. Multiplexing is defined as sending multiple electronic messages through the same signal path at the same time—in this case, through the vehicle's wiring.

Multiplexing allows a vehicle's electrical system to simultaneously perform tasks and to monitor components. A multiplexed system uses electronic control units (ECUs) to operate the system. The electrical system components, such as switches and lamps, are connected to the ECUs, which collect and control all information about the components by communicating on the datalink.

A less formal description might be that multiplexing is much like the interstate highway system. Trucks and cars share the roadway, with each vehicle bound for a different destination. Every vehicle travels at different speeds, enters and exits at different places, and the occupants of every vehicle have different objectives. Whether it is a truck driver hauling goods from a factory to a store or a saleswoman heading home from work, highway users are like the electronic signals flashing along the datalink.

Multiplexing was introduced in vehicles in the 1980's with the first electronically controlled engines and the initial use of the J1708/J1587 datalink. 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

The multiplexed electrical system replaces traditional power distribution module (PDM) devices, such as relays and circuit breakers, with electronic devices that communicate over the vehicle datalinks. These electronic devices control power distribution to the vehicle's electric loads. This is done by monitoring inputs (such as sensors and switches) and supplying power to outputs (such as lighting, displays, gauges, and indicators). This distributed approach to handling switch inputs and controlling electrical load outputs sharply reduces the number of wires 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 shared-wire J1939 datalink to control outputs.

The system communicates on two datalinks: the J1939 datalink and the J1708/J1587 datalink. J1939 is the primary datalink and is used for all control messaging and troubleshooting; J1708/J1587 is the secondary datalink and is used for limited troubleshooting. Fault codes are displayed on the instrument cluster display and they may also be viewed on ServiceLink.

The multiplexed system utilizes the following controllers: the Bulkhead Module (BHM), the Chassis Module (CHM), the optional Expansion Module (EXM), and the optional Switch Expansion Module (SEM). The most important part of the multiplexed electrical system is the BHM. The BHM is the brain of the entire system, and controls all of the outputs in response to changes in any of the inputs. The CHM, EXM, and SEM are slaves to the BHM and respond to commands from the BHM and broadcast the status of the inputs and outputs connected to them. See **Fig. 1**.

See **Fig. 2** 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 to know which outputs it should activate for each input signal and where those outputs are located (i.e. 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. However, because the right headlamp low beam outputs are located on the CHM, the BHM must send a message over J1939 to the CHM to tell 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.

For an example of the flash-to-pass function, see **Fig. 3**. In this case, the input comes from the multifunction (turn signal) switch mounted on the steering column. It goes into the instrument cluster (ICU3-M2) for processing. The instrument cluster sends a message on J1939 to the BHM informing it of the multifunction switch status. The output for the left head-

General Information

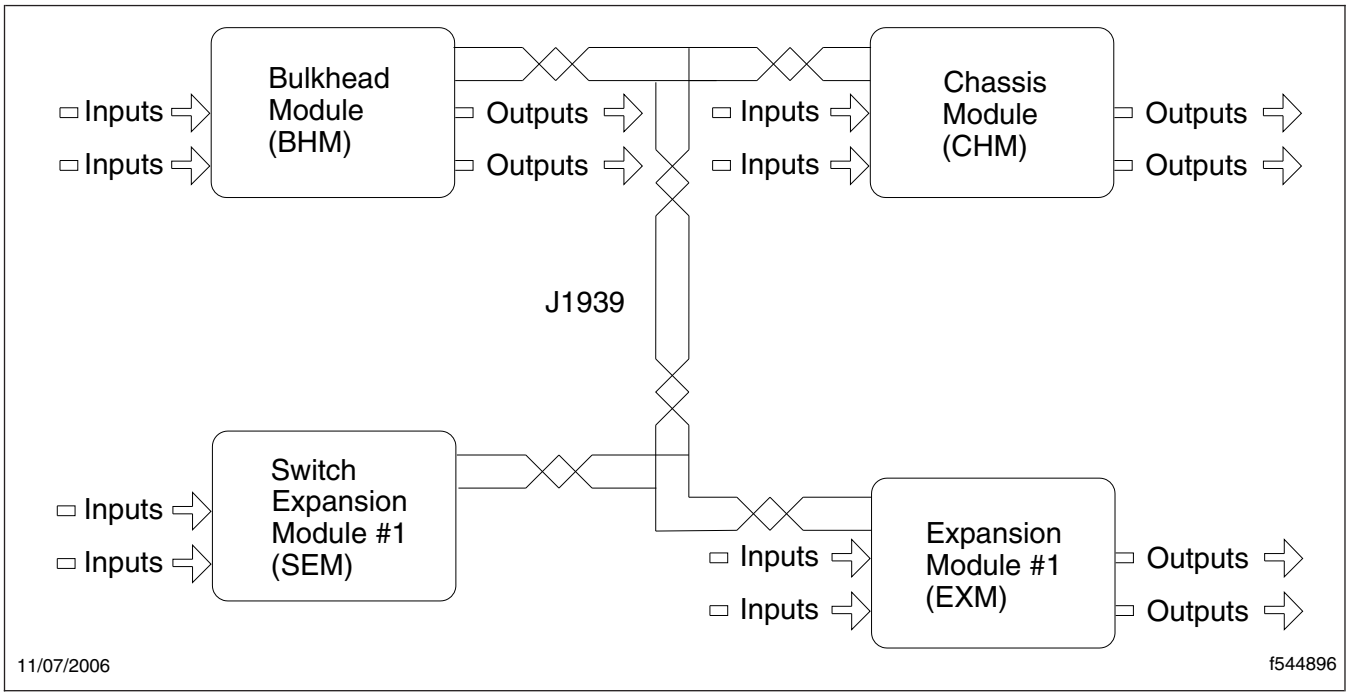


Fig. 1, Multiplexed System Controllers

lamp high beam is located on the BHM and the output for the right headlamp high beam is located on the CHM. The BHM directly flashes the left headlamp high beam and sends a message over J1939 to the CHM to tell it to flash the right headlamp high beam. Once the CHM receives the message, it flashes the headlamp high beam and sends a message back to the BHM reporting the new status of the output. To complete the loop, the BHM sends a message over J1939 to the instrument cluster reporting that the command was completed. These messages are transmitted so quickly that the entire process takes only a fraction of a second.

The final example is the parking brake telltale. See **Fig. 4**. To avoid driving away with the parking brake set, the system is designed to warn the driver. When the driver pulls out the parking brake switch on the dash to set the parking brake, the CHM senses the air pressure input from the parking brake switch in the air management unit (AMU). On vehicles equipped with an auxiliary air valve assembly (AAVA), the pressure switch is located in the air line behind the dash. The CHM sends a J1939 message to the BHM, the BHM sends a J1939 message to the ICU, and the ICU turns on the parking brake telltale dash light.

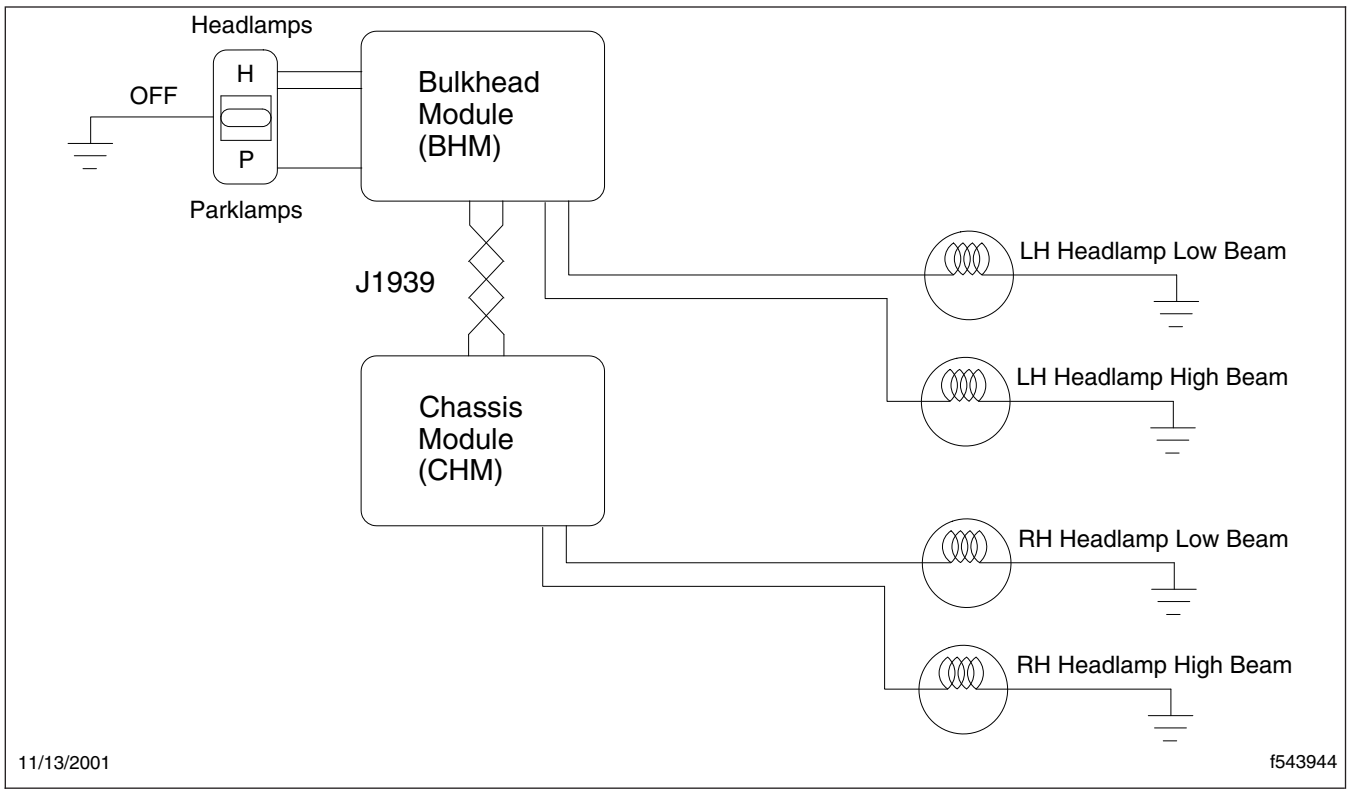


Fig. 2, Headlamp Switch Example

General Information

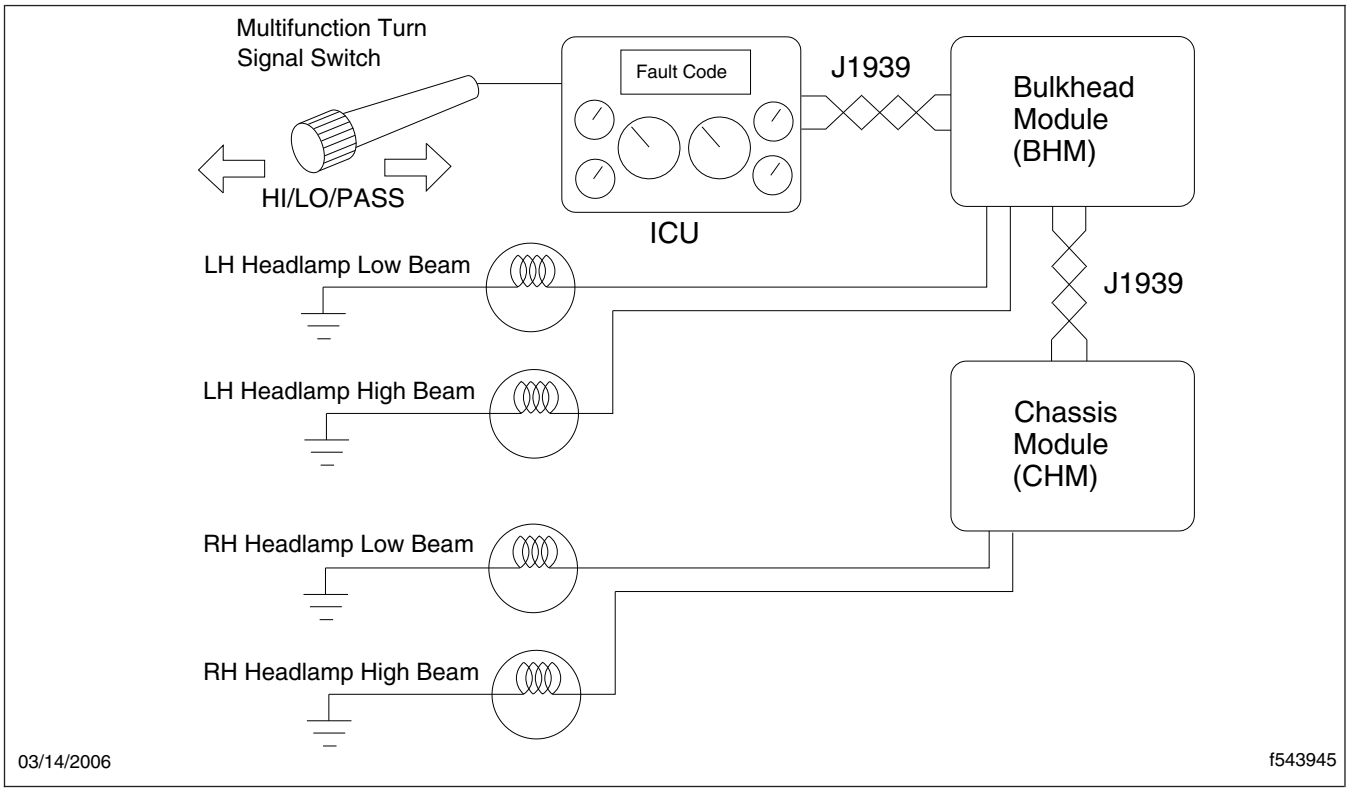


Fig. 3, Flash-To-Pass Example

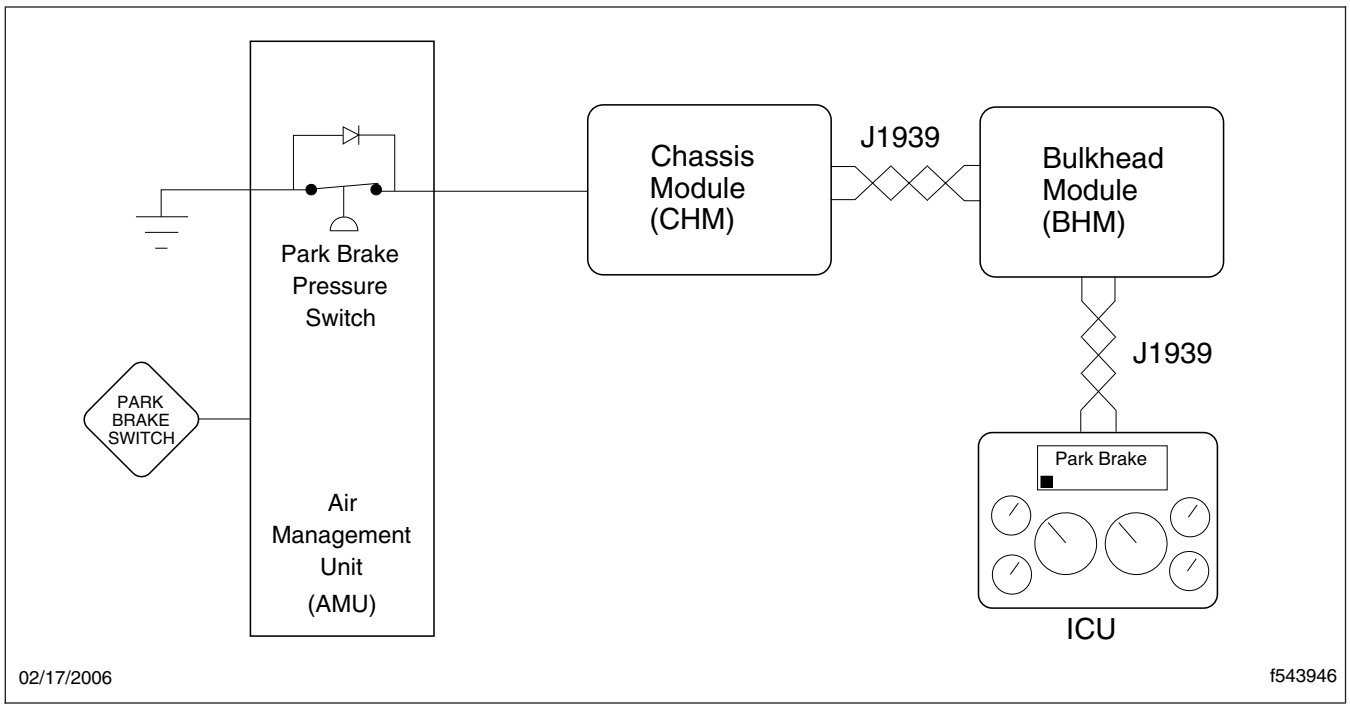


Fig. 4, Park Brake Telltale Example

Definition of Terms

Use the following list to determine the meaning of the abbreviations and terms used in **Group 54**.

8SB 8-Switch Bank. Connects Smart Switches to the Switch Hub Module (SHM).

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.

Datalink A collection of wires connecting system components through which data is transmitted.

DRL Daytime Running Lights

DTC Diagnostic Trouble Code

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 limited to a maximum number of characters by the display output and cross-referenced to a more descriptive message. On J1939, fault codes are made up of a SA, SPN, and FMI. On J1708/J1587, fault codes are made up of a MID, PID/SID, and FMI.

FMEA Failure Mode Effects Analysis

FMI Failure Mode Indicator. The part of a J1708/J1587 or 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, Ventilation, and Air Conditioning

ICU Instrumentation Control Unit

Input A device that feeds a signal into the system, or signal that feeds a message 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 J1708/J1587.

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

Definition of Terms

PID Parameter Identifier. The part of a J1708/J1587 fault code that identifies what part of or item on a device that failed. PIDs are not MID specific.

PRD Product Requirements Document

PWM Pulse Width Modulation

SA Source Address. Identifies any device that communicates on J1939.

SAE Society of Automotive Engineers

SEM Switch Expansion Module

SID Subsystem Identifier. The part of a J1708/J1587 fault code that identifies what part of or item on a device that failed. SIDs are MID specific.

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 item 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 program the BHM to know which outputs to activate for each input and where those outputs are located. The two types of reference parameters are default and optional. Every vehicle has one default reference parameter and zero to any number of optional reference parameters.

The default reference parameter programs the BHM with features that come standard on each vehicle, such as headlights. Optional reference parameters program the BHM for vehicle-specific features, such as heated mirrors.

Each reference parameter is given a part number just like any other hardware part on the vehicle. A reference parameter only programs the parameters of the BHM.

Reflashing or reprogramming the software is separate from programming the parameters, just as it is in an engine controller.

Changing Features and Options

Features can be changed with ServiceLink from the Features screen under the Bulkhead Module (BHM) Icon. The Features screen 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.

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 vehicle electrical system.

The modules of the multiplexed electrical system communicate on both J1939 and J1708/J1587. The primary datalink for the electrical system is J1939, and is used for all control messaging and troubleshooting. J1708/J1587 is the secondary datalink and is used for limited troubleshooting. Fault codes are displayed on the instrument cluster, and can also be viewed with ServiceLink.

Since the modules of the electrical system communicate on both J1939 and J1708/J1587, each icon in ServiceLink shows information for both datalinks. Although each module connected to the multiplexed electrical system is represented by an icon in ServiceLink, the Bulkhead Module (BHM) icon is the main icon for troubleshooting the system. This is because the Bulkhead Module (BHM) is the main controller of the multiplexed system. The other icons are secondary and contain generic screens.

The following generic screens can be accessed under the icon for any Electronic Control Unit (ECU) on the datalink.

- **General Info**—Displays information about the module, such as Make, Model, Hardware Version, and Software Version.
- **Faults**—BHM icon will contain all active and historic faults for the entire multiplexed electrical system. The other control modules, Chassis Module (CHM), Expansion Module (EXM), and Switch Expansion Module (SEM), will show only generic faults.
- **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.
- **Configuration**—Displays the pin-out for that particular module compared to the host.

  This screen can be accessed under all the control modules — the BHM, the CHM, the SHM, and the EXM.
- **Flashing**—Allows the user to update or reflash the software of the module.

  This screen can be accessed under the icons for the reflashable modules—BHM and the SEM.
- **Smart Switches**—Allows the user to view data about Smart Switches connected to these ECUs.

  This screen can be accessed under the icon for SEM.

  NOTE: This information is NOT available for Smart Switches that are connected to the BHM.
- **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.

  This screen can be accessed under the BHM icon only.

NOTE: For more specific information about the Bulkhead Module see **Section 54.01**. For more specific troubleshooting information see **Subject 300** in that same section.

Troubleshooting the J1939 Datalink

The J1939 datalink always has two 120 ohm terminating resistors, one at each end of the backbone. The purpose of the terminating resistors is to minimize the reflection of data on the datalink. Collision of reflected data can cause J1939 messages to become partially or completely lost. Data collision can also cause the data to be erratic. Terminating resistors prevent this from occurring. Although the J1939 datalink may function with a missing or failed terminating resistor, data collision can occur and cause problems.

Since the resistors are in parallel with one another, their total resistance equals 60 ohms. What this means is if you remove a terminating resistor and check its resistance, it should be 120 ohms. How-

ever, with both resistors installed in the circuit there should be 60 ohms measured at any two points between J1939+ and J1939– in the circuit (for example between pins C and D of the diagnostic connector).

NOTE: This only applies when the batteries are disconnected.

Use the following four basic steps in the order given to successfully locate J1939 datalink problems. Do not skip steps or tests unless directed to do so.

Step 1: J1939 Resistance Test

This test checks whether or not both terminating resistors are installed and it ensures that there is at least a complete circuit from the diagnostic connector through the backbone loop. It does not ensure that branch circuits to each ECU are working correctly.

IMPORTANT: The batteries must be disconnected prior to any J1939 resistance tests. Failure to do so will result in incorrect resistance measurements.

1. Turn the ignition OFF and disconnect the batteries.
2. Connect the leads of a digital multimeter (DMM) to pins C and D of the 9-pin diagnostic connector. Set the DMM to read in ohms.
3. Measure the resistance. See **Table 1** for test results and possible causes.
4. Connect the batteries.

J1939 Resistance Test	
Test Result	**Possible Cause(s)**
60Ω ± 6Ω	The J1939 datalink backbone is intact and both terminating resistors are installed. Go to step 2.
120Ω ± 12Ω	Either of the following: • One of the terminating resistors is missing. • One of the terminating resistors is open.
40Ω ± 4Ω	Three terminating resistors have been installed; one must be removed. There must be one terminating resistor at each end on the backbone for a total of two.
0Ω to 5Ω	J1939+ and J1939– are shorted together somewhere in the datalink.
Greater than 1000Ω	Either of the following: • An open in the circuit between the diagnostic connector and the J1939 backbone. • 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 1, J1939 Resistance Test

Step 2: ECU Communication Test Using Datalink Monitor Template

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.

Test 1: Check Whether Each ECU Connected to the J1939 Datalink Responds

1. Connect ServiceLink to the vehicle.
2. Open the "M2 J1939 Test" datalink monitor template.
3. Following the instructions in the template, check whether each ECU that is supposed to be connected to the datalink responds. See **Table 2** for test results and possible causes.

Test 2: Check the J1939 Datalink Wiring to the ECU that Does Not Respond

IMPORTANT: The batteries must be disconnected prior to any J1939 resistance tests. Failure to do so will result in incorrect resistance measurements.

1. Disconnect the batteries.
2. Locate the connector at the ECU in Step 2, Test 1 that did not respond, and disconnect it.
3. Locate the pins for J1939+ and J1939– (refer to appropriate wiring diagrams if necessary).
4. Check to make sure the J1939+ and J1939– polarity is correct at the component before proceeding. If reversed, correct the wiring and verify that this corrected the problem.
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 (harness side).
6. Connect the batteries when the test is completed. See **Table 3** for test results and possible causes.

Check Whether Each ECU Connected to the J1939 Datalink Responds	
Test Result	**Possible Cause(s)**
All ECUs respond	The J1939 datalink is probably not the problem.
One ECU fails to respond	Go to test 2.
No ECUs respond	Any of the following: • The polarity of J1939+ and J1939– at the diagnostic connector may be reversed. • There may be a problem with the computer to vehicle communications adapter or cables. • 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 2, Check Whether Each ECU Connected to the J1939 Datalink Responds

Check the J1939 Datalink Wiring to the ECU that Does Not Respond	
Test Result	**Possible Cause(s)**
60Ω ± 6Ω	The datalink itself is probably not the problem. Make sure there is power and ground to the suspect ECU. Go on to Test 3 after ECU power and ground connections have been confirmed.
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 3, Check the J1939 Datalink Wiring to the ECU that Does Not Respond

Test 3: Install a Test ECU to Confirm the Problem

1. Install a test ECU.
2. Connect ServiceLink to the vehicle.
3. Open the "M2 J1939 Test" datalink monitor template.
4. Following the instructions contained in the template, check whether each ECU that is supposed to be connected to the datalink responds. See **Table 4** for test results and possible causes.

Step 3: Testing J1939 for Circuit Faults (Shorts to Power and Ground)

This test checks for shorts to power and shorts to ground on the J1939 datalink.

NOTE: All tests are performed using a digital multimeter (DMM) set to read voltage.

Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition on, use a DMM to test for voltage at pin B by placing the positive (+) lead on pin B and the negative (–) lead on a good chassis ground.

Test 1: Test J1939+ for Shorts to Power and Ground

1. Turn the ignition ON.
2. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin C (J1939+) of the diagnostic connector. See **Table 5** for test results and possible causes.

Test 2: Test J1939– for Shorts to Power and Ground

1. Turn the ignition ON.
2. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin D (J1939–) of the diagnostic connector. See **Table 6** for test results and possible causes.

Step 4: Pinpointing Short Circuits on the J1939 Datalink

These tests pinpoint shorts to power and shorts to ground on the J1939 datalink. The tests will indicate which side of the cab/engine interface that the problem exists. It will also indicate whether the problem is in the wiring outside or inside the cab.

NOTE: All tests are performed using a DMM set to read voltage.

Before proceeding, verify that battery voltage (approximately +12 VDC) is available at pin B of the diagnostic connector. With the ignition on, use a DMM to test for voltage at pin B by placing the positive (+) lead on pin B and the negative (–) lead on a good chassis ground.

Test 1: Pinpoint J1939+ Short to Power or Ground

NOTE: Perform this test only if directed here in Step 3, Test 1.

1. Disconnect the 76-pin cab-to-engine bulkhead connector that contains J1939 wiring.
2. Turn the ignition ON.
3. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin C (J1939+) of

the diagnostic connector. See **Table 7** for test results and possible causes.

Test 2: Pinpoint J1939– Short to Power or Ground

NOTE: Perform this test only if directed here in Step 3, Test 2.

1. Disconnect the 76-pin cab-to-engine bulkhead connector that contains J1939 wiring.
2. Turn the ignition ON.
3. Touch the positive (+) lead to pin B (+12 VDC) and the negative (–) lead to pin D (J1939–) of the diagnostic connector. See **Table 8** for test results and possible causes.

Install a Test ECU to Confirm the Problem	
Test Result	**Possible Cause(s)**
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 the Customer Assistance Center.

Table 4, Install a Test ECU to Confirm the Problem

Test J1939+ for Shorts to Power and Ground	
Test Result	**Possible Cause(s)**
0 VDC	J1939+ is shorted to power. Go to Step 4, Test 1.
12 VDC (battery voltage)	J1939+ is shorted to ground. Go to Step 4, Test 1.
Any other reading	J1939+ is neither shorted to power or ground. Go to Step 3, Test 2.

Table 5, Test J1939+ for Shorts to Power and Ground

Test J1939+ for Shorts to Power and Ground	
Test Result	**Possible Cause(s)**
0 VDC	J1939– is shorted to power. Go to Step 4, Test 2.
12 VDC (battery voltage)	J1939– is shorted to ground. Go to Step 4, Test 2.
Any other reading	J1939– is neither shorted to power or ground. There may be a problem with the computer to vehicle communications adapter or cables. The datalink itself appears to be okay.

Table 6, Test J1939+ for Shorts to Power and Ground

Pinpoint J1939+ Short to Power or Ground	
Test Result	**Possible Cause(s)**
0 VDC	J1939+ is shorted to power inside the cab. Locate and repair the short.
12 VDC (battery voltage)	J1939+ is shorted to ground inside the cab. Locate and repair the short.

Pinpoint J1939+ Short to Power or Ground	
Test Result	**Possible Cause(s)**
Any other reading	J1939+ is shorted to power or ground outside of the cab. Locate and repair the short.

Table 7, Pinpoint J1939+ Short to Power or Ground

Pinpoint J1939– Short to Power or Ground	
Test Result	**Possible Cause(s)**
0 VDC	J1939– is shorted to power inside the cab. Locate and repair the short.
12 VDC (battery voltage)	J1939– is shorted to ground inside the cab. Locate and repair the short.
Any other reading	J1939– is shorted to power or ground outside of the cab. Locate and repair the short.

Table 8, Pinpoint J1939– Short to Power or Ground

Troubleshooting the J1587 Datalink

J1587 is a low-speed vehicle datalink that can communicate information between ECUs on the vehicle. The J1587 datalink is also referred to as J1708. J1708 refers to the Society of Automotive Engineers (SAE) standard for the physical part of the datalink, meaning the wiring and electronic component requirements. 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 synonymously.

Symptoms of a Malfunctioning J1587 Datalink

Possible symptoms of a malfunctioning J1587 datalink include the following:

- gauges are not working
- ICU displays "noJ1587", "no Eng", or "no Abs"
- warning lamp(s) on (ABS, Check Engine)
- cannot retrieve fault codes from an ECU
- ServiceLink will not connect to the vehicle
- one or more ECUs do not show up in the ServiceLink ECU list

See **Table 9** for diagnosing the J1587 datalink.

Diagnosing the J1587 Datalink			
Test	**Test Description**	**Result**	**Action**
1.	Attempt to connect ServiceLink and refresh the ECU list. If ServiceLink connects to the J1587 datalink, the ECU list will say "J1708--Detected" and some or all ECUs will show up in white under the J1708 ECU list. Will ServiceLink connect to the J1587 datalink?	Yes	Go to test 9.
		No	Go to test 2.

Diagnosing the J1587 Datalink			
Test	**Test Description**	**Result**	**Action**
2.	Repeat test 1 on another vehicle with a known good J1587 datalink. Will ServiceLink connect to the other vehicle?	Yes	Go to test 3.
		No	Check the cables between the computer and the vehicle. Check the vehicle interface adapter and the computer settings. Repair as necessary.
3.	Make sure the parking brake is set. Turn the ignition on. Does the ICU display "noJ1587"?	Yes	Go to test 5.
		No	Go to test 4.
4.	Is the power light illuminated on the vehicle interface adapter?	Yes	Check the J1587 datalink wiring between the diagnostic connector and the dash junction block for shorts. Repair as necessary.
		No	Check the power and ground supply to the diagnostic connector. If it is okay, check the computer cable and interface device. Repair as necessary.
5.	Disconnect BHM connector B1. Attempt to connect ServiceLink and refresh the ECU list. If ServiceLink connects to the J1587 datalink, the ECU list will say "J1708--Detected" and the ICU, BHM, and other ECUs (depending on vehicle configuration) will show up in white under the J1708 ECU list. Does ServiceLink connect to the J1587 datalink?	Yes	There is a problem in the J1587 wiring outside of the cab between the BHM connector B1 and the ABS and CHM. Locate the source of trouble and repair as necessary.
		No	Go to test 6.
6.	Check if the vehicle is equipped with any of the following: • Non M-B engine (CAT, etc.) • Allison transmission	Yes	Go to test 7.
		No	Go to test 8.
7.	Disconnect the BHM connector C2. Attempt to connect ServiceLink and refresh the ECU list. If ServiceLink connects to the J1587 datalink, the ECU list will say "J1708--Detected" and the ICU, BHM, CHM, and other ECUs (depending on vehicle configuration) will show up in white under the J1708 ECU list. Does ServiceLink connect to the J1587 datalink?	Yes	There is a problem in one of the following J1587 circuits: • Between the BHM and engine (non M-B only) • Between the BHM and the transmission (Allison only) Repair as necessary.
		No	Go to test 8.

Troubleshooting

Diagnosing the J1587 Datalink			
Test	**Test Description**	**Result**	**Action**
8.	Locate the J1587 junction block behind the center dash panel. Follow the steps below: 1. Disconnect one of the J1587 connectors on the junction block. 2. Attempt to connect ServiceLink and refresh the ECU list. Does either the ICU or the BHM now show up in the ECU list (in white)? If it does, stop and follow the "yes" test result action in the column to the right. If not, continue to step 3. 3. Plug the connector back into the junction block. 4. Unplug the connector on the J1587 junction block that has not yet been disconnected. 5. Refresh the ServiceLink ECU list. Does either the ICU or the BHM now show up in the ECU list (in white)? If it does, stop and follow the "yes" test result action in the column to the right. If not, continue to step 6. 6. Are there any remaining connectors on the junction block that have not yet been disconnected? If so, go to step 3. If not, follow the "no" test result action in the column to the right.	Yes	The J1587 circuit that was just disconnected from the junction block is shorted or the ECU on that circuit is faulty. Repair as necessary.
		No	There is a short between the J1587 junction block and the diagnostic connector.
9.	With ServiceLink connected, look at the ECU list and determine which ECU(s) do NOT show up in white: CASE 1: All ECUs show up. CASE 2: The BHM, CHM, and all other outside-of-cab ECUs. CASE 3: The ICU or one of the other inside-of-cab ECUs. CASE 4: One of the outside cab ECUs. CASE 5: All ECUs except the CHM.	CASE 1	There is no problem found.
		CASE 2	Check the J1587 wiring between the BHM and the J1587 junction block for an open circuit. Repair as necessary.
		CASE 3	Check the J1587 wiring between the ECU that does not show up and the J1587 junction block for an open circuit. Check the power and ground circuits to the missing ECU and the ECU itself.
		CASE 4	Check the J1587 wiring between the ECU that does not show up and the BHM for an open circuit. Check the power and ground circuits to the missing ECU and the ECU itself.
		CASE 5	Check the power and ground supply to the BHM. Check the BHM itself.

Table 9, Diagnosing the J1587 Datalink

General Information

This subject contains information on all proprietary Bulkhead Module (BHM) fault codes for J1587 and J1939 datalink protocols, how to view these codes, and what they mean. Each fault code contains three distinct pieces of information, as described below.

NOTE: References such as BHM B1.A (beginning with SID 050 in **Table 1**) indicate that the fault is sensed to be coming from the Bulkhead Module, connector B1, pin A. Similarly, CHM indicates the Chassis Module, and EXM1-5 indicates the first through fifth Expansion Modules on a vehicle.

J1587 fault codes consist of the following, in this order:

- Message Identifier (MID) – Identifies which Electronic Control Unit (ECU) the fault is coming from. The J1587 MID identifying all Bulkhead Module faults is 164.
- Subsystem Identifier (SID) – Indicates what function on the ECU has failed. All J1587 SIDs for the BHM are listed in **Table 1**.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed.

J1939 faults consist of the following, in this order:

- Source Address (SA) – Identifies which ECU the fault is coming from. The J1939 SA identifying all Bulkhead Module faults is 33.
- Suspect Parameter Number (SPN) – Indicates what function on the ECU has failed. All J1939 SPNs for the BHM are listed in **Table 2**.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed.

Also included is a reference table of all FMIs for both datalink protocols. See **Table 3**.

NOTE: In ServiceLink, J1587 fault codes are shown under J1708. J1587 and J1708 are essentially the same datalink protocol.

NOTE: As the SAE J1939 subcommittee approves new SPNs for use in J1939 messaging on a continual basis, J1939 SPNs used for diagnostic messages could change when the Bulkhead Module part changes. These changes could impact any diagnostic message with an SPN value of 6915 or higher.

J1587 SIDs for Bulkhead Module (BHM) MID 164

SID	Description	Possible FMI
000	Backlighting Dimmer Switch Fault	7
001	Clutch Switch Fault	7
002	Reserved for Future Use	—
003	Headlamp Switch Disagreement - Both Park and On Inputs are CLOSED	7
004	Stalk Switch High Beam Input Fault	2
005	Ignition Switch Fault	7
006	Marker Interrupt Switch Fault	7
007	Stalk Switch Disagreement - Both Wiper High and Wiper Low Inputs are ON	2
008	Stalk Switch Disagreement - Wiper On/Off Input is OFF and Wiper High or Low Input is ON	2
009	Wiper Park Input Fault	7
010	ICU3-M2 Hazard Switch CAN Feedback Error	2
011	Stalk Switch Left Turn Signal Input Fault	2

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
012	Stalk Switch Right Turn Signal Input Fault	2
013	Stalk Switch Washer Switch Input Fault	2
014	Stalk Switch Wiper On/Off Input Fault	2
015	Stalk Switch Wiper Low Input Fault	2
016	Stalk Switch Wiper High Input Fault	2
017	Wheel Based Vehicle Speed CAN Message Error	2
018	Wake up Hardware Fault (modules are kept awake)	7
019	Unknown Keep Awake Fault (modules are kept awake)	7
020	Extra Smart Switch	7
021	Duplicate Smart Switch	7
022	Missing Smart Switch	7
023	Fifth Wheel Solenoid Unexpected Pressure Feedback	7
024	Fifth Wheel Solenoid No Pressure Feedback	7
025	End of Frame Air Unexpected Pressure Feedback	7
026	End of Frame Air No Pressure Feedback	7
027	Axle Lift Unexpected Pressure Feedback	7
028	Axle Lift No Pressure Feedback	7
029	Suspension Dump Unexpected Pressure Feedback	7
030	Suspension Dump No Pressure Feedback	7
031	Suspension Proportioning Unexpected Pressure Feedback	7
032	Suspension Proportioning No Pressure Feedback	7
033	Cigar Lighter Output Fault	7
034	BHM / ICU3-M2 Ignition Mismatch	7
035	BHM / ICU3-M2 Hazard Switch Mismatch	2
036	BHM / ICU3-M2 Wiper Park Mismatch	2
037	Missing Transmission CAN Message	9
038	Missing Chassis Module CAN Message	9
039	Remote Bucket Switch Stuck Fault	7
040	Axle Lift 2 Feedback Fault	7
041	Axle Lift 2 No Feedback Fault	7
042	PTO 1 Feedback Fault	7
043	PTO 1 No Feedback Fault	7
044	PTO 2 Feedback Fault	7
045	PTO 2 No Feedback Fault	7
046-049	Reserved for Future Use	—

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
050	BHM B1.A	3,4
051	BHM B1.F, B1.P, B2.K, B2.L, B6.A8	5,6
052	BHM B1.J	3,4
053	BHM B1.K, B5.C	5,6
054	BHM B1.L	5,6
055	BHM B1.N	3,4
056	BHM B1.R	5,6
057	BHM B2.M	5,6
058	BHM B3.D	3,4
059	BHM B3.E	3,4,5,6
060	BHM B3.F	5,6
061	BHM B3.G	5,6
062	BHM B3.H	5,6
063	BHM B4.B	5,6
064	BHM B4.E, B4.F	3,4,5,6
065	BHM B4.G	3,4
066	BHM B4.K	3,4
067	BHM B4.M, B5.E	3,4,5,6
068	BHM B5.A, B7.A12	5,6
069	BHM B6.A9, B6.A10	5,6
070	BHM B5.B	5,6
071	BHM B5.D	5,6
072	BHM B5.F	3,4,5,6
073	BHM B5.G	3,4,5,6
074	BHM B5.H, B7.A1	3,4,5,6
075	CHM C1.A, C1.H, C1.J	5,6
076	CHM C1.G, C2.H, C3.N	5,6
077	CHM C1.L	5,6
078	CHM C1.N	5,6
079	CHM C1.P, C2.E, C3.R	5,6
080	CHM C2.A	3,4
081	CHM C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
082	CHM C3.A	3,4,5,6
083	CHM C3.C, C3.D	5,6
084	CHM C3.E	3,4

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
085	CHM C3.F	3,4
086	CHM C3.J	3,4
087	CHM C3.K	5,6
088	CHM C3.L	5,6
089	CHM C4.F	5,6
090	CHM C4.J	3,4
091	CHM C4.K	5,6
092	CHM C4.P	3,4
093	CHM C5.A	3,4
094	CHM C5.B	3,4
095	CHM C5.F	3,4
096	CHM C5.G	3,4
097	CHM C5.H	3,4
098	CHM C5.J	3,4
099	CHM C5.L	3,4
100	CHM C5.M	3,4
101	EXM1 C1.A, C1.H, C1.C	5,6
101	EXM1 C4.K	5,6
101	EXM1 C3.L	5,6
101	EXM1 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
101	EXM1 C1.N	5,6
101	EXM1 C1.L	5,6
101	EXM1 C1.P, C2.E, C3.R	5,6
101	EXM1 C1.G, C2.H, C3.N	5,6
101	EXM1 C2.A	3,4
101	EXM1 C3.A	3,4,5,6
101	EXM1 C3.C, C3.D	5,6
101	EXM1 C3.K	5,6
101	EXM1 C4.F	5,6
101	EXM1 C5.H	3,4
101	EXM1 C5.C	3,4
101	EXM1 C5.L	3,4
101	EXM1 C5.M	3,4
101	EXM1 C3.E	3,4
101	EXM1 C3.F	3,4

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
101	EXM1 C3.C	3,4
101	EXM1 C4.C	3,4
101	EXM1 C4.P	3,4
101	EXM1 C5.A	3,4
101	EXM1 C5.B	3,4
101	EXM1 C5.F	3,4
101	EXM1 C5.G	3,4
102	EXM2 C1.A, C1.H, C1.C	5,6
102	EXM2 C4.K	5,6
102	EXM2 C3.L	5,6
102	EXM2 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
102	EXM2 C1.N	5,6
102	EXM2 C1.L	5,6
102	EXM2 C1.P, C2.E, C3.R	5,6
102	EXM2 C1.G, C2.H, C3.N	5,6
102	EXM2 C2.A	3,4
102	EXM2 C3.A	3,4,5,6
102	EXM2 C3.C, C3.D	5,6
102	EXM2 C3.K	5,6
102	EXM2 C4.F	5,6
102	EXM2 C5.H	3,4
102	EXM2 C5.C	3,4
102	EXM2 C5.L	3,4
102	EXM2 C5.M	3,4
102	EXM2 C3.E	3,4
102	EXM2 C3.F	3,4
102	EXM2 C3.C	3,4
102	EXM2 C4.C	3,4
102	EXM2 C4.P	3,4
102	EXM2 C5.A	3,4
102	EXM2 C5.B	3,4
102	EXM2 C5.F	3,4
102	EXM2 C5.G	3,4
103	EXM3 C1.A, C1.H, C1.C	5,6
103	EXM3 C4.K	5,6

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
103	EXM3 C3.L	5,6
103	EXM3 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
103	EXM3 C1.N	5,6
103	EXM3 C1.L	5,6
103	EXM3 C1.P, C2.E, C3.R	5,6
103	EXM3 C1.G, C2.H, C3.N	5,6
103	EXM3 C2.A	3,4
103	EXM3 C3.A	3,4,5,6
103	EXM3 C3.C, C3.D	5,6
103	EXM3 C3.K	5,6
103	EXM3 C4.F	5,6
103	EXM3 C5.H	3,4
103	EXM3 C5.C	3,4
103	EXM3 C5.L	3,4
103	EXM3 C5.M	3,4
103	EXM3 C3.E	3,4
103	EXM3 C3.F	3,4
103	EXM3 C3.C	3,4
103	EXM3 C4.C	3,4
103	EXM3 C4.P	3,4
103	EXM3 C5.A	3,4
103	EXM3 C5.B	3,4
103	EXM3 C5.F	3,4
103	EXM3 C5.G	3,4
104	EXM4 C1.A, C1.H, C1.C	5,6
104	EXM4 C4.K	5,6
104	EXM4 C3.L	5,6
104	EXM4 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
104	EXM4 C1.N	5,6
104	EXM4 C1.L	5,6
104	EXM4 C1.P, C2.E, C3.R	5,6
104	EXM4 C1.G, C2.H, C3.N	5,6
104	EXM4 C2.A	3,4
104	EXM4 C3.A	3,4,5,6
104	EXM4 C3.C, C3.D	5,6

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
104	EXM4 C3.K	5,6
104	EXM4 C4.F	5,6
104	EXM4 C5.H	3,4
104	EXM4 C5.C	3,4
104	EXM4 C5.L	3,4
104	EXM4 C5.M	3,4
104	EXM4 C3.E	3,4
104	EXM4 C3.F	3,4
104	EXM4 C3.C	3,4
104	EXM4 C4.C	3,4
104	EXM4 C4.P	3,4
104	EXM4 C5.A	3,4
104	EXM4 C5.B	3,4
104	EXM4 C5.F	3,4
104	EXM4 C5.G	3,4
105	EXM5 C1.A, C1.H, C1.C	5,6
105	EXM5 C4.K	5,6
105	EXM5 C3.L	5,6
105	EXM5 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
105	EXM5 C1.N	5,6
105	EXM5 C1.L	5,6
105	EXM5 C1.P, C2.E, C3.R	5,6
105	EXM5 C1.G, C2.H, C3.N	5,6
105	EXM5 C2.A	3,4
105	EXM5 C3.A	3,4,5,6
105	EXM5 C3.C, C3.D	5,6
105	EXM5 C3.K	5,6
105	EXM5 C4.F	5,6
105	EXM5 C5.H	3,4
105	EXM5 C5.C	3,4
105	EXM5 C5.L	3,4
105	EXM5 C5.M	3,4
105	EXM5 C3.E	3,4
105	EXM5 C3.F	3,4
105	EXM5 C3.C	3,4

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
105	EXM5 C4.C	3,4
105	EXM5 C4.P	3,4
105	EXM5 C5.A	3,4
105	EXM5 C5.B	3,4
105	EXM5 C5.F	3,4
105	EXM5 C5.G	3,4
106	Reserved for Future Use	—
107	SHM J1.A, J1.E	6
108	SHM J3.G (PWM)	6
109	SHM J3.M (PWM)	6
110	SHM J3.F	5,6
111	SHM J3.K	5,6

Table 1, J1587 SIDs for Bulkhead Module (BHM) MID 164

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
70	Parking Brake Switch	2
80	Washer Fluid Level	2
84	Wheel Based Vehicle Speed	19
96	Fuel Level	19
97	Water In Fuel Indicator	19
163	Transmission Current Range	12,19
177	Transmission Oil Temperature Sensor	3,4
523	Transmission Current Gear	12,19
524	Transmission Selected Gear	12,19
597	ABS Service Brake Switch	2
598	Clutch Switch	7
879	Front Left Turn Signals Output Fault	5,6
880	Trailer Stop Lamp Relay Output Fault	4
881	Front Right Turn Signals Output Fault	5,6
882	Park / Marker Lights Output Fault	4,5,6
973	Engine Retarder Selection	19
1487	Backlighting Dimmer Switch Fault	7
1550	A/C Clutch Output Fault	5,6
2003	Missing Transmission CAN Message	9

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
2071	Missing Chassis Module CAN Message	9
6891	ID/Marker/Clearance Lamps - HW Override Output Fault	5,6
6892	Upper Right Tail Lamp Output Fault	5,6
6893	Upper Left Tail Lamp Output Fault	5,6
6894	Rear Passenger Dome Lamp Output Fault	6
6895	Front Passenger Dome Lamp Output Fault	6
6896	Right Side Air/Electric Entrance Door - Close - Output Fault	6
6897	Right Side Air/Electric Entrance Door - Open - Output Fault	6
6898	Right Side Turn Signal Output Fault	5,6
6900	Left Side Turn Signal Output Fault	5,6
6901	Stepwell Lights Output Fault	5,6
6902	Left Upper Backup Lamp Output Fault	5,6
6903	Right Upper Backup Lamp Output Fault	5,6
6904	Rear Right Turn Signal Output Fault	5,6
6905	Rear Left Turn Signal Output Fault	5,6
6906	PTO 2 No Feedback Fault	7
6907	PTO 2 Feedback Fault	7
6908	PTO 1 No Feedback Fault	7
6909	PTO 1 Feedback Fault	7
6910	Axle Lift 2 No Feedback Fault	7
6911	Axle Lift 2 Feedback Fault	7
6912	Remote Bucket Switch Stuck Fault	7
6915	Lamp and Gauge Ignition Output Fault	4,5,6
6916	BHM / ICU3-M2 Wiper Park CAN Message Mismatch	2
6917	BHM / ICU3-M2 Hazard Switch CAN Message Mismatch	2
6918	Missing Smart Switch	7
6919	Duplicate Smart Switch	7
6920	Extra Smart Switch	7
6921	Unknown Keep Awake Fault (modules are kept awake)	7
6922	Wake up Hardware Fault (modules are kept awake)	7
6923	Wiper Parked Input Fault	7
6924	Stalk Switch Disagreement - Wiper On/Off Input is OFF and Wiper High or Low Input is ON	2
6925	Stalk Switch Disagreement - Both Wiper High and Wiper Low Inputs are ON	2
6926	Marker Interrupt Switch Fault	7

Fault Code Information

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
6927	Utility Lamp Output Fault	3,4,5,6
6928	Suspension Proportioning No Pressure Feedback	7
6929	Suspension Proportioning Unexpected Pressure Feedback	7
6930	Suspension Proportioning Solenoid Output Fault	3,4,5,6
6931	Suspension Dump No Pressure Feedback	7
6932	Suspension Dump Unexpected Pressure Feedback	7
6933	Suspension Dump Solenoid Output Fault	3,4,5,6
6934	Spotlights Output Fault	3,4,5,6
6935	Snow Plow Relay Output Fault	3,4,5,6
6936	Rear 2 Differential Lock Pressure Feedback Fault	7
6937	Rear 2 Differential Lock Solenoid Output Fault	3,4,5,6
6938	Rear 1 Differential Lock Pressure Feedback Fault	7
6939	Rear 1 Differential Lock Solenoid Output Fault	3,4,5,6
6940	Optional Feature Output Fault	3,4,5,6
6941	Heated Mirrors Output Fault	3,4,5,6
6942	Interaxle Pressure Feedback Fault	7
6943	Interaxle Solenoid Output Fault	3,4,5,6
6944	Fuel Water Separator Heater Output Fault	4,5,6
6945	Front Differential Lock Pressure Feedback Fault	7
6946	Front Differential Lock Solenoid Output Fault	3,4,5,6
6947	Fog Lamp Output Fault	5,6
6953	5th Wheel Slide Solenoid Output Fault	3,4,5,6
6954	End of Frame Air No Pressure Feedback	7
6955	End of Frame Air Unexpected Pressure Feedback	7
6956	End of Frame Air Solenoid Output Fault	3,4,5,6
6957	Daytime Running Lights (DRL) Output Fault	5,6
6958	Brake Line Air Dryer Output Fault	3,4,5,6
6959	Axle Shift Pressure Feedback Fault	7
6960	Axle Shift Solenoid Output Fault	3,4,5,6
6961	Axle Lift No Pressure Feedback	7
6962	Axle Lift Unexpected Pressure Feedback	7
6963	Axle Lift Solenoid Output Fault	3,4,5,6
6964	Air Horn Solenoid Output Fault	5,6
6965	BHM VBAT 5 Input Fault	3,4
6966	BHM VBAT 4 Input Fault	3,4

J1939 SPNs for Bulkhead Module (BHM) SA 33		
SPN	**Description**	**Possible FMI**
6967	BHM VBAT 3 Input Fault	3,4
6968	BHM VBAT 2 Input Fault	3,4
6969	BHM VBAT 1 Input Fault	3,4
6970	Wiper High Output Fault	5,6
6971	Wiper Low Output Fault	5,6
6972	Stalk Switch Wiper High Input Fault	2
6973	Stalk Switch Wiper Low Input Fault	2
6974	Stalk Switch Wiper On/Off Input Fault	2
6975	ICU3-M2 Wiper Park CAN Feedback Error	2
6976	Washer Pump Output Fault	5,6
6977	Stalk Switch Washer Switch Input Fault	2
6978	Stalk Switch Right Turn Signal Input Fault	2
6979	Stalk Switch Left Turn Signal Input Fault	2
6980	Right Stop Lamp Output Fault	5,6
6981	Left Stop Lamp Output Fault	5,6
6982	Wake up Hardware Fault	5,6
6983	Starter Relay (Mag Switch) Output Fault	5,6
6984	Ignition System, Accessory Power Outputs Fault	5,6
6985	Ignition System, Ignition Power Outputs Fault	2,5,6
6986	Ignition Switch Fault	7
6987	Tail / Clearance / License Plate Lights Output Fault	5,6
6988	Left Low Beam Output Fault	5,6
6989	Right Low Beam Output Fault	5,6
6990	Left High Beam Output Fault	5,6
6991	Right High Beam Output Fault	5,6
6992	Stalk Switch High Beam Input Fault	2
6993	Headlamp Switch Disagreement - Both Park and On Inputs are CLOSED	7
6994	ICU3-M2 Hazard Switch CAN Feedback Error	19
6995	Horn Output Fault	3,4,5,6
6996	Dome Lamps Switched Power Output Fault	5,6
6997	Cigar Lighter Output Fault	3,4,5,6
6998	Dome Lamps Battery Power Output Fault	5,6
6999	Backup Lamps / Alarm Output Fault	5,6
7000	Panel Lamp Backlighting PWM Output Fault	3,4,5,6

Table 2, J1939 SPNs for Bulkhead Module (BHM) SA 33

Fault Code Information

Failure Mode Indicators		
FMI	**J1939 Description**	**J1587 Description**
00	Data valid but above normal operational range - Most severe level	Data valid but above normal operational range (engine overheating)
01	Data valid but below normal operational range - Most severe level	Data valid but below normal operational range (engine oil pressure too low)
02	Data erratic, intermittent, or incorrect	Data erratic, intermittent, or incorrect
03	Voltage above normal or shorted high	Voltage above normal or shorted high
04	Voltage below normal or shorted low	Voltage below normal or shorted low
05	Current below normal or open circuit	Current below normal or open circuit
06	Current above normal or grounded circuit	Current above normal or grounded circuit
07	Mechanical system not responding or out of adjustment	Mechanical system not responding properly
08	Abnormal frequency, pulse width, or period	Abnormal frequency, pulse width, or period
09	Abnormal update rate	Abnormal update rate
10	Abnormal rate of change	Abnormal rate of change
11	Root cause not known	Failure mode not identifiable
12	Bad intelligent device or component	Bad intelligent device or component
13	Out of Calibration	Out of Calibration
14	Special Instructions	Special Instructions
15	Data valid but above normal operational range - Least severe level	Reserved for future assignment by the SAE Subcommittee
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	Reserved for SAE Assignment	—
21	Reserved for SAE Assignment	—
22	Reserved for SAE Assignment	—
23	Reserved for SAE Assignment	—
24	Reserved for SAE Assignment	—
25	Reserved for SAE Assignment	—
26	Reserved for SAE Assignment	—
27	Reserved for SAE Assignment	—
28	Reserved for SAE Assignment	—
29	Reserved for SAE Assignment	—
30	Reserved for SAE Assignment	—

Failure Mode Indicators		
FMI	**J1939 Description**	**J1587 Description**
31	Not available or condition exists	—

Table 3, Failure Mode Indicators

Viewing Fault Codes in ServiceLink

Both J1587 and J1939 fault codes can be viewed in ServiceLink. To do so:

1. Connect to the vehicle using an approved communication device.
2. Open ServiceLink in either online or offline mode.
3. Turn the vehicle's ignition to the ON position.
4. Click on the Connect button in ServiceLink.

NOTE: The J1587 Message Identifier (MID) for the BHM is 164, and the J1939 Source Address (SA) for the BHM is 33, shown in the far left column of the main window in **Fig. 1** and **Fig. 2**.

5. From this point, either:
   - Click on the Faults tab from the main ECU List screen to display all faults present on the vehicle. See **Fig. 1**. Or,
   - Click on the Bulkhead Module icon first, then on the Faults tab to display faults coming from the BHM only. See **Fig. 2**.

Viewing Fault Codes on the Instrument Cluster

Fault codes for both datalink protocols (J1939 and J1587) can be viewed on the dash message center of the ICU3-M2 instrument cluster. See **Section 54.04**, Subject 410, for Mode/Reset Switch Functions and how to use the mode/reset switch on the ICU3-M2 to display fault information.

The following is one example using the ICU3-M2 dash message center to view a J1587 fault.

1. In this example, during an active fault the first screen shows "SYS 164". See **Fig. 3**. This indicates the fault is coming from the BHM, which has a J1587 MID of 164.

NOTE: The Bulkhead Module (BHM) will appear on the dash message center as "SYS 164." Be aware that the "SYS" looks like the numbers "545" on the digital display, as shown in **Fig. 3**.

2. Pressing the mode/reset switch displays the second fault screen, which shows "SID 022". See **Fig. 4**.
3. Next, find the description for SID 22 in **Table 1**, which lists the description as "Missing Smart Switch."
4. Press the mode/reset button again and the third ICU screen displays "Fail 07". See **Fig. 5**.
5. Next, find FMI 07 in the J1587 Description column. See **Table 3**. It indicates "Mechanical system not responding properly."

   In this example, the fault indicates that the mechanical system is not responding properly because the BHM senses that a Smart Switch is missing from the vehicle. There can be various possibilities for the cause of each fault.

Fault Code Information

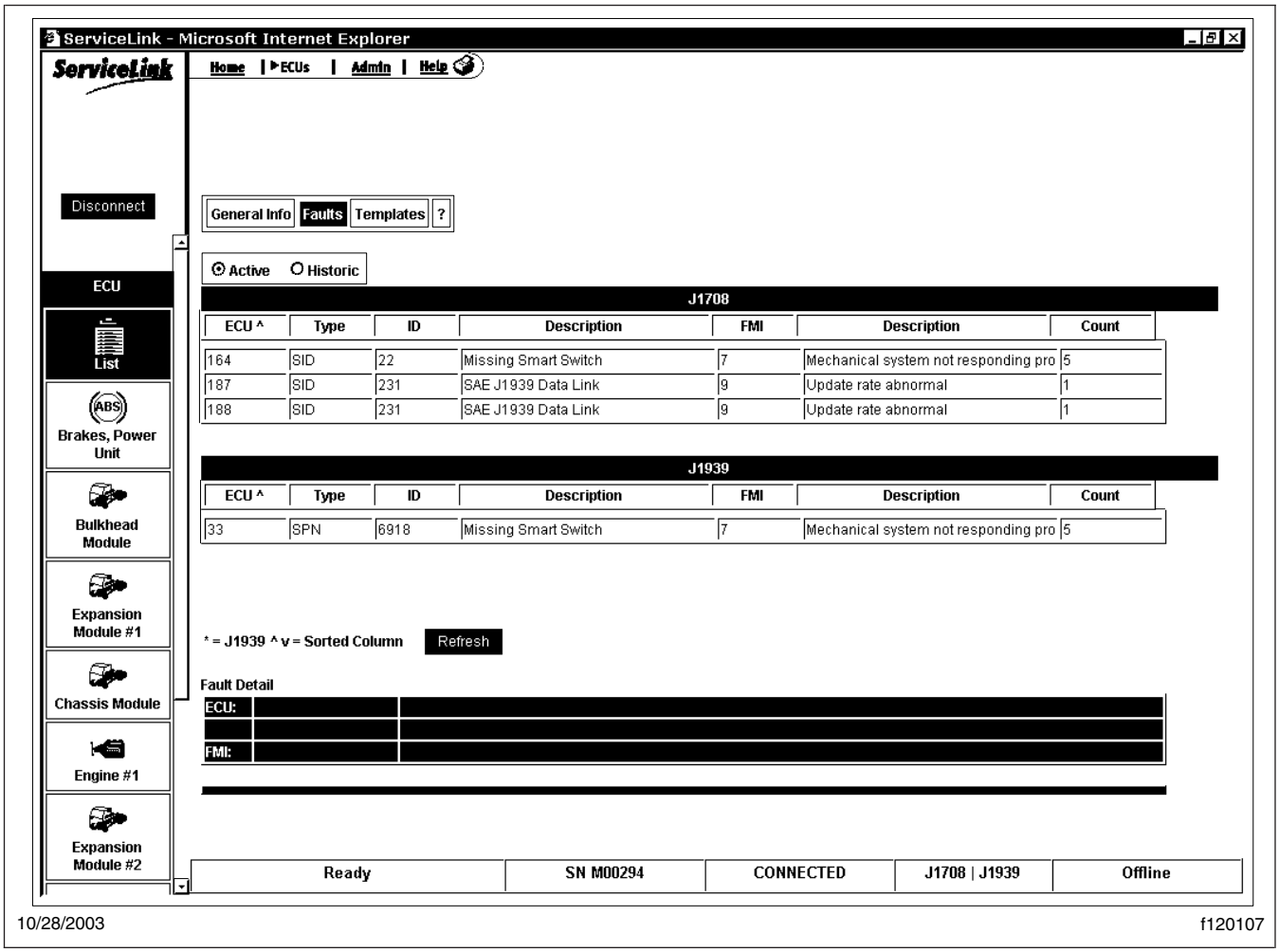


Fig. 1, ServiceLink Faults Screen for All ECUs on the Vehicle

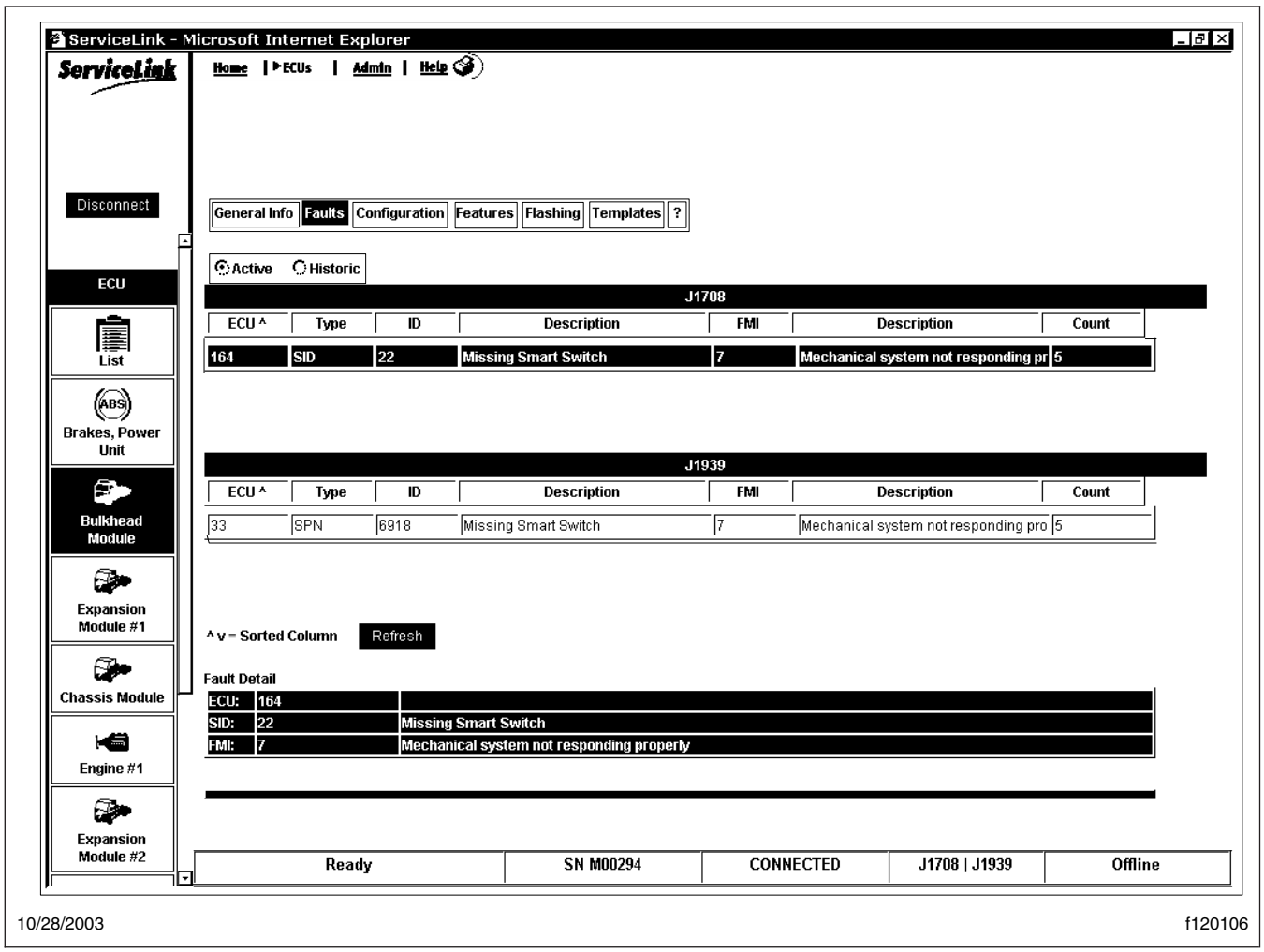


Fig. 2, ServiceLink Faults Screen for the BHM only

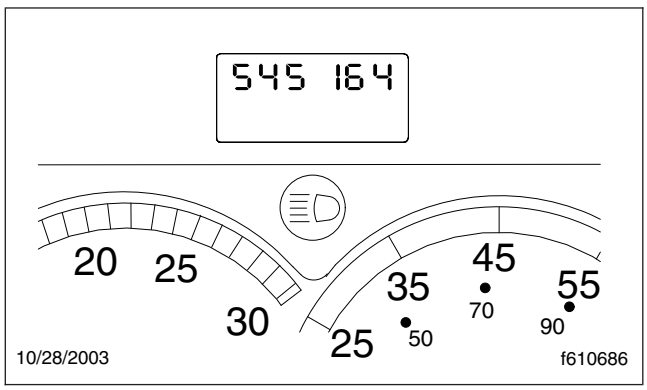


Fig. 3, J1587 Fault Code "SYS 164"

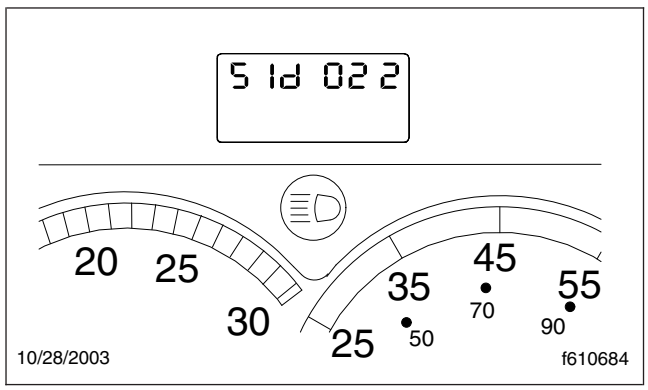


Fig. 4, J1587 Fault Code "SID 022"

Fault Code Information

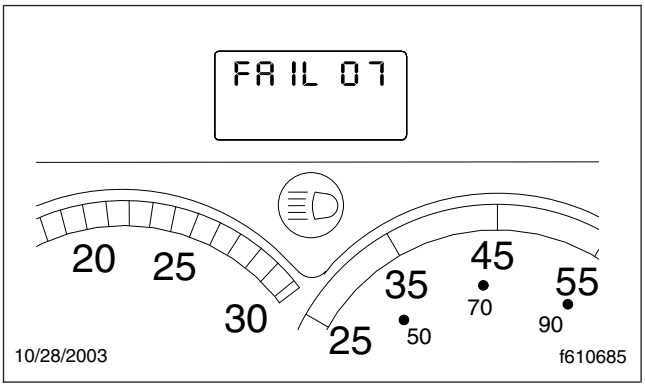


Fig. 5, Fault Code FMI 07

Device Communications

For information on cross-referencing a J1587 Message Identifier (MID) and a J1939 Source Address (SA), see **Table 1**.

Device Communications on J1587 and J1939		
Device Description	**J1587 MID**	**J1939 SA†**
Engine	128	0
Transmission	130	3
Anti-Lock Brakes	136	11
Instrument Cluster	140	23
Vehicle Security Unit (VSU)	163	–
Data Logging Unit (DLU)	179	251
Collision Avoidance System (Headway Controller)	219	42
Bulkhead Module	164	33
Chassis Module	249	71
Expansion Module #1	170	235
Expansion Module #2	187	236
Expansion Module #3	188	237
Expansion Module #4	178	238
Expansion Module #5	240	239
Switch Hub Module	221	49
Switch Expansion Module #1	n/a	128
Switch Expansion Module #2	n/a	129
Switch Expansion Module #3	n/a	130
Switch Expansion Module #4	n/a	131

Message Identifier
† Source Address

Table 1, Device Communications on J1587 and J1939

General Information

The Bulkhead Module (BHM) is the primary module of the vehicle electrical system, and controls the operation of the other multiplex modules in the system and a variety of other vehicle components either directly or indirectly.

The Bulkhead Module is mounted in an opening on the frontwall slightly below and outboard of the steering column. It has four harness connections on the engine compartment side of the frontwall and three harness connections on the cab side. Connections on the engine side are: the forward chassis harness, the engine harness, and two to the frontwall harnesses. Connections on the cab side include up to three dash harness connectors.

For more information about the vehicle electrical system, see **Section 54.00**, Electrical System.

Bulkhead Module Replacement

Replacement

IMPORTANT: It is normally not necessary to replace the Bulkhead Module. Removing and installing the electronic Bulkhead Module controller should be a last resort to solving electrical problems, unless the unit needs replacing due to physical damage. Follow troubleshooting procedures in this section to help solve electrical problems involving this module before replacing either the Bulkhead Module or Chassis Module. If troubleshooting indicates a malfunction of either module, try reflashing the parameters and the software before replacing the module. Check external wiring. Also see **Section 54.00**, Electrical System, for more information about the vehicle electrical system in general.

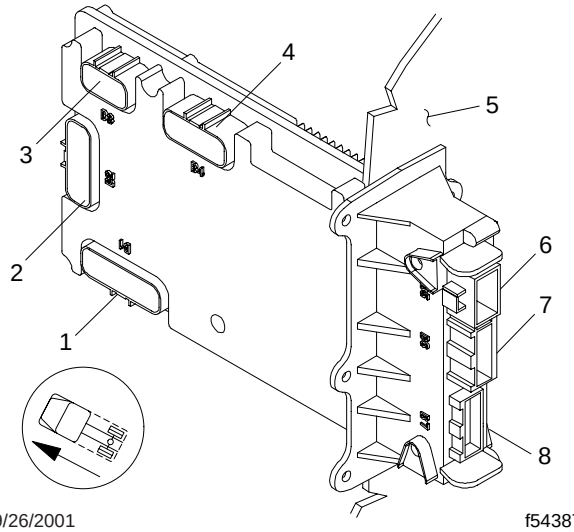
1. Tilt the hood.
2. Disconnect the negative leads from the batteries.

NOTE: The Bulkhead Module is located on the frontwall outboard of the steering column. See **Fig. 1** and **Fig. 2**.

3. Unplug bulkhead harnesses B1 through B4 from the engine compartment side of the frontwall.
4. Unplug bulkhead harnesses B5 through B7 from the Bulkhead Module on the cab side of the frontwall. See **Fig. 3**.
5. Remove the Torx fasteners that secure the Bulkhead Module to the cab side of the frontwall and remove the module by pulling it through the frontwall opening into the cab.

NOTE: Use ServiceLink to flash the Bulkhead Module for loading vehicle-specific features.

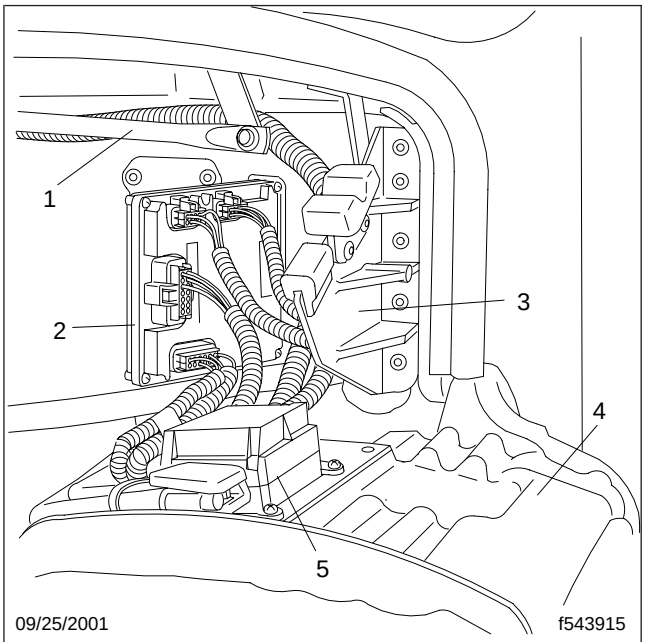
6. Place the Bulkhead Module through the frontwall opening from the cab side, then install and tighten the Torx screws 48 lbf·in (540 N·cm).
7. Plug in bulkhead harnesses B5 through B7 to the Bulkhead Module on the cab side of the frontwall.
8. Plug in bulkhead harnesses B1 through B4 to the Bulkhead Module on the engine side of the frontwall.
9. Connect the batteries.
10. Verify correct operation of the Bulkhead Module by cycling electrical components.



1. Connection B1, Forward Chassis Harness
2. Connection B2, Engine Harness
3. Connection B3, Frontwall Harness
4. Connection B4, Frontwall Harness
5. Frontwall
6. Connection B5, Dash Harness
7. Connection B6, Dash Harness
8. Connection B7, Dash Harness

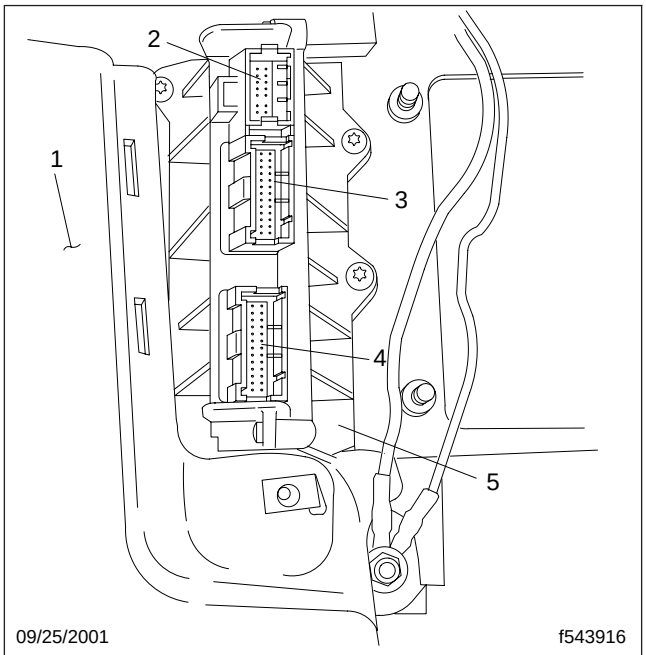
Fig. 1, Bulkhead Module (isometric view)

Bulkhead Module Replacement



1. Wiper Linkage Arm
2. Bulkhead Module
3. Hood Support Bracket
4. Quarter Fender
5. Power Distribution Module

Fig. 2, Bulkhead Module (engine compartment side)



1. Interior Cab Wall
2. Connection B5, Dash Harness
3. Connection B6, Dash Harness
4. Connection B7, Dash Harness
5. Bulkhead Module, Cab Side

Fig. 3, Bulkhead Module (cab side)

Bulkhead Module Troubleshooting

NOTE: The output for the following functions can be controlled by optional software or with the functionality shown in this subject.

When troubleshooting the Bulkhead Module (BHM), use ServiceLink as the diagnostic tool. Verify that the BHM is communicating over both J1708 and J1939 datalinks. Use the instructions below to determine if the BHM is communicating.

1. Park the vehicle, apply the parking brakes, shut down the engine, and chock the front and rear tires.
2. Connect a workshop PC to the diagnostics port on the datalink, using an approved communication adapter.
3. Open ServiceLink in Online mode.
4. Turn the vehicle ignition switch to the ON position.
5. Click on the Connect button in ServiceLink.
6. Verify that ServiceLink returns the correct vehicle serial number, then click “Continue.”
7. Verify that the BHM appears on the ECU list in ServiceLink. If the BHM is missing or not communicating, it will appear in red on the ServiceLink list. If the BHM is showing up in red, try clicking the “Refresh” button in ServiceLink. If after refreshing ServiceLink the BHM is still missing, check the connections for power, ground, and datalink, and reestablish communication.
8. If the BHM is not communicating (unresponsive) the hazard lights will be flashing, and the head lamps will be turned ON. Thoroughly troubleshoot all power/ground and datalink connections to the BHM. In addition, try disconnecting and reconnecting the batteries.
9. If all connections to the BHM are good, try to flash the BHM using ServiceLink, as follows.
   - 9.1 Click on the BHM icon on the left side screen.
   - 9.2 Click on the "Flashing" tab on the upper portion of the screen.
   - 9.3 Verify that the software version to be flashed is U.r.1.F1.01.00 or higher.
   - 9.4 Click the “Flash Now” button in the dialog box.

     ServiceLink should first return a message saying “The manufacturing block VIN matches the VIN on the host.”

     Click OK.

     ServiceLink will then bring up a message saying “Flashing BHM.”

     Wait until ServiceLink is finished. The next on-screen message should read “Please turn ignition off and on before continuing.” Continue following the prompts from ServiceLink to complete the flash.
10. If ServiceLink cannot flash the BHM due to the bulkhead module being unresponsive, and all wiring checks do not show problems with connections, then the BHM is defective. Replace the bulkhead module.
11. If the BHM is communicating over both J1708 and J1939, then use the descriptions of the S2 features and functions below to determine if the BHM is operating as it should, or to isolate where the problems may exist.

Bulkhead Module Functions

The BHM includes the following functions:

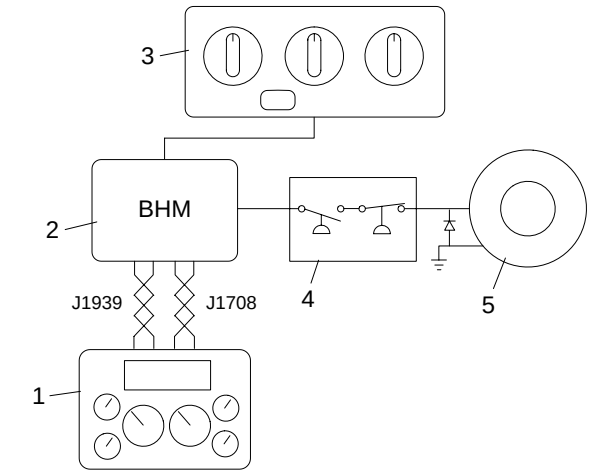
- A/C Clutch Function
- Alternating Charger Function
- Backlighting Function
- Headlight System
- Headlight System — Headlight Switch
- Headlight System — High Beams
- Headlight System — Low Beams
- Horn (Electric)
- Ignition System
- Ignition System — Accessory Power
- Ignition System — Ignition Power Function
- Ignition System — Ignition Switch function
- Starter Relay Signal
- Windshield Wiper/Washer System

- Windshield Wiper/Washer System — Wiper Motor 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 (see **Group 83** for more information), the control panel sends an A/C clutch request signal to the Bulkhead Module (BHM). Upon receiving this input, the BHM will respond 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 will send a signal to the BHM. The BHM will react by cycling the compressor. The HVAC control panel contains the logic to prevent the compressor from cycling more than four times per minute.



1. ICU
2. BHM
3. HVAC Control Panel
4. Binary Pressure Switch
5. A/C Compressor Clutch

Fig. 1, A/C Clutch Function

The BHM monitors the A/C compressor clutch wiring and is capable of detecting an open or shorted circuit when the A/C clutch is being driven. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through 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 I/O 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 I/O Conditions

Fault Conditions

Table 2 displays how the BHM will handle faults that it encounters in the A/C clutch system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is OFF.

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 or open	BHM may transmit a J1939 and/or a J1708 fault message

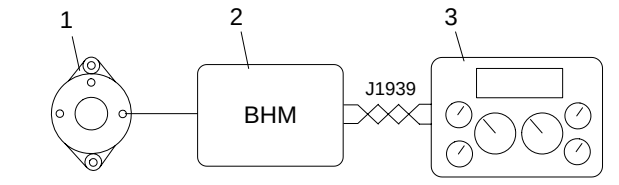
Table 2, A/C Clutch Function Fault Conditions

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 Bulkhead Module (BHM) will monitor a voltage input from the "I" terminal on the alternator and will send 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" indicator light on or off. The "No Charge" light on the dash will illuminate if the BHM does not detect voltage at the "I" terminal of the alternator. Once illuminated, the "No Charge" light will remain on until the BHM detects 14 Volts at the alternator "I" terminal. Once off, the "No Charge" light will remain off until the BHM detects 0 Volts at the alternator "I" terminal. See **Fig. 2**.



1. Alternator
2. BHM
3. ICU

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.

Alternator Charging Function I/O 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

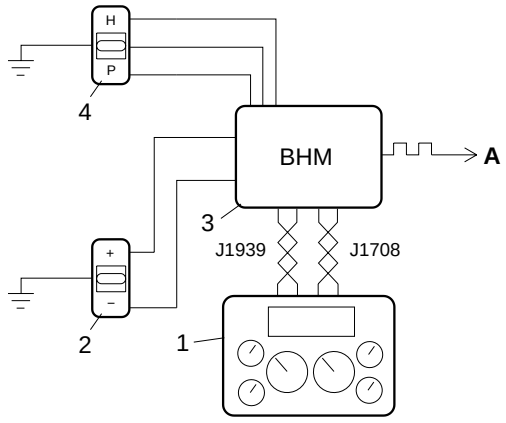
Table 3, Alternator Charging Function I/O Conditions

Backlighting Function

Description

The Backlighting function illuminates the dash display. Backlighting power is provided to the following components: instrument cluster, HVAC control panel, headlight switch, and smart switches.

The backlighting switch is a two-position momentary switch. When the driver pushes the "+" on the top of the switch, a ground path to the Bulkhead Module (BHM) is completed, indicating the driver's desire to increase the panel light backlighting. Upon seeing this ground, the BHM will increase the backlighting voltage to the components. When the driver pushes the "–" on the bottom of the switch, a different pin at the BHM is grounded, indicating the driver's desire to decrease the panel light backlighting. Upon seeing this ground, the BHM will decrease the backlighting voltage to the components. See **Fig. 3**.



A. Pulse-width modulated signal to ICU, HVAC control panel, headlight switch, hazard switch, and smart switches.

1. ICU
2. Dimmer Switch
3. BHM
4. Headlight Switch

Fig. 3, Backlighting Function

Instead of controlling the level of backlighting illumination with a rheostat, the backlighting functionality in the S2 is controlled by a pulse-width modulated signal (400 Hz) from the BHM. Effective backlighting voltage to the components can be varied between 10% and 90% of battery voltage.

The BHM monitors the backlighting voltage output and is capable of detecting a short circuit when the backlighting output is being driven. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Table 4 displays how the backlighting system inputs to the BHM and how it will react to these inputs.

Backlighting Function I/O Conditions				
Inputs to BHM		**Outputs from BHM**		
Headlight Switch	**Marker Interrupt Switch**	**Backlight Status**	**Illumination**	**% Battery Voltage Output**
ON/PARK	OFF	On	Dependant on dimmer switch position (range dim to bright)	Dependant on dimmer switch position (range 10–90%)
OFF	ON	On	Bright	100%
ON/PARK	ON	Off	Off	0%
OFF	OFF	Off	Off	0%

Table 4, Backlighting Function I/O Conditions

Fault Conditions

Table 5 displays how the BHM will handle faults that it encounters in the backlighting system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until both the headlight switch and the marker interrupt switch are turned OFF.

Backlighting Function 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 and/or a J1708 fault message
Headlight switch	Headlight switch is in error	BHM will assume the headlight switch is ON
Backlighting power output	Backlighting power wiring is shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 5, Backlighting Function Fault Conditions

Headlight System

Description

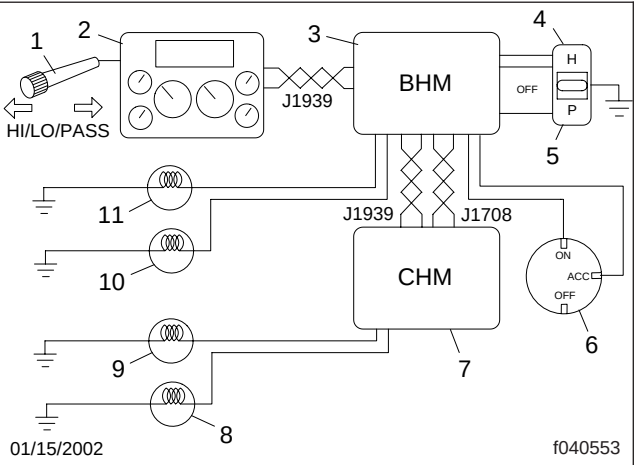
The headlight system is made up of multiple components. The Bulkhead Module (BHM) takes inputs from the multifunction switch via a J1939 message from the Instrumentation Control Unit (ICU) as well as the combination headlight/parking light switch and uses the information to control the headlights. See **Fig. 4**.

Headlight System, Headlight Switch Function

Description

The headlight switch on the dash has three positions: OFF, PARK (parking lights), and ON (headlights). The Bulkhead Module (BHM) continuously monitors the position of the dash-mounted 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 will allow the headlights to work even if one of the two wires is damaged or disconnected. See **Fig. 4**.



1. Multifunction Switch
2. ICU
3. BHM
4. Headlight Switch
5. Parking Light Switch
6. Ignition Switch
7. CHM
8. Right-Hand Headlamp, Low Beam
9. Right-Hand Headlamp, High Beam
10. Left-Hand Headlamp, High Beam
11. Left-Hand Headlamp, Low Beam

Fig. 4, Headlight System Function

The BHM monitors the headlight switch wiring and is capable of detecting error conditions in the headlight switch circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Table 6 displays how the BHM will react given the status of the headlight switch.

Fault Conditions

Table 7 displays headlight switch circuit combinations that will create a fault. In these cases, the BHM assumes the headlight switch status is ON. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

Headlight (Hdlt) Switch Function I/O Conditions					
Inputs to BHM			Outputs from BHM		
Hdlt Switch Park Circuit	Hdlt Switch On Circuit	Hdlt Switch On 2 Circuit	Hdlt Switch Status	J1939 Hdlt On/Off Message	J1939 Hdlt 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 the Fault Conditions paragraph that follows.

Table 6, Headlight (Hdlt) Switch Function I/O Conditions

Headlight Switch Function Fault Conditions			
Description of Fault			Action Taken by BHM
Headlight Switch Park Circuit	Headlight Switch On Circuit	Headlight Switch On 2 Circuit	
Closed	Closed	Open	BHM may transmit a J1939 and/or a J1708 fault message
Closed	Open	Closed	BHM may transmit a J1939 and/or a J1708 fault message
Closed	Closed	Closed	BHM may transmit a J1939 and/or a J1708 fault message

Table 7, Headlight Switch Function Fault Conditions

Headlight System, High (HI) Beams Function

Description

The Bulkhead Module (BHM) continually monitors the position of the dash-mounted headlight switch and the position of the multifunction switch to determine if the headlights should be on low (LO) beams or high (HI) beams. The Instrumentation Control Unit (ICU) transmits the multifunction switch position information to the BHM via a J1939 message. When the headlight switch is ON, and HI beam or PASS is selected at the multifunction switch, the BHM will activate the left high beam and send a J1939 message to the Chassis Module (CHM) instructing it to activate the right high beam.

The BHM is capable of detecting open and shorted circuits in the left high beam wiring and the right high beam wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 4**.

Input and Output Conditions

Table 8 displays the high beam headlight system inputs to the BHM and how it reacts based on these inputs.

Headlight High (HI) Beams Function I/O Conditions				
Inputs to BHM			Outputs from BHM	
Ignition Switch Position	Headlight Switch Position	Multi-function Switch Position	Left HI Beam	Right HI Beam*
ON	ON	HI/PASS	On	On
ON	ON	LO	Off	Off
ON	OFF	HI/PASS	Off	Off
OFF	ON	HI/PASS	Off	Off

* Via J1939 message to the CHM

Table 8, Headlight High (HI) Beams Function I/O Conditions

Fault Conditions

Table 9 displays how the BHM will handle faults it encounters in the high beam headlight system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

Headlight High (HI) Beams Function 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 and/or J1708 datalinks
Position of multifunction switch is unavailable or in error	BHM will assume the multifunction switch position is LO
BHM fails to receive five consecutive J1939 multifunction switch position messages from the ICU	BHM may transmit a J1939 and/or a J1708 fault message

Headlight High (HI) Beams Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
BHM receives a J1939 multifunction switch error message from the ICU	BHM may transmit a J1939 and/or a J1708 fault message
Left HI beam wiring open or shorted	BHM may transmit a J1939 and/or a J1708 fault message
Right HI beam wiring open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 9, Headlight High (HI) Beams Function Fault Conditions

Headlight System, Low (LO) Beams Function

Description

The Bulkhead Module (BHM) continually monitors the position of the dash-mounted headlight switch and the position of the multifunction switch to determine if the headlights should be on low (LO) beams or high (HI) beams. The Instrumentation Control Unit (ICU) transmits the multifunction switch position information to the BHM via a J1939 message. When the headlight switch is ON and LO beam is selected at the multifunction switch, the BHM will activate the left low beam and send a J1939 message to the Chassis Module (CHM) instructing it to activate the right low beam. High beams operate only with the key ON.

NOTE: If the CHM doesn't see J1939 messages from the BHM, the right low beam is activated. If the BHM fails, the left low beam is activated.

The BHM is capable of detecting open and shorted circuits in the left low beam wiring and the right low beam wiring on the CHM. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 4**.

Input and Output Conditions

Table 10 displays the low beam headlight system inputs to the BHM and how it reacts based on these inputs.

Headlight Low (LO) Beams Function I/O Conditions			
Inputs to BHM		**Outputs from BHM**	
Headlamp Switch Position	**Multifunction Switch Position**	**Left LO Beam**	**Right LO BEAM***
ON	LO	On	On
ON	HI/PASS	Off	Off
OFF	HI/PASS	Off	Off

* Via J1939 message to the CHM

Table 10, Headlight Low (LO) Beams Function I/O Conditions

Fault Conditions

Table 11 displays how the BHM will handle faults it encounters in the low beam headlight system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

Headlight Low (LO) Beams Function 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 and/or J1708 datalinks
Position of multifunction switch is unavailable or in error	BHM will assume the multifunction switch position is LO
BHM fails to receive five consecutive J1939 multifunction switch position messages from the ICU	BHM may transmit a J1939 and/or a J1708 fault message
BHM receives a J1939 multifunction switch error message from the ICU	BHM may transmit a J1939 and/or a J1708 fault message
Left LO beam wiring open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Headlight Low (LO) Beams Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Right LO beam wiring open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 11, Headlight Low (LO) Beams Function Fault Conditions

Horn (electric) Function

Description

The electric horn is controlled by the bulkhead module (BHM). See **Fig. 5**. 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. 5**.

Refer to **Table 12** for horn troubleshooting topics.

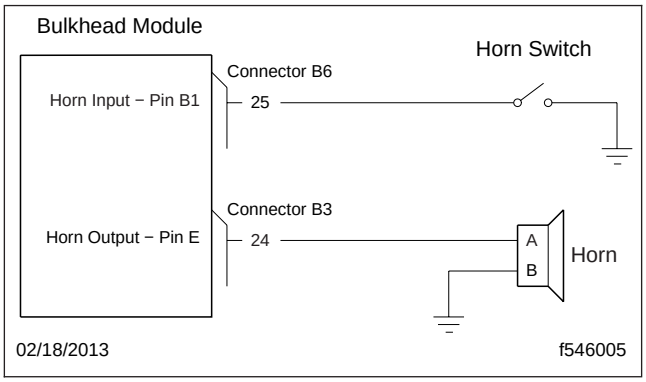


Fig. 5, Horn (electric) Function

Electric Horn Troubleshooting	
Problem	**Reference Table**
Fault code SPN 6995 is active.	**Table 13**
The horn stays on all the time.	**Table 14**
The horn does not work at all.	**Table 15**

Table 12, 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 14** or **Table 15**.

Table 13, 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 14, The Horn Stays ON All the Time

Troubleshooting

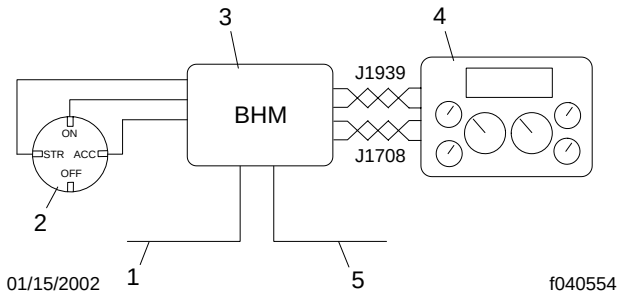
The Horn Does Not Work at All			
Test No.	**Test Procedure**	**Test Result**	**Action**
1	Connect ServiceLink, then open the BHM template for the electric horn. Press and hold the horn button. Does the template show that the horn button input is active?	Yes	Go to step 2.
		No	Remove the horn button from 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 15, The Horn Does Not Work at All

Ignition System

Description

The ignition system is made up of multiple components. The Bulkhead Module (BHM) takes input from the ignition switch and uses the information to crank the starter and to supply ignition and accessory power to the vehicle. See **Fig. 6**.



1. Accessory Power (12V+)
2. Ignition Switch
3. BHM
4. ICU
5. Ignition Power (12V+)

Fig. 6, Ignition System Function

Ignition System, Accessory Power Function

Description

The Bulkhead Module (BHM) continuously monitors the position of the ignition switch to determine if the accessory power outputs should be energized. Accessory power is provided to the HVAC control panel and the radio. Separate power feeds are used for each of the accessory outputs.

The BHM is capable of detecting open and shorted circuits in the accessory power outputs. Faults discovered by the BHM will be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 6**.

Input and Output Conditions

Table 16 displays the accessory power system inputs to the BHM and how it will react to these inputs.

Accessory Power Function I/O Conditions	
Input to the BHM from the Ignition Switch	**Output from the BHM to the Accessory Power Circuits**
ACC	On
OFF	Off

Accessory Power Function I/O Conditions	
Input to the BHM from the Ignition Switch	**Output from the BHM to the Accessory Power Circuits**
ON	On
START	Off

Table 16, Accessory Power Function I/O Conditions

Fault Conditions

Table 17 displays how the BHM will handle faults it encounters in the accessory power system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

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 message on the J1939 and/or J1708 datalinks
The accessory power output wiring is open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 17, Accessory Power Function Fault Conditions

Ignition System, Ignition Power Function

Description

The Bulkhead Module (BHM) continuously monitors the position of the ignition switch to determine if the ignition power outputs should be energized. Ignition power is provided to the following components: Antilock Brake System Electronic Control Unit (ABS ECU), Instrumentation Control Unit (ICU), engine ECU, transmission ECU, and the Vehicle Control Unit (VCU) if applicable. Separate power feeds are used for each of the ignition outputs.

The BHM is capable of detecting open and shorted circuits in the ignition power outputs. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 18**.

Input and Output Conditions

Table 16 displays the ignition power system inputs to the BHM and how it will react to these inputs.

Ignition Power Function I/O Conditions	
Input to the BHM from the Ignition Switch	**Output from the BHM to the Ignition Power Circuits**
OFF	Off
ACC	Off
ON	On
START	On

Table 18, Ignition Power Function I/O Conditions

Fault Conditions

Table 19 displays how the BHM will handle faults it encounters in the ignition power system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

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 message on the J1939 and/or J1708 datalinks
The ignition power output wiring is open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 19, Ignition Power Function Fault Conditions

Ignition System, Ignition Switch Function

Description

The ignition switch has four positions: OFF, ACC, ON, and START. The Bulkhead Module (BHM) continuously monitors the position of the ignition switch and broadcasts this information on the J1939 datalink. There are three circuits that run from the ignition switch to the BHM. One is for the accessory (ACC) position, one is for the ON position, and one is for the START position.

The BHM monitors the ignition switch wiring and is capable of detecting error conditions in the ignition switch circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

Input and Output Conditions

Table 20 displays how the BHM will react given the status of the ignition switch.

Ignition Switch Function I/O Conditions			
Inputs to BHM			Output from BHM
Ignition Switch Accessory Circuit	Ignition Switch On Circuit	Ignition Switch Crank 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 that follows.

Table 20, Ignition Switch Function I/O Conditions

Fault Conditions

Table 21 displays ignition switch circuit conditions that will create a fault. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until a valid ignition switch status is detected.

Ignition Switch Function Fault Conditions			
Description of Fault			Action Taken by BHM
Ignition Switch Accessory Circuit	Ignition Switch On Circuit	Ignition Switch Crank Circuit	
Open	Open	Closed	BHM will transmit a J1939 and/or a J1708 fault message
Closed	Open	Closed	BHM will transmit a J1939 and/or a J1708 fault message
Open	Closed	Open	BHM will transmit a J1939 and/or a J1708 fault message

Table 21, Ignition Switch Function Fault Conditions

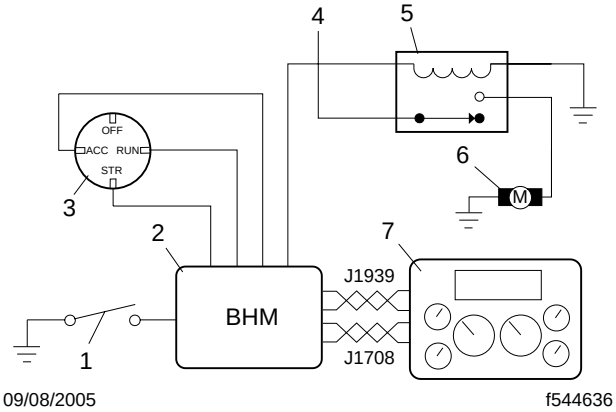
Starter Relay Signal Function

Description

The starter relay referred to in this document is also known as the starter mag switch. When the ignition switch is in the START position, the Bulkhead Module (BHM) sends a signal to the starter mag switch, which engages the starter.

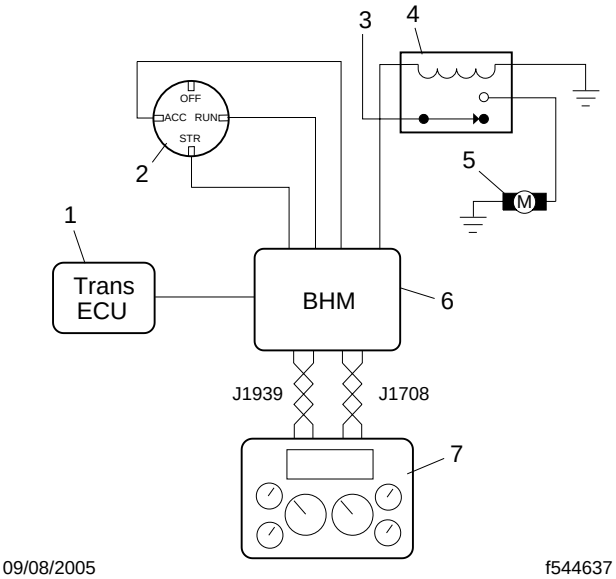
The BHM is capable of detecting open and short circuits in the starter relay wiring. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink.

For manual transmissions, see **Fig. 7**. For automatic transmissions, see **Fig. 8**.



1. Bottom of Clutch Switch (normally open)
2. BHM
3. Ignition Switch
4. Battery Power
5. Magnetic Relay (Mag Switch)
6. Starter
7. ICU

Fig. 7, Starter Relay Signal Function, Manual Transmission



1. Transmission ECU
2. Ignition Switch
3. Battery Power
4. Magnetic Relay (Mag Switch)
5. Starter
6. BHM
7. ICU

Fig. 8, Starter Relay Signal Function, Automatic Transmission

Input and Output Conditions

Activation of the starter relay system is dependent on the transmission type. A manual transmission uses the bottom of clutch switch to tell the BHM when the clutch is released (pedal depressed). Automatic transmissions will send a ground signal via relay to the BHM when they are in NEUTRAL or PARK. **Table 22** displays the input necessary for the BHM to allow activation of the starter relay circuit.

Starter Relay Signal Function Input		
Transmission Type	**Input to BHM**	**BHM Conclusion**
Manual transmission	Bottom of clutch switch is CLOSED	Transmission is in NEUTRAL
Automatic transmission	Ground signal via transmission neutral relay	Transmission is in NEUTRAL

Table 22, Starter Relay Signal Function Input

Table 23 displays the starter relay system inputs to the BHM and how it will react to these inputs.

Starter Relay Signal Function I/O Conditions		
Inputs to BHM		**Output from BHM**
Ignition Switch	**Transmission Status**	**Starter Relay Signal**
OFF/ACC/ON	NEUTRAL	Deactivated
START	NOT NEUTRAL	Deactivated
START	NEUTRAL	Activated

Table 23, Starter Relay Signal Function I/O Conditions

Fault Conditions

Table 24 displays how the BHM will handle faults it encounters in the starter relay system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

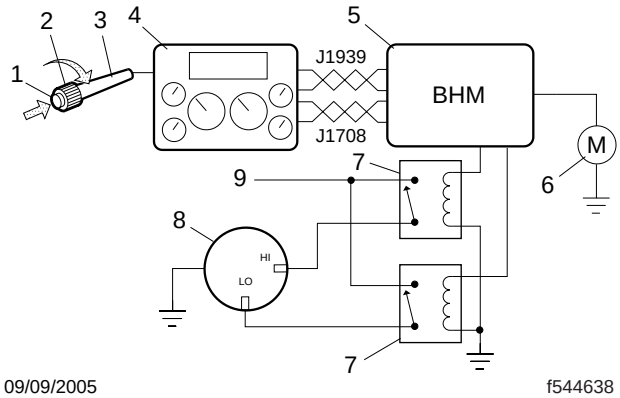
Starter Relay Signal Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Transmission state is unavailable or in error	BHM will assume the transmission state is not neutral
Ignition switch is in error	BHM will assume ignition switch is ON, and may transmit a fault message on the J1939 and/or J1708 datalinks
Starter relay signal wiring is shorted or open	BHM may transmit a J1939 fault message

Table 24, Signal Function Fault Conditions

Windshield Wiper/Washer System

Description

The Windshield Wiper/Washer System is made up of multiple components. The Instrumentation Control Unit (ICU) monitors input information regarding windshield wiper and washer switch positions from the multifunction switch and sends this information via J1939 messages to the Bulkhead Module (BHM). The BHM takes these messages from the ICU and uses the information to control the windshield wiper motor and the washer pump motor. See **Fig. 9**.



1. Washer Switch
2. Wiper Switch
3. Multifunction Switch
4. ICU
5. BHM
6. Washer Pump Motor
7. Relay
8. Wiper Motor
9. Battery

Fig. 9, Windshield Wiper/Washer System Function

Windshield Wiper/Washer System, Washer Pump Function

Description

The Instrumentation Control Unit (ICU) constantly monitors input information from the multifunction switch regarding windshield washer switch position and sends this information via J1939 messages to the Bulkhead Module (BHM). The BHM takes these messages from the ICU and uses the information to control the windshield washer pump motor. Under normal operating conditions, when the washer pump is activated the ICU also sends a wiper low command.

The BHM monitors the washer pump motor wiring and is capable of detecting open or shorted circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 9**.

Fault Conditions

Table 25 displays how the BHM will handle faults that it encounters in the washer pump system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks until the ignition switch is turned OFF.

Windshield Wiper/Washer System, Washer Pump Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
J1939 washer pump message from the ICU is unavailable or in error	BHM assumes 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 and/or a J1708 fault message
BHM fails to receive five consecutive J1939 washer pump messages from the ICU	BHM may transmit a J1939 and/or a J1708 fault message

Windshield Wiper/Washer System, Washer Pump Function Fault Conditions	
Description of Fault	**Action Taken by BHM**
Washer pump motor wiring shorted or open	BHM may transmit a J1939 and/or a J1708 fault message

Table 25, Windshield Wiper/Washer System, Washer Pump Function Fault Conditions

Windshield Wiper/Washer System, Wiper Motor Function

Description

The Instrumentation Control Unit (ICU) constantly monitors input information from the multifunction switch regarding windshield wiper switch position and sends this information via J1939 messages to the Bulkhead Module (BHM). The BHM takes these messages from the ICU and uses the information to control the windshield wiper motor.

The BHM monitors the wiper motor wiring and is capable of detecting open or shorted circuits. Faults discovered by the BHM may be reported on the J1939 and/or J1708 datalinks and may be viewed through ServiceLink. See **Fig. 9**.

Input and Output Conditions

The wiper motor has a low speed, a high speed, and five intermittent speeds. The BHM controls the wiper motor speed by monitoring three J1939 messages that it receives from the ICU and acting accordingly. The three messages are: J1939 wiper on/off message, J1939 wiper low message, and J1939 wiper high message. When one of the intermittent speeds is selected at the multifunction switch, the ICU controls the timing of the wipers by pulsing the J1939 wiper on/off and J1939 wiper low messages.

Table 26 displays the multifunction switch inputs to the ICU and the J1939 message outputs.

Table 27 displays the wiper motor system inputs to the BHM and how it will react to these inputs.

Windshield Wiper/Washer System, Multifunction Switch I/O Conditions				
Inputs to ICU		**Outputs from ICU**		
Multifunction Switch Position	**Wiper Operation Timing**	**J1939 Wiper On/Off Message**	**J1939 Wiper Low Message**	**J1939 Wiper High Message**
OFF	Wiper Off	Off	Off	Off
Intermittent 1	Wipe every 17 seconds	Pulsed on	Pulsed on	Off
Intermittent 2	Wipe every 12 seconds	Pulsed on	Pulsed on	Off
Intermittent 3	Wipe every 8 seconds	Pulsed on	Pulsed on	Off
Intermittent 4	Wipe every 5 seconds	Pulsed on	Pulsed on	Off
Intermittent 5	Wipe every 3 seconds	Pulsed on	Pulsed on	Off
LOW	Wiper low speed	On	On	Off
HIGH	Wiper high speed	On	Off	On

Table 26, Windshield Wiper/Washer System, Multifunction Switch I/O Conditions

Windshield Wiper/Washer System, Wiper Motor System I/O 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

Troubleshooting

Windshield Wiper/Washer System, Wiper Motor System I/O 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
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 the Fault Conditions paragraph for more information.

Table 27, Windshield Wiper/Washer System, Wiper Motor System I/O Conditions

Fault Conditions

Table 28 displays multifunction switch combinations that will create a fault. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks.

Table 29 displays how the BHM will handle any other faults that it encounters in the wiper motor system. The reference parameters that program the BHM determine whether a fault code will be broadcasted. 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 either or both the J1939 and J1708 datalinks.

Windshield Wiper/Washer System, Wiper Motor System Multifunction Switch Fault Conditions			
Description of Multifunction Switch Fault			Action Taken by BHM
J1939 Wiper On/Off Message	J1939 Wiper Low Message	J1939 Wiper High Message	
Off	On	Off	BHM may transmit a J1939 and/or a J1708 fault message
On	Off	Off	BHM may transmit a J1939 and/or a J1708 fault message
On	On	On	BHM may transmit a J1939 and/or a J1708 fault message
Off	On	On	BHM may transmit a J1939 and/or a J1708 fault message
Off	Off	On	BHM may transmit a J1939 and/or a J1708 fault message

Table 28, Windshield Wiper/Washer System, Wiper Motor System Multifunction Switch Fault Conditions

Windshield Wiper/Washer System, Other Wiper Motor 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 message on the J1939 and/or J1708 datalinks
Wiper commutator switch is unavailable or in error	BHM will assume the wiper commutator switch is in PARK
J1939 wiper on/off message from the ICU is unavailable or in error	BHM may transmit a J1939 and/or a J1708 fault message
J1939 wiper low message from the ICU is unavailable or in error	BHM may transmit a J1939 and/or a J1708 fault message
J1939 wiper high message from the ICU is unavailable or in error	BHM may transmit a J1939 and/or a J1708 fault message
Contradictory J1939 messaging between the ICU and BHM	BHM may transmit a J1939 and/or a J1708 fault message
ICU sends an error indicator in any of the J1939 wiper messages to the BHM	BHM may transmit a J1939 and/or a J1708 fault message
BHM fails to receive any five consecutive J1939 wiper messages from the ICU	BHM may transmit a J1939 and/or a J1708 fault message
Wiper motor wiring open or shorted	BHM may transmit a J1939 and/or a J1708 fault message

Table 29, Windshield Wiper/Washer System, Other Wiper Motor Fault Conditions

Features and Options

The outputs for the following features can be controlled by software parameters, sensory inputs, manually controlled switch, or a combination of these. Read the descriptions for the various features and options below to help determine if a system is operating correctly.

- Back-Up Alarm
- Daytime Running Lights
- Directional/Hazard Lights
- Heater Booster Pump
- ID/Marker Lights
- Reverse Lights
- Service Brake

Back-Up Alarm

Activation of the backup lights/alarm is different depending on the transmission type. A manual transmission uses a standard switch to tell the BHM when the transmission is in reverse. Automatic transmissions will send a J1939 message to the BHM when they are placed into reverse gear. Described below is the standard automatic transmission.

The back-up alarm enables whenever the ignition switch is in the ON position and activates when the transmission selector is in reverse.

The back-up alarm produces an intermittent beeping sound until the transmission selector is no longer in reverse or there is no ignition power. See **Table 30** for back-up alarm inputs, and **Table 31** for back-up alarm outputs.

Body Taillights

The body Taillights output is activated when the park/headlamp switch is in the park lamp or headlamp position. See **Table 32** for body taillight inputs.

Daytime Running Lights

The daytime running lights (DRL) are enabled when the ignition switch is in the ON position, the headlamps are turned OFF, and the park brake is disengaged. See **Table 31** daytime running light inputs, and **Table 34** for daytime running light outputs.

Troubleshooting

Back-Up Alarm Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
Transmission in Reverse	Parameter on datalink: Vehicle transmission in reverse gear	Parameter used to notify the controller that the vehicle transmission is in reverse gear	—	—	—
Ignition	Vehicle ignition switch	Notifies the controller that the ignition switch is in the ON position	BHM	B6	A3

Table 30, Back-Up Alarm Inputs

Back-Up Alarm Outputs				
Output	**Function**	**Module**	**Connector**	**Pin**
Backup Alarm	Body backup alarm output	CHM	C5	J

Table 31, Back-Up Alarm Outputs

Body Taillights Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
Park Lamps	Parameter on datalink: Vehicle park lamps	Parameter used to notify the controller that the park lamp circuit is active	BHM	B6	B9
Headlamps	Parameter on datalink: Vehicle headlamps	Parameter used to notify the controller that the headlamp circuit is active	BHM	B6	B10

Table 32, Body Taillights Inputs

Daytime Running Light Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
IGN	Vehicle ignition switch in the ON position	Notifies the controller that the ignition switch is in the ON position	BHM	B6	A3
Headlamp Switch	Standard switch	Controls the headlamp operation	BHM	B6	B9 B10 B11
Park Brake	Standard pin switch	Notifies the controller if the park brake is set	CHM	C3	F

Table 33, Daytime Running Light Inputs

Daytime Running Light Outputs				
Outputs	**Function**	**Module**	**Connector**	**Pin**
Headlights — Left Low Beam	Front left low beams output	BHM	B1	R
Headlights — Right Low Beam	Front right low beams output	CHM	C3	L

Table 34, Daytime Running Light Outputs

Directional/Hazard Lights

Hazard lights are enabled regardless of the ignition switch position, and activate with the hazard switch located on the stalk switch. The rear and side hazard lights flash in sequence with the front and fender hazard lights.

The directional signals are enabled whenever the ignition switch is in the IGN or ACC position, and activate with the stalk (turn signal) switch. See **Table 35** for directional/hazard lights inputs, and **Table 36** for directional/hazard lights outputs.

Directional/Hazard Lights Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
Stalk Switch Left Turn Signal	Turn signal switch	Operates the left turn signal	N/A	N/A	N/A
Stalk Switch Right Turn Signal	Turn signal switch	Operates the right turn signal	N/A	N/A	N/A
Stalk Switch Hazard Signal	2-Position hazard signal switch	Operates the hazard signal	BHM	B6	B8
ACC	Vehicle ignition switch in the ACC position	Notifies the controller that the ignition switch is in the ACC position	BHM	B6	A1
IGN	Vehicle ignition switch in the ON position	Notifies the controller that the ignition switch is in the ON position	BHM	B6	A3

Table 35, Directional/Hazard Lights Inputs

Directional/Hazard Lights Outputs				
Outputs	**Function**	**Module**	**Connector**	**Pin**
Left Side Turn Lights	Body left side turn light output	CHM	C1, C2, C3	G, H, N
Right Side Turn Lights	Body right side turn light output	CHM	C1, C2, C3	P, E, R
Left Rear Turn Lights	Body left rear turn light output	BHM	B5	E
Right Rear Turn Lights	Body right rear turn light output	BHM	B5	G

Table 36, Directional/Hazard Lights Outputs

Reverse Lights

The reverse light (backup light) functions when the driver engages the transmission in the reverse gear, and is enabled whenever the ignition switch is in the IGN position only. When the transmission is in reverse, the standard upper left and right reverse lights and the optional lower left and right reverse lights

illuminate. See **Table 37** for reverse lights inputs, and **Table 38** for reverse lights outputs.

Reverse Lights Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
Trans In Reverse	Parameter on datalink: transmission in reverse	Parameter used to notify the controller that the vehicle transmission is in reverse gear	N/A	N/A	N/A
IGN	Vehicle ignition switch in the ACC position	Notifies the controller that the ignition switch is in the ACC position	BHM	B6	A3

Table 37, Reverse Lights Inputs

Reverse Lights Outputs				
Output	**Function**	**Module**	**Connector**	**Pin**
Left Reverse Lamp	Body left brake lamp output	CHM	C3	C, D
Right Reverse Lamp	Body right brake lamp output	CHM	C1	A, H, J

Table 38, Reverse Lights Outputs

Service Brake

The service brake circuit is enabled regardless of the ignition switch position.

Pressing the service brake pedal activates the brake pilot light and the rear brake lights. See **Table 39** for service brake inputs, and **Table 40** for service brake outputs.

Service Brake Inputs					
Input	**Type**	**Function**	**Mux Device**	**Connector**	**Pin**
Service Brake Switch	Switch located on the vehicle service brake pedal mechanism	Notifies the system that the vehicle service brake has been pressed	SHM	J1	R

Table 39, Service Brake Inputs

Service Brake Outputs				
Output	**Function**	**Module**	**Connector**	**Pin**
Lower Left Brake Lamps	Body lower left brake lamp output	SHM	J3	H
Upper Left Brake Lamps	Body upper left brake lamp output	CHM	C1	N
Lower Right Brake Lamps	Body lower right brake lamp output	SHM	J2	R
Upper Right Brake Lamps	Body upper right brake lamp output	CHM	C1	L

Table 40, Service Brake Outputs

General Information

Use **Table 1** to identify J1939 fault codes and an overview of the diagnostic procedure for fault codes generated by the bulkhead module (BHM), SA 33.

Use **Table 2** to identify J1587/J1708 BHM fault codes. J1587 fault codes consist of the following elements in the order listed:

- Message Identifier (MID) – Identifies which electronic control unit (ECU) the fault is coming from. The J1587 MID identifying all BHM information faults is 164.
- Subsystem Identifier (SID) – Indicates what function on the ECU has failed.
- Failure Mode Indicator (FMI) – Indicates in what way the function failed. See **Table 3** for a list of the J1587 failure mode indicators.

Always use the appropriate schematic for the vehicle as different option content will modify which connector and pin are actually used. BHM B1, A indicates that the typical circuit is BHM connector B1, pin A.

J1587 fault codes are shown under J1708 in ServiceLink. J1587 and J1708 are the same datalink protocol.

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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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.	—	—

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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.	—	—
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
6984	6	Ignition accessory output circuit — current above expected value	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.	295A or 98	**BHM** B6,A9 or B6,A10
6985	5	Ignition output circuit — current below expected value	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.	439W+ 376C, 223A, 439A, 81C	**BHM** B1, F B1, P B2, L B2, K B6, A8
6985	6	Ignition output circuit — current above expected value	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.	439W+ 376C, 223A, 439A, 81C	**BHM** B1, F B1, P B2, L B2, K B6, A8
6985	7	The CHM ignition input circuit is not measuring the same state as the BHM ignition output circuit	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.	81C	**CHM** C3, M and **BHM** B6, A8

<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>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>
<tr><td>6987</td><td>5</td><td>Tail lamp circuit — current below expected value</td><td>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.</td><td>23, 23A, 23C</td><td>BHM
B1, K
and
CHM
C1, D
C1, E
C1, F
C2, G
C3, P</td></tr>
<tr><td>6987</td><td>6</td><td>Tail lamp circuit — current above expected value</td><td>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.</td><td>23, 23A, 23C</td><td>BHM
B1, K
and
CHM
C1, D
C1, E
C1, F
C2, G
C3, P</td></tr>
<tr><td>6988</td><td>5</td><td>Left low beam headlamp circuit — current below expected value</td><td>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.</td><td>20L</td><td>BHM
B1, R</td></tr>
<tr><td>6988</td><td>6</td><td>Left low beam headlamp circuit — current above expected value</td><td>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.</td><td>20L</td><td>BHM
B1, R</td></tr>
</table>

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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

Fault Code Information

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	**FMI**	**Fault Description**	**Diagnosis**	**Circuit**	**ECU Conn/ Pin**
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
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.	—	—

J1939 Fault Codes From Bulkhead Module (SA 33)					
SPN	FMI	Fault Description	Diagnosis	Circuit	ECU Conn/ Pin
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)

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	Description	Possible FMI
000	Backlighting Dimmer Switch Fault	7
001	Clutch Switch Fault	7
002	Reserved for Future Use	—
003	Headlamp Switch Disagreement - Both Park and On Inputs are CLOSED	7
004	Stalk Switch High Beam Input Fault	2
005	Ignition Switch Fault	7
006	Marker Interrupt Switch Fault	7
007	Stalk Switch Disagreement - Both Wiper High and Wiper Low Inputs are ON	2
008	Stalk Switch Disagreement - Wiper On/Off Input is OFF and Wiper High or Low Input is ON	2
009	Wiper Park Input Fault	7
010	ICU3-M2 Hazard Switch CAN Feedback Error	2
011	Stalk Switch Left Turn Signal Input Fault	2
012	Stalk Switch Right Turn Signal Input Fault	2
013	Stalk Switch Washer Switch Input Fault	2
014	Stalk Switch Wiper On/Off Input Fault	2
015	Stalk Switch Wiper Low Input Fault	2
016	Stalk Switch Wiper High Input Fault	2
017	Wheel Based Vehicle Speed CAN Message Error	2
018	Wake up Hardware Fault (modules are kept awake)	7
019	Unknown Keep Awake Fault (modules are kept awake)	7
020	Extra Smart Switch	7
021	Duplicate Smart Switch	7
022	Missing Smart Switch	7
023	Fifth Wheel Solenoid Unexpected Pressure Feedback	7

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
024	Fifth Wheel Solenoid No Pressure Feedback	7
025	End of Frame Air Unexpected Pressure Feedback	7
026	End of Frame Air No Pressure Feedback	7
027	Axle Lift Unexpected Pressure Feedback	7
028	Axle Lift No Pressure Feedback	7
029	Suspension Dump Unexpected Pressure Feedback	7
030	Suspension Dump No Pressure Feedback	7
031	Suspension Proportioning Unexpected Pressure Feedback	7
032	Suspension Proportioning No Pressure Feedback	7
033	Cigar Lighter Output Fault	7
034	BHM / ICU3-M2 Ignition Mismatch	7
035	BHM / ICU3-M2 Hazard Switch Mismatch	2
036	BHM / ICU3-M2 Wiper Park Mismatch	2
037	Missing Transmission CAN Message	9
038	Missing Chassis Module CAN Message	9
039	Remote Bucket Switch Stuck Fault	7
040	Axle Lift 2 Feedback Fault	7
041	Axle Lift 2 No Feedback Fault	7
042	PTO 1 Feedback Fault	7
043	PTO 1 No Feedback Fault	7
044	PTO 2 Feedback Fault	7
045	PTO 2 No Feedback Fault	7
046-049	Reserved for Future Use	—
050	BHM B1.A	3,4
051	BHM B1.F, B1.P, B2.K, B2.L, B6.A8	5,6
052	BHM B1.J	3,4
053	BHM B1.K, B5.C	5,6
054	BHM B1.L	5,6
055	BHM B1.N	3,4
056	BHM B1.R	5,6
057	BHM B2.M	5,6
058	BHM B3.D	3,4
059	BHM B3.E	3,4,5,6
060	BHM B3.F	5,6
061	BHM B3.G	5,6

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
062	BHM B3.H	5,6
063	BHM B4.B	5,6
064	BHM B4.E, B4.F	3,4,5,6
065	BHM B4.G	3,4
066	BHM B4.K	3,4
067	BHM B4.M, B5.E	3,4,5,6
068	BHM B5.A, B7.A12	5,6
069	BHM B6.A9, B6.A10	5,6
070	BHM B5.B	5,6
071	BHM B5.D	5,6
072	BHM B5.F	3,4,5,6
073	BHM B5.G	3,4,5,6
074	BHM B5.H, B7.A1	3,4,5,6
075	CHM C1.A, C1.H, C1.J	5,6
076	CHM C1.G, C2.H, C3.N	5,6
077	CHM C1.L	5,6
078	CHM C1.N	5,6
079	CHM C1.P, C2.E, C3.R	5,6
080	CHM C2.A	3,4
081	CHM C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
082	CHM C3.A	3,4,5,6
083	CHM C3.C, C3.D	5,6
084	CHM C3.E	3,4
085	CHM C3.F	3,4
086	CHM C3.J	3,4
087	CHM C3.K	5,6
088	CHM C3.L	5,6
089	CHM C4.F	5,6
090	CHM C4.J	3,4
091	CHM C4.K	5,6
092	CHM C4.P	3,4
093	CHM C5.A	3,4
094	CHM C5.B	3,4
095	CHM C5.F	3,4
096	CHM C5.G	3,4

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
097	CHM C5.H	3,4
098	CHM C5.J	3,4
099	CHM C5.L	3,4
100	CHM C5.M	3,4
101	EXM1 C1.A, C1.H, C1.C	5,6
101	EXM1 C4.K	5,6
101	EXM1 C3.L	5,6
101	EXM1 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
101	EXM1 C1.N	5,6
101	EXM1 C1.L	5,6
101	EXM1 C1P, C2.E, C3.R	5,6
101	EXM1 C1.G, C2.H, C3.N	5,6
101	EXM1 C2.A	3,4
101	EXM1 C3.A	3,4,5,6
101	EXM1 C3.C, C3.D	5,6
101	EXM1 C3.K	5,6
101	EXM1 C4.F	5,6
101	EXM1 C5.H	3,4
101	EXM1 C5.C	3,4
101	EXM1 C5.L	3,4
101	EXM1 C5.M	3,4
101	EXM1 C3.E	3,4
101	EXM1 C3.F	3,4
101	EXM1 C3.C	3,4
101	EXM1 C4.C	3,4
101	EXM1 C4.P	3,4
101	EXM1 C5.A	3,4
101	EXM1 C5.B	3,4
101	EXM1 C5.F	3,4
101	EXM1 C5.G	3,4
102	EXM2 C1.A, C1.H, C1.C	5,6
102	EXM2 C4.K	5,6
102	EXM2 C3.L	5,6
102	EXM2 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
102	EXM2 C1.N	5,6

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
102	EXM2 C1.L	5,6
102	EXM2 C1P, C2.E, C3.R	5,6
102	EXM2 C1.G, C2.H, C3.N	5,6
102	EXM2 C2.A	3,4
102	EXM2 C3.A	3,4,5,6
102	EXM2 C3.C, C3.D	5,6
102	EXM2 C3.K	5,6
102	EXM2 C4.F	5,6
102	EXM2 C5.H	3,4
102	EXM2 C5.C	3,4
102	EXM2 C5.L	3,4
102	EXM2 C5.M	3,4
102	EXM2 C3.E	3,4
102	EXM2 C3.F	3,4
102	EXM2 C3.C	3,4
102	EXM2 C4.C	3,4
102	EXM2 C4.P	3,4
102	EXM2 C5.A	3,4
102	EXM2 C5.B	3,4
102	EXM2 C5.F	3,4
102	EXM2 C5.G	3,4
103	EXM3 C1.A, C1.H, C1.C	5,6
103	EXM3 C4.K	5,6
103	EXM3 C3.L	5,6
103	EXM3 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
103	EXM3 C1.N	5,6
103	EXM3 C1.L	5,6
103	EXM3 C1P, C2.E, C3.R	5,6
103	EXM3 C1.G, C2.H, C3.N	5,6
103	EXM3 C2.A	3,4
103	EXM3 C3.A	3,4,5,6
103	EXM3 C3.C, C3.D	5,6
103	EXM3 C3.K	5,6
103	EXM3 C4.F	5,6
103	EXM3 C5.H	3,4

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
103	EXM3 C5.C	3,4
103	EXM3 C5.L	3,4
103	EXM3 C5.M	3,4
103	EXM3 C3.E	3,4
103	EXM3 C3.F	3,4
103	EXM3 C3.C	3,4
103	EXM3 C4.C	3,4
103	EXM3 C4.P	3,4
103	EXM3 C5.A	3,4
103	EXM3 C5.B	3,4
103	EXM3 C5.F	3,4
103	EXM3 C5.G	3,4
104	EXM4 C1.A, C1.H, C1.C	5,6
104	EXM4 C4.K	5,6
104	EXM4 C3.L	5,6
104	EXM4 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
104	EXM4 C1.N	5,6
104	EXM4 C1.L	5,6
104	EXM4 C1P, C2.E, C3.R	5,6
104	EXM4 C1.G, C2.H, C3.N	5,6
104	EXM4 C2.A	3,4
104	EXM4 C3.A	3,4,5,6
104	EXM4 C3.C, C3.D	5,6
104	EXM4 C3.K	5,6
104	EXM4 C4.F	5,6
104	EXM4 C5.H	3,4
104	EXM4 C5.C	3,4
104	EXM4 C5.L	3,4
104	EXM4 C5.M	3,4
104	EXM4 C3.E	3,4
104	EXM4 C3.F	3,4
104	EXM4 C3.C	3,4
104	EXM4 C4.C	3,4
104	EXM4 C4.P	3,4
104	EXM4 C5.A	3,4

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
104	EXM4 C5.B	3,4
104	EXM4 C5.F	3,4
104	EXM4 C5.G	3,4
105	EXM5 C1.A, C1.H, C1.C	5,6
105	EXM5 C4.K	5,6
105	EXM5 C3.L	5,6
105	EXM5 C2.F, C4.C, C4.D, C4.L, C4.M	3,4,5,6
105	EXM5 C1.N	5,6
105	EXM5 C1.L	5,6
105	EXM5 C1P, C2.E, C3.R	5,6
105	EXM5 C1.G, C2.H, C3.N	5,6
105	EXM5 C2.A	3,4
105	EXM5 C3.A	3,4,5,6
105	EXM5 C3.C, C3.D	5,6
105	EXM5 C3.K	5,6
105	EXM5 C4.F	5,6
105	EXM5 C5.H	3,4
105	EXM5 C5.C	3,4
105	EXM5 C5.L	3,4
105	EXM5 C5.M	3,4
105	EXM5 C3.E	3,4
105	EXM5 C3.F	3,4
105	EXM5 C3.C	3,4
105	EXM5 C4.C	3,4
105	EXM5 C4.P	3,4
105	EXM5 C5.A	3,4
105	EXM5 C5.B	3,4
105	EXM5 C5.F	3,4
105	EXM5 C5.G	3,4
106	Reserved for Future Use	—
107	SHM J1.A, J1.E	6
108	SHM J3.G (PWM)	6
109	SHM J3.M (PWM)	6
110	SHM J3.F	5,6

Fault Code Information

J1587 SIDs for Bulkhead Module (BHM) MID 164		
SID	**Description**	**Possible FMI**
111	SHM J3.K	5,6

Table 2, J1587 SIDs for Bulkhead Module (BHM) MID 164

Failure Mode Identifiers	
FMI	**J1587 Description**
00	Data valid but above normal operational range (engine overheating)
01	Data valid but below normal operational range (engine oil pressure too low)
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 properly
08	Abnormal frequency, pulse width, or period
09	Abnormal update rate
10	Abnormal rate of change
11	Failure mode not identifiable
12	Bad intelligent device or component
13	Out of Calibration
14	Special Instructions

Table 3, Failure Mode Identifiers

Specifications

For an isometric view of the Bulkhead Module, see **Fig. 1**.

For a side view of the Bulkhead Module with pinout assignments, see **Fig. 2**.

For connector B1 forward chassis harness pinouts, see **Table 1**.

For connector B2 engine harness pinouts, see **Table 2**.

For connector B3 frontwall harness pinouts, see **Table 3**.

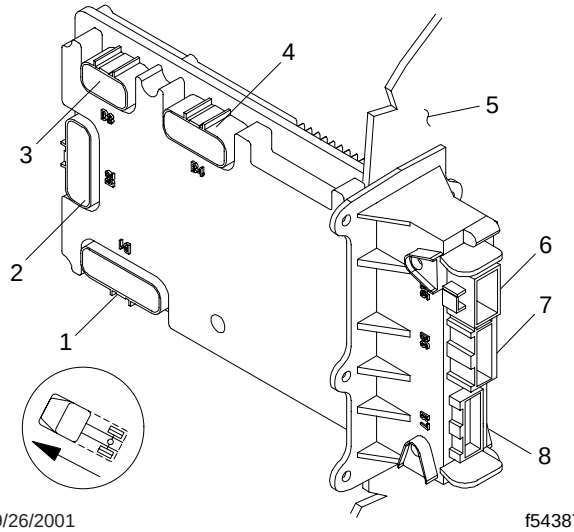
For connector B4 frontwall harness pinouts, see **Table 4**.

For connector B5 dash harness pinouts, see **Table 5**.

For connector B6 dash harness pinouts, see **Table 6**.

For connector B7 dash harness pinouts, see **Table 7**.

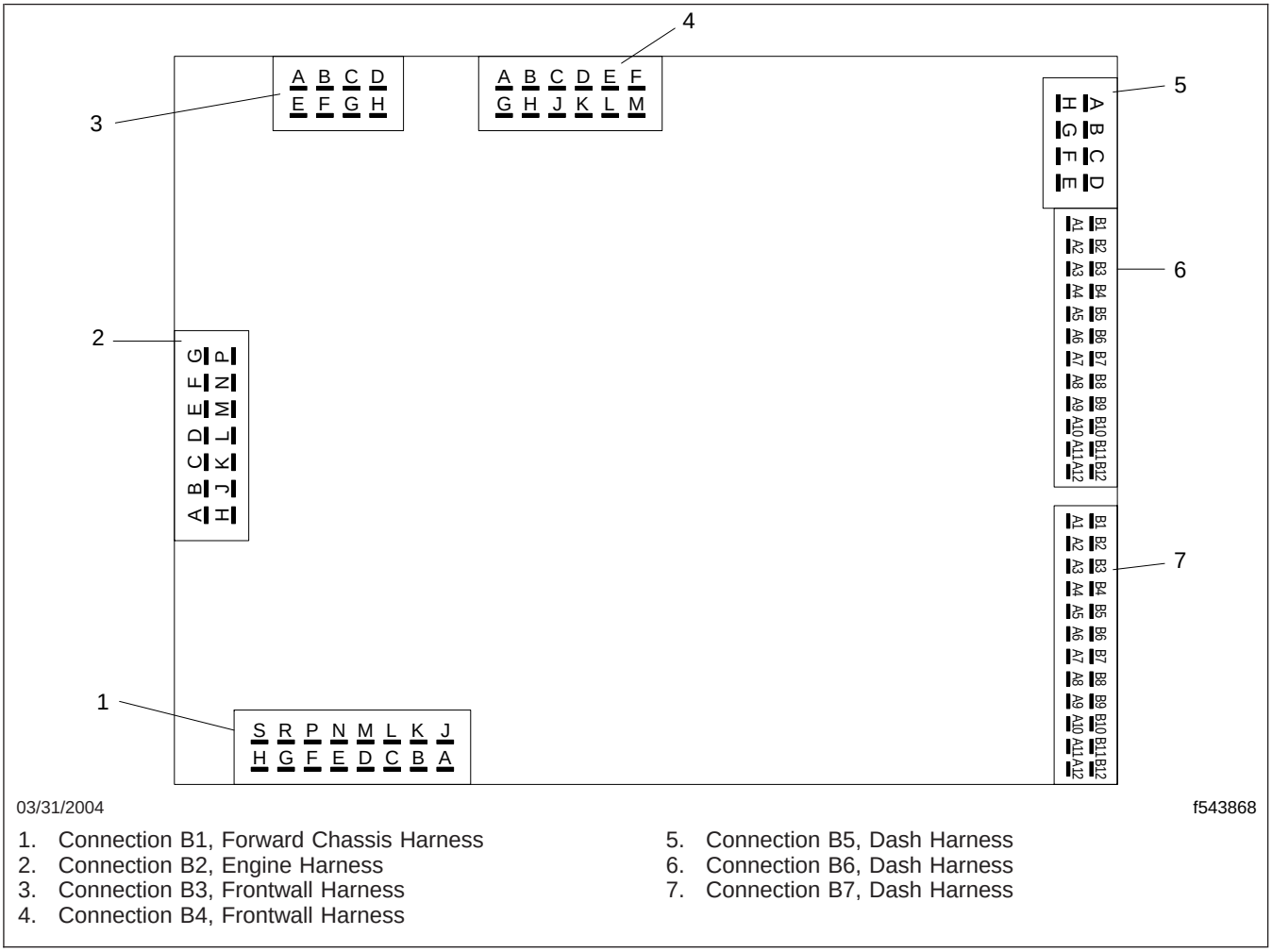
For power supply fuses and associated outputs for the Bulkhead Module, see **Table 8**.



1. Connection B1, Forward Chassis Harness
2. Connection B2, Engine Harness
3. Connection B3, Frontwall Harness
4. Connection B4, Frontwall Harness
5. Frontwall
6. Connection B5, Dash Harness
7. Connection B6, Dash Harness
8. Connection B7, Dash Harness

Fig. 1, Bulkhead Module (isometric view)

Specifications



1. Connection B1, Forward Chassis Harness
2. Connection B2, Engine Harness
3. Connection B3, Frontwall Harness
4. Connection B4, Frontwall Harness
5. Connection B5, Dash Harness
6. Connection B6, Dash Harness
7. Connection B7, Dash Harness

Fig. 2, Bulkhead Module (side view) With Pinout Assignments

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	—	—
B1-D	—	—
B1-E	Ground	Power Ground
B1-F	Fuel/Water Sensor Ignition Power	Digital Output
B1-G	Fuel Level Sensor Ground	Signal Ground
B1-H	J1587+ Datalink	Datalink
B1-J	Battery Power (VBAT5)	Power

Connector B1 Forward Chassis Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B1-K	—	—
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	J1587– Datalink	Datalink

Table 1, Connector B1 Forward Chassis Harness Pinouts

Connector B2 Engine Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B2-A	J1587+ Datalink	Datalink
B2-B	J1939+ Datalink	Datalink
B2-C	J1587+ Datalink	Datalink
B2-D	J1587– Datalink	Datalink
B2-E	—	—
B2-F	—	—
B2-G	Reverse Signal from Manual Transmission	Digital Input
B2-H	J1587– Datalink	Datalink
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

Specifications

Connector B3 Frontwall Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B3-F	Wiper Motor High Speed	Digital Output
B3-G	—	—
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 Digital Input 9	Digital Input
B4-B	Starter Relay	Digital Output
B4-C	Ground	Ground
B4-D	Hydraulic Brake Lamp Signal	Digital Input
B4-E	—	—
B4-F	—	—
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	—	—
B4-M	—	—

Table 4, Connector B4 Frontwall Harness Pinouts

Connector B5 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
B5-A	—	—
B5-B	Neutral Interlock Park Brake	Digital Output
B5-C	Marker Lamps	Digital Output
B5-D	Instrument Cluster Wake-up	Digital Input/Output
B5-E	Auxiliary Ignition	Digital Output
B5-F	ID/Marker Lights	Digital Output
B5-G	—	—
B5-H	Panel Lamp Backlighting (PWM)	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/Output
B6-A3	Ignition Switch ON	Digital Input
B6-A4	—	—
B6-A5	Ignition Switch CRANK	Digital Input
B6-A6	Wheelchair Lift Power	Digital Input
B6-A7	—	—
B6-A8	VCU Ignition Power	Digital Output
B6-A9	HVAC/Radio Accessory Power	Digital Output
B6-A10	Radio Accessory Power	Digital Output
B6-A11	J1587– Datalink	Datalink
B6-A12	J1587+ Datalink	Datalink
B6-B1	Horn Switch	Digital Input
B6-B2	Top of Clutch Switch Shifter Lockout (automatic transmission) (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

Specifications

Connector B7 Dash Harness Pinouts		
Connector Pin	**Signal Name**	**Signal Type**
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
B7-A11	Smart Switch 5 ID 2	Analog Input
B7-A12	—	—
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

Specifications

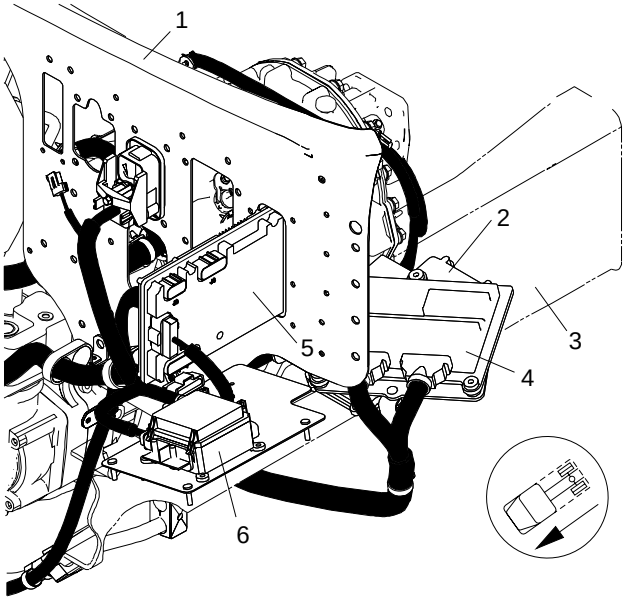
Power Supply Fuses and Associated Outputs for the Bulkhead Module				
BHM Power Input	**BHM Power Input Pin**	**Fuse Supplying BHM Power Input**	**BHM Outputs Supplied**	**BHM Output Pin**
Power In			**Power Out**	
VBAT1	B3.D	Fuse 22 (30A)	Buzzer for Emergency Doors	B5.A
			Battery (Smart Switches)	B7.A12
			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
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
			Right Rear Turn Lamp	B5.G
			Panel Lamps	B5.H
			Panel Lamps (Smart Switch)	B7.A1
VBAT4	B4.K	Fuse 15 (30A)	Clearance Lamps	B5.C
			Washer Pump	B3.G
VBAT5	B1.J	Fuse 7 (30A)	Left Rear Turn Lamp	B5.E / B4.M

Table 8, Power Supply Fuses and Associated Outputs for the Bulkhead Module

General Information

The Chassis Module (CHM) is the secondary module of the vehicle electrical system, and acts as a slave to the Bulkhead Module.

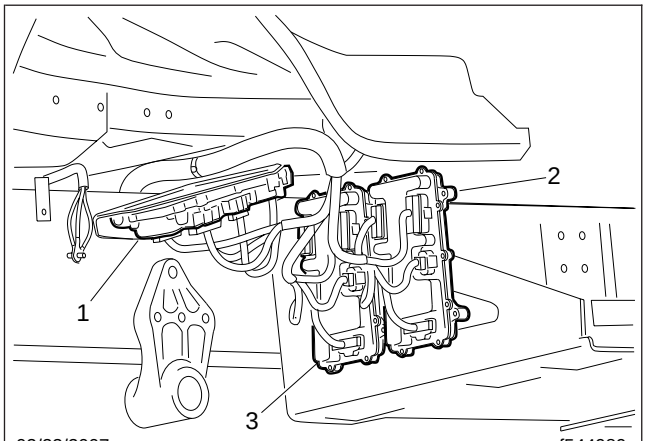
The Chassis Module is mounted to the bracket that holds the transmission control unit on the outside of the left-hand frame rail just behind the front wheel well. See **Fig. 1** and **Fig. 2**. It has five harness connections. See **Fig. 3**.



08/23/2004 f544515

1. Frontwall
2. Chassis Module
3. Left-Hand Frame Rail
4. Transmission ECU
5. Bulkhead Module
6. Main PDM

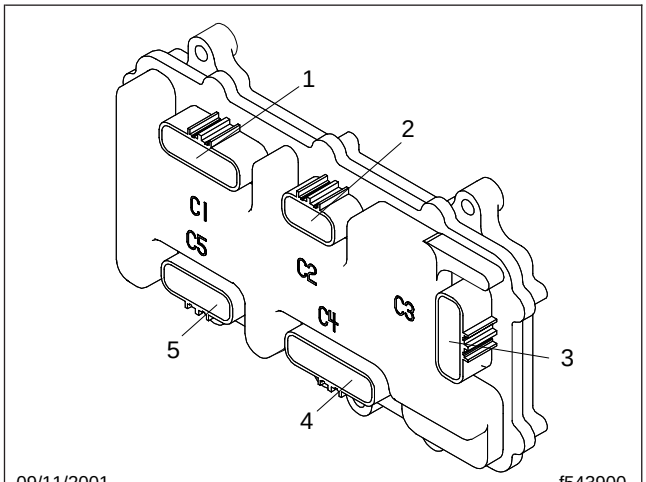
Fig. 1, Chassis Module Mounted to Frame Rail (vehicles built through 12/31/06)



02/23/2007 f544989

1. Expansion Module 2 (optional)
2. Expansion Module 1 (optional)
3. Chassis Module

Fig. 2, Chassis Module (vehicles built from 1/1/07)



09/11/2001 f543900

1. Connection C1, Forward Chassis Harness
2. Connection C2, Forward Chassis Harness
3. Connection C3, Forward Chassis Harness
4. Connection C4, Forward Chassis Harness
5. Connection C5, Forward Chassis Harness

Fig. 3, Chassis Module Connectors

Chassis Module Removal and Installation

Removal

IMPORTANT: It is normally not necessary to replace the Chassis Module. Removing and installing the electronic Chassis Module controller should be a last resort to solving electrical problems, unless the unit needs replacing due to physical damage. Follow procedures in Bulkhead Module **Section 54.01, Troubleshooting 300** to help solve electrical problems involving this module before replacing either the Bulkhead Module or Chassis Module. If troubleshooting indicates a malfunction of either module, try reflashing the parameters and the software before replacing the module. Also check external wiring.

Also see **Section 54.00**, Electrical System, for more information about the vehicle electrical system in general, and **Troubleshooting 300** of that section for help in troubleshooting the entire electrical system.

1. Disconnect the negative leads from the batteries.

NOTE: The chassis module is mounted under the transmission ECU on a bracket mounted outside the left-hand frame rail aft of the front wheels. See **Fig. 1**.

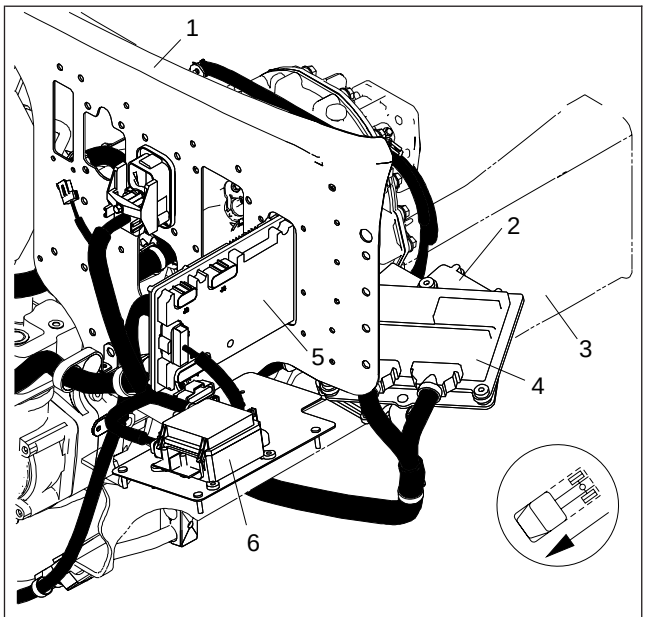
2. Unplug harness connectors C1 through C5 from the chassis module. See **Fig. 2**.

NOTE: Before removing the Chassis Module from its mounting plate, take note of its orientation. Connector C3 should be toward the rear of the vehicle and connectors C1 and C5 should be toward the front.

3. Remove the mounting nuts and washers that secure the Chassis Module to the mounting plate and remove the Chassis Module.

Installation

1. Properly orient the Chassis Module on its mounting plate. See **Fig. 3**. Install the module on the mounting plate with the mounting nuts and washers.
2. Plug the wiring harness connectors into Chassis Module connectors C1 through C5. See **Fig. 2**.



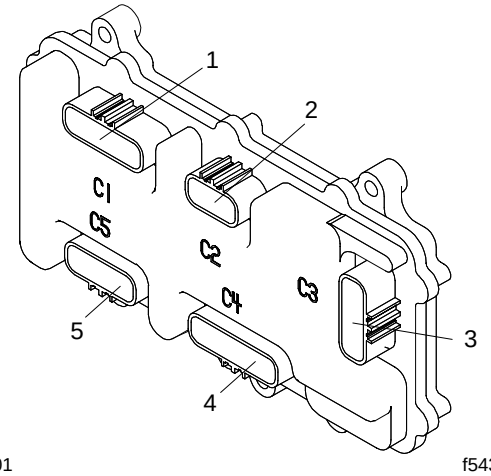
08/23/2004 f544515

1. Frontwall
2. Chassis Module
3. Left-Hand Frame Rail
4. Transmission ECU
5. Bulkhead Module
6. Main PDM

Fig. 1, Chassis Module Mounted to Frame Rail

3. Connect the batteries.
4. Check to make sure electrical components work.

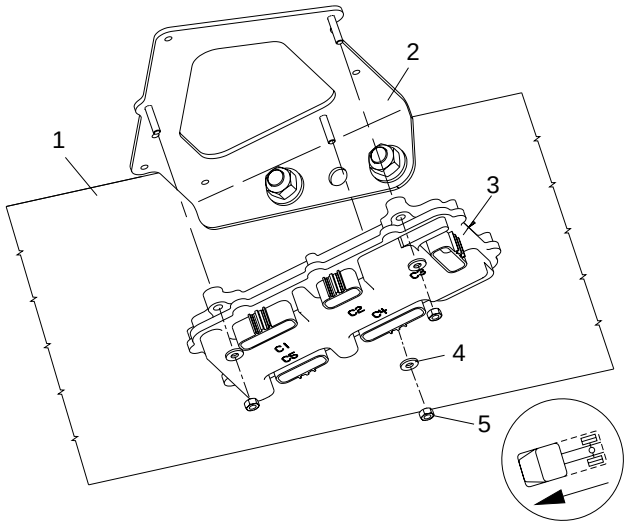
Chassis Module Removal and Installation



09/11/2001 f543900

1. Connection C1, Forward Chassis Harness
2. Connection C2, Forward Chassis Harness
3. Connection C3, Forward Chassis Harness
4. Connection C4, Forward Chassis Harness
5. Connection C5, Forward Chassis Harness

Fig. 2, Chassis Module Connectors



08/23/2004 f544516

1. Left-Hand Frame Rail
2. Transmission ECU Mounting Bracket
3. Chassis Module
4. Washer, 1/4-Inch i.d., Stainless Steel
5. Hexnut, 1/4–20

Fig. 3, Chassis Module Installation

Specifications

For an isometric view of the Chassis Module, see **Fig. 1**.

For a side view of the Chassis Module with pinout assignments, see **Fig. 2**.

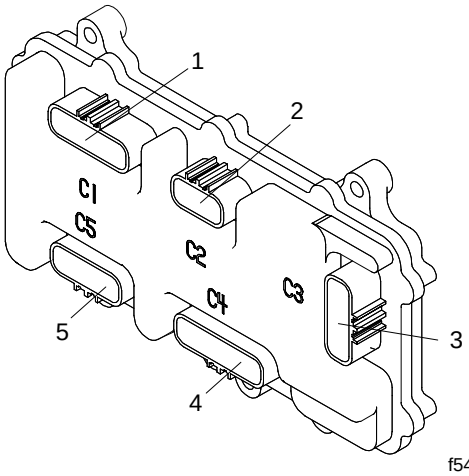
For forward chassis harness pinouts at connector C1, see **Table 1**.

For forward chassis harness pinouts at connector C2, see **Table 2**.

For forward chassis harness pinouts at connector C3, see **Table 3**.

For forward chassis harness pinouts at connector C4, see **Table 4**.

For power supply fuses and associated outputs for the Chassis Module, see **Table 5**.



09/11/2001 f543900

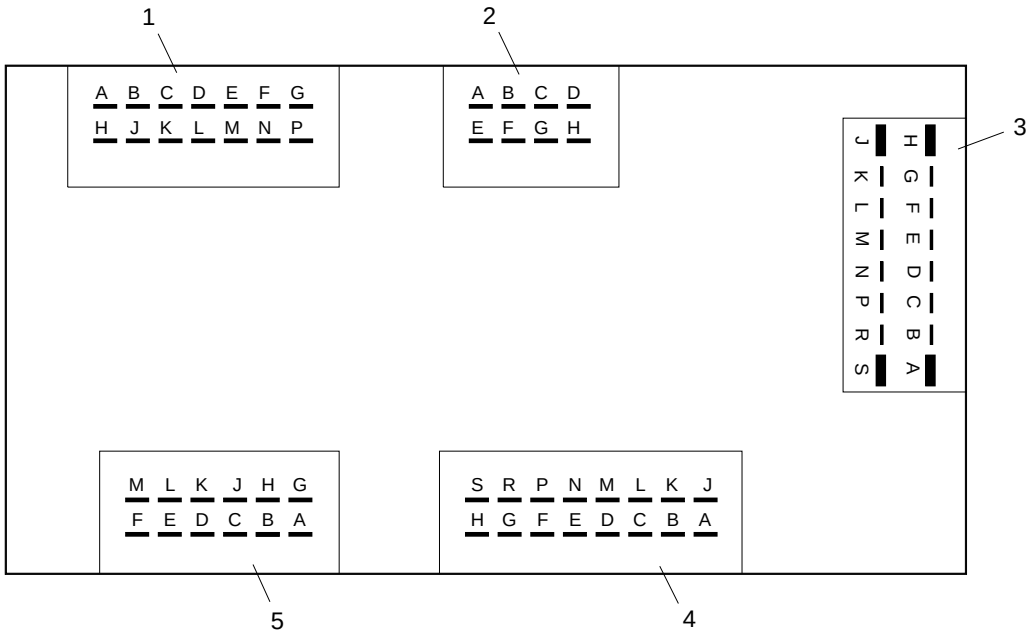
1. Connection C1, Forward Chassis Harness
2. Connection C2, Forward Chassis Harness
3. Connection C3, Forward Chassis Harness
4. Connection C4, Forward Chassis Harness
5. Connection C5, Forward Chassis Harness

Fig. 1, Chassis Module (isometric view)

Forward Chassis Harness Pinouts at Connector C1			
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Number**
C1-A	—	—	See C1-H
C1-B	—	—	—
C1-C	—	—	—
C1-D	—	—	—
C1-E	—	—	—
C1-F	—	—	—
C1-G	—	—	See C3-N
C1-H	Reverse Light—Right Side	Digital Output	120E
C1-J	—	—	See C1-H
C1-K	—	—	—
C1-L	Right Brake Light	Digital Output	36K
C1-M	—	—	—
C1-N	Left Brake Light	Digital Output	36J
C1-P	—	—	See C3-R

Table 1, Forward Chassis Harness Pinouts at Connector C1

Specifications



1. Connection C1, Forward Chassis Harness
2. Connection C2, Forward Chassis Harness
3. Connection C3, Forward Chassis Harness
4. Connection C4, Forward Chassis Harness
5. Connection C5, Forward Chassis Harness

Fig. 2, Chassis Module With Pinout Assignments

Forward Chassis Harness Pinouts at Connector C2			
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Number**
C2-A	—	—	—
C2-B	—	—	—
C2-C	—	—	—
C2-D	—	—	—
C2-E	—	—	See C3-R
C2-F	License Plate Lamp	Digital Output	23C
C2-G	—	—	—
C2-H	—	—	See C3-N

Table 2, Forward Chassis Harness Pinouts at Connector C2

Forward Chassis Harness Pinouts at Connector C3			
Connector Pin	**—**	**—**	**—**
C3-A	Fuel/Water Separator Heater	Digital Output	196
C3-B	J1587– Datalink	Datalink	1587–
C3-C	—	—	See C3-D

Forward Chassis Harness Pinouts at Connector C3			
Connector Pin	**—**	**—**	**—**
C3-D	Reverse Light—Left Side	Digital Output	120D
C3-E	Spare Input CAS1—Low Air	Digital Input (Active Low)	18
C3-F	Spare Input CAS0—Park Brake	Digital Input (Active Low)	125S
C3-G	Service Brake	Digital Input (Active Low)	36
C3-H	Ground	Power Ground	GND
C3-J	Main Battery Power (VBAT2)	Power	14G
C3-K	Turn Lights—Front Right (DRL)	Digital Output	38R
C3-L	Right Low Beam	Digital Output	21L
C3-M	Ignition	Digital Input (Active High)	376C
C3-N	Turn Lights—Left Side, Fender	Digital Output	38E
C3-P	—	—	—
C3-R	Turn Lights—Right Side, Fender	Digital Output	38F
C3-S	J1587+ Datalink	Datalink	1587+

Table 3, Forward Chassis Harness Pinouts at Connector C3

Forward Chassis Harness Pinouts at Connector C4			
Connector Pin	**Signal Name**	**Signal Type**	**Circuit Number**
C4-A	Module Wake-Up Signal	Digital Input/Output	—
C4-B	Address Identification A	Analog Input	481
C4-C	Left Park Lamp	Digital Output	102A
C4-D	Left Marker Lamp	Digital Output	46E
C4-E	Address Identification C	Analog Input	481
C4-F	Turn Lights—Front Left (DRL)	Digital Output	38L
C4-G	J1939+ Datalink	Datalink	1939+
C4-H	Ground (Address Identification D)	Signal Ground	—
C4-J	Main Battery Power (VBAT3)	Power	14G
C4-K	Right High Beam	Digital Output	21H
C4-L	Right Park Lamp	Digital Output	102B
C4-M	Right Marker Lamp	Digital Output	46F
C4-N	Address Identification B	Analog Input	—
C4-P	Main Battery Power (VBAT1)	Power	14G
C4-R	J1939– Datalink	Datalink	1939–
C4-S	Ground	Power Ground	GND

Table 4, Forward Chassis Harness Pinouts at Connector C4

Specifications

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 Lights—Right Side, Fender	C3.R
			Turn Lights—Right Side, Fender	C1.P
			Right Brake Light	C1.L
			Left Brake Light	C1.N
			Turn Lights—Front Right	C3.K
			Reverse Light—Left Side	C3.D
			Turn Lights—Right Side, Fender	C2.E
VBAT2	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
			Reverse Light—Right Side	C1.H
			Turn Lights—Left Side, Fender	C3.N
			Turn Lights—Front Left	C4.F
VBAT3	C4.J	Fuse 13 (30A)	Fuel Water Separator Heater	C3.A

Table 5, Power Supply Fuses and Associated Outputs for the Chassis Module

NOTE: The power supply to the Bulkhead Module microprocessor is supplied from any of the five VBAT inputs (VBAT1, VBAT2, VBAT3, VBAT4, or VBAT5) through an internal diode network. The same is true for the Chassis Module with its input VBAT1, VBAT2, or VBAT3. In theory, if any one of the module's VBAT inputs is supplying power, the module will be functional.

General Information

The main power distribution module (PDM) is mounted under the hood on the left-hand front fender and distributes battery power to the vehicle control modules, including the Bulkhead Module, Chassis Module, Expansion Modules, and vehicle ECUs. The main PDM contains the fuses required to protect the power feed circuits to these modules. While the main PDM provides power to them, the modules themselves control power flow and circuit protection to the various components of the vehicle electrical systems. Because of this, traditional PDM devices such as relays and circuit breakers are no longer necessary on the main PDM.

The cab PDM is located in the switch panel cavity at the driver's left elbow and powers the Switch Hub Module, as well as circuits inside the vehicle, such as heaters, doors, fans, lights, and other interior accessories.

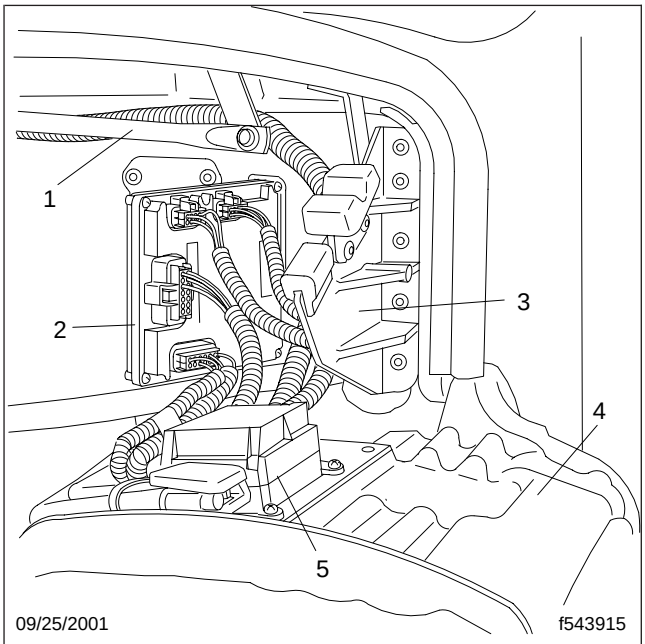
Main Power Distribution Module (PDM) Replacement

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 quarter fender. See **Fig. 1**.

2. Disconnect the battery power electrical ring connectors from the power studs by removing the two nuts and removing the cables. See **Fig. 2** and **Fig. 3**.



1. Wiper Linkage Arm
2. Bulkhead Module
3. Hood Support Bracket
4. Quarter Fender
5. Power Distribution Module

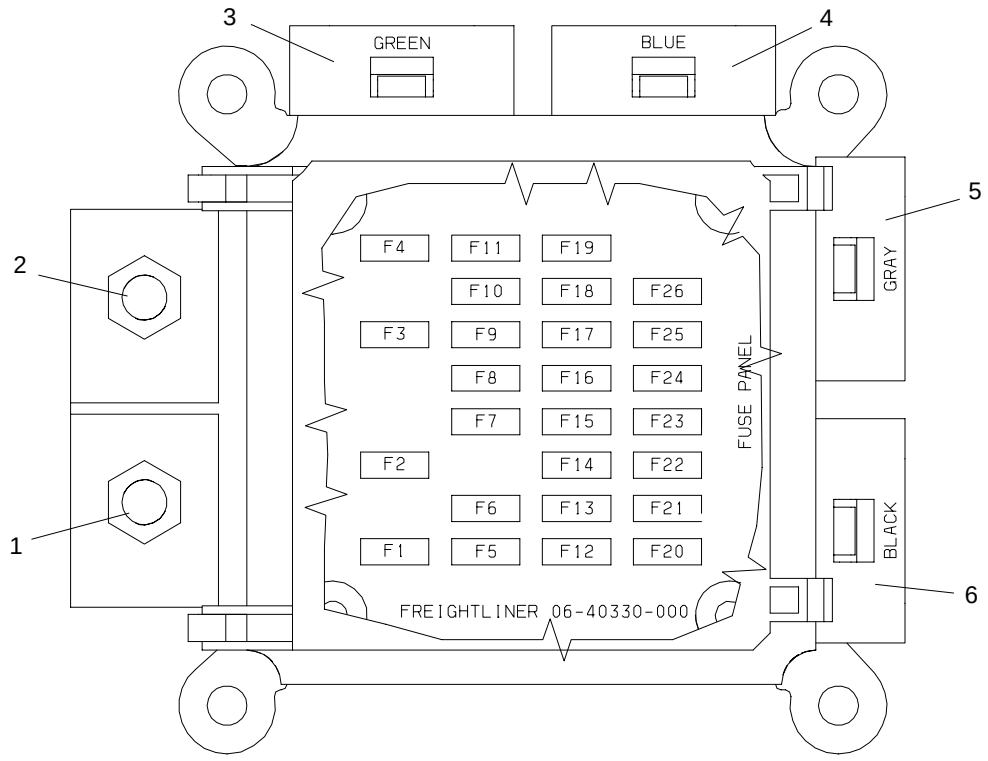
Fig. 1, Main Power Distribution Module Location

3. Remove the four harness connectors (green, blue, gray, and black) from the PDM.
4. Remove the four Torx capscrews and remove the PDM.

Installation

1. Properly orient the PDM and tighten the four Torx capscrews.
2. Plug in the four electrical harness connectors (green, blue, gray, and black) to the PDM.
3. Place the battery power electrical ring connectors on the battery power studs and secure the connectors with nuts and washers.
4. Connect the batteries.
5. Verify correct operation of the electrical components.

Main Power Distribution Module (PDM) Replacement

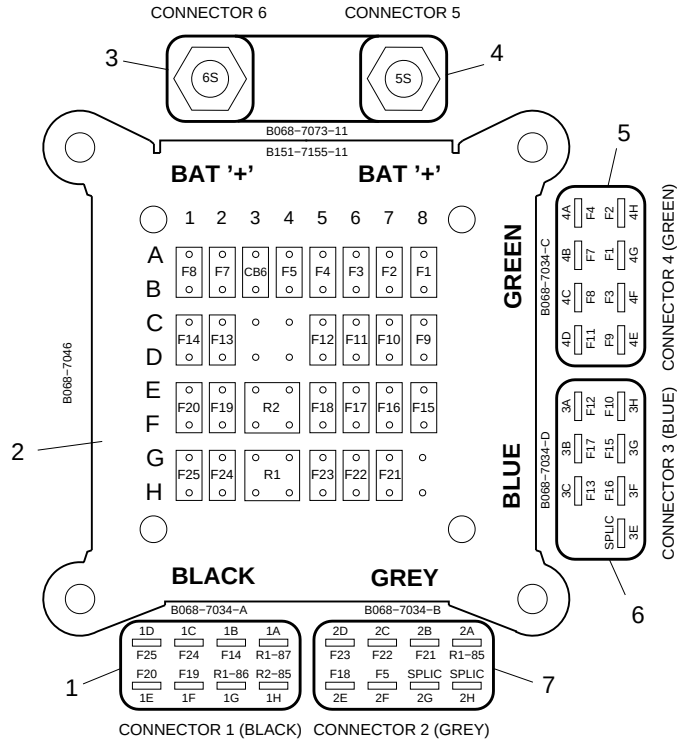


09/12/2001 f543902

1. Battery Power to 125-Amp Mega Fuse 2
2. Battery Power to 125-Amp Mega 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 for Chassis Built Through December 31, 2006 (top view)

Main Power Distribution Module (PDM) Replacement



03/12/2007 f545003

1. Frontwall Harness Connector (black)
2. Fuse Panel
3. Battery Power to 125-Amp Mega Fuse 2
4. Battery Power to 125-Amp Mega Fuse 1
5. Forward Chassis Harness Connector (green)
6. Forward Chassis Harness Connector (blue)
7. Frontwall Harness Connector (gray)

Fig. 3, Main PDM Fuse Panel Layout for Chassis Built from January 1, 2007 (top view)

Main PDM Specifications

See **Table 1** and **Table 2** for Main Power Distribution Module (PDM) fuse information for vehicles with a Mercedes-Benz engine and pneumatic ABS.

See **Fig. 1** and **Fig. 2** for a top view of the Main PDM fuse panel layout and its connections.

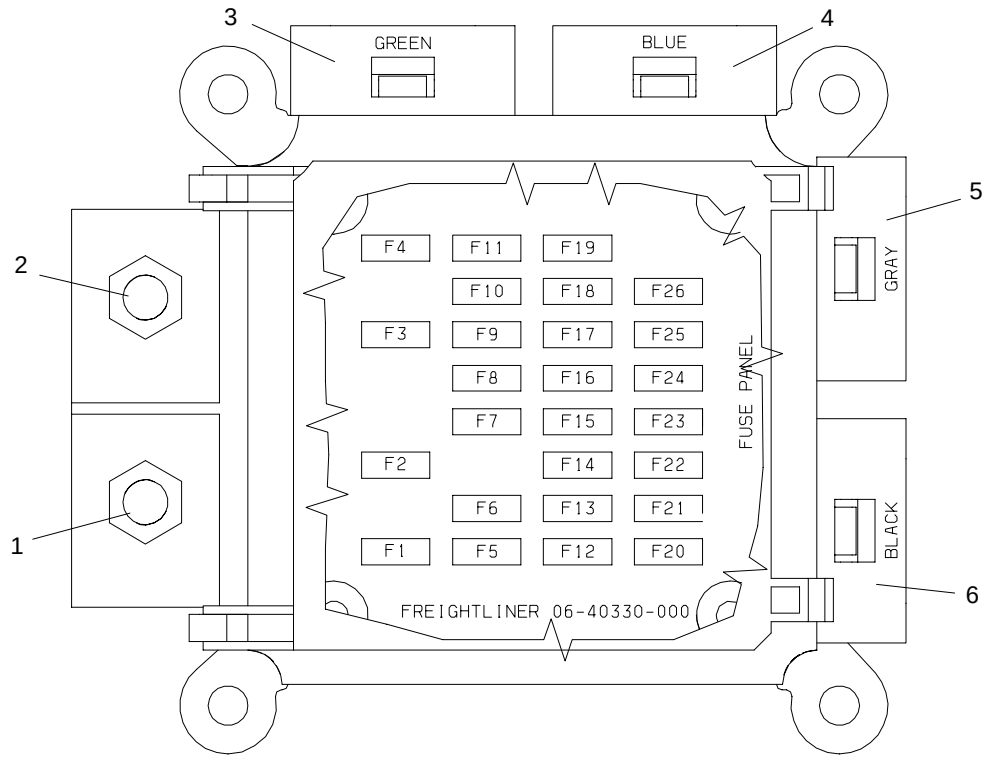
Main PDM Fuse Information for Mercedes-Benz Engine with Pneumatic ABS (for chassis built through December 31, 2006)		
Cavity	**Description**	**Fuse**
F1	VCU	10A
F2	Blower Motor	30A
F3	Engine ECU	20A
F4	Spare	–
F5	Ignition Switch	5A
F6	Spare	–
F7	Bulkhead Module (BHM)	30A
F8	ICU3-M2	10A
F9	Transmission ECU	10A
F10	Spare	–
F11	Spare	–
F12	Radio/Diagnostic	20A
F13	Chassis Module (CHM)	30A
F14	Spare	–
F15	Bulkhead Module (BHM)	30A
F16	ABS ECU	15A
F17	Chassis Module (CHM)	30A
F18	Bulkhead Module (BHM)	30A
F19	Chassis Module (CHM)	30A
F20	Bulkhead Module (BHM)	30A
F21	Spare	–
F22	Bulkhead Module (BHM)	30A
F23	Spare	–
F24	Spare	–
F25	Spare	–
F26	Spare	–

Table 1, Main PDM Fuse Information for Mercedes-Benz Engine with Pneumatic ABS (for chassis built through December 31, 2006)

Main PDM Fuse Information for Mercedes-Benz Engine (for chassis built from January 1, 2007)		
Cavity	**Description**	**Fuse**
F1	Spare	–
F2	Spare	–
F3	Chassis Module (CHM)	30A
F4	Chassis Module (CHM)	30A
F5	Ignition Switch	10A
F6	Spare	–
F7	Bulkhead Module (BHM)	30A
F8	Bulkhead Module (BHM)	30A
F9	Spare	–
F10	Chassis Module (CHM)	30A
F11	ABS ECU	15A
F12	Coolant Heater	20A
F13	Spare	–
F14	Adjustable Pedals	10A
F15	Spare	–
F16	Spare	–
F17	Spare	–
F18	Spare	–
F19	Bulkhead Module (BHM)	30A
F20	Radio/Diagnostic	20A
F21	External Door Control	2A
F22	Hydromax	30A
F23	ICU3	10A
F24	Bulkhead Module (BHM)	30A
F25	Bulkhead Module (BHM)	30A
F26	Spare	–

Table 2, Main PDM Fuse Information for Mercedes-Benz Engine with Pneumatic ABS (for chassis built from January 1, 2007)

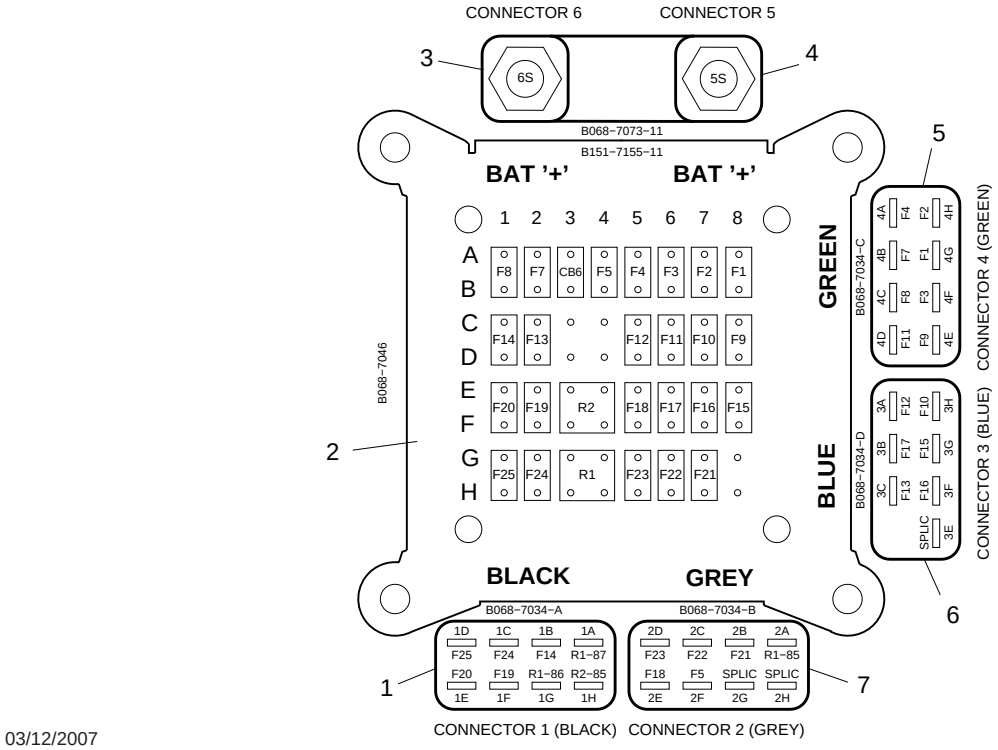
Specifications



09/12/2001 f543902

1. Battery Power, to 125-Amp Mega Fuse 2
2. Battery Power, to 125-Amp Mega 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 for Chassis Built Through December 31, 2006 (top view)



1. Frontwall Harness Connector (black)
2. Fuse Panel
3. Battery Power to 125-Amp Mega Fuse 2
4. Battery Power to 125-Amp Mega Fuse 1
5. Forward Chassis Harness Connector (green)
6. Forward Chassis Harness Connector (blue)
7. Frontwall Harness Connector (gray)

Fig. 2, Main PDM Fuse Panel Layout for Chassis Built from January 1, 2007 (top view)

General Description

The ICU3-M2 is a basic electronic dashboard that accepts input from the fuel level sensor, the transmission temperature sensor (if installed), the J1587 datalink, and the J1939 datalink. To interpret datalink messages, see **Section 54.00, Subject 310**. The information is processed by a micro-computer and displayed on electronic gauges driven by stepper motors. Only the air gauges operate mechanically.

The following gauges are available:

- Speedometer
- Tachometer (optional)
- Engine Oil Pressure
- Coolant Temperature
- Fuel Level
- Transmission Fluid Temperature (optional)
- Primary Air Pressure (optional)
- Secondary Air Pressure (optional)

The transmission fluid temperature gauge is required on vehicles with automatic transmissions.

The speedometer and tachometer are large-faced electronic gauges located below the dash message center. See **Fig. 1**.

The other gauges are small-faced gauges on the driver's instrument panel, on either side of the speedometer and tachometer. The engine oil pressure, coolant temperature, transmission fluid temperature, and fuel level gauges are electronic; the air pressure gauges are mechanical. The ICU3-M2 cannot drive gauges located on the auxiliary instrument panel.

The following items are replaceable:

- air pressure gauges
- mode/reset button
- top row light bulbs
- top row warning and indicator lenses (telltales)

NOTE: The two air pressure gauges and the mode/reset button are one assembly. All three must be replaced at the same time.

Dash Message Center

The dash message center is the heart of the instrument cluster. It has two parts, a set of 26 warning and indicator lights similar to those found on a conventional lightbar, and a dash 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 smaller one-line by three-character LCD that shows voltmeter readings.

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
- a listing of active faults

Mode/Reset Switch

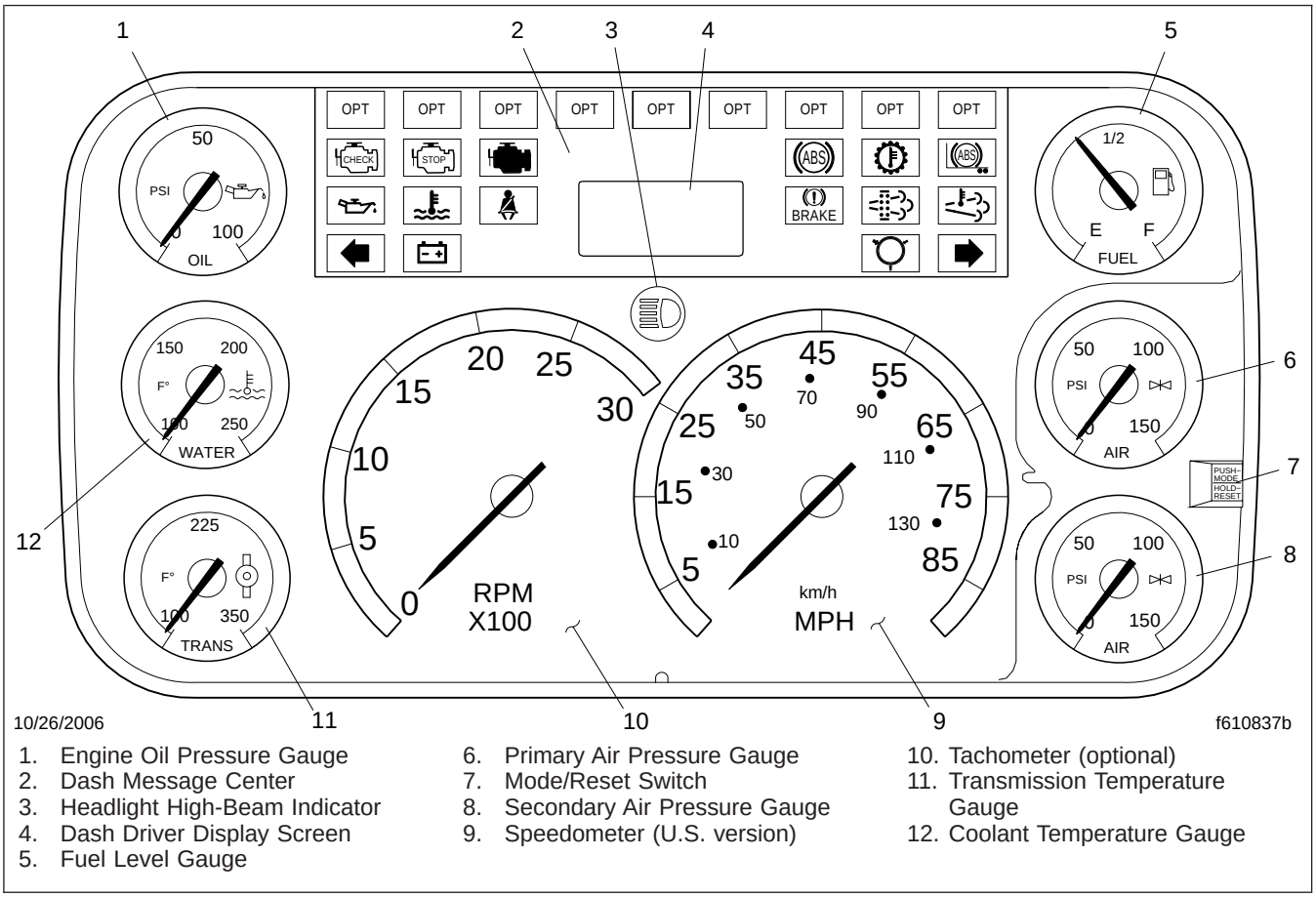
The mode/reset switch (located on the right side of the instrument cluster) is used to scroll through the displays on the driver display screen, and to reset the trip distance and trip hours values to zero.

There are two basic functions: the mode function and the reset function. To activate the mode function, press and release the mode/reset switch. This will take you to the next screen in the series. To activate the reset function, press and hold the mode/reset switch for at least one second. In most cases, this will allow you to change the information on that screen. In some cases, this will take you to new screens that give you more information.

When the odometer reading is displayed and the parking brake is applied:

- Press the mode/reset switch once to display the trip odometer.
- Press the mode/reset switch again to display trip engine hours.
- Press the mode/reset switch once more to display the select (SELECt) screen and the current units, MI or KM.
- Press the mode/reset switch once more to display the diagnostic (DiAG) screen. If the ve-

General Information



1. Engine Oil Pressure Gauge
2. Dash Message Center
3. Headlight High-Beam Indicator
4. Dash Driver Display Screen
5. Fuel Level Gauge
6. Primary Air Pressure Gauge
7. Mode/Reset Switch
8. Secondary Air Pressure Gauge
9. Speedometer (U.S. version)
10. Tachometer (optional)
11. Transmission Temperature Gauge
12. Coolant Temperature Gauge

Fig. 1, Gauge Layout (typical, U.S.)

hicle has gone past its next scheduled service, the service screen will appear as an active fault.

- Press the mode/reset switch once more to display total engine miles.
- Press the mode/reset switch once more to display total engine hours.
- Press the mode/reset switch once more to display engine oil level (if the oil level message is enabled).

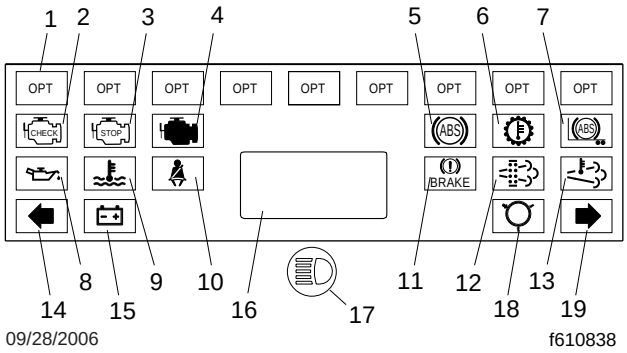
  NOTE: If the ICU3-M2 senses an oil level message from the MBE900 engine, the oil level screen displays automatically. Otherwise, this screen will not appear.
- Press the mode/reset switch once more to display the setup (SEt UP) screen. The setup screen can be used to reset the service interval.
- Press the mode/reset switch once more to return to the odometer reading.

To toggle between MI (miles) or KM (kilometers), go to the select screen and hold the mode/reset switch. To see more information about active faults, go to the diagnostic screen and hold the mode/reset switch.

To reset trip miles and/or trip hours to zero, go to that screen and hold the mode/reset switch. To reset the service interval, and for detailed information about mode/reset switch function, go to the flow charts in **Subject 410**.

Warning and Indicator Lights

The ICU3-M2 has spaces for 26 warning and indicator lights. See **Fig. 2** for a typical installation.



1. Optional Indicator
2. Check Engine Indicator
3. Stop Engine Warning
4. Malfunction Indicator Lamp
5. ABS Indicator
6. Check Transmission Indicator
7. Trailer ABS Indicator (not used)
8. Low Oil Pressure Warning
9. High Coolant Temperature Warning
10. Fasten Seat Belt Warning
11. Brake System Warning/Parking Brake On Indicator
12. Diesel Particulate Filter (DPF) Lamp
13. High Exhaust System Temperature (HEST) Lamp
14. Left-Turn Signal Arrow
15. Low Battery Voltage Warning
16. Dash Driver Display Screen
17. Headlight High-Beam Indicator
18. Low Air Pressure Warning
19. Right-Turn Signal Arrow

Fig. 2, Warning and Indicator Lights

There are four rows of warning and indicator lights. The lights (also called "telltales") in the top row are optional, and may be installed in any order. The light in position 8 (counting left to right across the top row) is a permanently mounted amber LED. The remaining top row positions use replaceable incandescent lamps.

NOTE: Positions 1 through 8 are ground and datalink-activated circuits; position 9 is power-activated and datalink-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:

- Check Engine Indicator (amber)
- Engine Protection Warning (red)
- Low Air Pressure Warning (red)
- Low Engine Oil Pressure Warning (red)
- High Coolant Temperature Warning (red)
- Fasten Seat Belt Warning (red)
- Low Battery Voltage Indicator (red)
- Parking Brake On Warning (red)
- Tractor ABS Indicator (amber)
- Left Turn Signal (green)
- Right Turn Signal (green)
- High Beams On Indicator (blue)

The following fixed-position lights are optional:

- Air Filter Restriction Indicator (amber)
- Alternator No Charge Indicator (amber)
- High Transmission Temperature Warning (amber)—installed on vehicles with automatic transmissions
- Recirculated Air Indicator (amber)

The following lights are optional and their location may vary anywhere in the top row:

- Stop Engine Warning (red)
- Low Coolant Level Warning (red)
- EBS (Electronic Braking System) Warning (red)
- Check Transmission Indicator (amber)
- Intake Heater Indicator (amber)
- Low Washer Fluid Indicator (amber)
- Optimized Idle Indicator (amber)
- Wait To Start Indicator (amber)
- Water In Fuel Indicator (amber)
- Wheel Spin Indicator (amber)

Other optional lights may be specified.

Principles of Operation

Ignition Sequence

When the ignition keyswitch is turned on, the ICU3-M2 runs through the ignition sequence. See **Fig. 3**. If the headlights are turned on, the screen displays the odometer and waits for the ignition to be turned on.

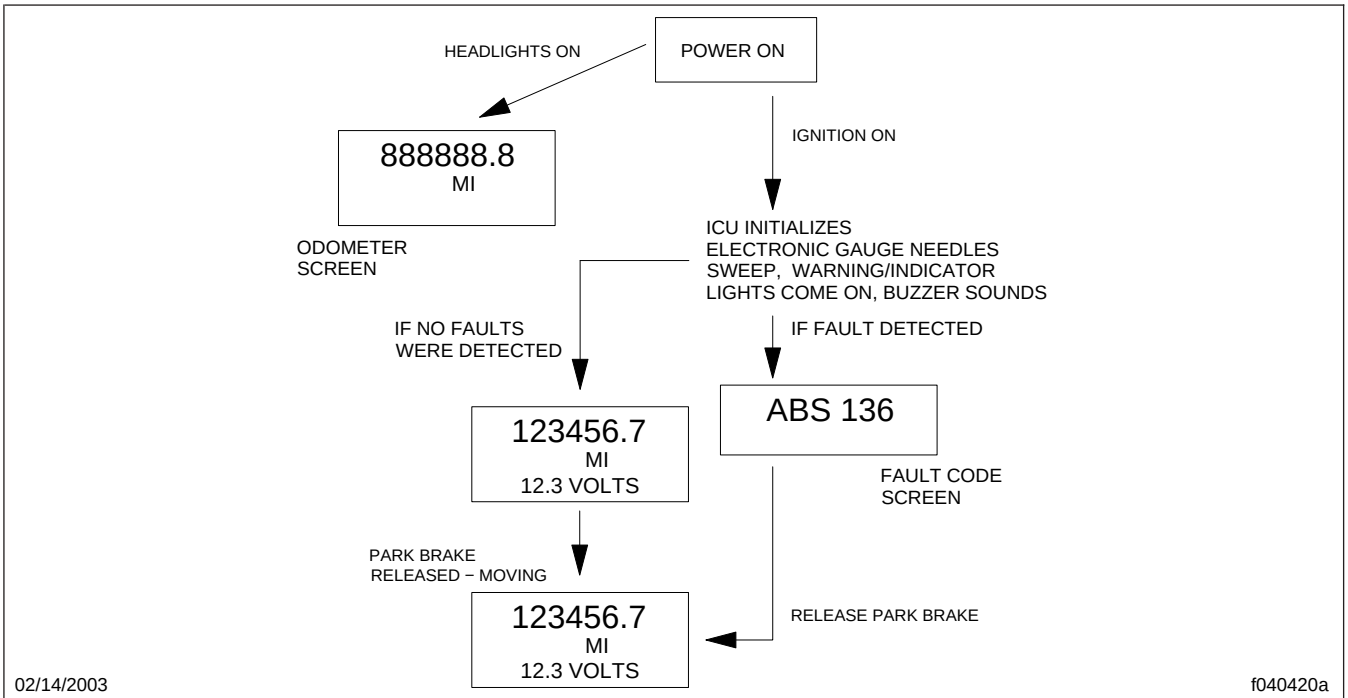
IMPORTANT: When the ignition keyswitch is first turned on, all the electronic gauges complete a full sweep of their dials, the warning and indicator lights light up, and the buzzer sounds for 3 seconds.

The following warning and indicator lights go on during the ignition sequence:

- 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
- All engine warning and indicator lights, including Engine Protection, Check Engine, and Stop Engine
- All ABS warning and indicator lights, including Wheel Spin and Tractor ABS

NOTE: While the engine and ABS warning lights go on during the ignition sequence, they are not controlled by the ICU3-M2, but by their own system ECU (electronic control unit).

Once the ignition keyswitch has been turned on, the ICU performs a self-test, looking for active faults. During the first half of the self-test, all segments of the display illuminate as follows: "888888.8." During the second half of the self-test, the software revision level is displayed.



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.

NOTE: If there is more than one fault, the ICU3-M2 displays them, one after another, changing every 3 seconds, until the park brake is released.

Fig. 3, ICU3-M2 Ignition Sequence

If there are no active faults, the screen displays the odometer.

If, however, the ICU3-M2 has received active fault codes from other devices, it displays the three-letter acronym and MID number for each for 3 seconds, one after the other, until the parking brake is released or the ignition keyswitch is turned off.

The screen displays a code, called the message identifier (MID), indicating the ECU or system that is not functioning properly.

NOTE: If the ICU3-M2 receives a message from an ECU that has not been pre-programmed into the ICU's memory, it displays "SYS ###" instead, where ### is replaced by the MID of the broadcasting device.

Once the parking brake is released, the ICU3-M2 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.

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).

IMPORTANT: Although the odometer uses data supplied by the engine ECU 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

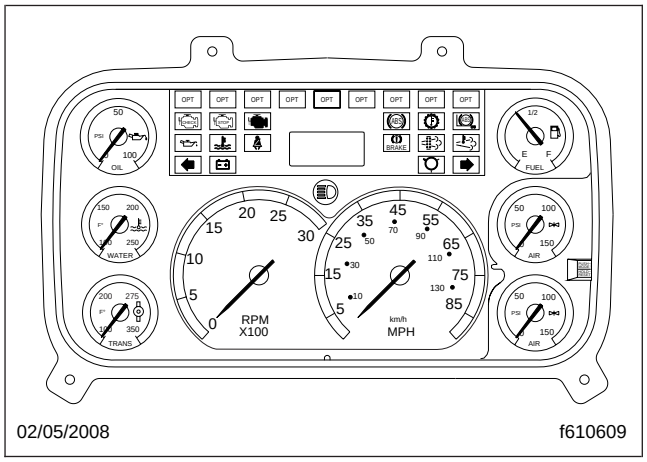
The buzzer sounds during the ignition sequence and whenever one of the following conditions exist.

- 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 189°F (87°C) on MBE900 engines, and 215°F (101°C) on Caterpillar 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 J1939 heartbeat message is not received from the ABS.

Instrumentation Control Unit (ICU3-M2) Removal and Installation

Removal

The instrumentation control unit (ICU3-M2) is a self-contained one-piece unit, including housing, gauges, and the dash message center. See **Fig. 1**.



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Fig. 1, ICU3-M2

1. Disconnect all negative leads from the batteries.
2. Drain the primary and secondary air tanks.
3. Remove the top steering column (clam-shell) cover. For instructions, see **Section 54.09, Subject 100**.

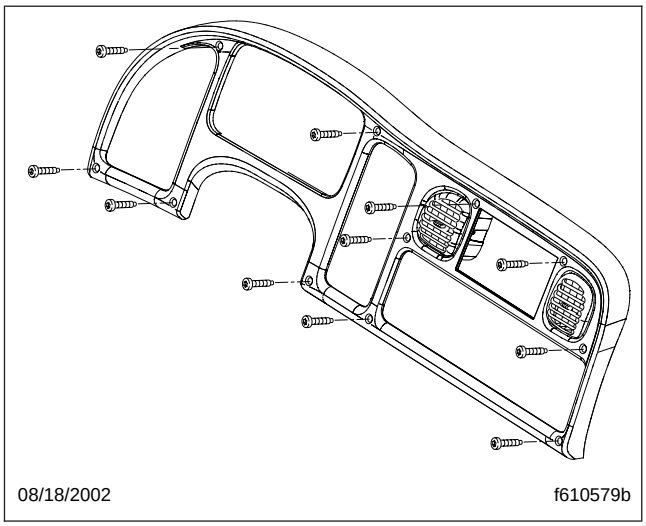
CAUTION

Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

4. Remove the dash trim piece by removing the 11 screws that secure it. All fasteners for this procedure are 10–16 Torx-drive dog-point screws, 7/8-inch (22 mm) long. See **Fig. 2**.

CAUTION

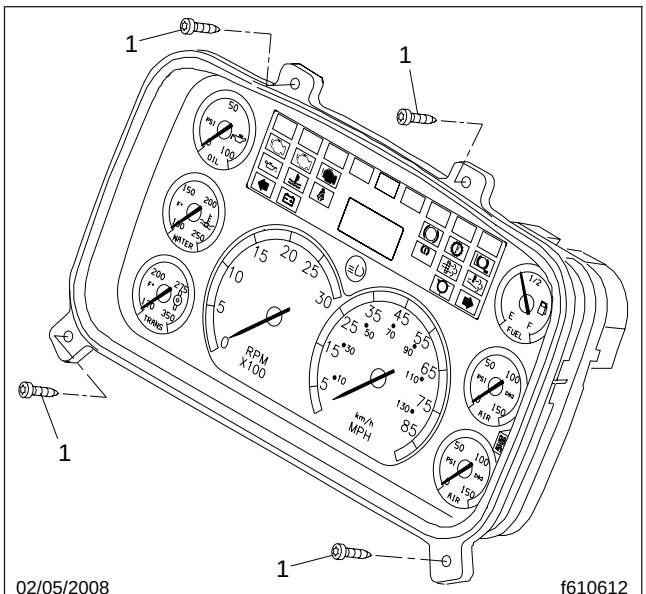
Do not forcibly pull the ICU3-M2 from the dash. This may dislodge or damage electrical connections or air hoses from the back of the ICU3-M2, or damage the dash.



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Fig. 2, Dash Trim Piece

5. Remove the four screws that secure the ICU. Carefully remove the ICU from the dash. See **Fig. 3**.



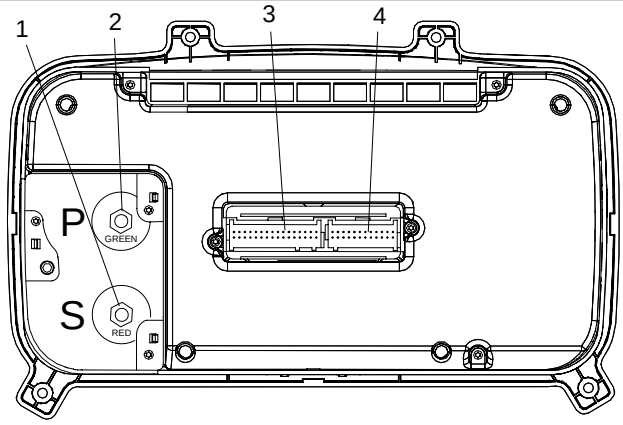
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1. 10–16 Torx Dog-Point Screw, 7/8" (22 mm) Long

Fig. 3, ICU3-M2 Installation

6. Unplug the two electrical connectors from the back of the ICU. See **Fig. 4**.
7. Remove the air hoses by pressing the push-lock connectors, then pulling the air hoses away from

Instrumentation Control Unit (ICU3-M2) Removal and Installation



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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-M2, Rear View

the gauges. The hoses are color-coded for ease of installation. The primary air hose is green and is connected to the upper gauge. The secondary air hose is red and is connected to the lower gauge.

Installation

1. Connect the air hoses to the air gauges by pressing the correct air line firmly into its push-lock connector on the back of the gauge. The primary (upper) gauge connects to the green air line. The secondary (lower) gauge connects to the red air line. See **Fig. 4**.
2. Plug the electrical connectors into the back of the ICU3-M2.

NOTE: All fasteners for this procedure are 10–16 Torx-drive dog-point screws, 7/8-inch (22 mm) long.

3. Place the ICU3-M2 in the dash opening and secure it with the four 10–16 dog-point screws. Tighten the screws 30 lbf·in (340 N·cm).
4. Install the dash trim piece and secure it with the 11 dog-point screws. Tighten the screws 30 lbf·in (340 N·cm).
5. Connect the negative battery leads.
6. Turn the ignition switch to RUN and test the operation of the cluster. All the electronic gauges should make one complete sweep and return to their normal indicating positions; the warning and indicator lights should turn on, then off.

   If any gauges are not working properly, the ICU3-M2 will need to be serviced or replaced.

NOTE: Mechanical (air) gauges do not make a sweep.

7. Install the top steering column cover. For instructions, see **Section 54.09, Subject 100**.

Replacement

NOTE: The mode/reset switch is part of the air gauge module and is replaced when the air gauges are replaced.

The only replaceable gauges on the ICU3-M2 are the air pressure gauges. If any other gauge fails, the entire unit must be replaced. See **Fig. 1**.

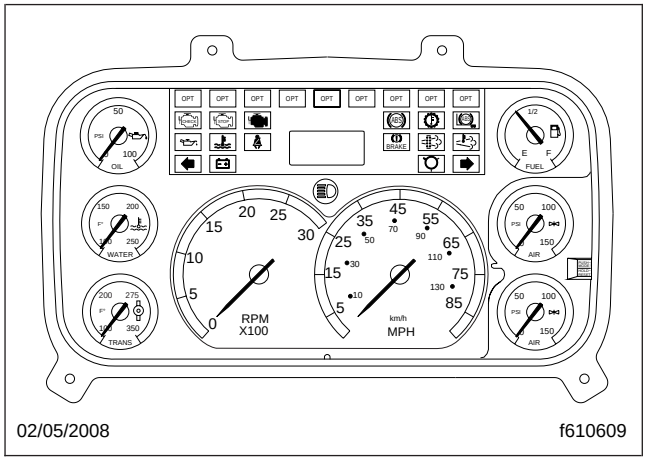


Fig. 1, ICU3-M2

1. Drain the primary and secondary air tanks.

CAUTION

Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

2. Remove the ICU3-M2 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-M2 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-M2 face down on a smooth surface and remove the three Torx screws that secure the air gauge module to the ICU. Do not remove the air gauge module cover. See **Fig. 2**.

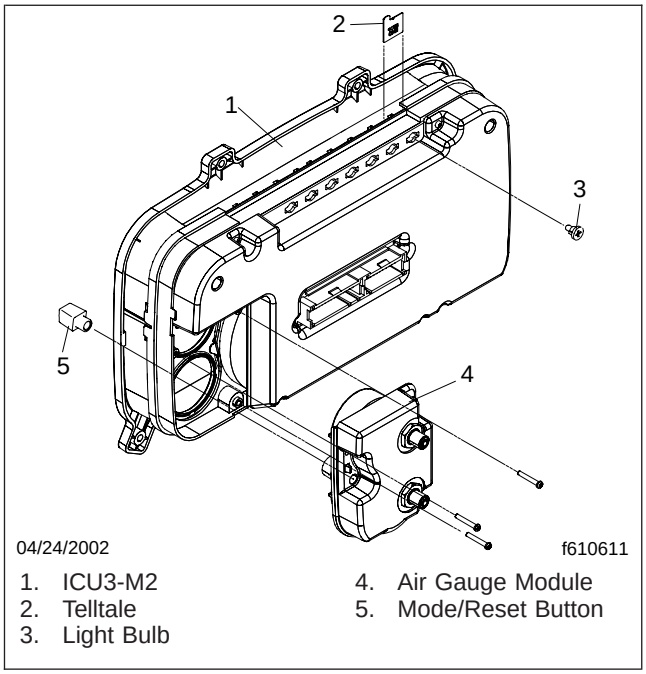


Fig. 2, ICU3-M2, Rear View (exploded)

4. Remove the button from the mode/reset switch.
5. Separate the air gauge module slightly from the ICU to allow access to the electrical ribbon that connects the module to the ICU.
6. Remove the electrical connection ribbon from the ICU, not from the air gauge module. Grip the ribbon firmly at each side and lift out, then remove the air gauge module.
7. Place the ICU3-M2 face down on a clean, smooth surface. Placing the unit on a clean towel or cloth will help keep the plastic face from getting scratched during this procedure.
8. 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

Air Pressure Gauge Replacement

firmly at the edges, place the ribbon end into the slot and push it straight in until it stops.

9. Place the air gauge module into its opening in the ICU3-M2. Make sure the rubber alignment pin in the ICU cavity lines up with the matching alignment receptacle in the air gauge module when placing the module in the ICU.
10. Install and tighten the three Torx screws to secure the air gauge module. See **Fig. 2**.
11. Install the button on the mode/reset switch, as removed.
12. Install the ICU3-M2, including the electrical connectors and the air lines. For detailed instructions, see **Subject 100**.
13. After installing the ICU3-M2, start the engine and verify the proper operation of the air gauge module as the air pressure builds.

Replacement

The instrumentation control unit (ICU3-M2) is a self-contained one-piece unit, including housing, gauges, and the dash message center. See **Fig. 1**.

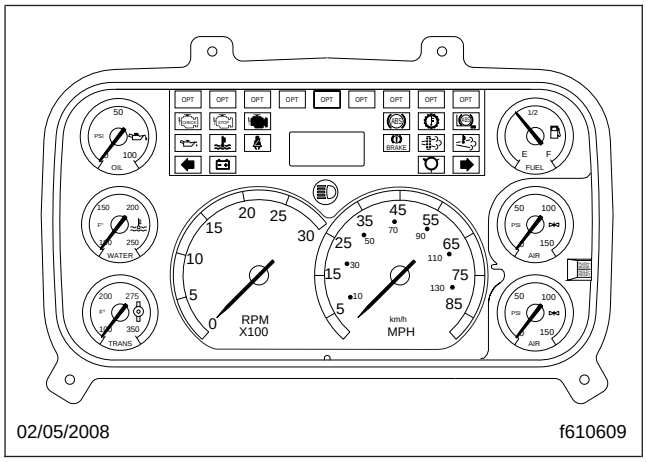


Fig. 1, ICU3-M2

CAUTION

Electronic components of the ICU3-M2 are vulnerable to damage from static electricity. If available, wear a wrist grounding strap connected to a ground in the cab or workbench. If a grounding strap is not available, touch a grounded component immediately before doing any work that could bring a tool or body part in contact with ICU3-M2 circuitry.

NOTE: Since the top-row warning and indicator lights are optional, not all positions in the row may have a bulb and telltale installed.

The nine top-row warning and indicator bulbs are all replaceable except for the bulb in position 8, counting left to right; the bulb in that position is a permanent LED. The replaceable light bulbs are incandescent.

The term "telltale" refers to the small plastic bezel in the top row with a warning or indicator message printed on it. These are also replaceable.

1. Remove the dash trim piece by removing the 11 screws that secure it. All fasteners for this procedure are 10–16 Torx-drive dog-point screws, 7/8-inch (22 mm) long. See **Fig. 2**.

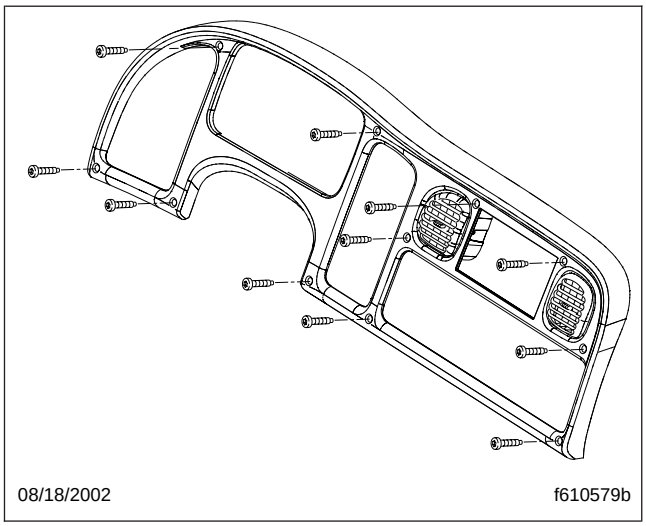


Fig. 2, Dash Trim Piece

CAUTION

Do not forcibly pull the ICU3-M2 from the dash. This may dislodge or damage electrical connections or air hoses from the back of the ICU3-M2, or damage the dash.

2. Remove the four screws that secure the ICU. Carefully remove the ICU from the dash. See **Fig. 3**.
3. Carefully pull the unit forward to access the top row of replaceable light bulbs and telltales. Take care not to scratch the clear plastic front of the unit. Placing a clean towel over the front of the unit before pulling it forward may help prevent scratches.

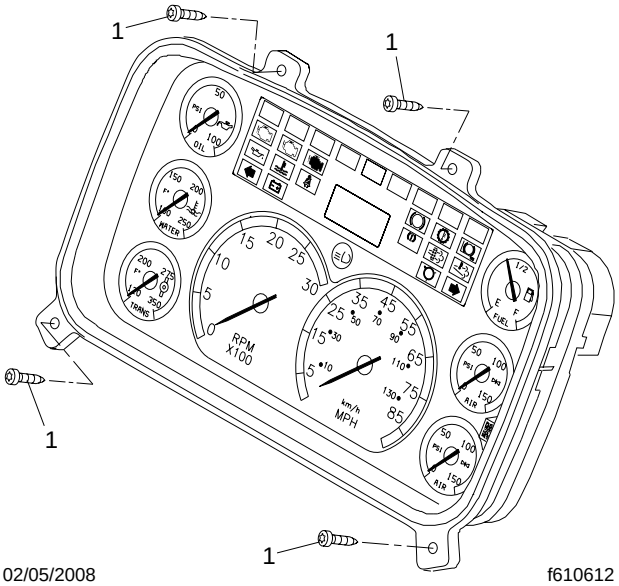
To Replace Light Bulbs

1. Use a small screwdriver or flat blade to twist out the bulb by its base behind the affected telltale. Turn the bulb 1/4 turn and remove. See **Fig. 4**.
2. Place a good bulb in the opening and twist 1/4 turn to install.

To Replace Telltales

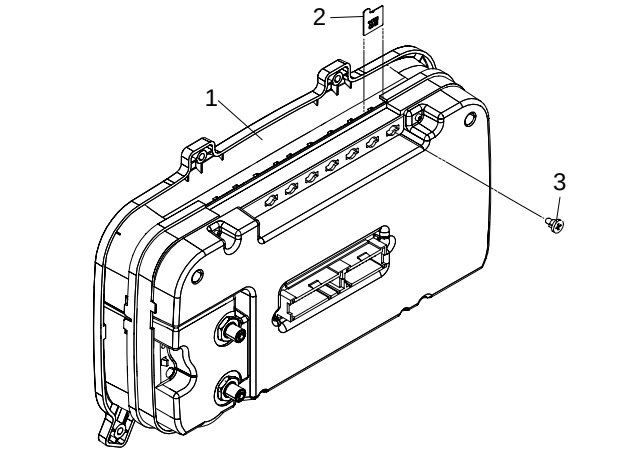
1. Using a pair of needlenose pliers or a similar tool, grab the exposed tab at the top of the telltale slot and carefully pull the telltale out from the top of the ICU. See **Fig. 4**.

Light Bulb/Telltale Replacement



1. 10–16 Torx Dog-Point Screw, 7/8"(22 mm) Long

Fig. 3, ICU3-M2 Installation



NOTE: For clarity, air gauge and electrical connections are shown removed.

1. ICU3-M2
2. Telltale
3. Light Bulb

Fig. 4, ICU3-M2, Rear View (exploded)

2. Place the telltale in its correct 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.

Turn on the ignition keyswitch. Check all bulbs and telltales for correct operation.

See **Table 1** for an ICU symptom chart.

ICU Symptom Chart	
Problem	**Where to Begin Diagnosis**
Gauges (except air pressure gauges) are not working or are inaccurate.	See **Table 2** for initial gauge test procedures.
Single-datalink-driven gauge is not working or is inaccurate.	See **Table 3** to diagnose the single-datalink-driven gauge.
Multiple-datalink-driven gauges are not working or are inaccurate.	See **Table 4** to diagnose multiple-datalink-driven gauges.
Air pressure gauges are not working or are inaccurate.	See **Table 5** for air pressure gauge diagnosis.
Fuel gauge is not working or is inaccurate.	See **Table 6** for fuel gauge diagnosis.
Transmission temperature gauge is not working or is inaccurate.	See **Table 7** for transmission temperature gauge diagnosis.
Active ICU fault codes (MID 140) are inaccurate.	See **Table 8** for ICU3-M2 fault code (MID 140) diagnosis.
Backlighting is not working.	See **Table 9** for gauge backlighting diagnosis.
Mode/Reset button is not working.	See **Table 10** for Mode/Reset button diagnosis.
The parking brake and ABS warning lights stay on with the key off.	There is feedback in the ignition circuit providing power to the ICU while the key is off. Isolate the source of this feedback and repair as necessary.
LCD displays seven hyphens.	Indicates a program memory failure. Fault code 140 s240 12 may be active in Servicelink. See **Table 8**, "ICU3-M2 Fault Code (MID 140) Diagnosis" for more information. This failure requires replacement of the ICU.
LCD displays "no Eng" or "no ABS."	These are roll call faults indicating the engine or ABS is not detected by the ICU on the J1587 datalink. This does not indicate an ICU problem, nor does it indicate a J1587 datalink problem to the ICU.
LCD displays "no data."	The ICU is unable to detect any data on the J1587 datalink. If the ICU is the only ECU not showing up in the Servicelink ECU list, check J1587 datalink to ICU. If no ECUs show up in the Servicelink ECU list, the problem could be anywhere in the J1587 datalink—troubleshoot accordingly.
LCD displays "no J1939."	The ICU is unable to detect any data on the J1939 datalink. Use the "M2 J1939 Test" Datalink Monitor template in Servicelink to troubleshoot. If only the ICU is not communicating, then check the J1939 branch circuit to the ICU. If no ECUs are communicating, the problem could be anywhere in the J1939 datalink—troubleshoot accordingly.
The "No Charge" light stays on after replacing the bulkhead module.	Apply reference parameter 26-01001-000 to the bulkhead module.

Table 1, ICU Diagnosis Symptom Chart

Troubleshooting

Initial Test Gauge Procedure			
Test	**Test Description**	**Test Result**	**Action**
1	Turn the ignition on. 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?	Yes	Go to test 3.
		No	Go to test 2.
2	Check the power and ground to the ICU. • +12V Battery on D14 • +12V Ignition on D15 • Ground on D13 Are the power and ground supplies OK?	Yes	Replace the ICU.
		No	Repair the power and/or ground supply as necessary.
3	Are any engine fault codes active (MID 128)?	Yes	Correct any active engine fault codes first. If the gauge problem is still present, go to test 4.
		No	Go to test 4.
4	Are any ICU fault codes active (MID 140)?	Yes	See **Table 8** – ICU3-M2 Fault Code (MID 140) Diagnosis.
		No	Go to test 5.
5	Which gauge(s) has a problem? NOTE: Datalink-driven gauges include the following: speedometer, tachometer, engine oil pressure, and engine coolant temperature.	Single-datalink-driven gauge	See **Table 3** – Diagnosis for Single-Datalink-Driven Gauge Not Working or is Inaccurate.
		Multiple-datalink-driven gauges	See **Table 4** – Diagnosis for Multiple-Datalink-Driven Gauges Not Working.
		Air pressure gauge	See **Table 5** – Air Pressure Gauge Diagnosis.
		Fuel level gauge	See **Table 6** – Fuel Gauge Diagnosis.
		Transmission temperature	See **Table 7** – Transmission Temperature Gauge Diagnosis.

Table 2, Initial Test Gauge Procedure

Diagnosis for Single-Datalink-Driven Gauge not Working or is Inaccurate			
Test	**Test Description**	**Test Result**	**Action**
1	Connect Servicelink and open the "ICU3-M2 J1587 Gauges" Datalink Monitor template. Make sure the operating conditions are such that the gauge would be registering (e.g. engine at operating temperature). Start the engine. NOTE: A test drive may be necessary if diagnosing the speedometer. Do the readings closely match?	Yes	Go to test 2.
		No	Replace the ICU.
2	Which best describes the problem with the ICU gauge?	Gauge not working	Check the sensor that the engine ECM uses to supply data to the ICU (e.g. if the oil pressure gauge is not working, check the oil pressure sensor and wiring). Refer to engine manufacturer's service information if necessary.
		Gauge inaccurate	Go to test 3.
3	It is necessary to independently verify the gauge accuracy. For the speedometer, drive the vehicle with another vehicle pacing to note the speed or monitor the ABS wheel speed sensors using Meritor Toolbox. For engine coolant temperature and oil pressure, it may be necessary to connect a mechanical gauge. For the tachometer, it will be necessary to use a tool that measures engine speed. Does the independent verification confirm the ICU gauge is inaccurate?	Yes	Check the sensor the engine ECM uses to supply data to the ICU (e.g. if the oil pressure gauge is inaccurate, check the oil pressure sensor). Refer to the engine manufacturer's service information if necessary.
		No	No problem found.

Table 3, Diagnosis for Single-Datalink-Driven Gauge not Working or is Inaccurate

Diagnosis for Multiple-Datalink-Driven Gauges Not Working			
Test	**Test Description**	**Test Result**	**Action**
1	Connect Servicelink to the vehicle. Will Servicelink connect?	Yes	Go to test 2.
		No	Assuming Servicelink and the vehicle adapter are functioning, check the J1587 datalink for shorts or opens. Repair as necessary.
2	Does the engine ECM (MID 128) show up in the Servicelink J1708 ECU list?	No	Go to test 3.
		Yes	Check the J1587 datalink to the engine ECM. If OK, see engine OEM's literature for further diagnosis.

Troubleshooting

Diagnosis for Multiple-Datalink-Driven Gauges Not Working			
Test	**Test Description**	**Test Result**	**Action**
3	Does the ICU3-M2 (MID 140) show up in the Servicelink J1708 ECU list?	No	Go to test 4.
		Yes	Check the J1587 datalink to the ICU, repair as necessary. If OK, replace the ICU.
4	In Servicelink, open the ICU3-M2 Datalink Monitor template. Start the engine. Make sure the operating conditions are such that the gauge would be registering (e.g. engine at operating temperature). NOTE: A test drive may be necessary if diagnosing the speedometer. Monitor the problem gauges on both the ICU and on the template. Do the affected gauges function in the template?	Yes	Replace the ICU.
		No	Refer to engine OEM service literature for further diagnosis.

Table 4, Diagnosis for Multiple-Datalink-Driven Gauges Not Working

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Which air pressure gauge is not functioning correctly?	Primary or secondary	Go to test 2.
		Application	Go to test 3.
		Suspension	Go to test 4.
2	Drain the air tanks. Connect an accurate pressure gauge to the primary or secondary air tank (whichever one corresponds with the problem gauge). Start the engine and build air pressure until the compressor cuts out. Is the air pressure gauge in the cluster within 6 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the air pressure gauge module.
3	Connect an accurate pressure gauge to a delivery port on the foot valve. Make a 90 psi 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 3 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the gauge.

Air Pressure Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
4	Connect an accurate pressure gauge to the air suspension. Is the air pressure gauge in the cluster within 3 psi of the test gauge?	Yes	The gauge is OK.
		No	Check the air line to gauge for kinks. If OK, replace the gauge.

Table 5, Air Pressure 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 6** 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.

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.

Troubleshooting

Fuel Level Gauge Diagnosis			
Step	**Test Procedure**	**Test Result**	**Action**
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 6, Fuel Level Gauge Diagnosis

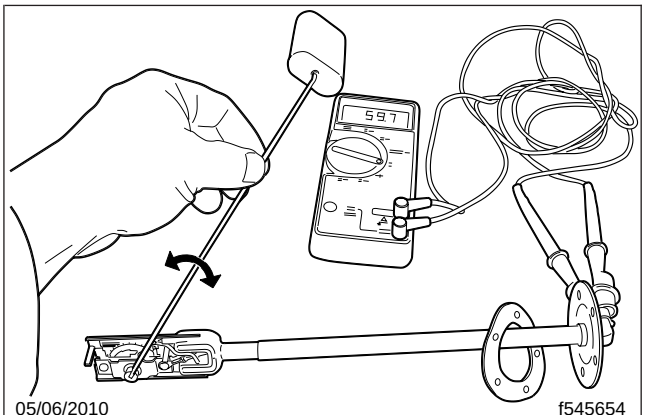


Fig. 1, Testing the Fuel Level Sending Unit

Transmission Temperature Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	What best describes the problem with the transmission oil temperature gauge?	Reads minimum scale all the time	Go to test 2.
		Reads maximum scale all the time	Go to test 3.
		Reads inaccurate	Go to test 4.

Transmission Temperature Gauge Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
2	Disconnect the transmission oil temperature sensor connector. Short the terminals on the transmission oil temperature sensor harness connector. Turn the ignition on. Does the transmission oil temperature gauge now read full scale (350°F / 177°C)?	Yes	Replace transmission temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor; there may be an open in one of these circuits. If the wiring is OK, replace the ICU.
3	Disconnect the transmission oil temperature sensor connector. Turn the ignition on. Does the transmission oil temperature gauge now read minimum scale?	Yes	Replace transmission temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor; circuit 30 may be shorted to ground or circuit 30 and 30G may be shorted together. If the wiring is OK, replace the ICU.
4	Disconnect the transmission oil temperature sensor. Now, apply 267 ohms across the terminals on the transmission oil temperature sensor harness connector. Turn the ignition on. Does the transmission oil temperature gauge read approximately 2 needle widths above or below 275°F (135°C)?	Yes	The transmission oil temperature gauge and the wiring between the ICU and the sensor are functioning normally. If the temperature displayed on the gauge is still suspected to be inaccurate, check the transmission oil temperature sensor.
		No	Check circuits 30 and 30G between the ICU and the transmission oil temperature sensor for excess resistance. If none is found, replace the ICU.

Table 7, Transmission Temperature Gauge Diagnosis

Troubleshooting

ICU3-M2 Fault Code (MID 140) Diagnosis				
MID	**PID/SID**	**FMI**	**Fault Description**	**Action**
140	p168	01	"ICU3-M2 low voltage—less than 10.5 volts."	Check the power and ground circuits to the ICU and repair as necessary. If OK, check vehicle batteries and charging system.
	s240	12	"ICU3-M2 program memory failure—odometer read/write to EEPROM fails." NOTE: When this failure occurs, the ICU will be unable to display the fault on the LCD, but the fault will display in Servicelink. However, when this fault is active, the LCD display will show a series of seven hyphens.	Replace ICU.
	s254	12	"ICU3-M2 Controller Failure—ICU self test detects checksum errors."	Replace ICU.

Table 8, ICU3-M2 Fault Code (MID 140) Diagnosis

Gauge Backlighting Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Is only the air pressure gauge backlighting affected?	Yes	Go to test 2.
		No	Go to test 3.
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 there is no corrosion and 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	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage in pins A1(+) and D3(–) while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (full dim) and 11.3V (full bright). Is the backlighting voltage OK?	Yes	Replace the ICU.
		No	Go to test 4.

Gauge Backlighting Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
4	Access the back of the ICU and disconnect the two electrical connectors. Turn the headlights on. Measure voltage in pins A1(+) and a known good ground while increasing and decreasing the dimmer switch. The voltage should range between approximately 2.5V (full dim) and 11.3V (full bright). Is the backlighting voltage OK?	Yes	Repair the backlighting ground circuit to ICU pin D3 as necessary.
		No	Check circuit 29A between the BHM and the ICU. If OK, check dimmer switch and BHM. Repair as necessary.

Table 9, Gauge Backlighting Diagnosis

Mode/Reset Button Diagnosis			
Test	**Test Description**	**Test Result**	**Action**
1	Does the mode reset button stick or fail to spring back when released?	Yes	Replace the air pressure gauge module.
		No	Go to test 2.
2	Remove the three air gauge module screws and carefully lift the air gauge module off the back of the ICU. Leave the ribbon cable connected. Inspect the ribbon cable connection to the ICU PC board. Make sure there is no corrosion and that it is plugged in all the way. Is the ribbon cable connection OK?	Yes	If the mode/reset button is not working and the ribbon cable connection is OK, replace the air gauge module.
		No	Repair the ribbon cable connection as necessary.

Table 10, Mode/Reset Button Diagnosis

The two ICU3-M2 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**.

See **Table 3** for Message Identifiers (MIDs).

See **Table 4** for fuel level sensor resistance.

See **Table 5** for transmission oil temperature sensor resistance, standard gauge.

See **Table 6** for transmission oil temperature sensor resistance, metric gauge.

ICU3-M2 Connector #1 Pin Assignments, Pins A1 Through B12		
Pin	**Description**	**Wire**
A1	Panel Backlight Power (+)	29A
A2	Multifunction Switch Windshield Wiper Input	473C
A3	Low Air Pressure Input	18B
A6	Traction Control Switch (Optional Indicator #2)	376T
A7	Preheater Relay #1 Coil Signal (Optional Indicator #3)	431B1
B1	Wheel Spin Warning Lamp (Optional Indicator #5)	376S
B3	J1708 Network (–)	1587–
B5	Multifunction Switch Common Input	473
B6	Multifunction Switch Turn Signal Input	473A
B7	Multifunction Switch High Beam/Washer Input	473B
B9	Cruise Control Switch Input	440D
B10	J1708 Network (+)	1587+
B11	Tractor ABS Indicator	376L

Table 1, ICU3-M2 Connector #1 Pin Assignments, Pins A1 Through B12

ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
C1	Do Not Shift Warning Lamp (Optional Indicator #8)	E115
C5	Park Brake Indicator	125S
C11	Wheel Spin Warning Lamp (Optional Indicator #7)	376S
C12	Transmission Oil Temperature (–)	30G
C13	Transmission Oil Temperature (+)	30
C15	Check Engine Warning Lamp	440A
C16	Engine Protection Warning Lamp	440S
D1	Fuel Level (+)	47
D2	Fuel Level (–)	47G
D3	Panel Backlight Ground (–)	GND
D5	J1939 (+)	1939+

Specifications

ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16		
Pin	**Description**	**Wire**
D9	J1939 (–)	1939–
D12	Trailer ABS Warning Lamp	376F1
D13	PC Board Ground (–)	GND
D14	Battery Power (+)	437
D15	Ignition Power (+)	81C
D16	Headlamp Power (+)	81C

Table 2, ICU3-M2 Connector #2 Pin Assignments, Pins C1 Through D16

Message Identifiers (MIDs)		
MID	**Description**	**Text Message**
128	Engine Control Unit	ECU128
130	Transmission Control Unit	tCU130
136	Antilock Brake System (ABS)	AbS136
140	Instrumentation Control Unit	ICU140
181	Satellite Communications	SAT181
219	Collision Detection Unit	CdU219
223	Transmission Shift Unit	tSU223
231	Cellular Phone	CEL231
232	SPACE (Seat Belt Unit)	SbU232
###	Generic MID	SYS###

Table 3, Message Identifiers (MIDs)

Fuel Level Sensor Resistance (Stewart-Warner)		
Gauge Reading	**Sensor Resistance: ohms**	
	Acceptable Range	**Nominal**
Empty	244.0 to 249.0	246.5
Empty Stop	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 4, Fuel Level Sensor Resistance (Stewart-Warner)

Transmission Oil Temperature Sensor (Hi-Stat) Resistance Standard Gauge (ºF)	
Gauge Temperature: ºF	**Sensor Resistance: ohms**
125	3318
163	1626
200	837
238	460
275	267
313	162
350	102

Table 5, Transmission Oil Temperature Sensor (Hi-Stat) Resistance Standard Gauge (ºF)

Transmission Oil Temperature Sensor (Hi-Stat) Resistance Metric Gauge (ºC)	
Gauge Temperature: ºC	**Sensor Resistance: ohms**
60	2490
80	1255
100	680
120	390
140	234
160	145
180	95

Table 6, Transmission Oil Temperature Sensor (Hi-Stat) Resistance Metric Gauge (ºC)

Mode/Reset Switch Functions

Use the following flow charts to cycle through the Mode/Reset switch functions and screens.

See **Fig. 1** for the start sequence. See **Fig. 2** for the trip miles and hours screens, and **Fig. 3** for the engine miles and service interval setup screens.

See **Fig. 4** for the fault code screens, and **Fig. 5** for the service hour screens. See **Fig. 6** for the oil level screens, and **Fig. 7** for the reset and toggle function screens.

Mode/Reset Switch Functions

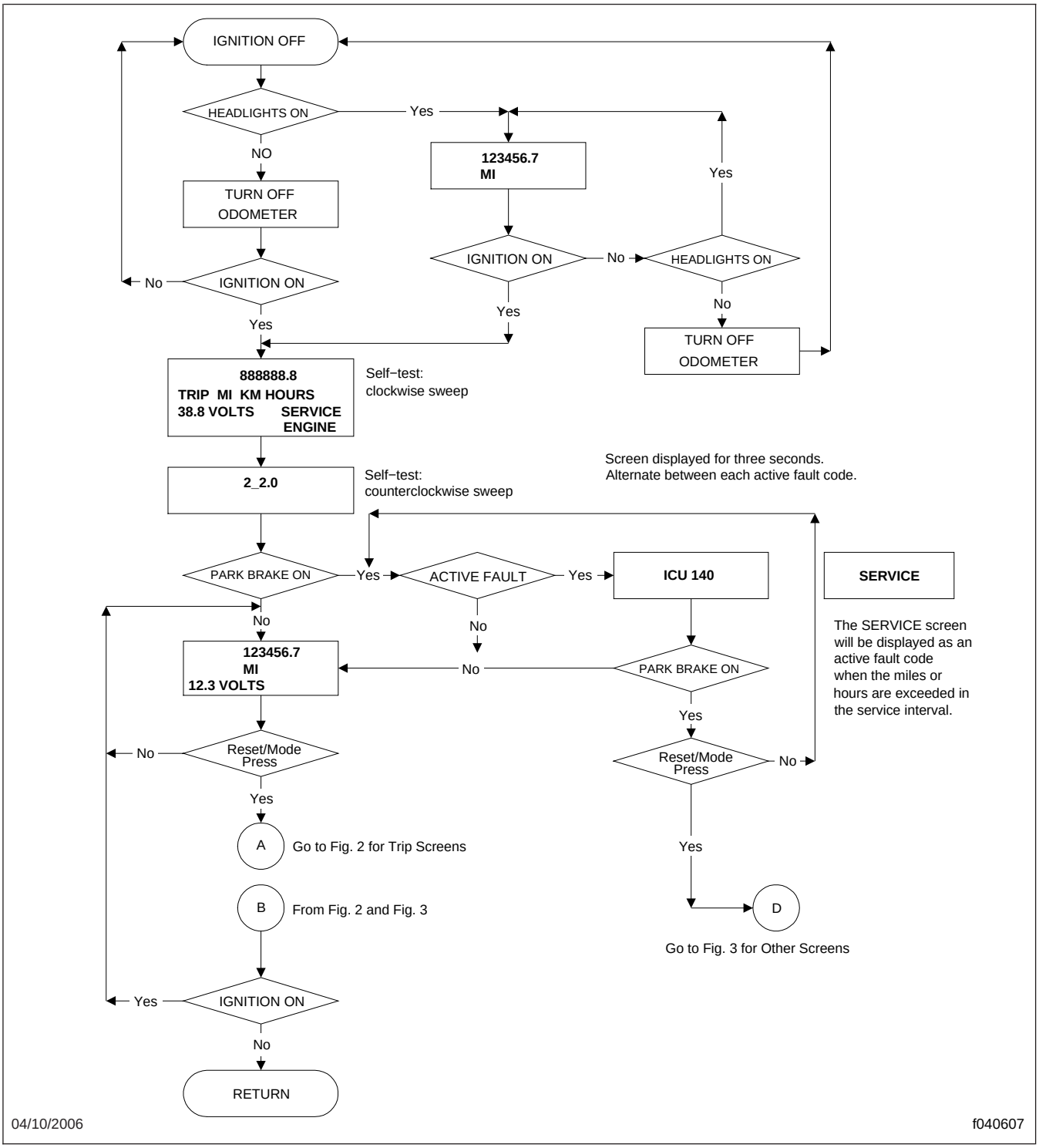


Fig. 1, Start Sequence

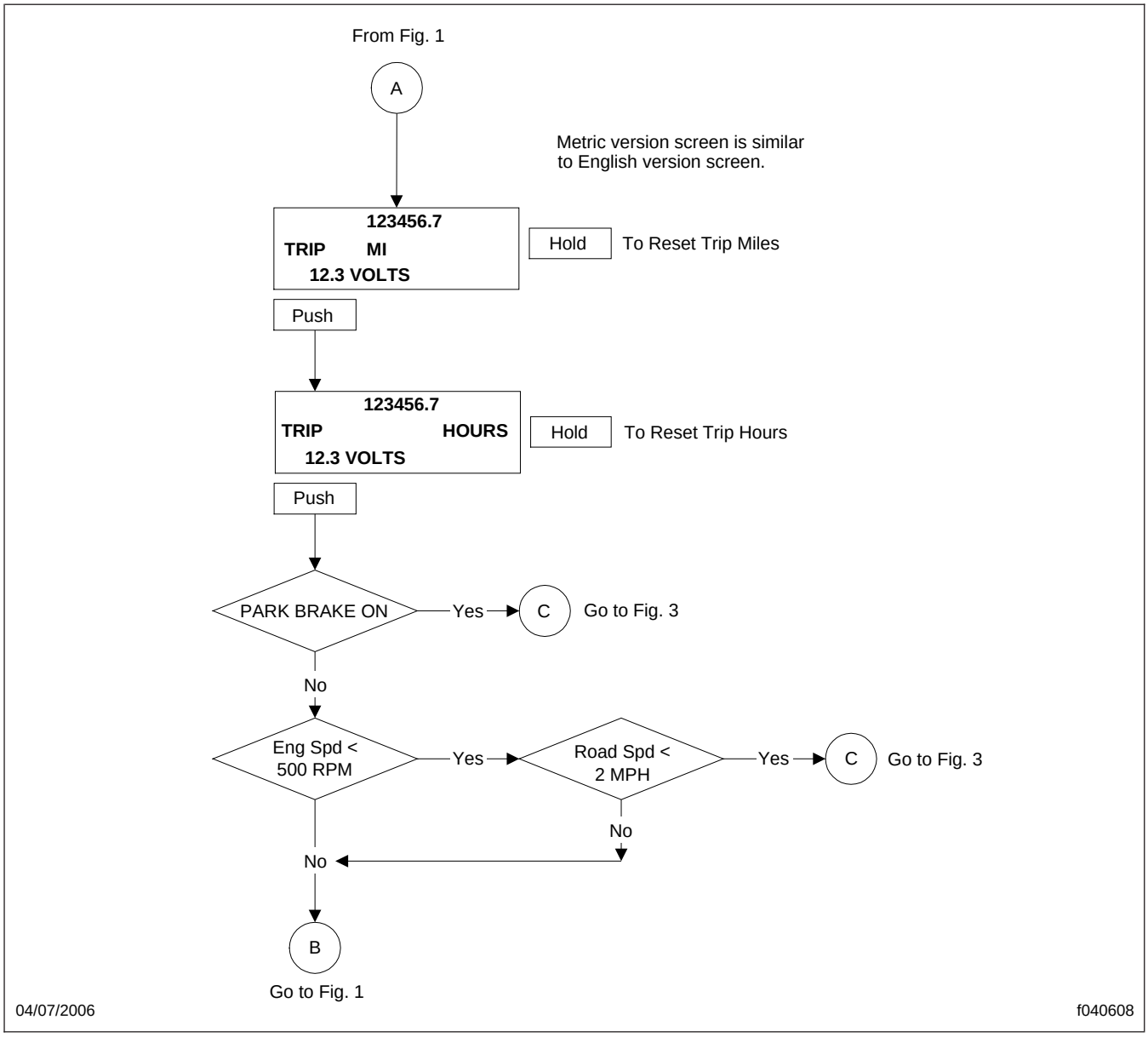


Fig. 2, Trip Screens

Mode/Reset Switch Functions

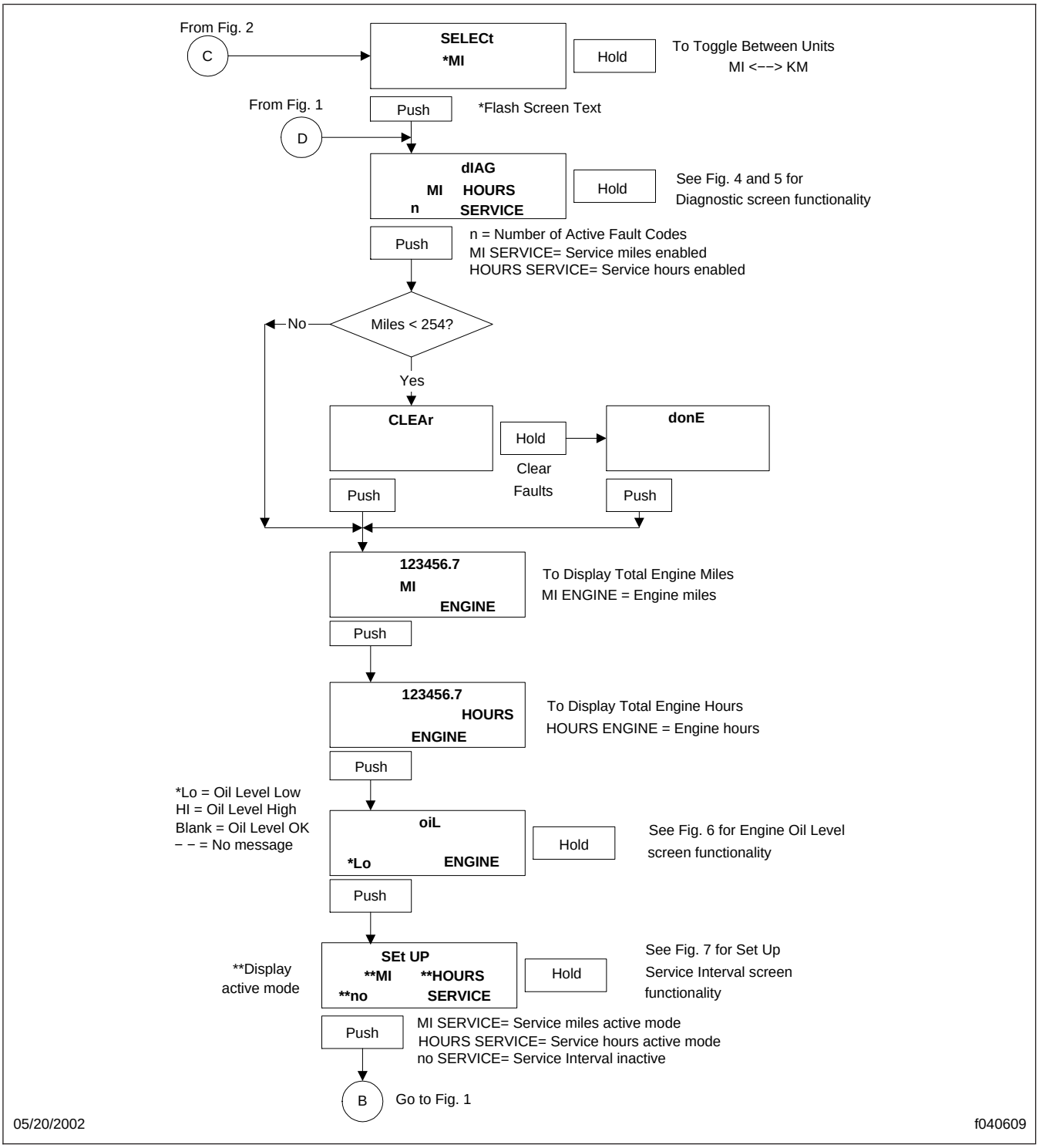


Fig. 3, Engine Miles and Service Interval Setup Screens

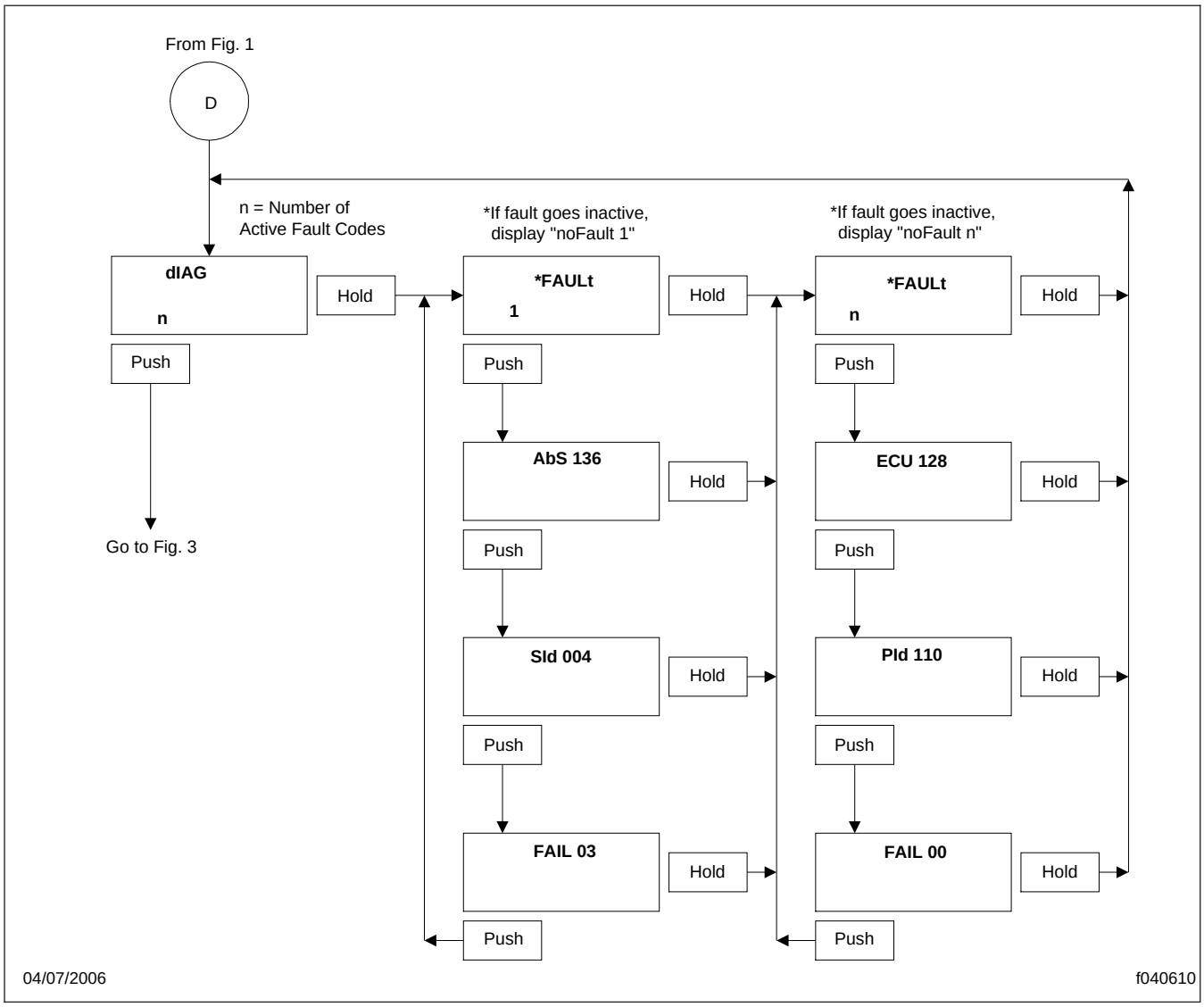


Fig. 4, Fault Screens

Mode/Reset Switch Functions

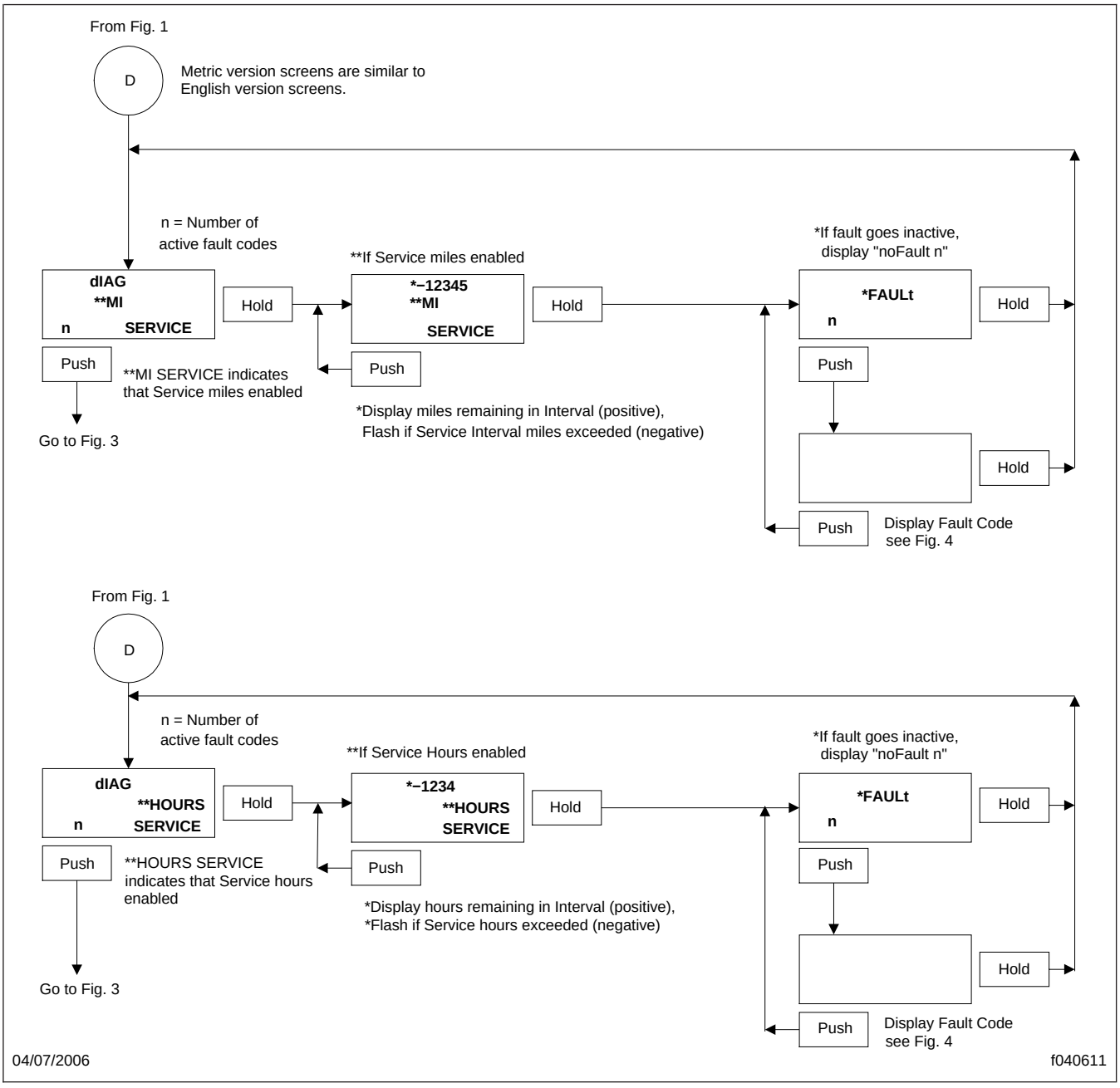


Fig. 5, Service Hour Screens

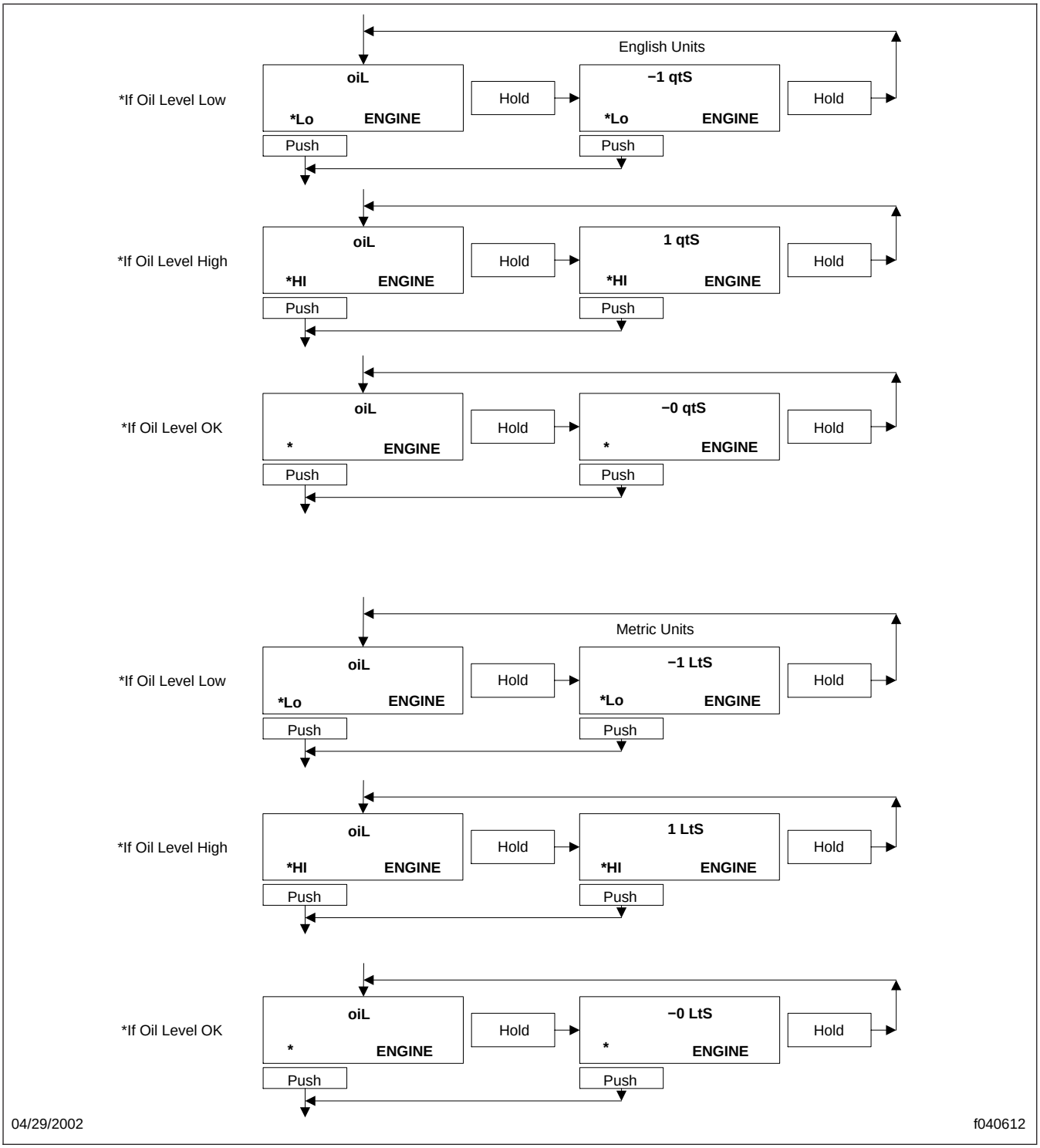


Fig. 6, Oil Level Screens

Mode/Reset Switch Functions

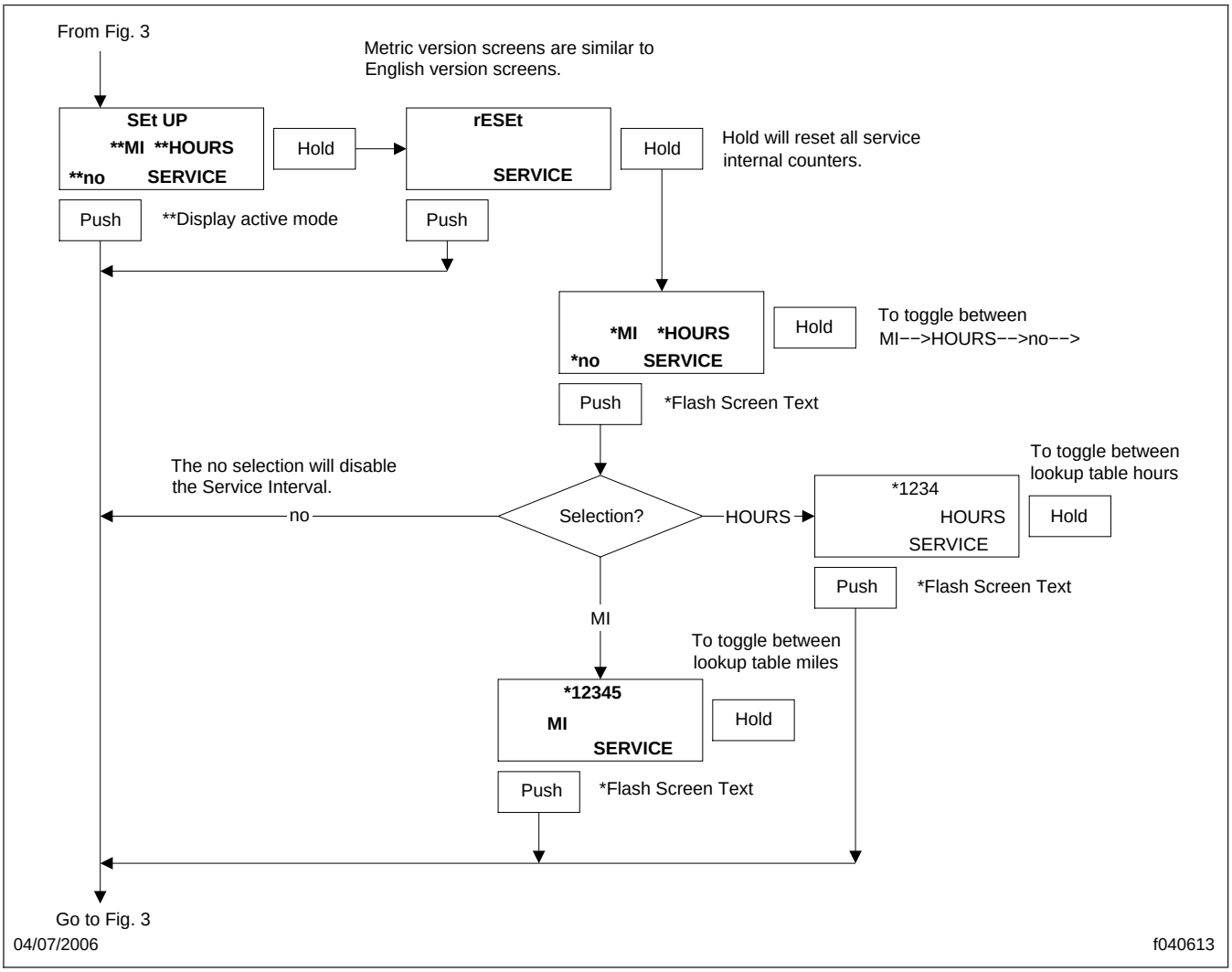


Fig. 7, Reset and Toggle Function Screens

Headlight Aim Checking and Adjusting

Before checking or adjusting the headlight aim, do the following.

- Remove large amounts of mud or ice from the underside of the fenders.
- Check the springs for sagging or broken leaves.
- Check the suspension for proper functioning of the leveling mechanism.
- Check for damage to the hood and hinge assembly. Repair as necessary.
- Clean the headlight lenses.
- With the vehicle unloaded, check that the tires are inflated to the recommended air pressure.

Checking

1. Park the vehicle on a level surface 25 feet (7.6 m) from a screen or wall that can be used for aiming the headlights. See **Fig. 1**. Shut down the engine, apply the parking brakes, and chock the front tires.

NOTE: The low-beam headlight is the top bulb in the dual-beam assembly.

2. On each headlight, find the bulb center. See **Fig. 2**.
3. Measure the distance from the ground to the center of each low-beam bulb. Note those distances.
4. On the screen or wall 25 feet (7.6 m) away, make the appropriate markings directly across from each headlight and at the same height as measured for the low-beam bulb.
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, follow the adjusting procedure below.
    - If both headlights come close to the inside of each headlight centerline (as shown), no further work is needed. Turn off the headlights and remove the chocks from the front tires.

Adjusting

1. Lift the flap over the rear end of the headlight bucket to expose the two plastic adjusting knobs on each headlight. See **Fig. 4**.

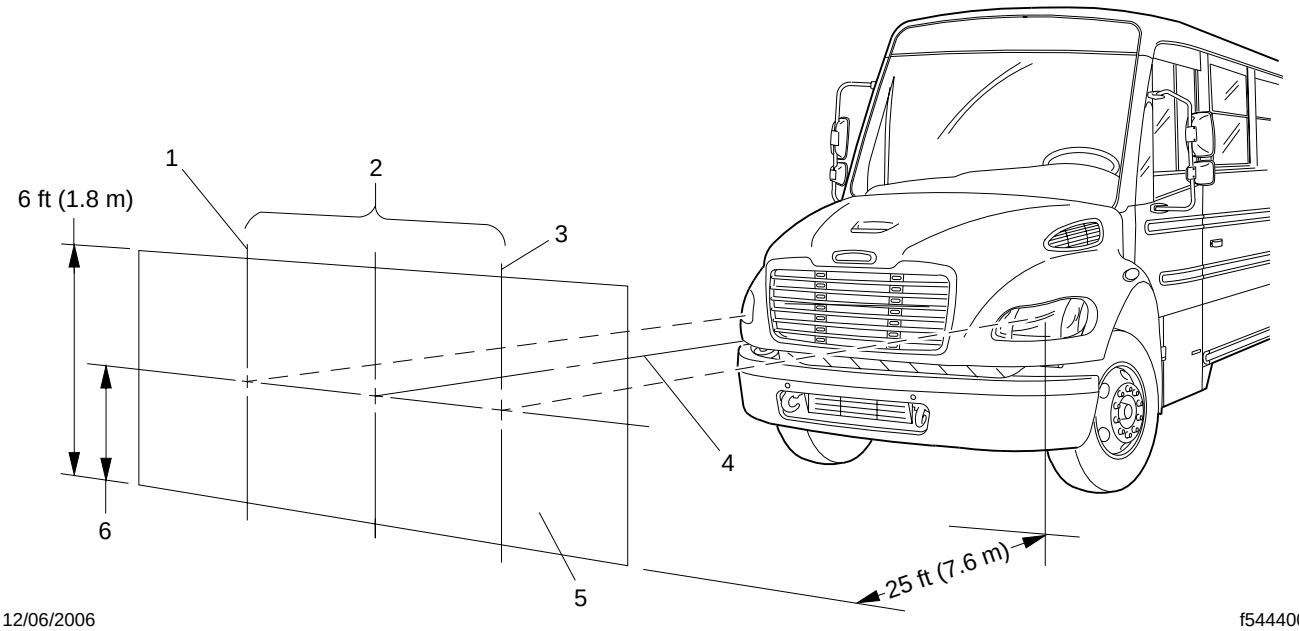
NOTE: Horizontal aim should not be adjusted in the field.

2. With the vehicle parked 25 feet (7.6 m) from the screen or wall, put the headlights on low beams, and turn both adjusting knobs the same amount, as needed to adjust the lights until the beam pattern meets the acceptable standard in **Fig. 3**.

NOTE: Blocking off each light is not necessary, but it can help to present a clearer beam pattern.

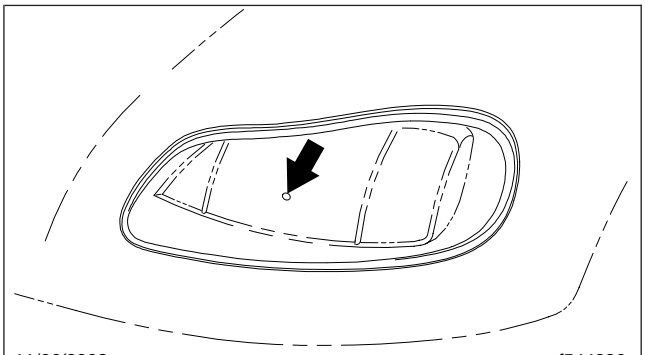
3. Remove the chocks from the front tires.

Headlight Aim Checking and Adjusting



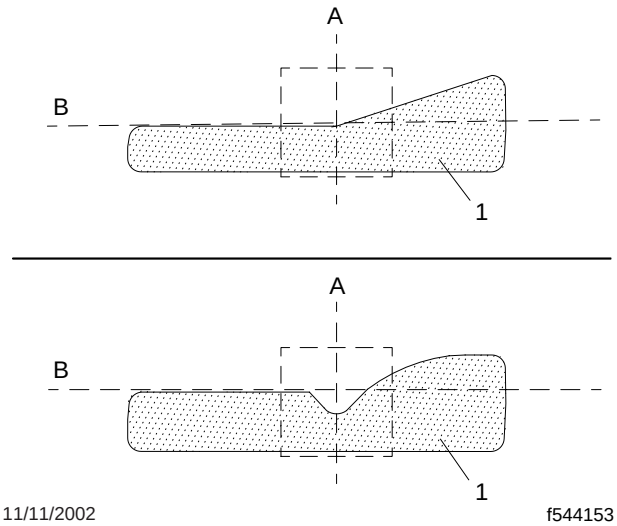
1. Vertical Centerline of Right Headlight
2. Distance Between Headlights
3. Vertical Centerline of Left Headlight
4. Projected Vehicle Centerline
5. Screen or Wall
6. Height of Lamp Centers

Fig. 1, Headlight Aiming Screen or Wall



Measure beam height from the ground to the small dot roughly in the center of the headlight lens.

Fig. 2, Headlight Beam Height Adjusting Dot



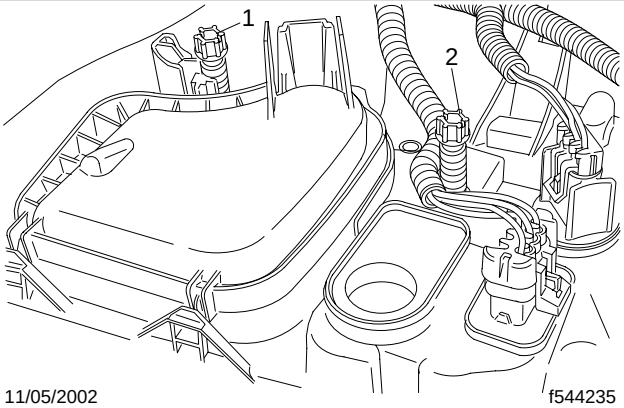
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NOTE: The top view shows the ideal beam pattern; the bottom view shows an acceptable standard.

A. Vertical Centerline B. Horizontal Centerline

1. Bright Area

Fig. 3, Headlight Beam Pattern



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NOTE: The right-hand side headlight bucket is shown. The left-hand side is opposite.

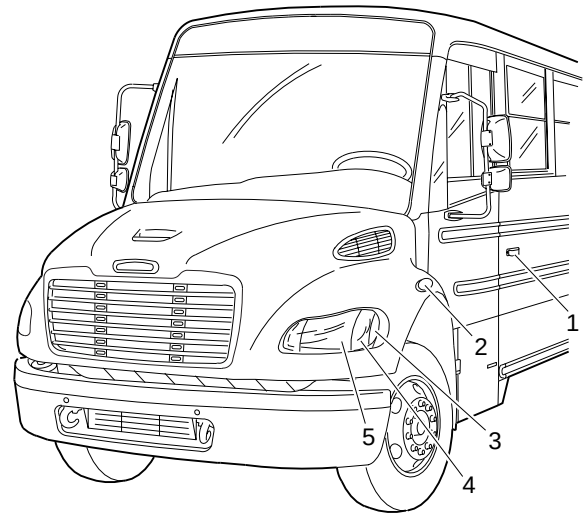
1. Inboard Adjusting Knob
2. Outboard Adjusting Knob

Fig. 4, Headlight Adjusting Knobs

See **Fig. 1** for an overview of the exterior lights.

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; don't 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.



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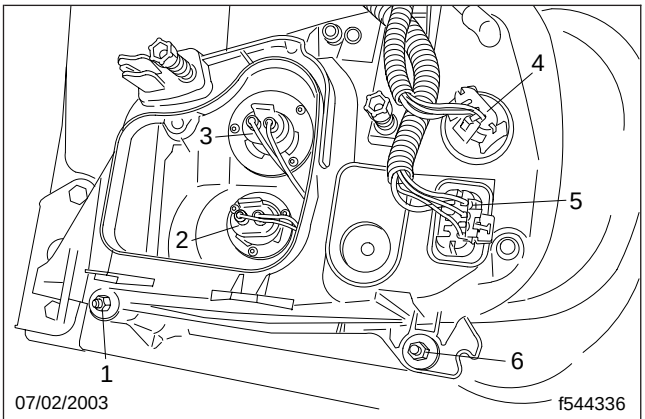
NOTE: The parking lights, front clearance lights, and taillights all function as turn signals.

1. Side Body Marker Light
2. Front Fender Marker Light
3. Headlamp-Mounted Turn Signal/Hazard Light
4. Parking Light
5. Headlamp

Fig. 1, Exterior Lights

Headlight/Turn Signal Assembly Replacement

1. Tilt the hood.
2. Secure the headlight splash guard out of the way.
3. Unplug the headlight and turn signal electrical connectors and cut any tie straps that may be holding them to the headlight bucket assembly.
4. Remove the nuts from the two lower mounting adjustment studs. See **Fig. 2**.



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1. Lower Mounting Adjustment
2. High Beam Socket
3. Low Beam Socket
4. Turn Signal Socket and Connector Assembly
5. Headlight Connector
6. Lower Mounting Adjustment

Fig. 2, Headlight Bucket (Rear View)

5. Remove the Torx® capscrew from the upper mounting bracket.
6. Remove the headlight/turn signal assembly.
7. Place a new assembly onto the mounting studs and install the two nuts and washers.

NOTE: Before installing the new assembly, verify that the lower mounting adjustments on the new assembly are set the same as the old assembly.

8. Install the Torx capscrew in the upper mounting bracket.
9. Plug in the two electrical connectors.
10. Verify the proper operation of the lights.
11. Return the headlight splash guard to its original operating position.
12. Check and adjust the headlight aim as described in **Subject 100**, Headlight Aim Checking and Adjusting.

Headlight Bulb Replacement

1. Tilt the hood.

2. Remove the inner headlight cover by pressing the tab at the top and pulling out.
3. Unplug the headlight connector. See **Fig. 2**.
4. Twist the high beam or low beam socket assembly 1/8 of a turn counterclockwise to remove it from the headlight bucket assembly and access the bulb.
5. Unplug the bulb from the socket. The bottom bulb in the assembly is the high beam lamp; the top bulb in the assembly is the low beam lamp.
6. While protecting the new bulb with gloves or a cloth, line up the bulb tabs and insert it in the socket, then twist it 1/8 of a turn clockwise to secure it.
7. Plug in the connector.
8. Return the inner headlight cover and snap it into place.
9. Close the hood.
10. Verify operation of the lights.
11. Check and adjust the headlight aim as described in **Subject 100**, Headlight Aim Checking and Adjusting.

Front Turn Signal Bulb Replacement

1. Tilt the hood.
2. Twist the turn signal connector and socket assembly 1/8 turn counterclockwise and remove it from the headlight bucket.
3. Pull the bulb straight out from the socket.
4. To provide corrosion protection, coat the base of the new bulb with dielectric grease. For approved lubricants, see the applicable table in **Specifications 400**.
5. Protecting the bulb with gloves or a cloth, push the new bulb straight into the socket.
6. Place the connector and socket assembly in the headlight bucket and twist it 1/8 turn clockwise to lock it in place.
7. Verify proper operation of the turn signal lights.

Front Fender Marker Light Assembly Replacement

1. Tilt the hood.
2. If the harness is being replaced, cut the two tie straps that secure it at the molded splash guard.
3. Twist the marker light connector 1/8 turn counterclockwise to unplug the connector and harness.
4. Remove the two screws that attach the lens to the fender. Remove the lens.
5. Install a new marker light lens on the fender, attaching it with the two screws.

IMPORTANT: Do not overtighten the screws, or damage to the lens may occur.

6. Install a new harness if required, and plug in the electrical connector and bulb socket. Twist it clockwise 1/8 turn to secure.
7. 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 Fender Marker Light Bulb Replacement

1. Tilt 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.

Specifications

Approved Electrical Lubricants	
Manufacturer	**Lubricant**
Standard Oil Co.	White Vasoline
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 1, Approved Electrical Lubricants

Replacement Bulb Part Numbers	
Description	**Part Number**
Headlight, Low Beam	WEE 9006
Headlight, High Beam	WEE 9005
Front Turn Signal Light	WEE 3157
Brake/Rear Turn Signal Light	WEE 1157
Backup Light	WEE 1156
Front Fender Marker Light	WEE 194

Table 2, Replacement Bulb Part Numbers

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, locate and correct the cause of the damage before continuing 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.

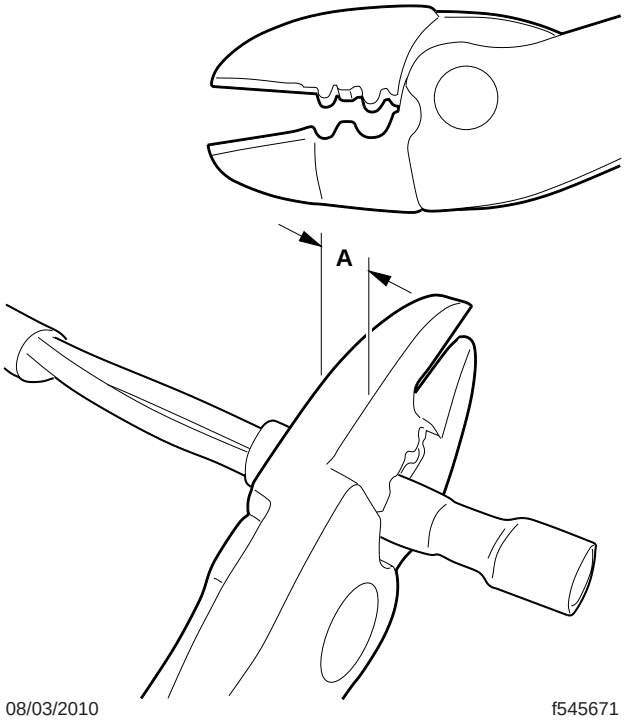
Wiring Repair Using Phillips STA-DRY® Solderless Connctors

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**.

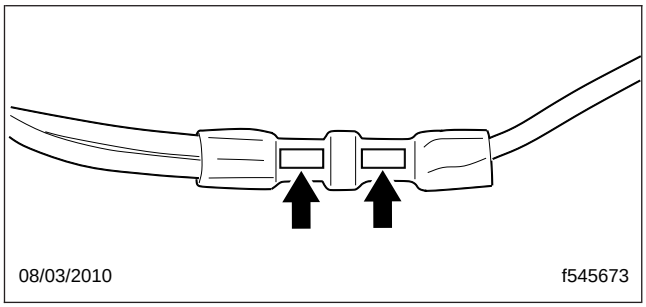


Fig. 2, Properly Crimped Splice

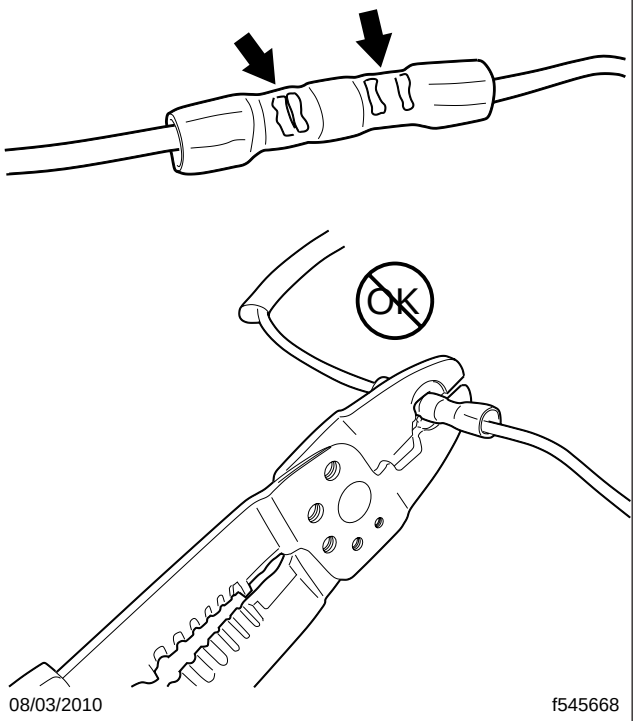
3. Pull test the wires by hand to ensure the crimp is mechanically solid.
4. A crimp tool that is too narrow will leave excessive air gaps in the crimp. The connection will not have the required amount of mechanical strength and the solder will not bond the wire to the connector. **Figure 3** shows an 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 Connctors

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.

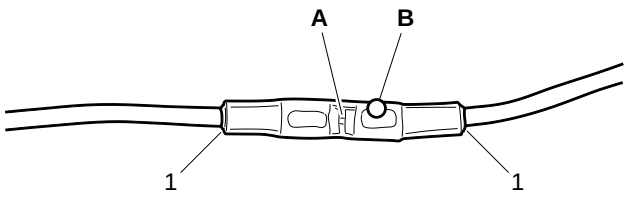
Table 1, Solderless Connector Parts



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NOTE: Even with two crimps, there is too much air gap; the solder will not bond.

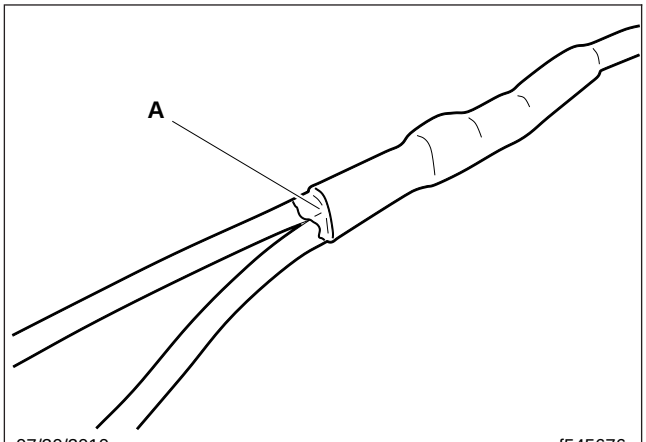
Fig. 3, Wrong Tool Being Used and a Crimp That Will Fail



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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

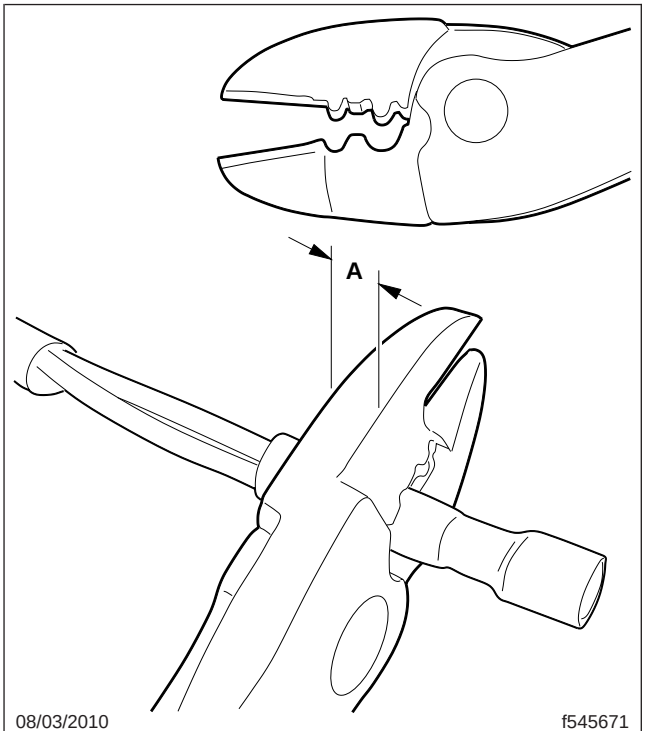
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

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).



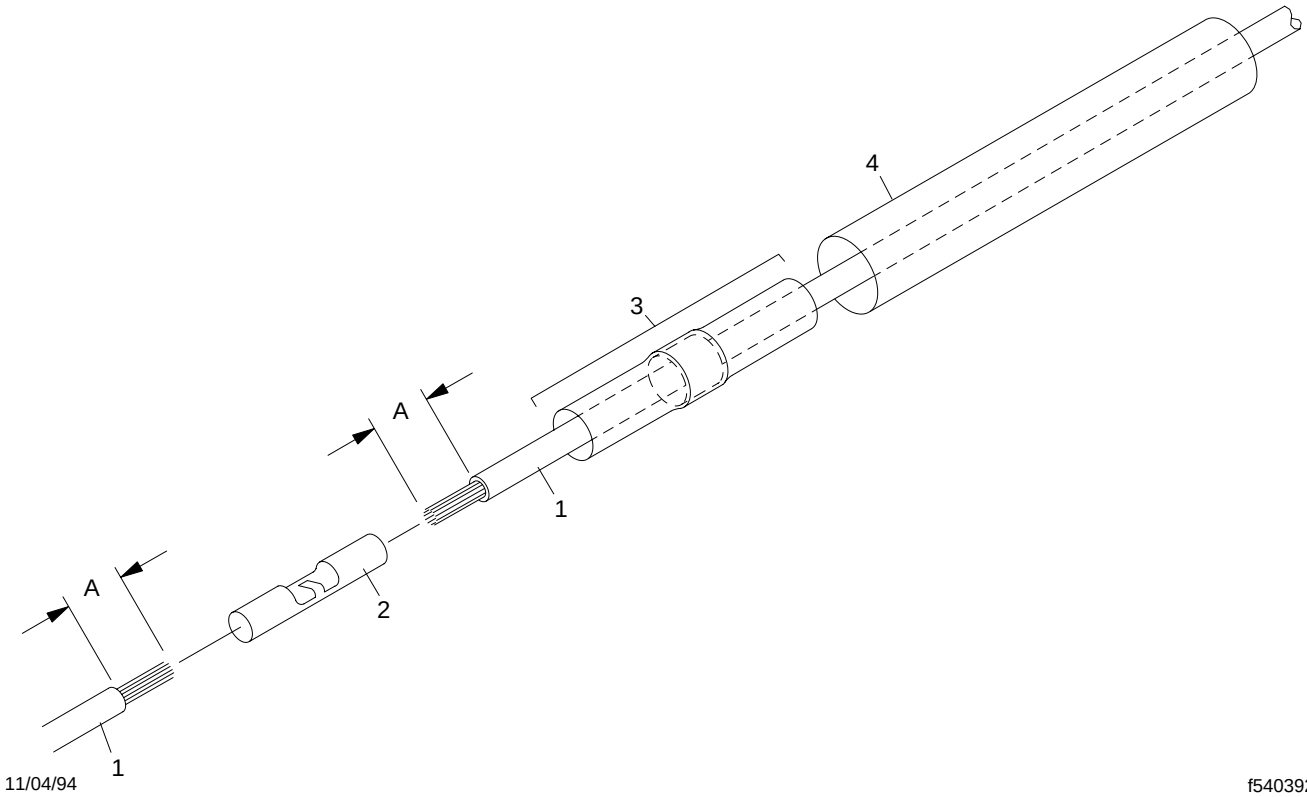
A. Minimum 3/16 inch width.

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.

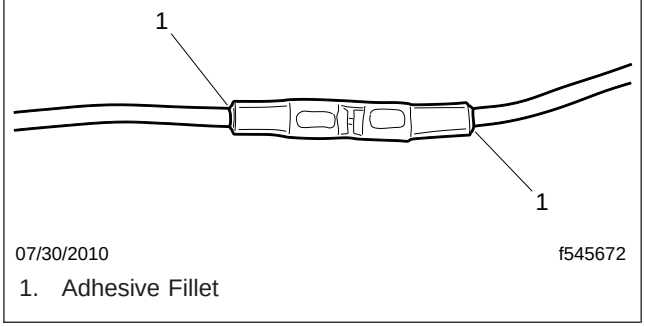
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404



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

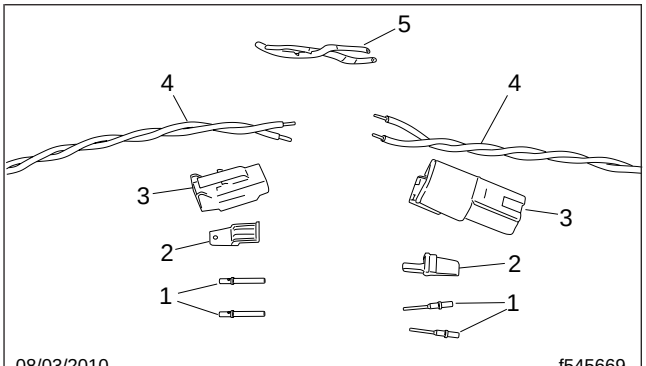
Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

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 DatalinkWires

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**.

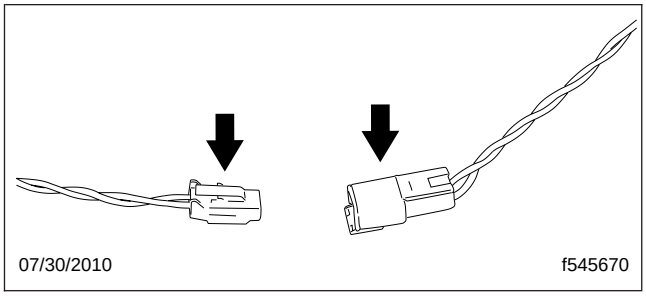


Fig. 2, Datalink Connectors

Corrosion 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/Cab-Tilt
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
40	Fan, Windshield/Sleeper	287 320 716 718
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

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
75	Starter Mag Switch, Ground	146 155 156 157 158 286 895
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
113	Baggage Compartment Lamps	287 320 322 324 325 32C
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

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
162	Tachometer Sensor +	283 286 320 812 819
163	Tachometer Sensor –	283 286 320 812 819
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
171	Brakesaver, Cat	128 129 286 343 34B 34C 34W 353
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
193	Cab Tilt Pump	288 320 670
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
211	Security System, Rockwell	287 320 656 787
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

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
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
250	Predictive Cruise Control	149 283 286
253	Cab Tilt Indicator	288 320 670
254	Roof Mounted Emergency Lamp/ Strobe	264 271 275 27A 27B 27C 27E 288 31A 31B 31C 31D 31G 320 327 33A
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

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
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
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
444	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
445	Body Controls/Dump Lock	288 320 329
446	Tire Pressure Monitor System	288 320 489

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
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
455	Instrument Left/Right Side Selection	320
457	Dash Controls, Datalink, (BPU)	164 283 286
458	Step Deployment Unit, Passenger Side	320 675 676 677 67E 67F
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
466	Land Departure System	160 288 320 736
467	Engine Coolant Flow Systems	152 286 320 856
468	Obstacle Detection System/VORAD	160 288 320 736 73B 73C
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
477	Hazard Lights, USPS	320 327 329
478	E-Stroke Brake Monitoring System	320 486 838 840 877 880 882

Specifications

Circuit Numbers		
Circuit Number	**Description**	**Modules**
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
490	Bus Door and Window Sensing and Warning	287 288 294 300 320 327 329 654 655 656 66A 675 676 677 67E 67F 700 703 723 787 811 814 860
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
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
507	MUX Control, MSF/CGW	287 320 786 78A 79H 80D
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
511	Bus Door and Window Sensing and Warning	146 155 156 157 158 286 895
512	Emergency Vehicle Auxilixry Switches	—
513	Emergency Vehicle Door Switches	—

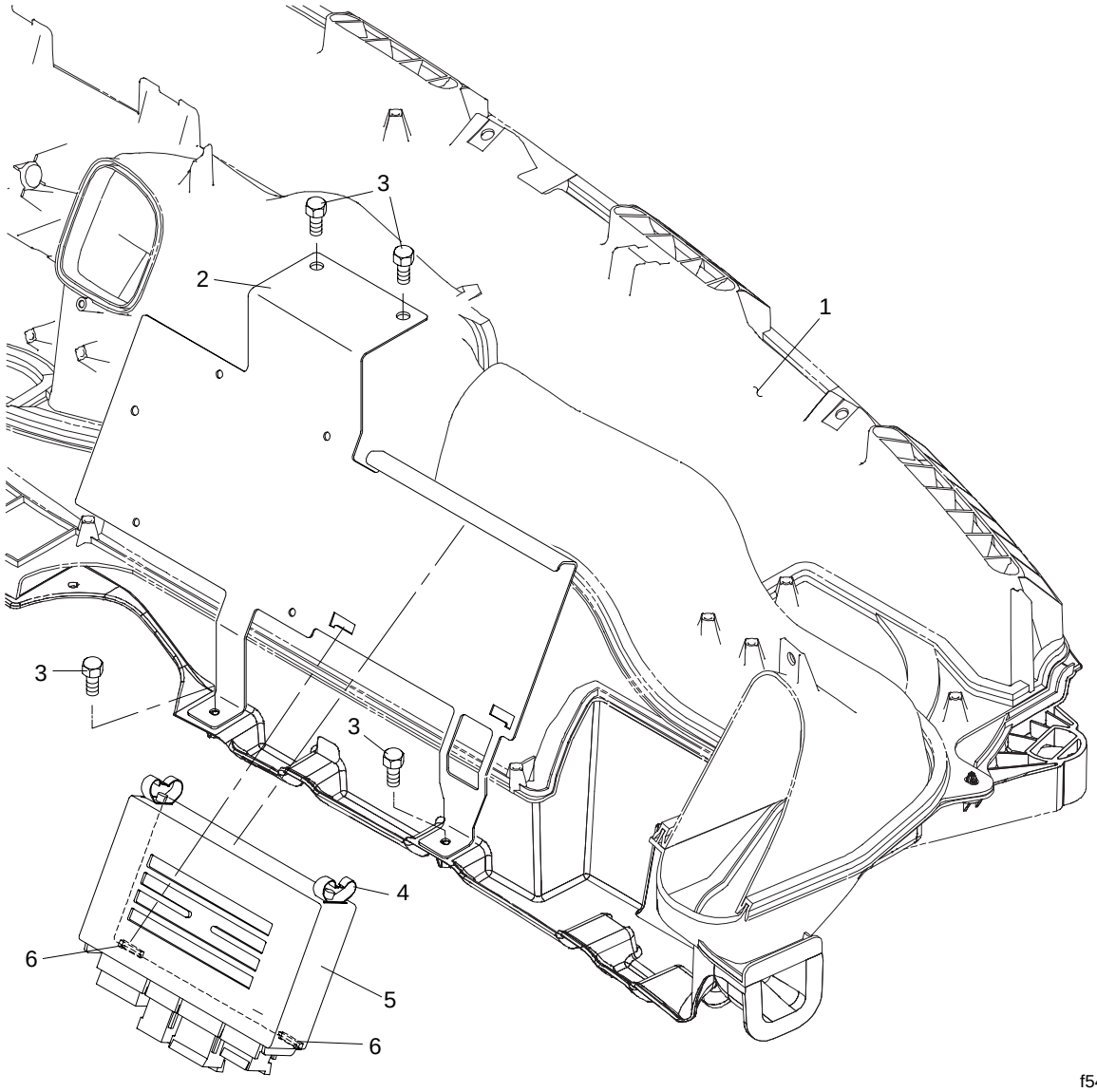
Circuit Numbers		
Circuit Number	**Description**	**Modules**
514	Emergency Vehicle Lights and Alarm	288 294 320 471 721
515	Emergency Vehicle Tank Level Systems	—
518	Emergency Vehicle Ladder and Rack Systems	—
519	Emergency Vehicle Body Lighting	—
520	Emergency Vehicle Body Lighting	—
521	Emergency 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
533	Engine ECU and Controls, Alternative Fuel	106 148 152 164 283 286 320 856
1587	J1587/J1708 Datalink	160 283 286 320 32A 330 338 343 725 732 733 736 811 812 813 819 835 888
1922	J1922 Datalink	160 283 286 330 343
1939	J1939 CAN Datalink	160 283 286 320 330 343 725 732 736 811 813 888

Table 2, Circuit Numbers

Vehicle Control Unit Removal and Installation

Removal

1. Park the vehicle on a level surface, turn off the engine, set the parking brake, and chock the tires.
2. Remove the right-side dash pads. See **Section 75.11** for the procedure.
3. Disconnect the three electrical connectors (violet, gray, and brown) by pressing the release at the bottom of each connector.
4. Press up on the bottom of the vehicle control unit (VCU) to compress the mounting clips. See **Fig. 1**.



12/14/2001 f544012

1. Dash
2. VCU Bracket
3. Panhead Screw, 10–14 x 1/2
4. Mounting Clip
5. Vehicle Control Unit (VCU)
6. Mounting Tab

Fig. 1, VCU Removal and Installation

Vehicle Control Unit Removal and Installation

5. With the mounting clips compressed, pull outward on the VCU to clear the mounting tabs from the slots in the VCU bracket.
6. Pull downward to release the mounting clips from the lip of the bracket and remove the VCU from the bracket.

NOTE: Do the following steps if it is also necessary to remove the VCU bracket.

7. Using a T25 Torx® screwdriver, remove the four 10–14 x 1/2 panhead screws that attach the bracket to the dash. Remove the bracket from the dash.

Installation

1. If removed, position the VCU bracket on the dash. Install the four panhead screws to hold it in place. Using a T25 Torx screwdriver, tighten the screws until firm in the nutserts.
2. Insert the VCU into the lip of the VCU bracket and press upward to compress the mounting clips on top of the VCU.
3. When the mounting clips are compressed enough, slide the tabs on the back of the VCU into the slots in the VCU bracket. Make sure the VCU is secured in place.
4. Connect the violet, gray, and brown electrical connectors to the VCU, as removed.

IMPORTANT: Because they each have different numbers of pins, the connectors cannot be installed on the wrong plug location on the VCU. Connector VC2 is not used at this time.

- Connector VC1 (brown) has 21 pins.
- Connector VC3 (gray) has 18 pins.
- Connector VC4 (violet) has 15 pins.

5. Install the dash pads. See **Section 75.11** for the procedure.
6. Remove the tire chocks.

General Information

A spring-loaded air restriction indicator indicates how much air filter capacity has been used and how much remains. It registers the actual maximum restriction of the filter element when the engine is operating at full load.

The standard air restriction indicator is mounted on the air intake piping and has a reset button. See **Fig. 1**. There is an optional air restriction indicator that is mounted on the surge tank mounting bracket and is connected to a dash light that illuminates when the air restriction is too high.

The air restriction indicator has a yellow index marker that retains the reading so that the remaining capacity can be read even after the engine is shut down. To reset the indicator, press the reset button.

The air restriction indicator and fitting may become plugged with moisture or engine vapors, possibly causing an incorrect reading.

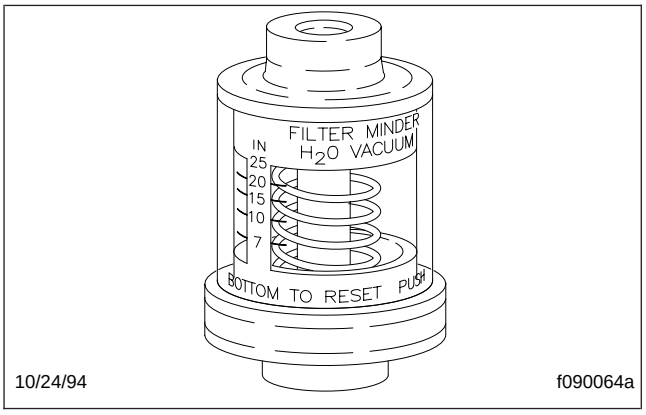


Fig. 1, Air Restriction Indicator

IMPORTANT: Many of the fluids used in vehicles, including brake fluid, fuel, antifreeze, engine oil, engine cleaners, windshield washer fluid, automatic transmission fluid, and power steering fluid, are harmful to the polycarbonate (Lexan) plastics that are used in the air restriction indicator. Keep these fluids away from the air restriction indicator.

Replacement

Mounted on the Air Intake Piping

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the air restriction indicator from the air intake piping by hand. If necessary, hold the fitting with a wrench. See **Fig. 1**.

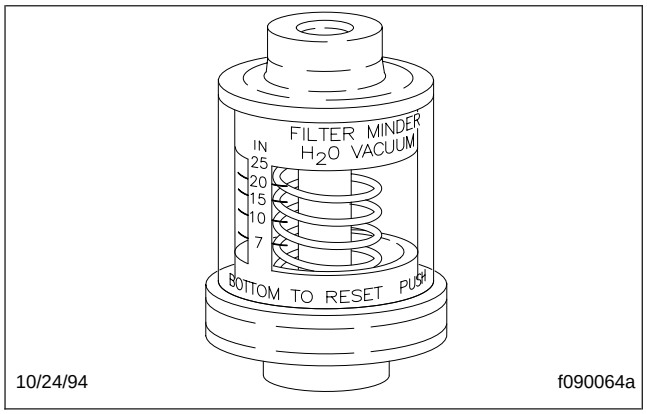


Fig. 1, Air Restriction Indicator

4. Install a new air restriction indicator on the fitting and tighten it firmly by hand.

NOTE: The fitting in the air intake duct is a special fitting consisting of an orifice and a filter. Be sure that the correct fitting is installed.

5. Lower the hood and remove the chocks from the tires.

Mounted on the Bulkhead

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the air hose from the air restriction indicator.
4. Remove the screws that attach the air restriction indicator to the surge tank mounting bracket.
5. Remove the backing from the adhesive strips and position the new indicator on the surge tank mounting bracket. Install the screws.
6. Connect the air hose to the air restriction indicator and check that it is securely attached.
7. Lower the hood and remove the chocks from the tires.

Troubleshooting Tables

Problem—No Restriction Reading

Problem—No Restriction Reading	
Possible Cause	**Remedy**
The indicator leaks.	Remove the air restriction indicator. Apply a vacuum to the indicator until the yellow index marker reaches the red line. With your thumb on the mounting fitting, close the end of the indicator airtight. Hold in the reset button. The yellow index marker will drop slightly and then not move unless the indicator has a leak. If the indicator is functioning properly, install it and press the reset button. If the yellow index marker continues to move, replace the air restriction indicator. Repeat the troubleshooting procedure to verify that the new indicator does not leak. When the indicator is functioning properly, install it and press the reset button.
Engine airflow is too low to generate a reading.	Turbocharged engines must be at full load to pull full engine airflow. Run engine at high idle. If there is still no restriction reading, check for leaks in the indicator or vacuum hose, as appropriate, and take corrective action. Check the air filter for holes or tears.

Problem—High Restriction Readings

Problem—High Restriction Readings	
Possible Cause	**Remedy**
The filter element in the air cleaner is plugged or dirty.	Install a new filter element.
The safety filter (if equipped) in the air intake piping is plugged.	Do not clean the safety filter. Replace it with a new one.
The air cleaner is undersized.	The air cleaner may be too small if a larger engine has been installed. Replace the undersized unit with a properly-sized air cleaner.
The air restriction indicator is too close to the intake of an engine blower or turbo.	Under certain circumstances, air turbulence near the blower intakes may cause a high vacuum reading. Locate the indicator away from the blower intake by at least 1-1/2 times the diameter of the intake tube.
The intake screens or ducts are plugged.	Check the system upstream from the air restriction indicator and remove any debris. Check for damage or improper installation, and take any necessary corrective action.
Heavy snow or rain.	Temporary high restriction can occur during a rain or snow storm and disappear after drying out. However, the cold air may be so dense that high restriction may not reduce the engine power before the air cleaner filter element is damaged. If the indicator reads maximum restriction (red line), check the element for damage and replace if necessary. NOTE: Before replacing the indicator, check the reading twice to be sure the high restriction reading is correct.

General Information

The multifunction turn signal switch is mounted on the left-hand side of the steering column just below the steering wheel. The switch controls the following functions:

- turn signals
- windshield wipers and washers
- headlight dimmer/flash-to-pass
- hazard warning flasher

The switch uses a low-current resistive ladder network for the switch functions. Low-current switches allow the use of smaller diameter wires and the resistive ladder network reduces the number of wires. Each switch function corresponds to a resistive output. The resistive ladder output is connected to the Instrumentation Control Unit (ICU3-M2) where the signals are processed and sent to the Bulkhead Module to actuate high-current devices such as the headlamps, turn signals, and wiper motor. The hazard switch is a traditional switch and is directly wired to the Bulkhead Module.

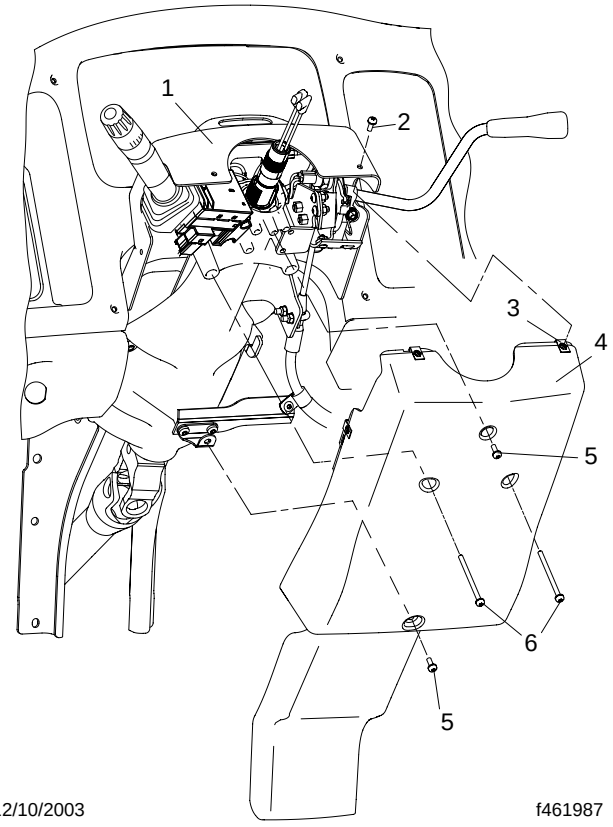
Multifunction Turn Signal Switch Removal and Installation

Removal

1. Disconnect the negative leads from the batteries.

NOTE: The multifunction turn signal switch is mounted on the left-hand side of the steering column just below the steering wheel.

2. Remove the steering column clamshell cover assembly by removing the eight machine capscrews that secure the two pieces. See **Fig. 1**.



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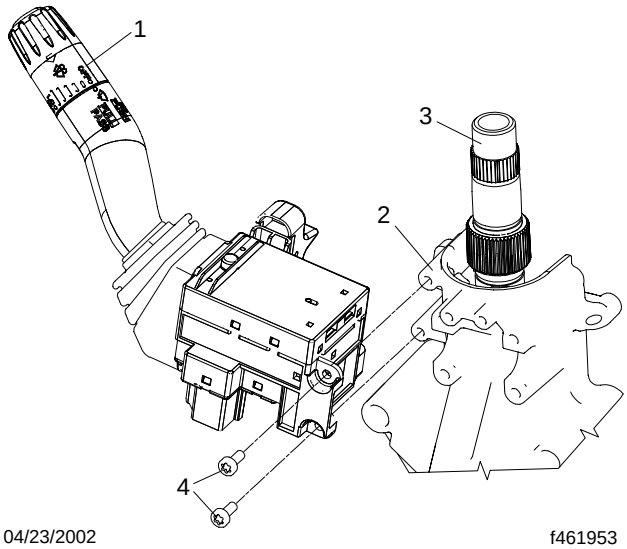
NOTE: Steering wheel shown removed for clarity.

1. Upper Clamshell Cover
2. Machine Capscrew
3. Spring Nut
4. Lower Clamshell Cover
5. M5 x 0.8 x 12 Capscrew
6. M5 x 0.8 x 70 Capscrew

Fig. 1, Removing/Installing the Steering Column Clamshell Cover Assembly

3. Remove the multifunction turn signal switch, as follows.

3.1 Remove the two panhead capscrews. See **Fig. 2**.



04/23/2002 f461953

1. Multifunction Turn Signal Switch
2. Switch Mounting Bracket
3. Steering Column
4. M6 x 1.0 x 15 Capscrews

Fig. 2, Removing/Installing the Mounting Capscrews

3.2 Disconnect the electrical harness connector.

Installation

1. Plug in the two electrical harness connectors.
2. Properly orient the multifunction turn signal switch, then secure the switch with the two capscrews (M6 x 1.0 x 15), and tighten 7 lbf·ft (9 N·m). See **Fig. 2**.
3. Connect the batteries.
4. Verify operation of the switch functions.
5. Install the steering column clamshell cover. See **Fig. 1**.

Specifications

For multifunction turn signal switch resistor values, see **Table 1**.

For multifunction turn signal switch resistance range values, see **Table 2**.

See **Fig. 1** for a schematic of the multifunction turn signal switch.

Resistor Values		
Description	**Resistor**	**Resistance: 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 1, Resistor Values

Resistance Range Values		
Description	**Resistor**	**Resistance Range: 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

Specifications

Resistance Range Values		
Description	**Resistor**	**Resistance Range: Ohms**
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 2, Resistance Range Values

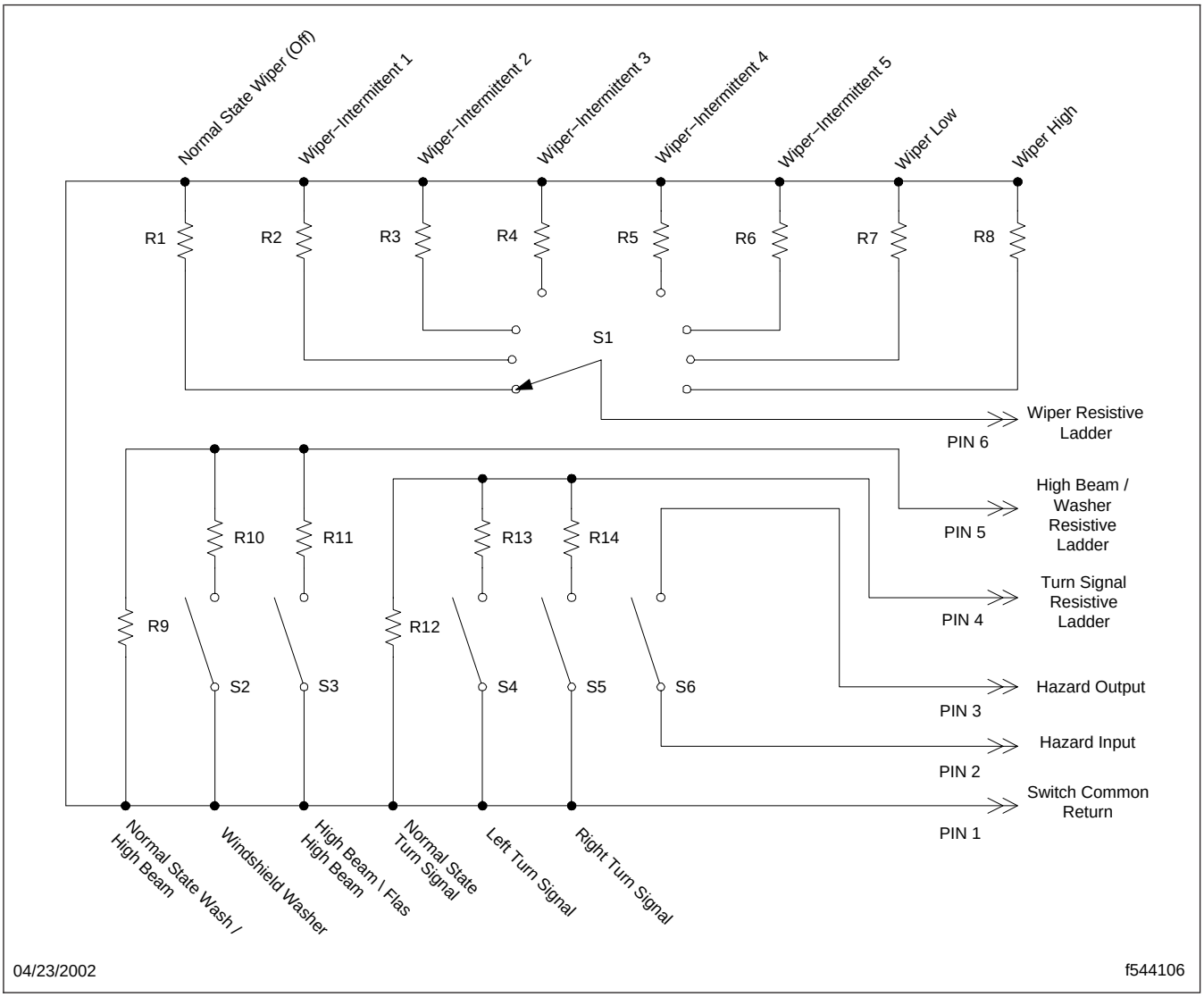


Fig. 1, Multifunction Turn Signal Switch Schematic

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.

General Safety Precautions

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:

1. 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.
2. Make sure that the area is well ventilated.

⚠ 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.

3. Make certain 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.
4. 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 of chargers.
5. Don't smoke near batteries that are being charged or have recently been charged. Keep the batteries away from open flames or sparks.
6. If the battery is frozen, let it reach room temperature before trying to charge it. Check for leaks and cracks before charging the battery. Replace the battery if leaks or cracks are seen.
7. Take care that tools or metal objects do not fall across the battery terminals.

⚠ 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

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 and 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.

⚠ 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.

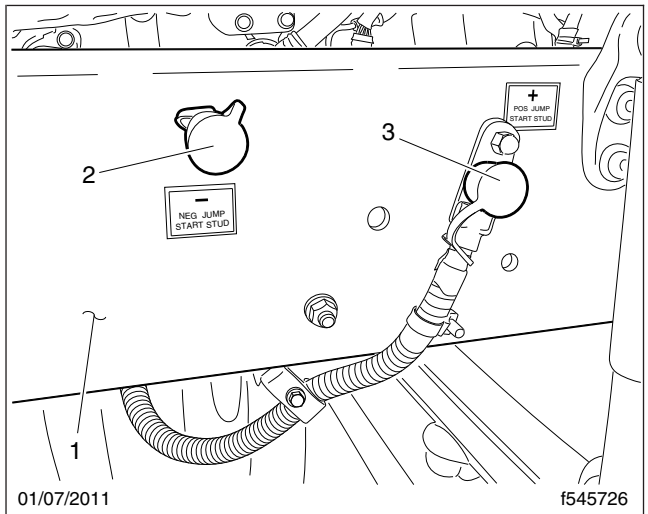
2. Remove the battery box cover.

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. 1.

3. Connect the positive (+) jumper cable to the positive terminal or jump start post on the discharged battery. See Fig. 2.



1. Frame Rail
2. Negative Jump Start Post
3. Positive Jump Start Post

Fig. 1, Possible Jump Start Post Location (passenger-side engine compartment)

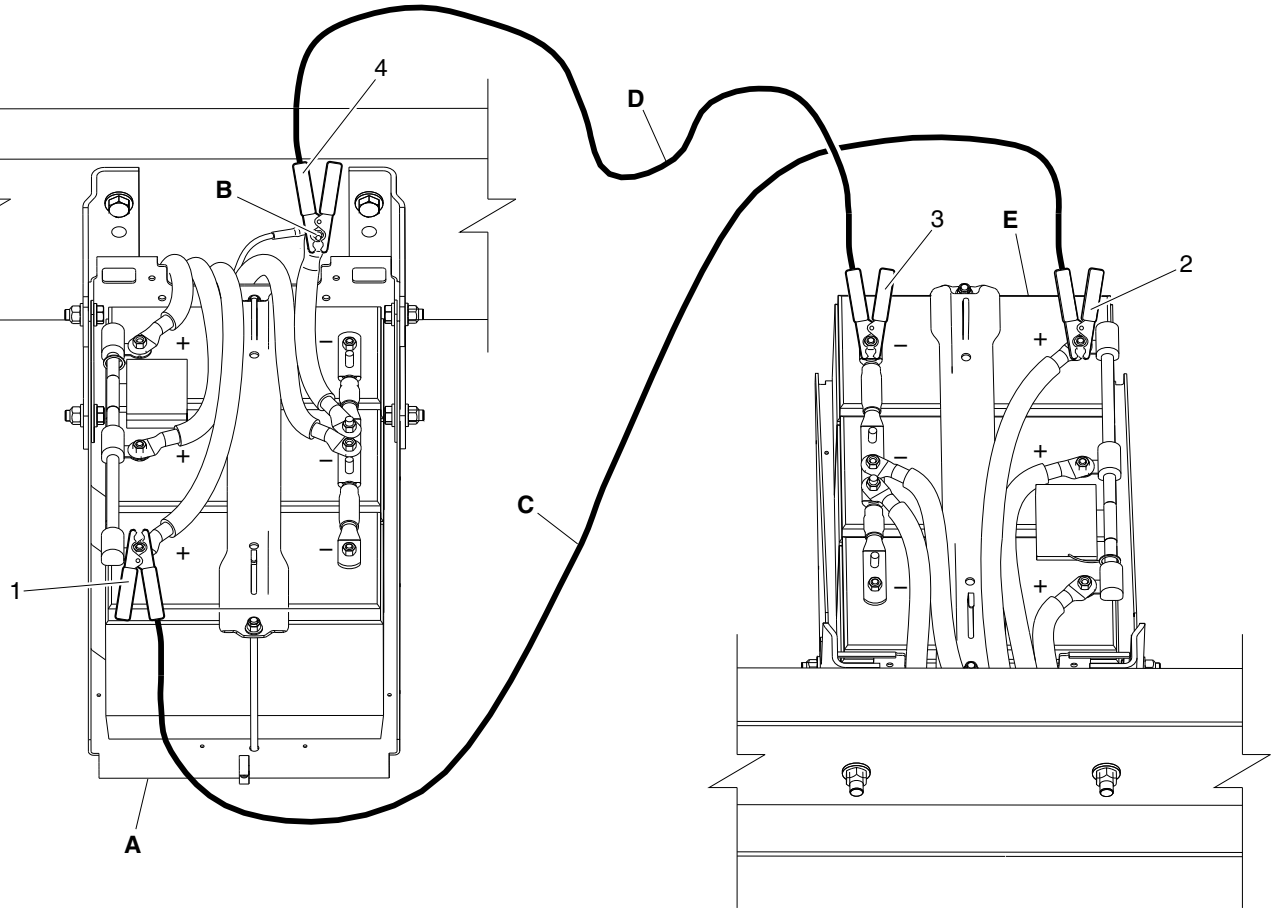
4. Connect the other end of the positive jumper cable to the positive terminal or jump start post on the booster battery providing the charge.

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.
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.

Emergency Starting Using Booster Cables



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. 2, Jumper Connections

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.

⚠ 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 (lights, ignition, accessories) are turned off.
2. Open the battery access door, release the pin latches, and slide the drawer out.
3. Disconnect the negative battery cable lead.
4. Disconnect the negative battery jumper post.
5. Disconnect the positive battery cable lead.
6. Disconnect the positive battery jumper post.
7. Remove the battery holddown and retainer, if so equipped; 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 battery to be installed has a sufficient capacity to cover the electrical needs of the vehicle.

⚠ CAUTION

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 boost-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 should rest level in the carrier.
4. Install the battery holddown, and tighten it until the batteries are secure. See Fig. 1.

⚠ CAUTION

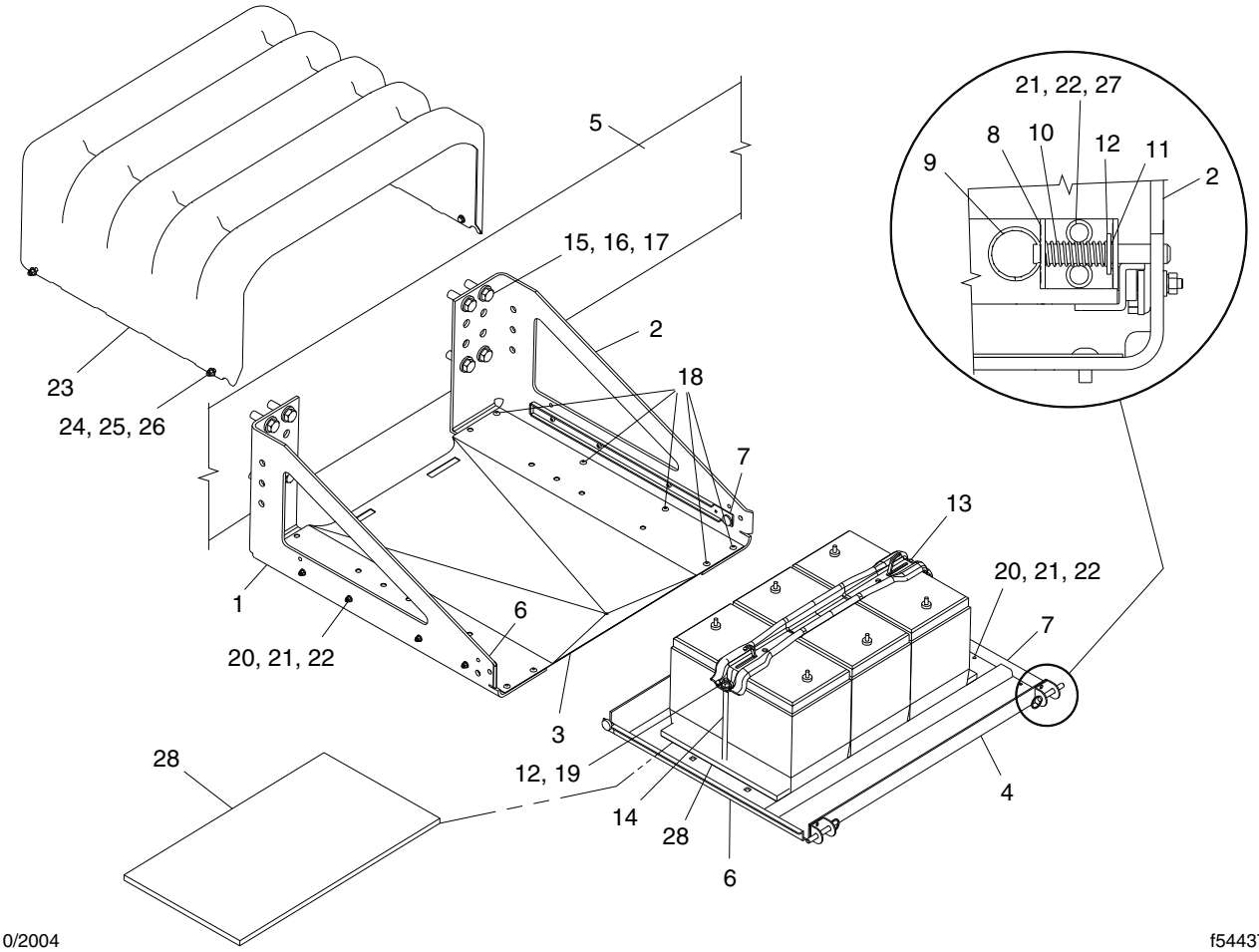
Do not overtighten the battery holddown. Overtightening could damage the batteries.

5. To provide corrosion protection, liberally apply pumpable dielectric grease to the terminal pads, then install the inter-connectors. For a list of approved suppliers, see Specifications 400.

IMPORTANT: Many electrical components are located outside of the cab in areas subjected to harsh weather, road spray, etc. Some components also have exposed metal electrical terminals, which, when subjected to harsh conditions, may suffer corrosion at the electrical connection. Spray dielectric sealant on all exposed electrical terminals, and use dielectric grease on all covered terminals. See Specifications 400 for a list of approved products.

6. Connect the battery cables to the batteries; check for correct polarity with respect to the vehicle. Connect the ground cable last.
   - 6.1 Install the positive battery jumper post.
   - 6.2 Install the positive battery cable lead.

Battery Removal, Cleaning and Inspection, and Installation



1. LH Mounting Bracket
2. RH Mounting Bracket
3. Drip Pan
4. Drawer
5. Frame Rail
6. LH Drawer Slide
7. RH Drawer Slide
8. Latch Bracket
9. Latch Pin
10. Latch Spring
11. Cotter Pin, 1/16 x 3/4
12. Washer
13. Battery Holddown
14. Bolt, Round Head, Square Neck, 3/8–16
15. Hexbolt 5/8–11
16. Washer
17. Hexnut, 5/8–11
18. Monobolt, 1/4–0.375
19. Hexnut, 3/8–16
20. Machine Screw, 10–24
21. Flatwasher, #10
22. Hexnut, Locking Collar, 10–24
23. Battery Cover
24. Machine Screw, 1/4–20 x 3/4-inch
25. Washer, 1/4-inch i.d.
26. Hexnut, 1/4–20
27. Machine Screw, 10–24
28. Plywood Liner (8D batteries only)

Fig. 1, Frame-Mounted Battery Box

6.3 Install the negative battery jumper post.

6.4 Install the negative battery cable lead.

⚠ CAUTION

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. Generally 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, adjust or repair the charging system to obtain the correct charging output. For instructions, see the appropriate section in **Group 15**.

Battery Box Removal and Installation

⚠ WARNING

Before doing any of the following procedures, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery box, make sure all electrical loads (lights, ignition, accessories) are turned off.
2. Open the battery access door, release the pin latches, slide out the drawer, and remove the batteries.
3. See **Subject 130** for procedures to remove the batteries.
4. Free the battery cables from the side of the battery box.
5. Remove the drawer from the drawer slides. See **Fig. 1**.
6. Remove the four fasteners from the battery cover and remove the cover.
7. Remove the eight sets of bolts, nuts, and washers that attach the battery box to the frame rail.
8. Remove the battery box.

Installation

1. Line up the holes in the battery box with the holes in the frame rail.
2. Install the eight sets of bolts, nuts, and washers that attach the battery box to the frame rail. **Do not tighten.**
3. Install the drawer in the slides.
4. Test the drawer operation by sliding it in and out several times. Adjust the mount brackets as necessary.

NOTE: The drawer latch pins should snap into the locked position without extra effort.

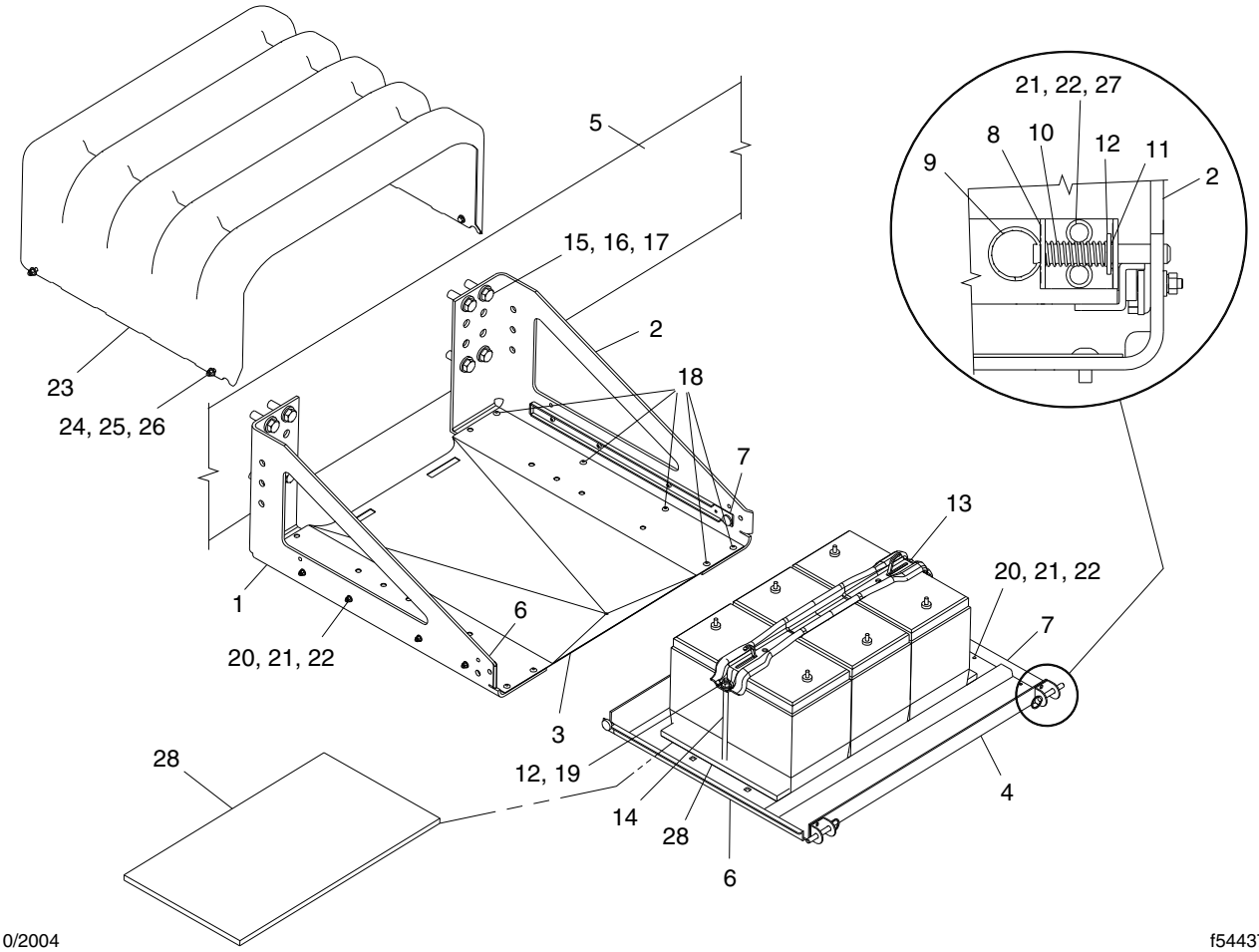
5. Tighten the mount bolts to 128 lbf·ft (173 N·m).
6. Install the battery box cover.
7. Place the batteries in the battery box with the terminals in the proper position. Make sure the batteries rest level in the box. See **Subject 160** for procedures to correctly install the batteries.
8. Install the battery holddowns. Tighten each nut to 10 lbf·ft (14 N·m).

⚠ CAUTION

Do not overtighten the battery holddowns. Overtightening could damage the batteries.

9. Return the battery drawer to the closed position. Close the access door.

Battery Box Removal and Installation



1. LH Mounting Bracket
2. RH Mounting Bracket
3. Drip Pan
4. Drawer
5. Frame Rail
6. LH Drawer Slide
7. RH Drawer Slide
8. Latch Bracket
9. Latch Pin
10. Latch Spring
11. Cotter Pin, 1/16 x 3/4-inch
12. Washer
13. Battery Holddown
14. Bolt, Round Head, Square Neck, 3/8–16
15. Hexbolt, 5/8–11
16. Washer
17. Hexnut, 5/8–11
18. Monobolt, 1/4–0.375
19. Hexnut, 3/8–16
20. Machine Screw, 10–24
21. Flatwasher, #10
22. Hexnut, Locking Collar, 10–24
23. Battery Cover
24. Machine Screw, 1/4–20 x 3/4
25. Washer, 1/4-inch
26. Hexnut, 1/4–20
27. Machine Screw, 10–24
28. Plywood Liner (8D batteries only)

Fig. 1, Frame-Mounted Battery Box

⚠ WARNING

Before charging a battery, read the instructions in Subject 120. 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

To charge a conventional liquid-electrolyte battery (wet cell), apply a charge rate in amperes for a period of hours. A 10-ampere charge rate for 5 hours would produce a 50 ampere-hour charge to the battery. Charge rates between 3 and 50 amperes are generally satisfactory for maintenance-free batteries.

An emergency boost-charge, or fast-charge, provides a high charging rate for a short period of time. Limit fast charges to specific charging times. See the charging table in **Specifications, 400**. The battery cannot be fully charged within these time periods, but it will receive a sufficient charge (70 to 90 percent) for practical service. To completely charge a battery, follow the fast-charge with a slow-charge.

IMPORTANT: Do not overcharge maintenance-free batteries. Overcharging causes excessive loss of water from the electrolyte and eventual battery damage.

On optional batteries with built-in hydrometers (charge indicators), the battery is sufficiently charged when the green dot in the hydrometer is visible. Gently shake or tilt the battery at hourly intervals during charging to mix the electrolyte and check to see if the green dot appears. Do not tilt the battery beyond a 45-degree angle.

⚠ CAUTION

Before shaking the battery, shut off the charger and disconnect it from the batteries. Shaking a battery with the charger hooked up may cause a spark that could ignite discharging gasses, leading to personal injury or property damage.

If the green dot does not appear after a 75 ampere-hour charge, continue charging for another 50 to 75 ampere-hours. If the green dot still does not appear, replace the battery.

NOTE: Batteries with built-in hydrometers (charge indicators) can't be charged if the indicator color is clear or light yellow; this indicates low electrolyte level. Replace these batteries.

To charge a wet cell, do the following steps:

1. Clean the battery terminals.

NOTE: If the battery is cold, let it warm up. This will allow a normal charging rate.

2. Make sure that the charger is turned off.
3. Connect the charger to the battery following the manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
4. Turn on the charger and slowly increase the charging rate until the recommended ampere value is reached. See the charging table in **Specifications, 400**.

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.

5. 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.

6. Disconnect the charger cables from the battery.

NOTE: If the vehicle is equipped with an isolated battery system, be sure that both battery systems are charged.

7. If the engine does not crank satisfactorily when a charged battery is installed, test the battery. For instructions, see **Subject 140**.

   If the battery passes the test, check the fuel, ignition, cranking, and charging systems to find and correct the problem.

   If the battery does not pass the test, replace it.

Battery Removal, Cleaning and Inspection, and Installation

⚠ WARNING

Before doing any of the following procedures, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery, make sure all electrical loads (lights, ignition, accessories) are turned off.
2. Open the battery access door, release the pin latches, and slide the drawer out.
3. Disconnect the negative battery cable lead.
4. Disconnect the negative battery jumper post.
5. Disconnect the positive battery cable lead.
6. Disconnect the positive battery jumper post.
7. Remove the battery holddown and retainer, if so equipped; then remove the batteries from the carrier.

Cleaning and Inspection

1. Inspect all battery cables and inter-connectors 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. There are two locations to service. First, at the battery, and, second, at the engine behind the left wheel. Inspect and ensure that the nut is a self-locking type and that a flatwasher is used. Do not use a split lockwasher or star washer. Torque the nut 15 to 18 lbf·ft (20 to 24 N·m). Seal the area with red dielectric spray enamel sealant.
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. Paint the retainer assembly, if needed, to prevent rusting.
4. Be sure foreign objects, such as stones, bolts, and nuts, are removed from the battery box.

Installation

1. Be sure that the battery to be installed has a sufficient capacity to cover the electrical needs of the vehicle. For more information, see **Subject 100**.

⚠ CAUTION

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 boost-charge before installing it. For instructions, see **Subject 150**.
3. Place the batteries in the carrier with the terminals in the proper position, as referenced earlier. The batteries should rest level in the carrier.
4. Install the battery holddown, and tighten it until the batteries are secure. See **Fig. 1**.

⚠ CAUTION

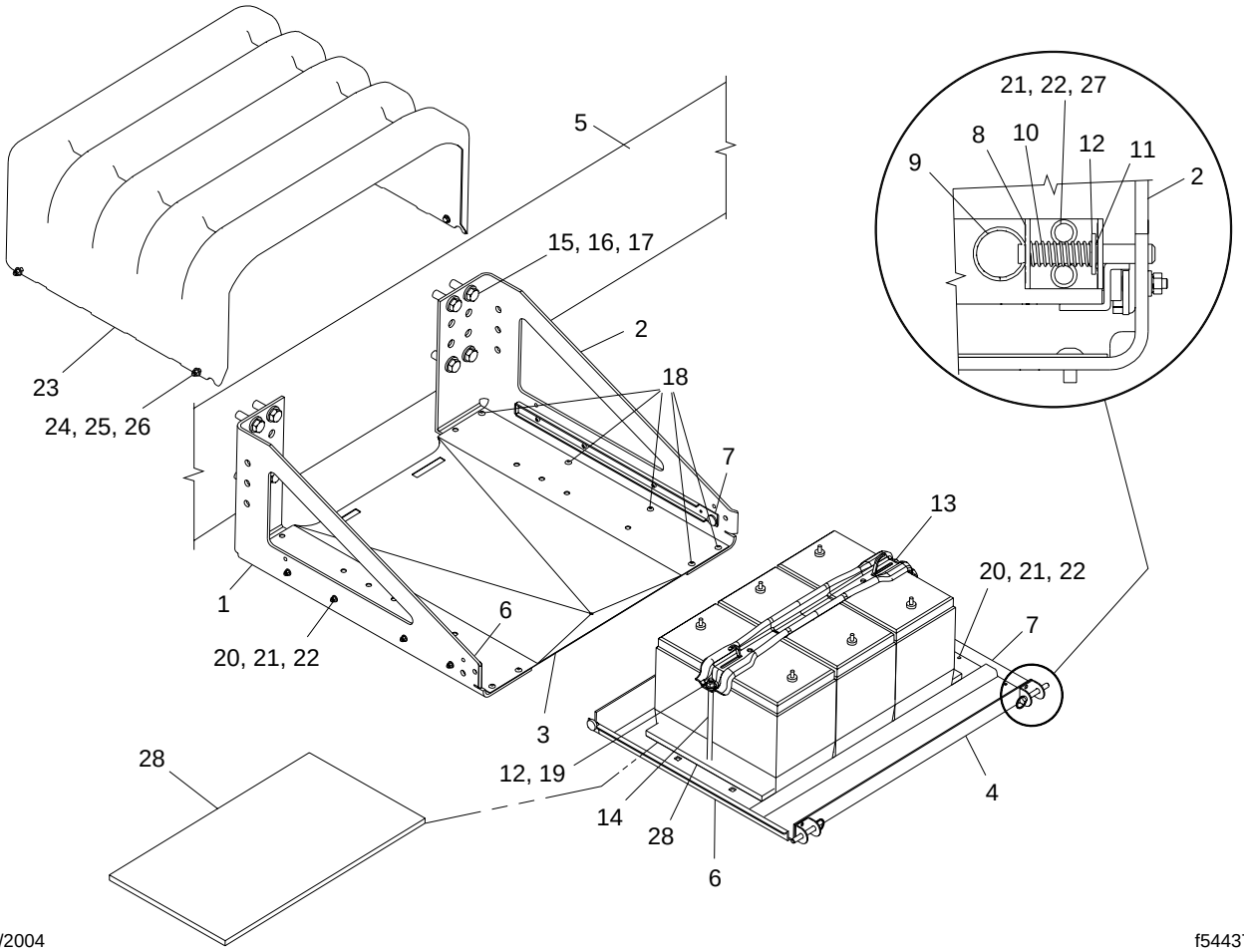
Do not overtighten the battery holddown. Overtightening could damage the batteries.

5. To provide corrosion protection, liberally apply pumpable dielectric grease to the terminal pads, then install the inter-connectors. For a list of approved suppliers, see **Specifications 400**.

IMPORTANT: Many electrical components are located outside of the cab in areas subjected to harsh weather, road spray, etc. Some components also have exposed metal electrical terminals, which, when subjected to harsh conditions, may suffer corrosion at the electrical connection. Spray dielectric sealant on all exposed electrical terminals, and use dielectric grease on all covered terminals. See **Specifications 400** for a list of approved products.

6. Connect the battery cables to the batteries; check for correct polarity with respect to the vehicle. Connect the ground cable last.
   - 6.1 Install the positive battery jumper post.
   - 6.2 Install the positive battery cable lead.

Battery Removal, Cleaning and Inspection, and Installation



1. LH Mounting Bracket
2. RH Mounting Bracket
3. Drip Pan
4. Drawer
5. Frame Rail
6. LH Drawer Slide
7. RH Drawer Slide
8. Latch Bracket
9. Latch Pin
10. Latch Spring
11. Cotter Pin, 1/16 x 3/4
12. Washer
13. Battery Holddown
14. Bolt, Round Head, Square Neck, 3/8–16
15. Hexbolt 5/8–11
16. Washer
17. Hexnut, 5/8–11
18. Monobolt, 1/4–0.375
19. Hexnut, 3/8–16
20. Machine Screw, 10–24
21. Flatwasher, #10
22. Hexnut, Locking Collar, 10–24
23. Battery Cover
24. Machine Screw, 1/4–20 x 3/4-inch
25. Washer, 1/4-inch i.d.
26. Hexnut, 1/4–20
27. Machine Screw, 10–24
28. Plywood Liner (8D batteries only)

Fig. 1, Frame-Mounted Battery Box

6.3 Install the negative battery jumper post.

6.4 Install the negative battery cable lead.

⚠ CAUTION

Reversed polarity may cause serious damage to the electrical system.

7. Tighten all battery connections to the torque specifications listed on the battery. Generally 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, adjust or repair the charging system to obtain the correct charging output. For instructions, see the appropriate section in **Group 15**.

Battery Box Removal and Installation

WARNING

Before doing any of the following procedures, read the instructions in Subject 120. Failure to follow the safety precautions could result in personal injury.

Removal

1. Before working on the battery box, make sure all electrical loads (lights, ignition, accessories) are turned off.
2. Open the battery access door, release the pin latches, slide out the drawer, and remove the batteries.
3. See **Subject 160** for procedures to remove the batteries.
4. Free the battery cables from the side of the battery box.
5. Remove the drawer from the drawer slides. See **Fig. 1**.
6. Remove the four fasteners from the battery cover and remove the cover.
7. Remove the eight sets of bolts, nuts, and washers that attach the battery box to the frame rail.
8. Remove the battery box.

Installation

1. Line up the holes in the battery box with the holes in the frame rail.
2. Install the eight sets of bolts, nuts, and washers that attach the battery box to the frame rail. **Do not tighten.**
3. Install the drawer in the slides.
4. Test the drawer operation by sliding it in and out several times. Adjust the mount brackets as necessary.

NOTE: The drawer latch pins should snap into the locked position without extra effort.

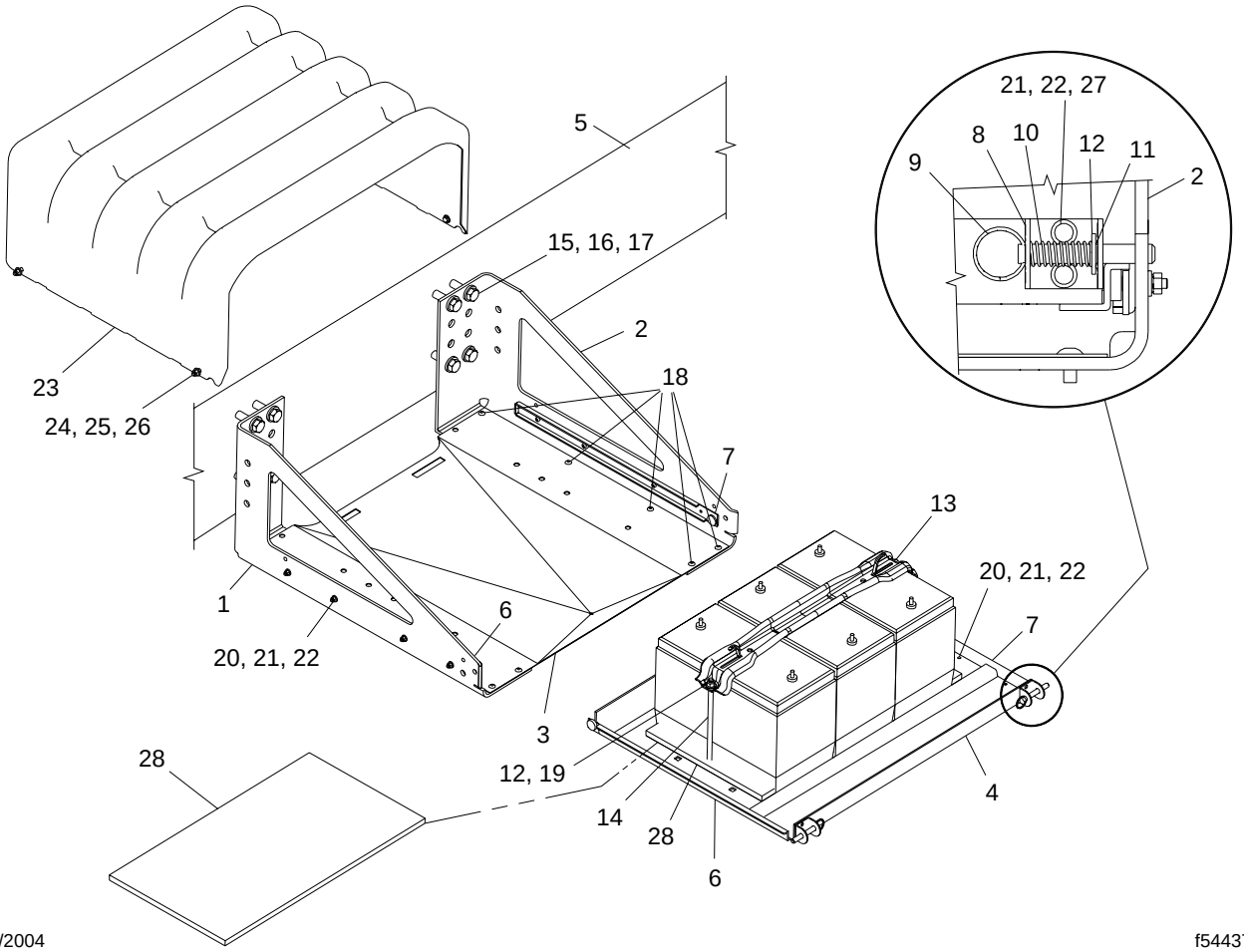
5. Tighten the mount bolts to 128 lbf·ft (173 N·m).
6. Install the battery box cover.
7. Place the batteries in the battery box with the terminals in the proper position. Make sure the batteries rest level in the box. See **Subject 160** for procedures to correctly install the batteries.
8. Install the battery holddowns. Tighten each nut to 10 lbf·ft (14 N·m).

CAUTION

Do not overtighten the battery holddowns. Overtightening could damage the batteries.

9. Return the battery drawer to the closed position. Close the access door.

Battery Box Removal and Installation



1. LH Mounting Bracket
2. RH Mounting Bracket
3. Drip Pan
4. Drawer
5. Frame Rail
6. LH Drawer Slide
7. RH Drawer Slide
8. Latch Bracket
9. Latch Pin
10. Latch Spring
11. Cotter Pin, 1/16 x 3/4-inch
12. Washer
13. Battery Holddown
14. Bolt, Round Head, Square Neck, 3/8–16
15. Hexbolt, 5/8–11
16. Washer
17. Hexnut, 5/8–11
18. Monobolt, 1/4–0.375
19. Hexnut, 3/8–16
20. Machine Screw, 10–24
21. Flatwasher, #10
22. Hexnut, Locking Collar, 10–24
23. Battery Cover
24. Machine Screw, 1/4–20 x 3/4
25. Washer, 1/4-inch
26. Hexnut, 1/4–20
27. Machine Screw, 10–24
28. Plywood Liner (8D batteries only)

Fig. 1, Frame-Mounted Battery Box

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

   3.2 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.

   3.3 Connect the battery tester's positive and negative clamps to the lead base terminal pads at the positive and negative studs. See **Fig. 1**.

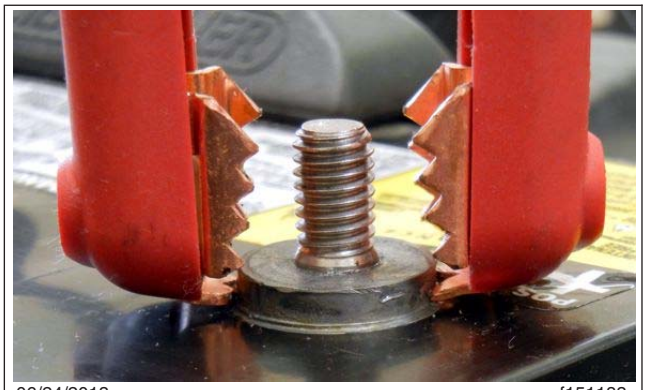


Fig. 1, Tester Clamps Attached to the Post

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**.

3.4 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

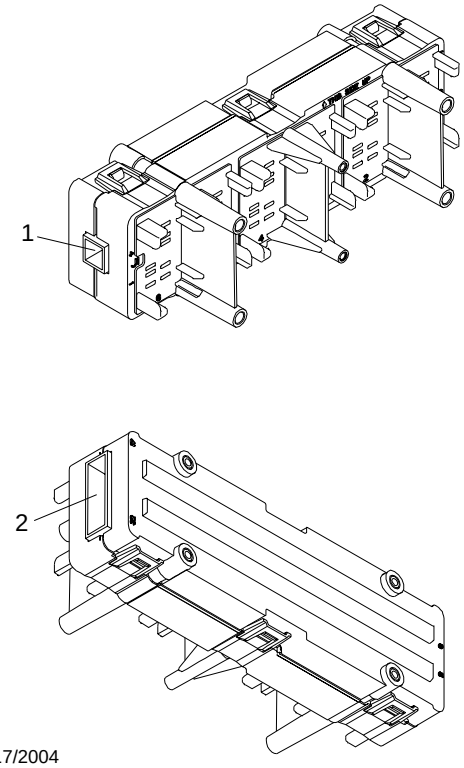
The Switch Expansion Module (SEM) is an optional module of the vehicle electrical system, and acts as a slave to the Bulkhead Module (BHM). An SEM is used on a vehicle to add smart switches when all smart switch locations on the vehicle are already in use, or when installing a smart switch in a location that existing smart switch harnesses or modules cannot access, such as overhead. The SEM does not control any outputs.

Since it is optional, there may be from zero to four SEMs on a vehicle. There can be up to six smart switches connected to each SEM. It has two harness connections, though both might not be used.

The SEM comes in two versions, dash-mounted and remote-mounted. When dash-mounted, the smart switches may plug directly into the unit. See **Fig. 1** and **Fig. 2**. When mounted remotely, the smart switches must be plugged in through a harness connected to connector J2.

Both versions are supported by a single version of software.

The SEM communicates over only the SAE J1939 datalink; it has no J1708/J1587 communication.



1. Connector J1
2. Connector J2

Fig. 1, Dash-Mounted SEM

General Information

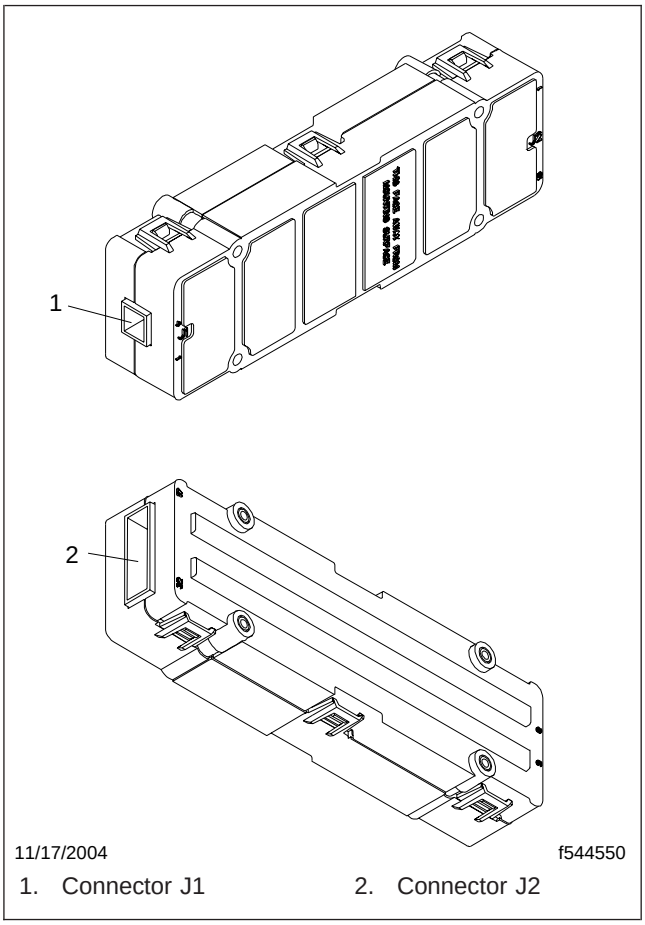


Fig. 2, Remote-Mounted SEM

SEM J1939 Source Address Claiming Scheme

Switch Expansion Modules (SEMs) on the J1939 datalink claim a J1939 "source address." The source address identifies the module and can be viewed using ServiceLink. See **Table 1** for a list of the possible SEM source addresses.

SEM J1939 Source Address Claiming Scheme	
Source Address	**SEM Number**
128	SEM #1
129	SEM #2
130	SEM #3
131	SEM #4

Table 1, SEM J1939 Source Address Claiming Scheme

Switch Expansion Modules on a vehicle are numbered SEM #1 through SEM #4 depending on the serial number of the SEM. The SEM with the lowest serial number (printed on a decal on the SEM casing) attempts to claim the lowest SEM source address, 128. Each additional SEM then claims a source address in similar fashion from low to high: the SEM with the next-highest serial number claims the next-highest source address (129), and so on until all SEMs have claimed a source address.

Once an SEM is installed and claims an address, it will store that as a preferred source address. Every time the vehicle is turned on after that, the SEM will attempt to re-use that preferred source address. This way, each SEM should appear in ServiceLink as the same SEM number (SEM #1 through SEM #4) each time ServiceLink is connected, regardless of whether an SEM is removed, or whether the physical locations of the SEMs on the vehicle have changed. The only exception is when an SEM with a lower serial number is added.

If a new SEM is installed that has a serial number lower than those already on the vehicle, the new SEM will claim the lowest source address (128) and bump up the source addresses of the other SEMs. The SEM that used to claim the source address of 128 must now claim 129, the SEM that used to claim 129 must now claim 130, and so on.

Invalid SEM (Unresponsive)

An SEM that has problems during flashing may no longer be able to claim an address in the proper way. Instead it will report on the J1939 datalink with a Source Address of 133, and appear in ServiceLink as an icon labeled "Invalid SEM (Unresponsive)." It will not report any make, model, or software ID. In this case, the technician can still access the Flashing tab and attempt to flash the SEM to recover it.

Locating the Correct SEM to Troubleshoot

To assist the technician in determining the specific SEM a given Smart Switch is connected to, ServiceLink has a "Smart Switches" tab, located under the SEM icon. There, the technician will find an "Identify SEM" button that can be used to briefly flash the indicator lights of a bank of Smart Switches connected to a specific SEM. This allows the technician to locate the correct SEM for troubleshooting Smart Switches.

Adding an SEM

After installing an SEM, turn the vehicle ignition to the ON position and connect to the vehicle using ServiceLink. Notice that the newly installed SEM appears in ServiceLink as a new SEM icon in the left side bar.

The following may be encountered in ServiceLink:

- If the new SEM's serial number is lower than those already on the vehicle, it claims source address 128 and appears as SEM #1.
- If the new SEM's serial number is higher than those already on the vehicle, it appears as the next SEM in numerical order. For example, if there are two SEMs already on the vehicle, appearing in ServiceLink as SEM #1 and SEM #2, the new SEM appears in ServiceLink as SEM #3.
- If the new SEM's serial number is between the serial numbers of SEMs already on the vehicle, the new SEM bumps up the 2nd SEM. The new SEM appears as SEM #2, and the SEM that used to be SEM #2 appears as SEM #3.

ServiceLink Interaction

Since SEM #1 still has the lowest serial number, it still appears as SEM #1.

- If there are already four SEMs installed on the vehicle, the installation of a fifth SEM causes an icon to appear in ServiceLink labeled "Invalid ECU (duplicate) – Unable to claim address," since four is the maximum number of SEMs allowed on a vehicle. The fifth SEM should show a source address of 254.

To identify an SEM, go into the SEM's icon in ServiceLink. Click on the "Smart Switches" tab, and use the "Identify SEM" button to flash the indicator lights of the Smart Switches connected to that particular SEM. This makes it possible to locate the SEM, and to see which Smart Switches are connected to which SEM.

Removing an SEM

1. Connect to the vehicle in ServiceLink and take note of the icons that appear for the SEMs connected to the vehicle.
2. Remove the SEM.
3. Reconnect to the vehicle in ServiceLink and take note of the icons that appear for the SEMs connected to the vehicle.
4. The icon for the removed SEM should be gone, and none of the other SEMs still on the vehicle should change their order. For example, if there are three SEMs on a vehicle, appearing in ServiceLink as SEM #1, SEM #2, and SEM #3, and the 2nd SEM is removed, on reconnecting to the vehicle in ServiceLink the icons for SEM #1 and SEM #3 still appear, and the icon for SEM #2 is gone.

Replacing an SEM

1. After removing the old SEM, the expected behavior should be as described under the previous heading "Removing an SEM." However, if the SEM being removed was not appearing in ServiceLink, then no change should occur.
2. After installing the new SEM, the expected behavior should be as outlined in the previous section "Adding an SEM."
3. When in doubt, use ServiceLink to identify a particular SEM. See the heading titled "Adding an SEM."

Fault Codes

This subject contains information on all proprietary Switch Expansion Module (SEM) fault codes for J1939 datalink protocols. See **Table 1**.

Also included is a reference table of Failure Mode Indicators (FMIs) for J1939 datalink protocols. See **Table 2**.

J1939 SPNs for Switch Expansion Module (SEM) SAs 128 through 131		
SPN	**SAE J1939 Description**	**Possible FMI**
2033	No CAN communication from BHM	19
6914	Smart Switch VBatt Short to Ground	04

Table 1, J1939 SPNs for Switch Expansion Module (SEM) SAs 128 through 131

Failure Mode Indicators	
FMI	**SAE J1939 Description**
19	Received network data in error
04	Voltage below normal or shorted low

Table 2, Failure Mode Indicators

For an isometric view of the dash-mounted Switch Expansion Module (SEM), see **Fig. 1**. For an end view of the dash-mounted module connectors, see **Fig. 2**.

For an isometric view of the remote-mounted SEM, see **Fig. 3**. For an end view of the remote-mounted module connectors, see **Fig. 4**.

For SEM pinout definitions at connector J1, see **Table 1**.

For SEM pinout definitions at connector J2, see **Table 2**.

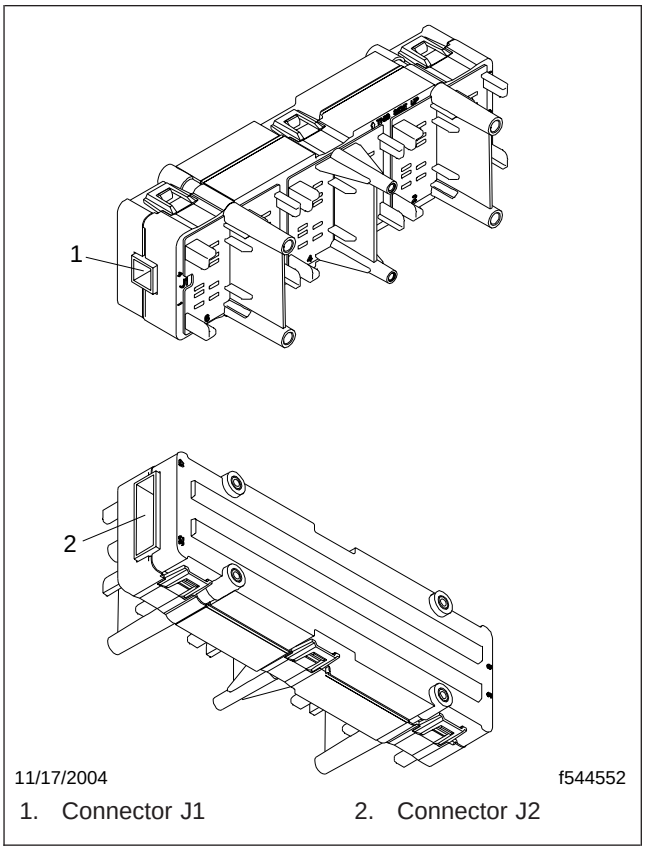


Fig. 1, Dash-Mounted SEM

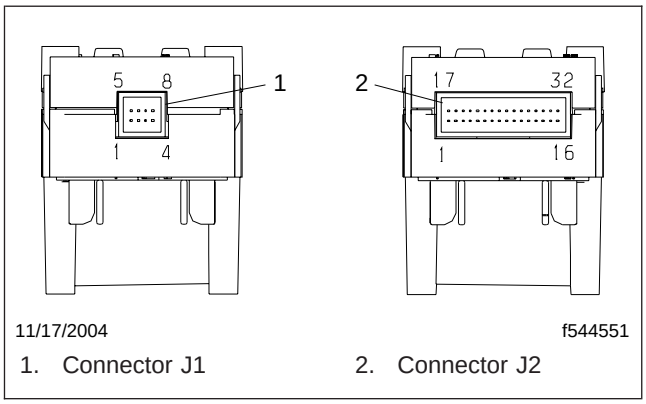


Fig. 2, Dash-Mounted SEM (end views, both ends)

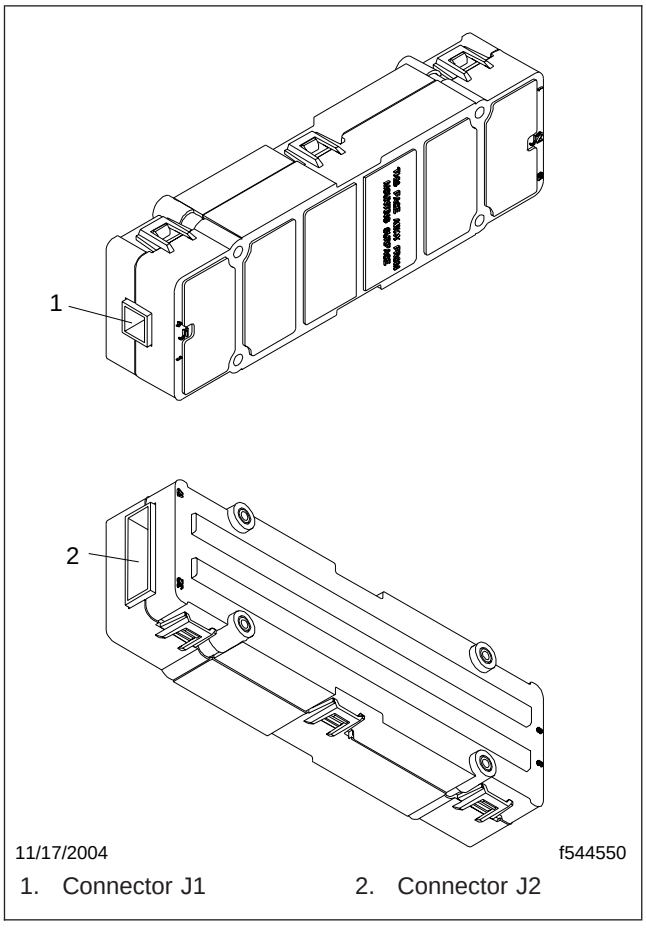
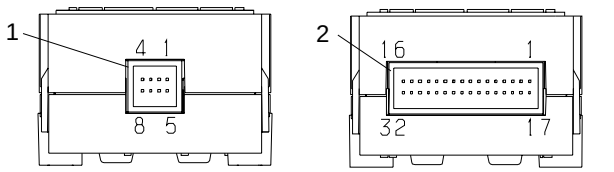


Fig. 3, Remote-Mounted SEM

Specifications



1. Connector J1
2. Connector J2

Fig. 4, Remote-Mounted SEM (end views, both ends)

SEM Pinout Definitions at Connector J1			
Connector Pin	**Signal Name**	**Type**	**Current: amps**
J1-1	VBAT1 (unswitched power)	Power	1
J1-2	System Wakeup	Bi-Directional	—
J1-3	System Ignition	Input	—
J1-4	J1939– Datalink	Comm	—
J1-5	GND	Ground	—
J1-6	GND	Ground	—
J1-7	GND	Ground	—
J1-8	J1939+ Datalink	Comm	—

Table 1, SEM Pinout Definitions at Connector J1

SEM Pinout Definitions at Connector J2			
Connector Pin	**Signal Name**	**Type**	**Current: amps**
J2-1	Smart Switch Ground	Signal Ground	—
J2-2	SS5 Indicator	Smart Switch LED Drive	—
J2-3	SS3 Indicator	Smart Switch LED Drive	—
J2-4	SS1 Indicator	Smart Switch LED Drive	—
J2-5	SS6 ID1	Smart Switch Analog Input	—
J2-6	SS5 ID2	Smart Switch Analog Input	—
J2-7	SS5 Switch Position	Smart Switch Analog Input	—
J2-8	Smart Switch Backlight	Smart Switch Backlight	0.2
J2-9	Smart Switch Vbat	Smart Switch Vbat	0.2
J2-10	SS4 ID2	Smart Switch Analog Input	—
J2-11	SS4 Switch Position	Smart Switch Analog Input	—
J2-12	SS3 ID1	Smart Switch Analog Input	—
J2-13	SS2 ID2	Smart Switch Analog Input	—

SEM Pinout Definitions at Connector J2			
Connector Pin	**Signal Name**	**Type**	**Current: amps**
J2-14	SS2 Switch Position	Smart Switch Analog Input	—
J2-15	SS1 ID1	Smart Switch Analog Input	—
J2-16	Smart Switch Ground	Signal Ground	—
J2-17	Smart Switch Ground	Signal Ground	—
J2-18	SS6 Indicator	Smart Switch LED Drive	—
J2-19	SS4 Indicator	Smart Switch LED Drive	—
J2-20	SS2 Indicator	Smart Switch LED Drive	—
J2-21	SS6 ID2	Smart Switch Analog Input	—
J2-22	SS6 Switch Position	Smart Switch Analog Input	—
J2-23	SS5 ID1	Smart Switch Analog Input	—
J2-24	Smart Switch Ground	Signal Ground	—
J2-25	Smart Switch Ground	Signal Ground	—
J2-26	SS4 ID 1	Smart Switch Analog Input	—
J2-27	SS3 ID2	Smart Switch Analog Input	—
J2-28	SS3 Switch Position	Smart Switch Analog Input	—
J2-29	SS2 ID1	Smart Switch Analog Input	—
J2-30	SS1 ID2	Smart Switch Analog Input	—
J2-31	SS1 Switch Position	Smart Switch Analog Input	—
J2-32	Smart Switch Ground	Signal Ground	—

Table 2, SEM Pinout Definitions at Connector J2

General Information

The Expansion Module (EXM) is an optional module of the vehicle electrical system, and acts as a slave to the Bulkhead Module. It is functionally equivalent to the Chassis Module (CHM). See **Section 54.02**. An EXM may be required on a vehicle in order to add non-standard functionality (such as heated mirrors) when all the required pins are already in use on the Chassis Module or on previously installed EXMs. Since it is optional, there may be from zero to five EXMs on a vehicle.

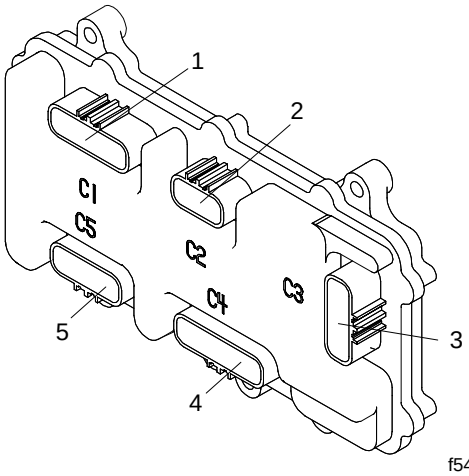
The EXM has five harness connections, though all might not be used. See **Fig. 1**.

NOTE: Since the hardware for the Chassis Module and the Expansion Module is the same, connector designations, such as C1, are the same for both modules.

The EXM comes in three sizes, based on vehicle options and customer specifications: Limited, Standard, and Full. The Limited and Standard EXMs use only connectors C1, C3, and C4; connectors C2 and C5 are sealed. All three sizes are supported by a single version of software.

All three EXM sizes use external strapping. External strapping assigns a unique pre-defined J1939 Source Address and J1587 Message ID to the module, viewable in ServiceLink.

External strapping involves connecting two predetermined pins on the module. The two specific pins that are connected depend on the desired functionality, such as a Chassis Module or the third Expansion Module. To get the desired configuration of size and functionality, connect the two pins according to **Table 1**, upon installation. **Table 1** shows the necessary connections between Address IDs A, B, C, and D. These Address IDs correspond to pins located on connector C4. See Table 4 in **Specifications 400**, to match the Address ID to the actual pin.



1. Connection C1
2. Connection C2
3. Connection C3
4. Connection C4
5. Connection C5

Fig. 1, Expansion Module

Module Configurations and External Strapping IDs			
System Definition	**Address ID Connection on Connector C4***	**J1939 Source Address**	**J1708 MID**
CHM	A–C Connection	71–CHM	249
EXM #1	A–D Connection	235	170
EXM #2	B–C Connection	236	187
EXM #3	B–D Connection	237	188
EXM #4	C–D Connection	238	178
EXM #5	A–B Connection	239	240

* Pin connections shown are Address IDs.

Table 1, Module Configurations and External Strapping IDs

Expansion Module Removal and Installation

Removal

IMPORTANT: It is normally not necessary to replace the Expansion Module (EXM). Removing and installing an Expansion Module should be a last resort for solving electrical problems, unless a unit needs replacing due to physical damage. Follow procedures in **Section 54.01, Troubleshooting 300**, Bulkhead Module, to help solve electrical problems involving the EXM before replacing either this module, the Bulkhead Module, or the Chassis Module. If troubleshooting indicates a malfunction of any of these modules, try reflashing the parameters and the software on the Bulkhead Module before replacing them. Also check external wiring.

Also see **Section 54.00**, Electrical System, for more information about the vehicle electrical system in general, and **Troubleshooting 300** in that section for help in troubleshooting the entire electrical system.

1. Disconnect the negative leads from the batteries.

NOTE: The EXM may be mounted anywhere on the vehicle. Refer to the configuration tab under the Bulkhead Module icon in ServiceLink to identify the proper circuits and modules involved.

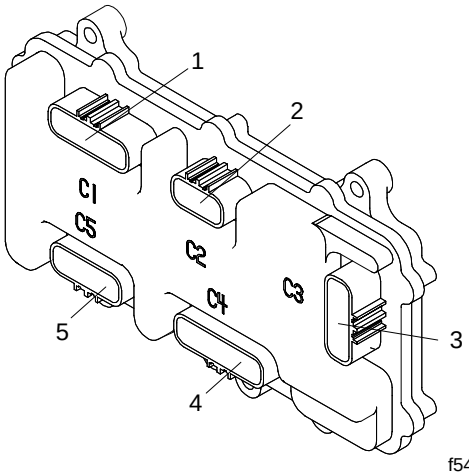
NOTE: The Expansion Module may not have harnesses plugged in to all connectors. Connections without a harness should be plugged. Also remember that Standard and Limited Expansion Modules do not use connectors C2 or C5.

2. Unplug harnesses C1 through C5 from the expansion module. See **Fig. 1**.
3. Remove the three bolts that secure the Expansion Module and remove the module.

Installation

1. Make sure the negative leads from the batteries are disconnected.
2. Properly orient the Expansion Module. Install the module with the three bolts and nuts.

NOTE: The Expansion Module may not have harnesses for all connectors. (Reminder: Standard and Limited Expansion Modules do not use connectors C2 or C5.) Connections without a harness should be plugged.



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1. Connection C1
2. Connection C2
3. Connection C3
4. Connection C4
5. Connection C5

Fig. 1, Expansion Module

3. Plug wiring harnesses into connectors C1 through C5. See **Fig. 1**.
4. Make sure all connectors, cavity plugs, and wire seals are fully seated.
5. Connect the batteries.
6. Check to make sure electrical components work.

General Specifications

For an isometric view of the Expansion Module, see **Fig. 1**.

For a side view of the Expansion Module with pinout assignments, see **Fig. 2**.

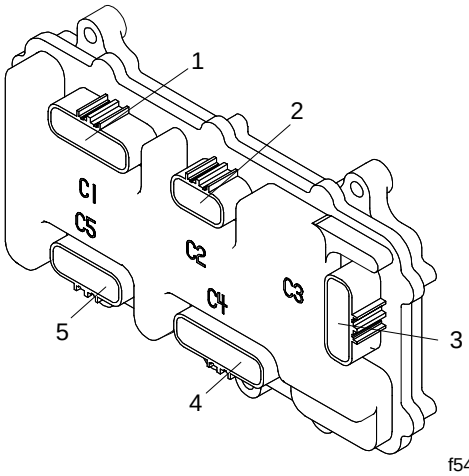
If any wiring is added to any of the common nodes listed in the groups below, that change will apply to all of the common nodes (or pins) in that respective grouping.

- C1-A, C1-H, C1-J
- C1-G, C2-H, C3-N
- C1-P, C2-E, C3-R
- C3-C, C3-D
- C2-F, C4-C, C4-D, C4-L, C4-M
- C2-D, C3-G

Expansion Module Connector Specifications

For harness pinouts at connector C1, see **Table 1**.

For harness pinouts at connector C2, see **Table 2**.



1. Connection C1
2. Connection C2
3. Connection C3
4. Connection C4
5. Connection C5

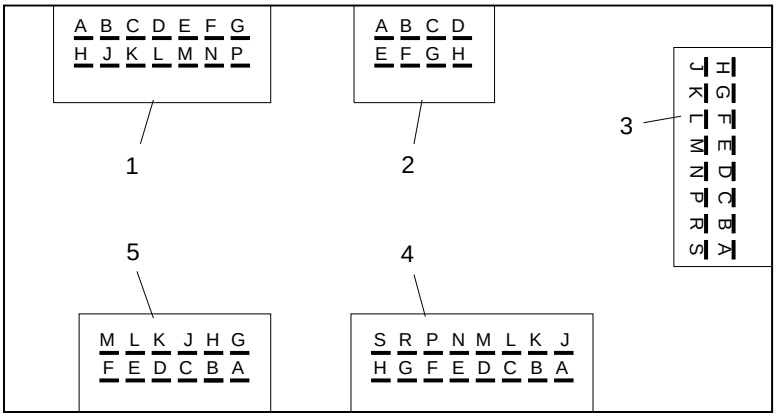
Fig. 1, Expansion Module (isometric view)

For harness pinouts at connector C3, see **Table 3**.

For harness pinouts at connector C4, see **Table 4**.

For harness pinouts at connector C5, see **Table 5**.

Specifications



03/16/2006 f543917

1. Connection C1
2. Connection C2
3. Connection C3
4. Connection C4
5. Connection C5

Fig. 2, Expansion Module With Pinout Assignments (side view)

Pinouts at Connector C1					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C1-A	Digital Output	6.7	2.5	2.5	—
C1-B	—	—	—	—	—
C1-C	—	—	—	—	—
C1-D	Pass-Through	N/A	0.7	0.7	—
C1-E	Pass-Through	N/A	0.7	0.7	—
C1-F	Pass-Through	N/A	0.7	0.7	—
C1-G	Digital Output	6.7	2.5	2.5	—
C1-H	Digital Output	6.7	0.5	0.5	—
C1-J	Digital Output	6.7	2.5	2.5	—
C1-K	—	—	—	—	—
C1-L	Digital Output	6.7	2.7	2.7	6.7
C1-M	—	—	—	—	—
C1-N	Digital Output	6.7	2.7	2.7	6.7
C1-P	Digital Output	6.7	2.5	2.5	—

Table 1, Pinouts at Connector C1

Pinouts at Connector C2					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C2-A	Digital Output	1	0.2	—	—
C2-B	—	—	—	—	—
C2-C	Module Ground	0.2	0.2	—	—
C2-D	Pass-Through	N/A	0.2	—	—
C2-E	Digital Output	6.7	0.2	—	—
C2-F	Digital Output	15	0.2	—	—
C2-G	Pass-Through	N/A	0.2	—	—
C2-H	Digital Output	6.7	0.2	—	—

Table 2, Pinouts at Connector C2

Pinouts at Connector C3					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C3-A	Digital Output	20	20	—	—
C3-B	Datalink Connection (J1708–)	—	—	—	—
C3-C	Digital Output	6.7	3.35	—	—
C3-D	Digital Output	6.7	3.35	—	—
C3-E	Digital (Active Low)/Analog Input	—	—	—	—
C3-F	Digital (Active Low)/Analog Input	—	—	—	—
C3-G	Digital (Active Low) Input	—	—	—	—
C3-H	Module Ground	—	—	—	—
C3-J	Module Power	30	30	30	—
C3-K	Digital Output	6.7	4.0	—	—
C3-L	Digital Output	6.7	4.8	4.8	6.7
C3-M	Digital Input (Active High)	—	—	—	—
C3-N	Digital Output	6.7	2.85	2.85	—
C3-P	Pass-Through	N/A	2.3	2.3	—
C3-R	Digital Output	6.7	2.85	2.85	6.7

Specifications

Pinouts at Connector C3					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C3-S	Datalink Connection (J1708+)	—	—	—	—

Table 3, Pinouts at Connector C3

Pinouts at Connector C4					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C4-A	Module Wake-up (Digital Input)	—	—	—	—
C4-B	Address ID A (Analog Input)	—	—	—	—
C4-C	Digital Output	15	0.7	0.7	—
C4-D	Digital Output	15	0.7	0.7	—
C4-E	Address ID C (Analog Input)	—	—	—	—
C4-F	Digital Output	6.7	4.0	—	—
C4-G	Datalink Connection (J1939+)	—	—	—	—
C4-H	Address ID D (Signal Ground)	—	—	—	—
C4-J	Module Power	30	30	—	—
C4-K	Digital Output	6.7	5.6	5.6	—
C4-L	Digital Output	15	0.7	0.7	—
C4-M	Digital Output	15	0.7	0.7	—
C4-N	Address ID B (Analog Input)	—	—	—	—
C4-P	Module Power	30	30	30	30
C4-R	Datalink Connection (J1939–)	—	—	—	—
C4-S	Module Ground	—	—	—	—

Table 4, Pinouts at Connector C4

Pinouts at Connector C5					
Connector Pin	Signal Type	Maximum Current: amps	Normal Current: amps		
			Full	Standard	Limited
C5-A	Analog Input	—	—	—	—
C5-B	Analog Input	—	—	—	—
C5-C	Signal Ground	—	—	—	—
C5-D	—	—	—	—	—
C5-E	—	—	—	—	—
C5-F	Analog Input	—	—	—	—
C5-G	Analog Input	—	—	—	—
C5-H	Digital Output	0.85	0.7	—	—
C5-J	Digital Output	0.85	0.7	—	—
C5-K	—	—	—	—	—
C5-L	Digital Output	0.85	0.7	—	—
C5-M	Digital Output	0.85	0.7	—	—

Table 5, Pinouts at Connector C5

General Information

Smart switches are optional low-current switches that are connected to the Bulkhead Module (BHM) or to an optional Switch Expansion Module (SEM) on an S2 chassis. A smart switch is used to activate an optional feature on the vehicle. These features may include, but are not limited to:

- fog lights
- differential lock control
- interaxle lock control
- PTO control
- marker light interrupt control

A smart switch is similar in appearance to a high-current switch. A smart switch can be differentiated from a high-current switch by the part number that is marked on the side of the switch. Each smart switch has a base part number of A06-37217.

Another way to differentiate a smart switch from a high-current switch is to look at the electrical connector used on the switch. See **Fig. 1** and **Fig. 2** for illustrations of the connectors used on smart switches and high-current switches.

A smart switch is significantly different from a high-current switch. Unlike a high-current switch, the smart switch is designed to control very low currents, and will be damaged if it is connected to a high-current circuit. A smart switch has an internal printed circuit board which contains:

- A light-emitting diode (LED) for backlighting the switch when the headlights are turned on;
- A light-emitting diode (LED) that, when on solid, indicates the feature is activated and, when blinking, indicates an error condition.
- Two precision resistors that are used to create a unique switch identifier that allows the BHM to identify each switch that is connected;
- Three precision resistors that are used to indicate the position of the switch.

A small number of smart switches do not have an LED indicator. Instead, these switches have two LEDs for backlighting.

A smart switch does not function correctly without programming the BHM. Optional features are designed around specific smart switch part numbers, and a different smart switch number cannot be substituted.

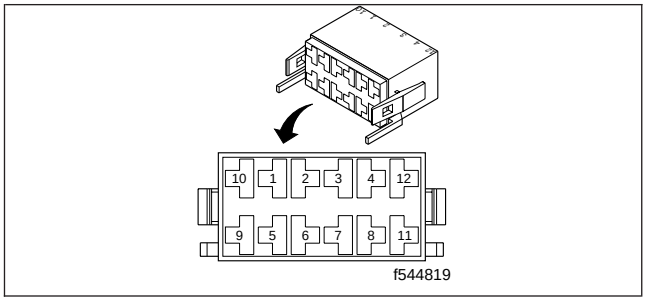


Fig. 1, Connector Used on a Smart Switch

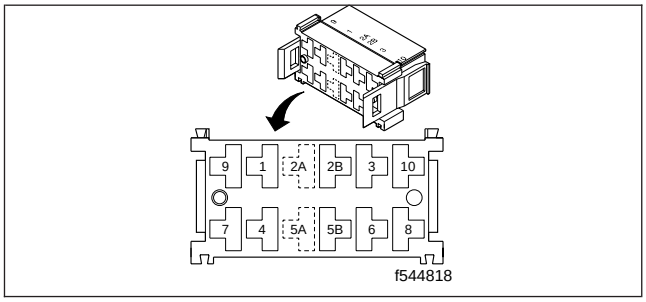


Fig. 2, Connector Used on a High-current Switch

Typical Smart Switch Faults

Smart switch faults must be diagnosed to determine if the smart switch itself is the cause of the problem. See **Table 1** for symptoms that might indicate a smart switch fault.

See **Table 2** for descriptions of smart switch faults.

Determining Which Smart Switches the Vehicle is Programmed to Use

Use the following instructions to determine which vehicle functions use a smart switch.

1. Log on to ServiceLink® and click on the BHM icon.
2. Click on the " Features" tab.
3. All of the reference parameters programmed into the Bulkhead Module (BHM) that use a smart switch have "Smart Switch" in the description of the reference parameter. See **Fig. 1**.

Smart Switch Faults						
J1587 Fault			J1939 Fault			Fault Description
MID	SID	FMI	SA	SPN	FMI	
164	022	07	33	6918	07	Missing Smart Switch
164	021	07	33	6919	07	Duplicate Smart Switch
164	020	07	33	6920	07	Extra Smart Switch
—	—	—	128	6914	04	Smart Switch VBAT Short to Ground
—	—	—	129	6914	04	Smart Switch VBAT Short to Ground
—	—	—	130	6914	04	Smart Switch VBAT Short to Ground
—	—	—	131	6914	04	Smart Switch VBAT Short to Ground

Table 1, Smart Switch Faults

Definition of Smart Switch Faults	
Problem	**Description**
Missing Smart Switch Fault	The BHM cannot detect a smart switch for a function that is programmed into the BHM by a reference parameter For example, no fog lamp switch, but a reference parameter for fog lamps is programmed into the BHM.
Duplicate Smart Switch Fault	The BHM has detected more than one smart switch for a particular function programmed into the BHM by a reference parameter. For example, two fog lamp smart switches are connected.
Extra Smart Switch Fault	The BHM detects a smart switch for a function that is not programmed into the BHM by a reference parameter. For example, a fog lamp switch is connected, but the vehicle is not programmed for fog lamps.
Smart Switch VBAT Short to Ground	The smart switch indicator and/or backlight drive circuit is overloaded. Only smart switches connected to a SEM report this fault.

Table 2, Definition of Smart Switch Faults

Troubleshooting

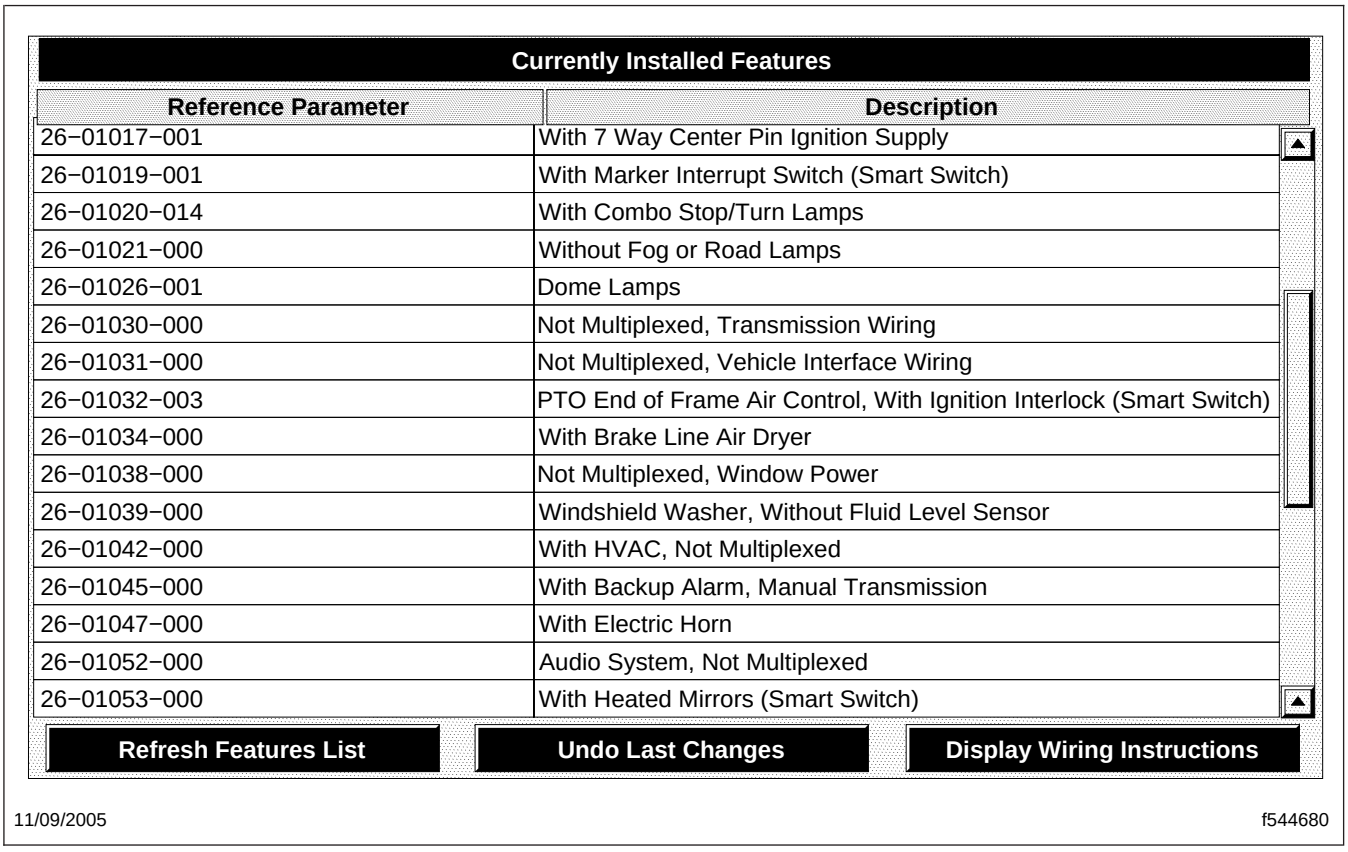


Fig. 1, Currently Installed Features Screen

NOTE: Some reference parameter descriptions may indicate there is a smart switch even if the description indicates the vehicle is not programmed with that feature. An example is 26-01019-000, "Without Marker Interrupt Switch (Smart Switch)." Since a vehicle with this reference parameter is not programmed with the marker interrupt switch, there is no marker interrupt smart switch.

4. If the vehicle is equipped with a Switch Expansion Module, there will be an icon on the left-side menu of ServiceLink for that ECU. Click on that icon to display a separate tab for smart switches. This screen lists all smart switches connected to the SEM.

NOTE: Smart switches connected to the Bulkhead Module are not listed in the Switch Expansion Module smart switch screen.

5. To verify which smart switches are connected to the SEM, click the **Identify SEM** button in ServiceLink on the SEM Smart Switch screen. See **Fig. 2**. The smart switch indicator lights will blink for the switches connected to the SEM.

Troubleshooting Smart Switch Faults

Use the following instructions to troubleshoot the smart switch faults described in **Table 2**.

Missing Smart Switch Fault

The Missing Smart Switch fault occurs when a smart switch that the BHM is programmed to use is not found connected to one of the five BHM ports or one of the six SEM ports. Use the following steps to troubleshoot this fault.

1. Access the Features screen in ServiceLink to determine which smart switches the vehicle is

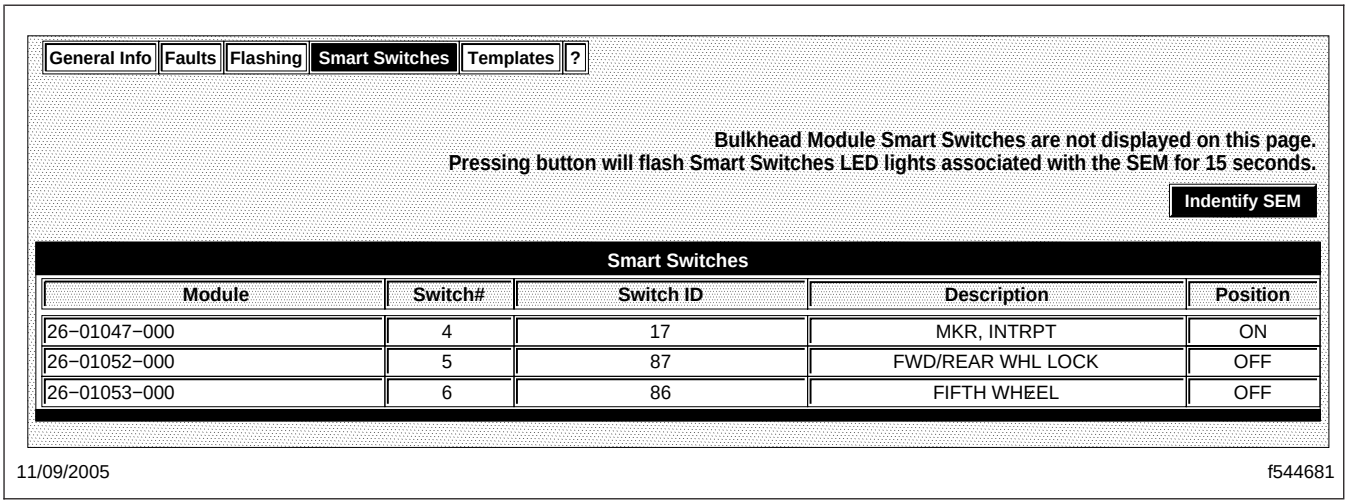


Fig. 2, SEM Smart Switch Screen

programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.

2. Identify which smart switches the vehicle recognizes as being installed using one of the appropriate J1939 templates in ServiceLink (for either the BHM or the SEM).

NOTE: See the ServiceLink User's Guide under "Templates" for instructions on using the datalink monitor templates. These templates provide the unique smart switch decimal value that indicates what smart switches the Bulkhead Module is programmed to use.

3. See the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400** to cross-reference the smart switch decimal value with the smart switch function. Compare this with the smart switches that were expected based on what features the Bulkhead Module was programmed to use.
4. Determine which smart switch is missing or not being correctly identified.

   A missing smart switch fault may occur due to one of the following conditions:

   - The smart switch is physically not connected.
   - There is a switch ID circuit wiring problem.
   - J1939 communication problems exist between an optional SEM and the BHM.
   - The switch ID resistors in the smart switch itself are faulty.
5. Remove the smart switch from the dash. Using the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**, determine the values of ID resistors R1 and R2. Add the R1 and R2 values. Measure the resistance between pins 7 and 8 of the smart switch. If the measurement is within 1 percent of the added resistance value, the switch is okay.

Extra Smart Switch Fault

The Extra Smart Switch fault indicates that a smart switch that the vehicle is not programmed to utilize is found connected to one of the five BHM or six SEM smart switch ports. Use the following steps to troubleshoot this fault.

1. Access the Features screen in ServiceLink to determine which smart switches the vehicle is programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.
2. Identify which smart switches the vehicle recognizes as being installed using one of the appropriate J1939 templates in ServiceLink (for either the BHM or the SEM).

NOTE: See the ServiceLink User's Guide under "Templates" for instructions on using datalink monitor templates. These templates provide the unique smart switch ID number that indicates

what smart switches the Bulkhead Module actually recognizes as being on the vehicle.

3. See the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400** to cross-reference the smart switch part number with the smart switch function. Compare this with the smart switches that were expected based on what features the Bulkhead Module was programmed to use.
4. Determine which smart switch is missing or not being correctly identified.

Duplicate Smart Switch Fault

The Duplicate Smart Switch fault indicates that there are two or more identical smart switches connected to either the BHM or SEM smart switch ports.

Determine which smart switches the vehicle is programmed to use. See the Features screen in ServiceLink to determine which smart switches the vehicle is programmed to use. For instructions, see "Determining Which Smart Switches the Vehicle is Programmed to Use" in this subject.

The switch function that is duplicated will be two or more smart switch ports that have the same smart switch ID number shown in the applicable template. The duplicate switch must be disconnected. See the ServiceLink User's Guide under "Templates" for instructions on using datalink monitor templates.

Smart Switch VBAT Short to Ground Fault

The Smart Switch VBAT Short to Ground fault indicates a smart switch indicator and/or backlight drive circuit is overloaded. Only smart switches connected to a SEM will report this fault. Use the following steps to troubleshoot this fault.

1. Access ServiceLink to determine which smart switches are connected specifically to the SEM.
2. Click on the "Switch Expansion Module" icon on the left-side list of the ECUs.
3. Click on the "Smart Switch" tab. A list of all smart switches that are connected to the SEM will be displayed.
4. Click on the "Identify SEM" button in ServiceLink. This causes the smart switch indicator lights to blink.
5. Based on the descriptions of the switches connected to the SEM, look for the smart switch that is connected to the SEM, but has an indicator light that is not blinking.
6. Once the affected smart switch is identified, troubleshoot the switch and check the wiring for a short circuit.

The Switch Controlled Option Does Not Work

When a smart switch controlled option does not work when the smart switch is activated, the problem is likely due to one of the conditions described in **Table 3**.

If a function does not work and there are no active smart switch fault codes, then the following procedure will help determine if the smart switch itself or its wiring is the cause of the problem. If smart switch fault code(s) are active, troubleshoot them first.

To determine if the smart switch or its wiring is the cause of the multiplexed function not working, see **Table 4**.

Smart Switch Controlled Option Faults	
Problem	**Description**
Hardware problems	Main VBAT fuse that supplies the output pin is open.
	BHM, CHM, or EXM output driver circuit is overloaded; too much current will cause the output to shut off.
	Faulty BHM, CHM, or EXM output driver (internal BHM, CHM, or EXM problem).

Smart Switch Controlled Option Faults	
Problem	**Description**
Output problems	The output device is faulty. For example, the suspension dump solenoid valve is faulty.
	The output device wiring is faulty.
	Output is not wired to the correct output pin.
	If the output is connected to the CHM, there are possible J1939 communication problems between the BHM and CHM.
	If the output is connected to an EXM, there are possible J1939 communication problems between the BHM and EXM.
Input problems	Faulty smart switch.
	Faulty smart switch wiring.
	Other input conditions for the function to activate are not met. For example, the BHM does not sense that the park brake is set in order to activate the suspension dump valve.
	J1939 communication problems exist between the optional SEM and the BHM.
Software problems	The reference parameter is not compatible with vehicle options.
	The reference parameter has errors.

Table 3, Smart Switch Controlled Option Faults

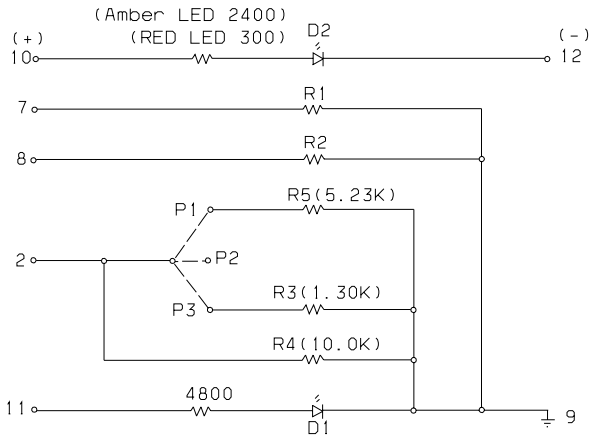
Smart Switch Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
1	Are any smart switch faults active?	Yes	Troubleshoot faults as outlined in this subject.
		No	Go to **step 2**.
2	Observe the smart switch indicator (if equipped) while attempting to operate the function with the switch. NOTE: If the switch does not have an indicator light, go to **step 3**.	Blinks steady	The function interlocks were met, but the BHM does not sense that the function actually engaged. For example, if a function uses an AMU/AAVA solenoid, the BHM may not be sensing that the function engaged through the AMU or AAVA solenoid pressure switch. This could be caused by the AMU/AAVA solenoid not switching, a bad pressure switch, or some other problem. This does not indicate a problem with the smart switch.
		On, then quickly off	Some other condition is not met in order for the function to work. For example, if the function requires that the park brake be set in order for the function to operate, and the park brake is not set, then the function will not work. This does not indicate a problem with the smart switch.
		Off	Go to **step 3**.
		Switch does not have indicator	Go to **step 3**.

Troubleshooting

Smart Switch Troubleshooting			
Step	**Test Procedure**	**Test Result**	**Action**
3	Using ServiceLink, access the BHM Features screen. Is there a reference parameter listed for the function, and does it indicate the use of a smart switch?	Yes	Go to **step 4**.
		No	The reference parameter for the function is not loaded into the BHM. Load the correct reference parameter using ServiceLink.
4	Find the part number on the smart switch for the function that is not working. Using the "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**, find the ID Number that corresponds to the part number of the switch. In ServiceLink, open the applicable smart switch template (either for the BHM, or SEM). Locate the column that has the smart switch ID that matches the ID Number in "Smart Switch Part Number, Function, and ID Number" table in **Specifications 400**. While observing the input or position status on the template, operate the switch through each position. There should be a change in either the voltage input, or position (depending on the template). Is there a change in switch position reflected in the template?	Yes	The problem is not with the smart switch or its wiring. The problem is either with the output to the function, or possibly a reference parameter problem.
		No	Go to **step 5**.
5	Remove the smart switch. Check resistance between pins 2 and 9 for each switch position. Compare readings with the values specified in the "Switch Position Input Resistance, Pin 2 to Pin 9" table in **Specifications 400**. Are the resistance values within specifications?	Yes	Check wiring (circuit 474B) between pin 2 of the smart switch and the BHM. Repair as necessary.
		No	Replace the smart switch.

Table 4, Smart Switch Troubleshooting

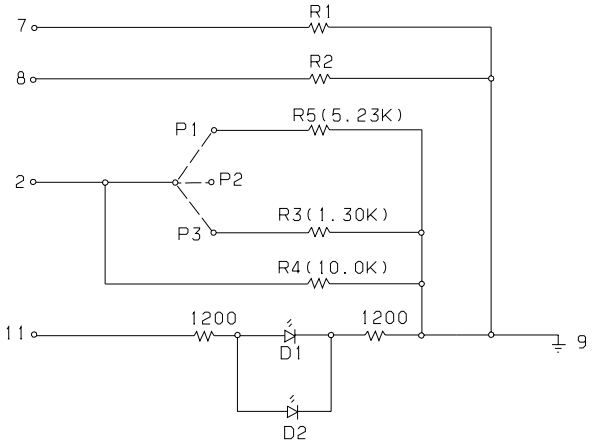
See **Fig. 1** for the wiring diagram of a two-position smart switch. See **Fig. 2** for the wiring diagram for a three-position smart switch.



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D2 Activation LED
R1 ID No. 1 Resistor
R2 ID No. 2 Resistor
R3 Switch Position No. 3 Resistor
R4 Switch Off Resistor (Same as switch position no. 2; only applies to switches with on/off/on pattern.)
R5 Switch Position No. 1 Resistor
D1 Backlighting LED

Fig. 1, Smart Switch Wiring Diagram, Circuit Diagram A



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R1 ID No. 1 Resistor
R2 ID No. 2 Resistor
R3 Switch Position No. 3 Resistor
R4 Switch Off Resistor (Same as switch position no. 2; only applies to switches with on/off/on pattern.)
R5 Switch Position No. 1 Resistor
D1 Backlighting LED
D2 Backlighting LED

Fig. 2, Smart Switch Wiring Diagram, Switch Circuit B

Smart Switch Pinout for Circuit A Switch		
Pin	**Circuit Number**	**Circuit Description**
2	474B	Switch Position Input
7	474C	Switch Function ID 1 Input
8	474D	Switch Function ID 2 Input
9	GND	Ground
10	14E	Indicator (+)
11	29A	Backlighting (+)
12	474A	Indicator (–)

Table 1, Smart Switch Pinout for Circuit A Switch

Smart Switch Pinout for Circuit B Switch		
Pin	**Circuit Number**	**Circuit Description**
2	474B	Switch Position Input

Specifications

Smart Switch Pinout for Circuit B Switch		
Pin	**Circuit Number**	**Circuit Description**
7	474C	Switch Function ID 1 Input
8	474D	Switch Function ID 2 Input
9	GND	Ground
11	29A	Backlighting (+)

Table 2, Smart Switch Pinout for Circuit B Switch

Switch Position Input Resistance, Pin 2 to Pin 9		
Lower Switch Position	**Mid Switch Position**	**Upper Switch Position**
1138–1162 ohms	9900–10,100 ohms	3400–3468 ohms

Table 3, Switch Position Input Resistance, Pin 2 to Pin 9

Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	**Smart Switch Function**	**Circuit Diagram**	**Smart Switch ID Number**	**R1 Value in Ohms**	**R2 Value in Ohms**
A06-37217-000	Marker Interrupt	A	17	1020	1020
A06-37217-001	Engine Retarder	A	18	1020	1300
A06-37217-002	Mirror Heat	A	19	1020	1620
A06-37217-003	Utility Lamp	A	20	1020	2000
A06-37217-005	Fog Lamp	A	22	1020	2940
A06-37217-006	Rear Fog Lamp	A	23	1020	3570
A06-37217-009	Engine Check	A	26	1020	6340
A06-37217-010	PTO	A	27	1020	7870
A06-37217-011	Transretarder	A	28	1020	10,000
A06-37217-012	Brake Check	A	33	1300	1020
A06-37217-013	Dome Lamp	A	34	1300	1300
A06-37217-014	Optional	A	35	1300	1620
A06-37217-015	Shutdown Override	A	36	1300	2000
A06-37217-016	Engine Fan	A	37	1300	2430
A06-37217-017	PTO	A	38	1300	2940
A06-37217-018	Transfer Case	A	39	1300	3570
A06-37217-019	Fuel Heater	A	40	1300	4320
A06-37217-020	Transfer Case	A	41	1300	5230
A06-37217-021	Spot Lamp	A	42	1300	6340
A06-37217-022	Advertising Light	A	43	1300	7870
A06-37217-024	Lift Axle	A	49	1620	1020
A06-37217-025	Air Unloader	A	50	1620	1300

Specifications

Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	**Smart Switch Function**	**Circuit Diagram**	**Smart Switch ID Number**	**R1 Value in Ohms**	**R2 Value in Ohms**
A06-37217-026	Axle Shift	A	51	1620	1620
A06-37217-027	Beacon	A	52	1620	2000
A06-37217-028	Increment/Decrement	B	53	1620	2430
A06-37217-030	Interaxle Lock	A	55	1620	3570
A06-37217-031	Forward Wheel Lock	A	56	1620	4320
A06-37217-032	Left Step	A	57	1620	5230
A06-37217-033	Right Step	A	58	1620	6340
A06-37217-034	Rear Wheel Lock	A	59	1620	7870
A06-37217-035	Auxiliary Transmission	A	60	1620	10,000
A06-37217-036	Suspension Dump	A	65	2000	1020
A06-37217-038	Alternate Flasher	A	67	2000	1620
A06-37217-039	DRL Override	A	68	2000	2000
A06-37217-040	Backup Alarm	A	69	2000	2430
A06-37217-041	Lift Axle 2	A	70	2000	2940
A06-37217-042	RPM Control	A	71	2000	3570
A06-37217-043	RPM+/RPM–	B	72	2000	4320
A06-37217-044	Center Wheel Lock	A	73	2000	5230
A06-37217-045	Interaxle Lock 2	A	74	2000	6340
A06-37217-046	Forward Wheel Lock	A	75	2000	7870
A06-37217-047	Transfer Case PTO	A	76	2000	10,000
A06-37217-048	Auxiliary Air	A	81	2430	1020
A06-37217-049	Auxiliary Air 2	A	82	2430	1300
A06-37217-050	Auxiliary Air 3	A	83	2430	1620
A06-37217-051	Auxiliary Air 4	A	84	2430	2000
A06-37217-052	Headlamp/Marker	B	85	2430	2430
A06-37217-053	Dimmer	B	86	2430	2940
A06-37217-056	Exhaust Brake	A	87	2430	3570
A06-37217-057	Electric/Air Horn	B	88	2430	4320
A06-37217-058	Front/Rear Wheel Lock	A	89	2430	5230
A06-37217-059	Interaxle Lock 1	A	90	2430	6340
A06-37217-060	Interaxle Lock 1 & 2	A	91	2430	7870
A06-37217-061	Forward Wheel Lock	A	92	2430	10,000
A06-37217-062	Rear Wheel Lock	A	91	2430	7870
A06-37217-063	Forward/Center Wheel Lock	A	92	2430	10,000
A06-37217-064	Center/Rear Wheel Lock	A	97	2940	1020

Specifications

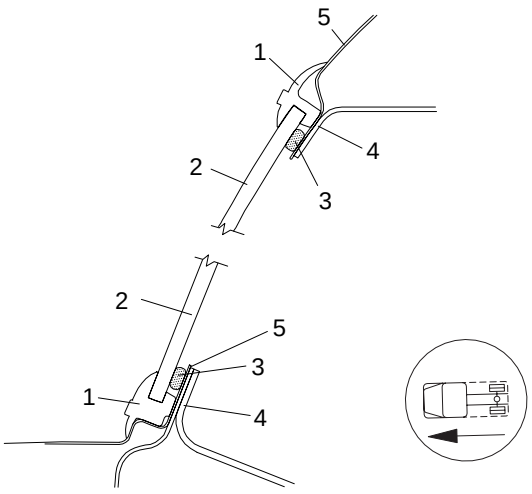
Smart Switch Part Number, Function, and ID Number					
Smart Switch Part Number	**Smart Switch Function**	**Circuit Diagram**	**Smart Switch ID Number**	**R1 Value in Ohms**	**R2 Value in Ohms**
A06-37217-065	Rear Wheel Lock	A	98	2940	1300
A06-37217-066	Forward/Center/Rear Wheel Lock	A	99	2940	1620
A06-37217-067	All Wheel Drive	A	100	2940	2000
A06-37217-068	Lift Axle 1	A	101	2940	2430
A06-37217-069	Lift Axle 3	A	102	2940	2940
A06-37217-070	Auxiliary Axle 5	A	103	2940	3570
A06-37217-073	Marker Interrupt	B	17	1020	1020
A06-37217-074	Engine Air Intake	A	105	2940	5230
A06-37217-077	Electric/Air Horn	A	86	2430	2940
A06-37217-078	Lift Axle	A	49	1620	1020
A06-37217-079	Lift Axle 1	A	101	2940	2430
A06-37217-080	Lift Axle 2	A	70	2000	2940
A06-37217-081	Lift Axle 3	A	102	2940	2940
A06-37217-084	Compartment Lamp	A	106	2940	6340
A06-37217-085	Right Compartment Lamp	A	107	2940	7870
A06-37217-086	Left Compartment Lamp	A	108	2940	10,000

Table 4, Smart Switch Part Number, Function, and ID Number

General Information

The one-piece windshield is available in two different styles: roped-in and encapsulated. The roped-in style is installed with a separate retainer that is not part of the windshield glass. The encapsulated style 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 encapsulated 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**.



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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)

The information and procedure in this section applies only to the encapsulated style of windshield. This is the standard windshield installation for S2 cab vehicles.

See **Specifications 400** for special tools and materials needed to replace a windshield.

Replacement

NOTE: Freightliner Custom Chassis Corporation (FCCC) 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.

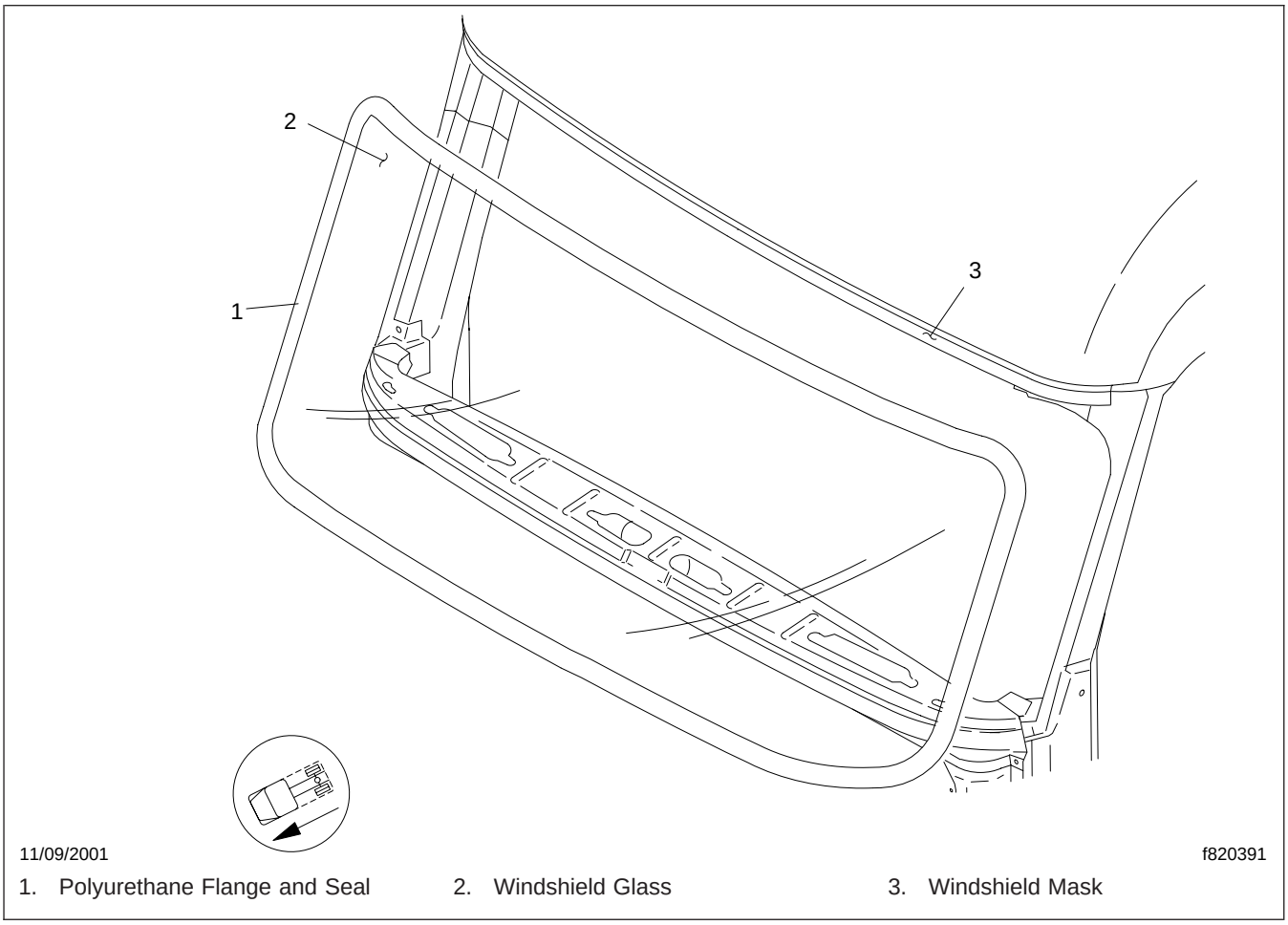


Fig. 1, Windshield Installation (encapsulated windshield)

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, a piano wire, or a pull knife, as shown in **Fig. 2**, **Fig. 3**, and **Fig. 4**, respectively, cut through the urethane sealant all around the edges of the windshield glass. See **Fig. 5** for a cross-sectional view.

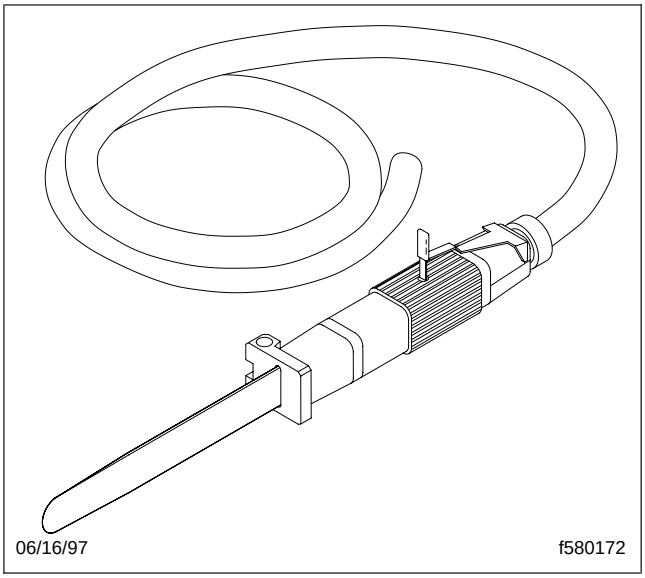
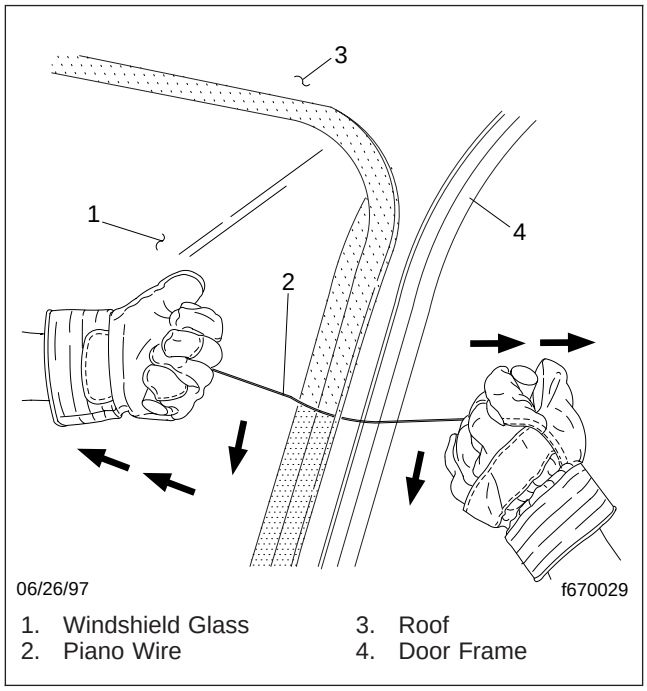


Fig. 2, BTB Pneumatic Cutting Tool

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

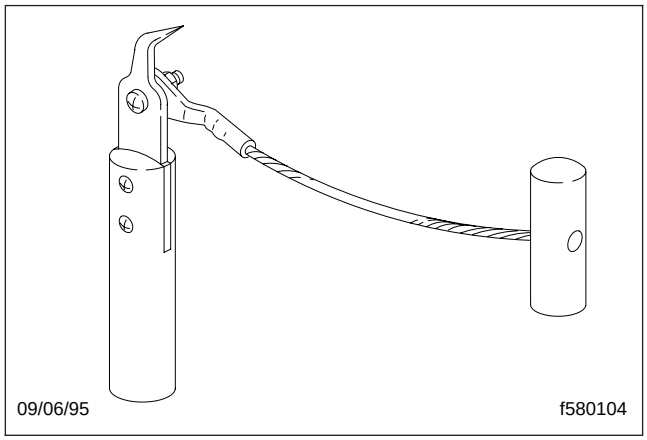
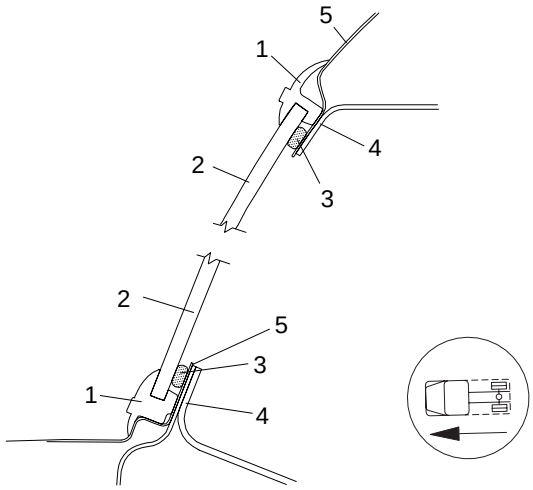


Fig. 4, Typical Pull Knife

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 Glass 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. See 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

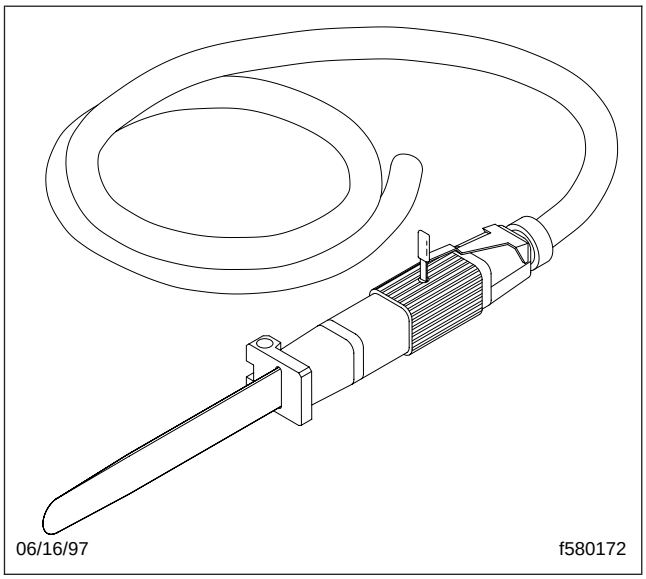


Fig. 1, BTB Pneumatic Cutting Tool (J-43029)

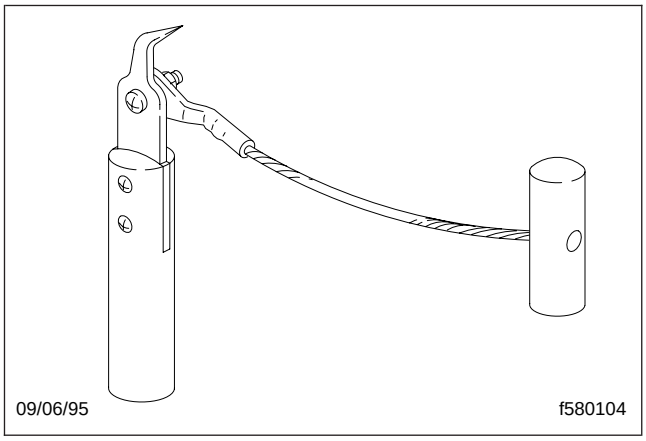
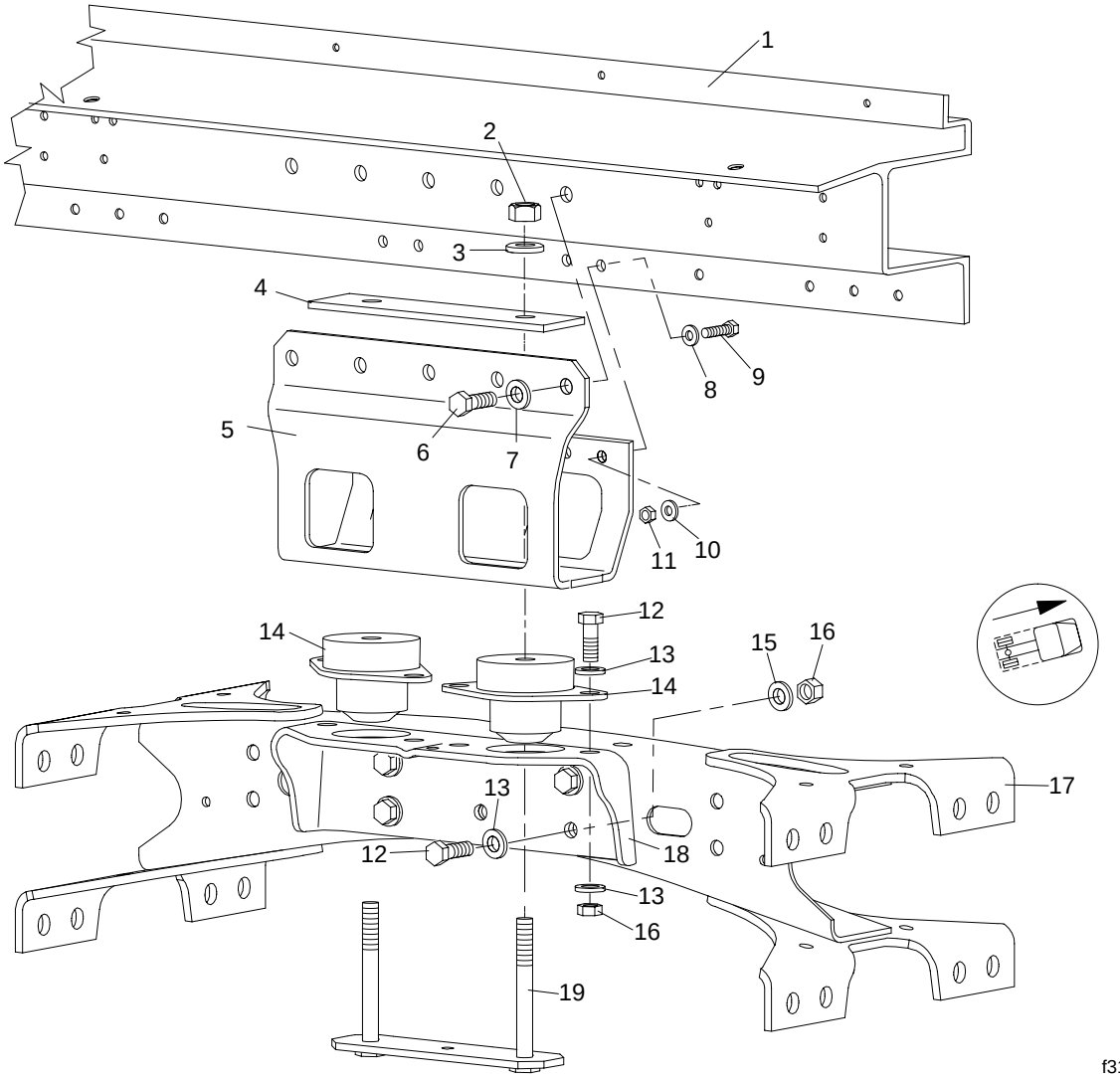


Fig. 2, Typical Pull Knife

General Information

See **Fig. 1** for the solid rubber cab suspension assembly.

The solid rubber cab suspension consists of a pair of rubber isolators positioned between two mounting brackets.



1. Cab Rear Sill
2. Hexnut, 5/8–11
3. Flatwasher
4. Upper Backing Plate
5. Upper Mounting Bracket
6. Hexbolt, M12 (5 qty.)
7. Flatwasher, M12 (5 qty.)
8. Flatwasher, M8
9. Hexbolt, M8
10. Flatwasher, M8
11. Hexnut, M8
12. Hexbolt, 1/2–13
13. Flatwasher
14. Isolator Assembly
15. Flatwasher
16. Hexnut, 1/2–13
17. Frame Rail Crossmember
18. Lower Mounting Bracket
19. Lower Backing Plate Assembly

Fig. 1, Cab Solid Rubber Suspension

General Information

The upper mounting bracket is attached to the cab rear sill, and the lower mounting bracket is attached to the frame rail crossmember.

The isolators are made of rubber with a steel mounting flange integral to each assembly. The isolators are not serviceable. Each is replaced as a complete assembly.

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Using a suitable jack, raise the cab enough to take the weight off the cab suspension.
3. Support the cab with safety stands, blocks of wood, or other suitable means.

⚠ WARNING

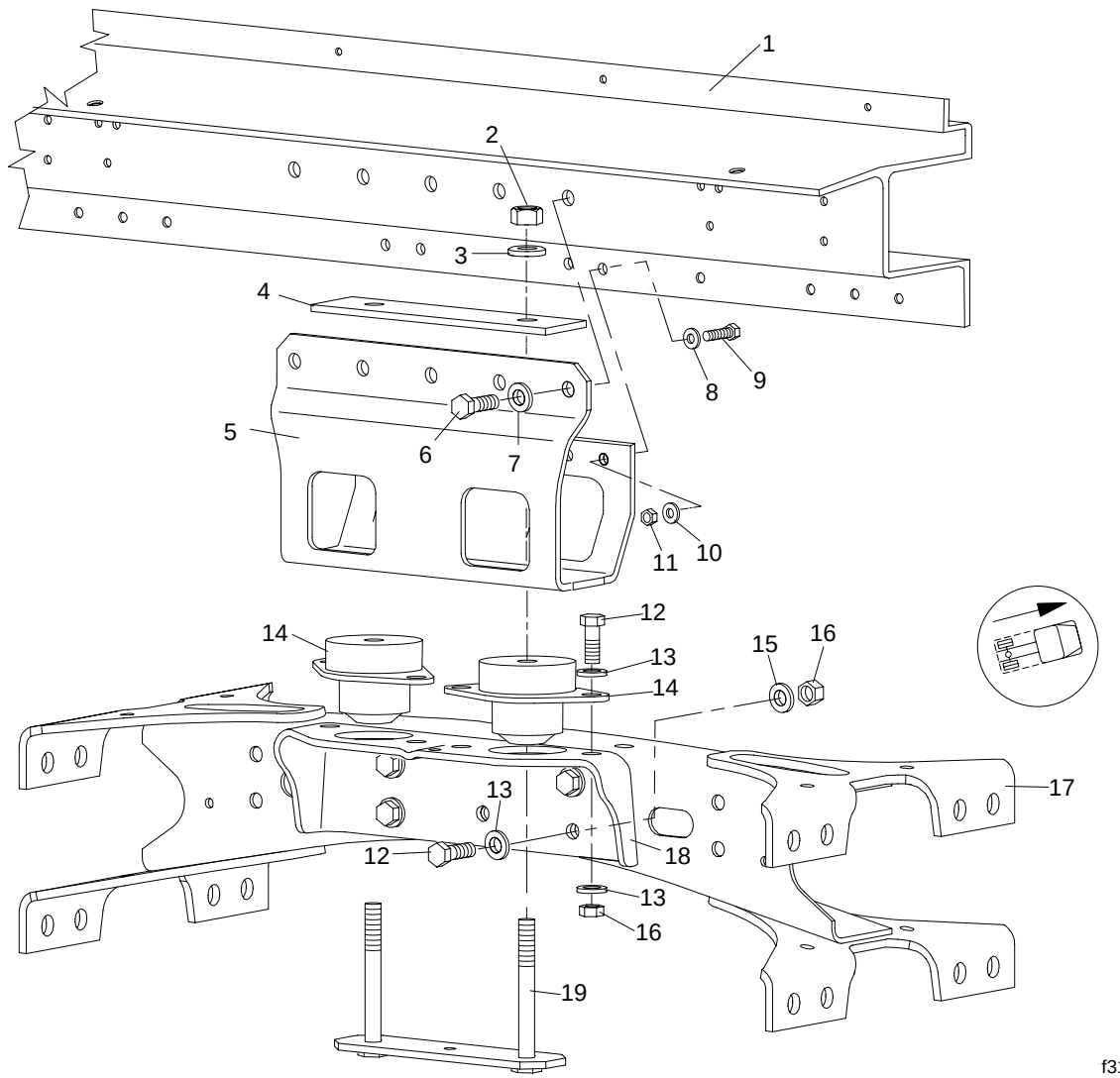
Do not work under the cab when it is supported only by a jack. Use safety stands or other suitable means to firmly support the cab. Jacks can slip, causing the cab to fall, which could result in serious injury or death.

4. Remove the hexnuts and washers from the lower backing plate studs. See **Fig. 1**.
5. If necessary, remove any fuel line, air line, or wiring standoff brackets from the frame rail crossmember. Move the lines/wiring out of the way.
6. Remove the fasteners holding the lower mounting bracket to the frame rail crossmember.
7. Remove the lower mounting bracket and the isolators from the vehicle and put them on a workbench.
8. Remove the fasteners that attach each isolator to the lower mounting bracket.

NOTE: The isolators are not serviceable. If they are damaged, replace the entire assembly.

9. If replacing the upper mounting bracket, remove the five fasteners holding it to the outside of the cab rear sill, then the four fasteners holding it to the inside of the cab rear sill.
10. Remove the upper mounting bracket from the vehicle.
11. If it was removed, install the upper mounting bracket onto the cab rear sill. See **Fig. 1**.
    - 11.1 Position the upper mounting bracket in place on the rear sill and install the four M8 hexbolts, flatwashers, and hexnuts from the inside surface of the rear sill. Install the hexbolts with their heads inboard. See **Fig. 1**. Tighten 12 lbf·ft (16 N·m).
    - 11.2 On the outside surface of the rear sill, install the M12 hexbolts and washers. Tighten 60 lbf·ft (81 N·m).
12. Install the isolators onto the lower mounting bracket. Tighten the 1/2–13 fasteners 68 lbf·ft (92 N·m).
13. Install the studs of the lower backing plate through the isolators.
14. Install the lower bracket and the isolators onto the frame rail crossmember. Tighten the 1/2–13 fasteners 68 lbf·ft (92 N·m).
15. Raise the cab, remove the blocks or stands, and lower the cab.
16. Install the 5/8–11 hexnuts and washers onto the isolator center-bolts. Tighten 136 lbf·ft (184 N·m).
17. As applicable, attach any fuel line, air line or wiring standoff brackets that were removed earlier. Route the lines/wiring.
18. Remove the chocks from the tires.

Cab Suspension Components Replacement



12/17/2001 f310895

1. Cab Rear Sill
2. Hexnut, 5/8–11
3. Flatwasher
4. Upper Backing Plate
5. Upper Mounting Bracket
6. Hexbolt, M12 (5 qty.)
7. Flatwasher, M12 (5 qty.)
8. Flatwasher, M8
9. Hexbolt, M8
10. Flatwasher, M8
11. Hexnut, M8
12. Hexbolt, 1/2–13
13. Flatwasher
14. Isolator Assembly
15. Flatwasher
16. Hexnut, 1/2–13
17. Frame Rail Crossmember
18. Lower Mounting Bracket
19. Lower Backing Plate Assembly

Fig. 1, Cab Solid Rubber Suspension

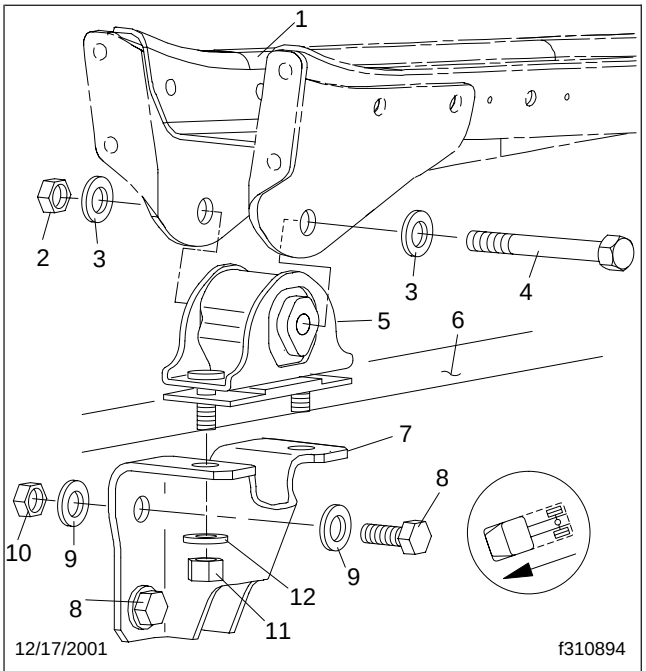
Specifications

Cab Suspension Fastener Torque Values		
Description	**Size**	**Torque: lbf·ft (N·m)**
Upper Mounting Bracket Rear Fasteners	M12	60 (81)
Upper Mounting Bracket Forward Fasteners	M8	12 (16)
Isolator Assembly Fasteners	1/2–13	68 (92)
Lower Mounting Bracket Assembly Fasteners	1/2–13	68 (92)
Lower Backing Plate Hexnuts	5/8–11	136 (184)

Table 1, Cab Suspension Fastener Torque Values

General Information

The forward part of the cab is attached to the frame rails with two cab mount assemblies. See **Fig. 1**. Each forward cab mount assembly consists of a hard rubber isolator surrounded by a steel bracket. The assembly is attached to a frame rail bracket and the cab underbody.



1. Cab Underbody Bracket
2. Hexnut, 5/8–11
3. Flatwasher
4. Isolator Hexbolt
5. Cab Mount Assembly
6. Left Frame Rail
7. Frame Rail Bracket
8. Hexbolt, 5/8–11
9. Flatwasher
10. Hexnut, 5/8–11
11. Hexnut, 5/8–11
12. Flatwasher

Fig. 1, Left Forward Cab Mount Installation

Forward Cab Mount Replacement

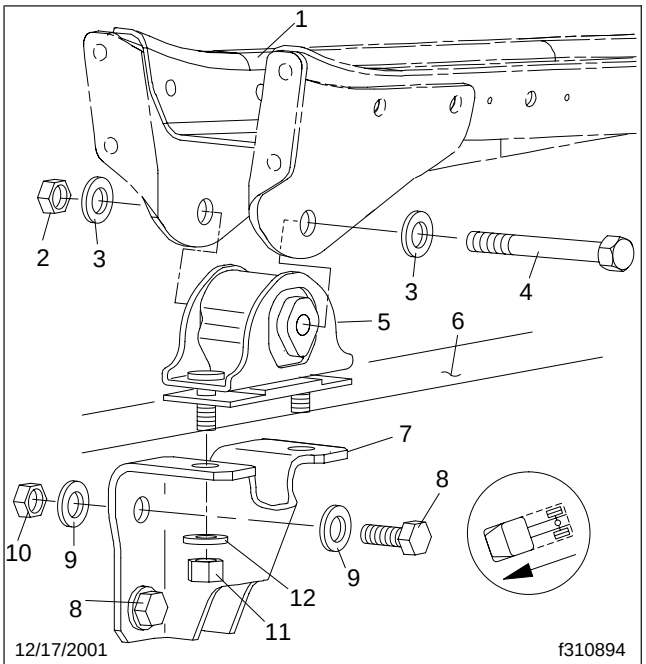
Replacement

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Jack up the front of the cab to take the weight off of the forward cab mount. Support the cab with jackstands.

⚠ 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 5/8–11 fasteners holding the cab mount assembly to the frame rail brackets. See **Fig. 1.**



1. Cab Underbody Bracket
2. Hexnut, 5/8–11
3. Flatwasher
4. Isolator Hexbolt
5. Cab Mount Assembly
6. Left Frame Rail
7. Frame Rail Bracket
8. Hexbolt, 5/8–11
9. Flatwasher
10. Hexnut, 5/8–11
11. Hexnut, 5/8–11
12. Flatwasher

Fig. 1, Left Forward Cab Mount Installation

4. Remove the 5/8–11 fasteners that hold the cab mount assembly to the cab underbody bracket.
5. If needed, raise the cab so the studs on the bottom of the cab mount assembly clear the holes on the frame rail bracket; then remove the cab mount assembly.
6. Install a new cab mount assembly.
   - 6.1 Place the cab mount assembly between the ears of the cab underbody bracket; then install the 5/8–11 isolator hexbolt, flatwashers and nut. Make sure the bolt head is facing outboard.
   - 6.2 Hand tighten the nut.
   - 6.3 Carefully lower the cab, making sure the studs at the bottom of the cab mount assembly line up with the holes in the frame rail bracket.

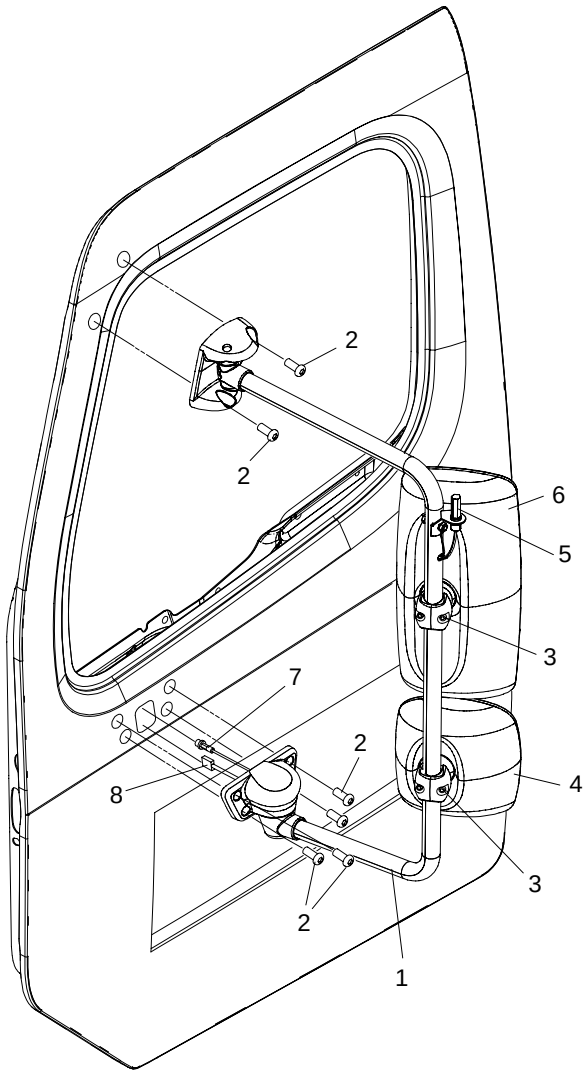
     Make sure the cab mount assembly is centered on the frame rail mounting bracket. Compare it with the cab mount assembly on the opposite side of the vehicle.
   - 6.4 Install the 5/8–11 nuts and washers onto the cab mount assembly studs. Tighten the nuts 136 lbf·ft (184 N·m).
   - 6.5 Tighten the nut on the isolator hexbolt 136 lbf·ft (184 N·m).
7. Raise the cab and remove the safety stands.
8. Lower the cab.
9. Remove the chocks from the tires.

General Information

The S2 cab exterior mirror unit consists of a rectangular (flat) mirror mounted on a fold-away tubular support loop. An optional lower square (convex) mirror is mounted on the same support loop, below the main mirror. See **Fig. 1**.

Both mirrors are mounted in separate housings, and the housings are attached to the support loop, which is mounted to the door by brackets and Torx®-head screws.

Additional options include electrically powered and heated mirrors. In such cases, the wiring is hidden within the support loop and the mirror housings.



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1. Fold-Away Tubular Support Loop
2. Torx-Head Screws, M8
3. Torx-Head Screws, Self-Tapping
4. Square, Convex Mirror Housing (optional)
5. CB Radio Antenna Lead (optional)
6. Rectangular, Flat Mirror Housing
7. CB Radio Antenna Cable (optional)
8. Electrical Wiring

Fig. 1, Exterior Mirror (manual, left side)

Exterior Mirror Removal and Installation

NOTE: The procedure below is for removing and installing the mirror housings and support loop assembly.

Removal

NOTE: The support loop and the mirror housings can be removed as a unit.

1. Park the vehicle, shut down the engine, set the parking brakes, and chock the tires.
2. Remove the mirror housings from the support loop assembly. See **Fig. 1**.
   - 2.1 If so equipped, mark the location of the square, convex mirror housing on the support loop.

     Remove the two Torx®-head screws holding the housing to the support loop. Disconnect any wiring, if present, and remove the housing assembly.
   - 2.2 Mark the location of the rectangular, flat mirror housing on the support loop.
   - 2.3 If equipped with a heated/power mirror, remove the mirror bezel and glass, then disconnect the wiring.

     Remove the two Torx-head screws holding the housing to the support loop.
3. Remove the support loop from the vehicle door.
   - 3.1 Remove the two Torx-head screws holding the upper bracket to the door.
   - 3.2 While holding the support loop assembly, remove the four Torx-head screws holding the lower bracket to the door.
   - 3.3 Disconnect any wiring or antenna cables, if present.
   - 3.4 Remove the support loop assembly.

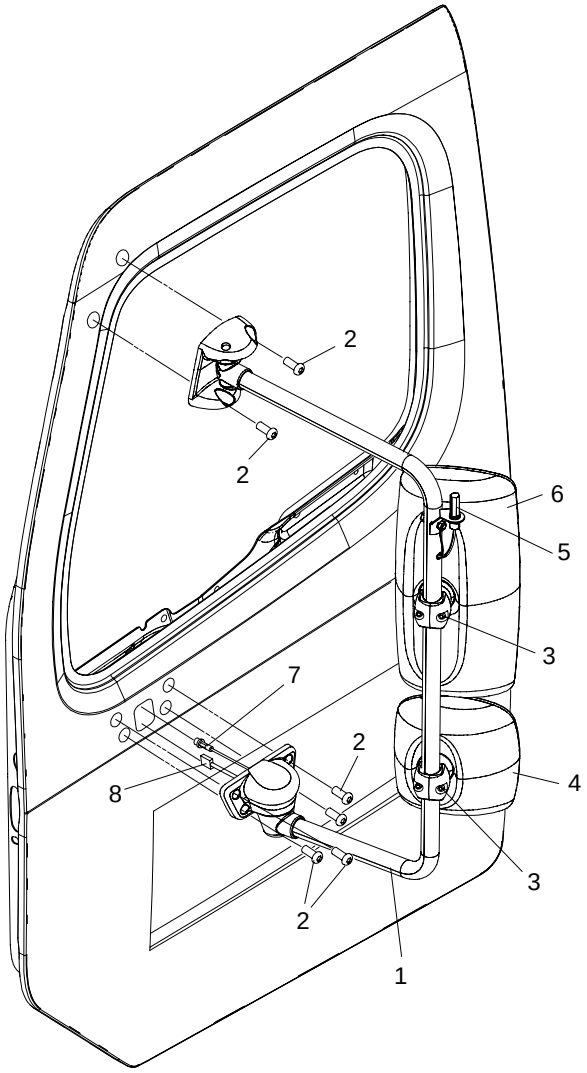
Installation

The mirror housings can be installed on the support loop and the entire assembly installed as a unit onto the door.

1. Install the support loop onto the door.
   - 1.1 Connect any wiring and antenna cables, as applicable.
   - 1.2 Holding the support loop in position, attach the upper bracket to the door, using the two M8 Torx-head screws. Tighten 10 lbf·ft (14 N·m).
   - 1.3 Using four M8 Torx-head screws, attach the lower bracket to the door. Tighten 10 lbf·ft (14 N·m).
2. If equipped with a heated/powered mirror, connect the wiring to the mirror, then install the mirror glass and bezel into the mirror housing.

   As previously marked, position the rectangular, flat mirror housing assembly onto the support loop. Install the self-tapping Torx-head screws. Tighten 96 lbf·in (1085 N·cm).
3. If so equipped, position the square convex mirror housing assembly onto the support loop as previously marked. Install the self-tapping Torx-head screws. Tighten 96 lbf·in (1085 N·cm).
4. Test the mirror for movement and heating. If there are problems, check the wiring.
5. Remove the chocks from the tires.

Exterior Mirror Removal and Installation



11/13/2001 f720404

1. Fold-Away Tubular Support Loop
2. Torx-Head Screws, M8
3. Torx-Head Screws, Self-Tapping
4. Square, Convex Mirror Housing (optional)
5. CB Radio Antenna Lead (optional)
6. Rectangular, Flat Mirror Housing
7. CB Radio Antenna Cable (optional)
8. Electrical Wiring

Fig. 1, Exterior Mirror (manual, left-side)

General Information

The aluminum cab is a semi-monocoque design, which means that the outer skin panels are load bearing as is the internal framework. This type of construction requires less framework than standard cab construction, and results in a very strong, yet lightweight cab. See **Fig. 1**.

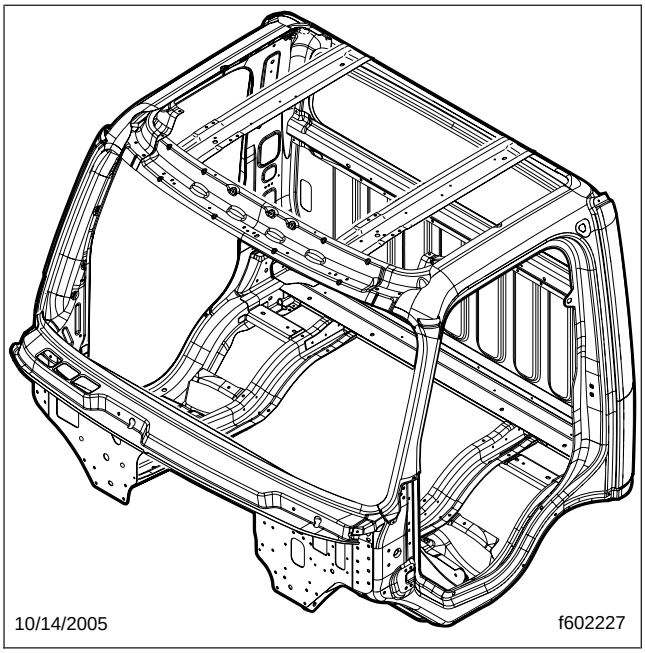


Fig. 1, Cab Structure (Day Cab Shown)

The basic configuration of the cab is a 106-inch flat-roof cab.

The major cab parts are the front-wall assembly, right and left door-frame (side-wall) assemblies, back-wall assembly, roof assembly, and the cab deck assembly. See **Fig. 2**.

The cab deck consists of a framework of longitudinal sills and transverse crossmembers, with a deck plate fastened to them. The cab deck is not available as an assembly; components must be ordered separately.

The door-frame assemblies consist of several panels that are riveted and glued together. In order to maintain structural integrity, the door-frame assemblies are available as complete units only.

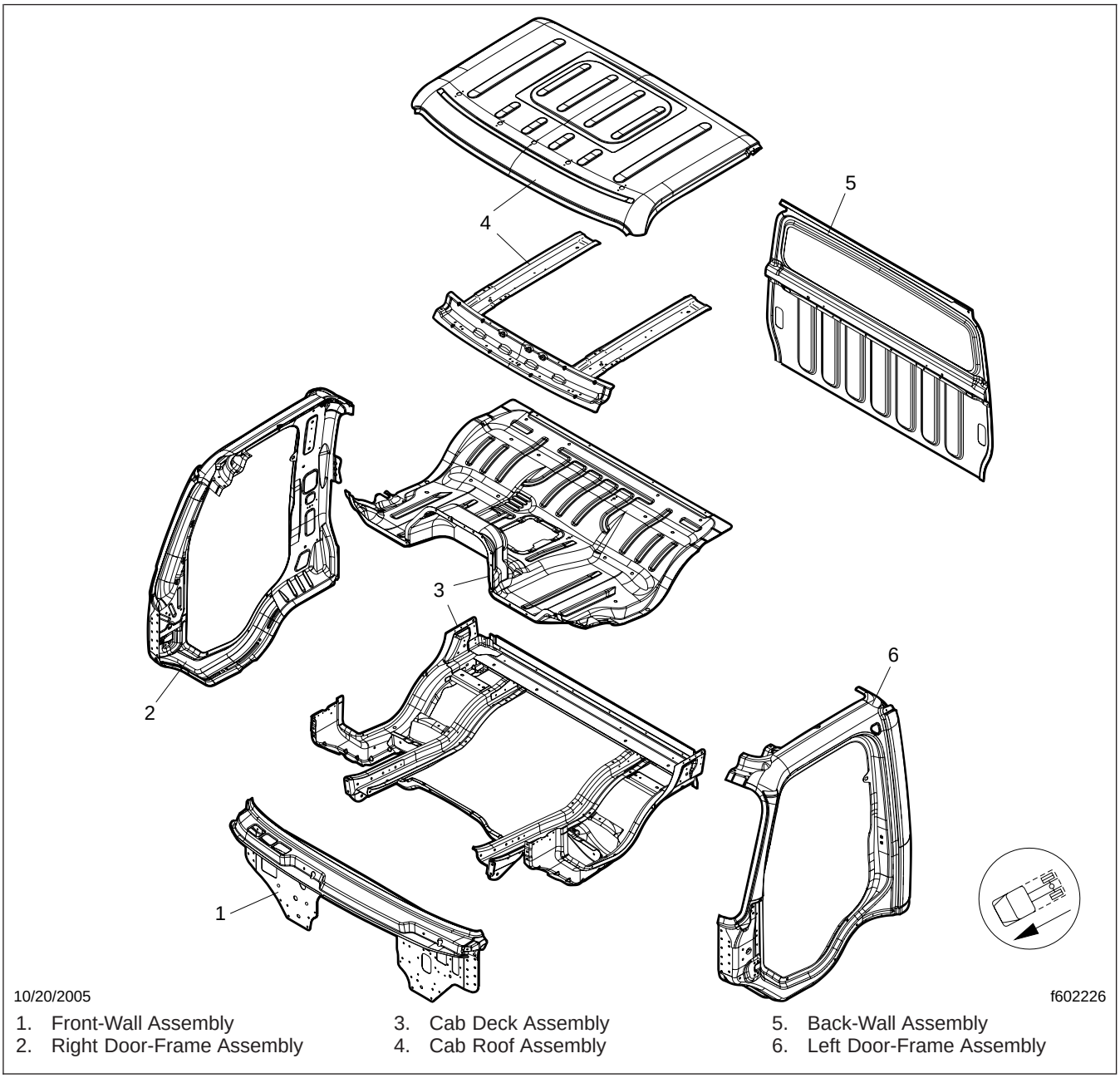
The cab back wall and cab roof components are available as individual pieces.

The cab front-wall assembly is a complete unit attached to the front of the door-frame assemblies, and must be replaced as an entire unit.

The cab parts are held together with a variety of fasteners, including Huck® bolts, blind rivets, and steel Henrob rivets. Structural foam or adhesive is used between the roof cap and roof bows to prevent flutter of the roof.

When any repairs are done to the cab, it is necessary to check the frame rails for correct alignment and squaring. The cab must be leveled and squared. If the cab is repaired without straightening the frame rails, undue stress could be put on the cab, which could weaken it. Also, it may be impossible then to square the cab.

General Information



1. Front-Wall Assembly
2. Right Door-Frame Assembly
3. Cab Deck Assembly
4. Cab Roof Assembly
5. Back-Wall Assembly
6. Left Door-Frame Assembly

Fig. 2, Major Cab Parts

Cab Water-Leak Detection

Use the following procedure to locate areas where water may intrude into the cab.

1. Park the vehicle, apply the parking brakes, and chock the front and rear tires.
2. Prepare a wash solution of at least one-quarter cup of soap to one gallon of water in a spray bottle.
3. Place tape over the cab exhausters.
4. Close all doors, windows, and vents.
5. With the HVAC system in "Fresh Air" mode, turn the fan blower motor on high.

NOTE: Perform the leak detection test with the HVAC system in the "Fresh Air" mode only. Do not set the system in the "Recirculation" mode.

6. Spray the cab with the wash solution and look for bubbles. See **Fig. 1**. Inspect all applicable areas listed below:
    - windshield perimeter
    - visor brackets (if so equipped)
    - roof deflector mounts (if so equipped)

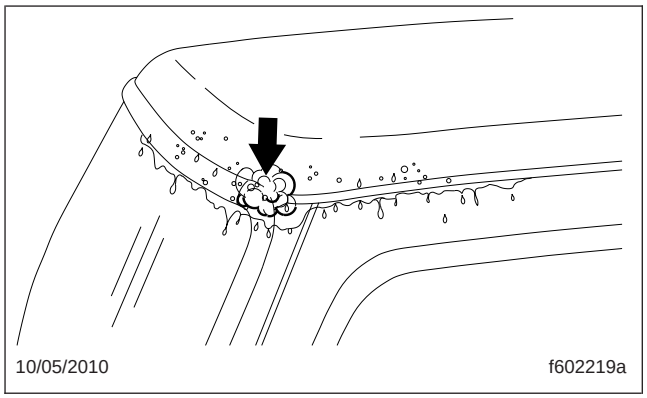


Fig. 1, Cab Water-Leak Detection with Wash Solution

7. Mark areas of suspected leaks.

NOTE: This method of leak detection may also identify areas that will not leak water, even though those areas produce bubbles. Bubbles around door seals and along the vehicle side walls will likely not cause water intrusion issues. If small bubbles are found in an area that is not suspected to leak, a repair may not be necessary.

8. Rinse the wash solution off the vehicle with water.
9. Turn off the fan blower motor.
10. Remove the tape from the cab exhausters.
11. Remove the chocks from the tires.

Cab Water-Leak Repair

If a leak is found, the repair method will depend on the area and type of leak. It may be necessary to remove some components, though most leaks should be repairable by sealing the area of the leak with silicone sealant.

Repair leaks in the windshield using the approved method. See **Section 60.00, Subject 100**.

NOTE: Interior components are varied and optional. The following generalized information is intended for broad use and should not be considered as a guide for a specific vehicle.

Headliner Replacement

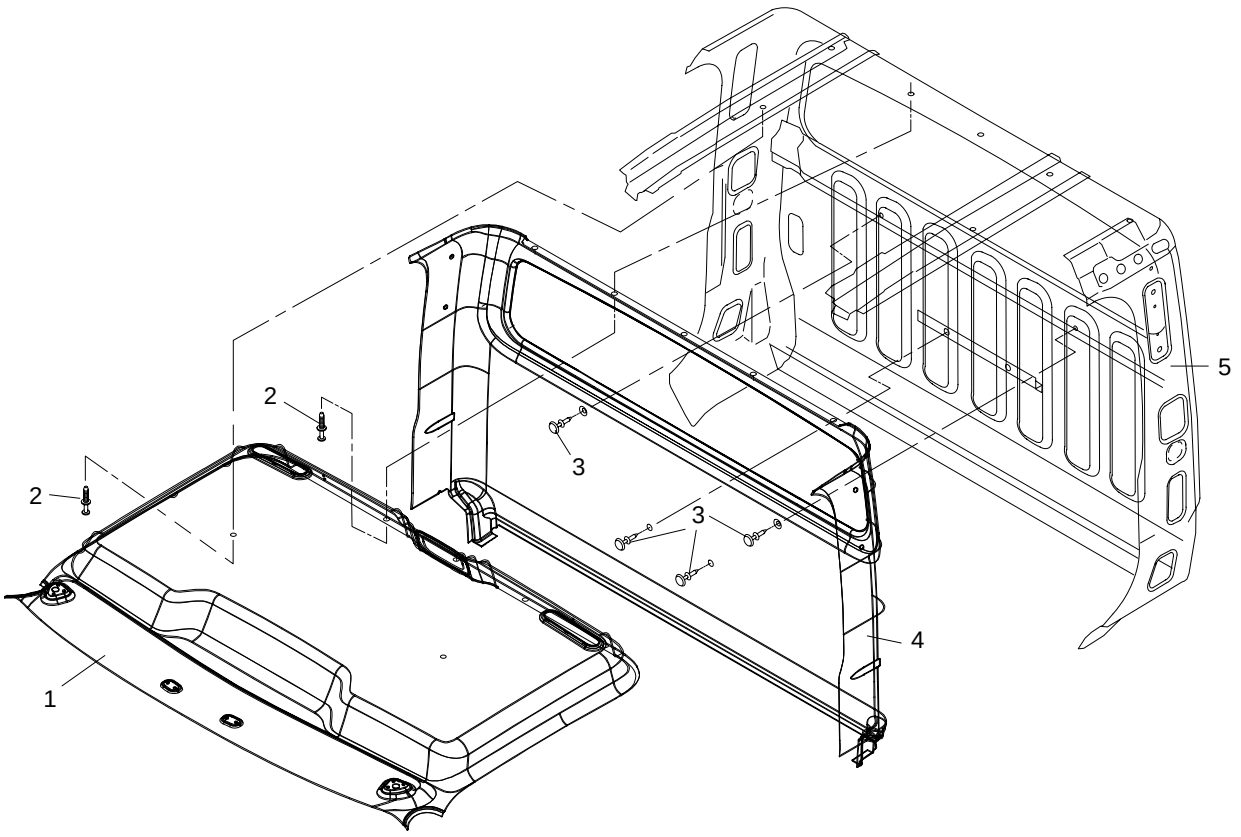
1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Drain the air tanks.
3. Disconnect the batteries at the negative terminals.
4. If applicable, remove all items from the overhead storage bins.
5. If so equipped, remove the front overhead storage bins by prying up around the edges of each bin.
6. Remove the sun visors.
   - 6.1 Remove the fasteners from the sun visor outboard brackets.
   - 6.2 Remove the sun visors.
7. Remove the inboard bracket for the sun visors.
8. Remove the dome light by prying it out from the upholstery panel, then disconnecting the wiring.
9. If so equipped, remove the center seat belt anchor.
10. Remove the small-head, Christmas-tree type fasteners attaching the headliner to the roof bows. See **Fig. 1**.
11. Remove the A-pillar covers and the passenger-side grab handle.
    - 11.1 Remove the Torx®-head screws holding the grab handle in place.
    - 11.2 Remove the Torx-head screws holding the A-pillar covers in place.
    - 11.3 Remove the driver's side A-pillar cover, then the passenger-side cover along with the grab handle.
12. If so equipped, disconnect the air horn lanyard from its anchor point on the roof structure, and pull it up and through the headliner.
13. Remove the remaining Christmas-tree type fasteners attaching the headliner to the rear wall upholstery panel.
14. Remove the headliner from the cab.
15. Put the new headliner into the cab, using a helper to hold it in place.
16. Using new Christmas-tree type fasteners, attach the rear of the headliner to the rear wall upholstery panel and the cab structure.
17. Install the sun visors.
    - 17.1 Install the outboard brackets.
    - 17.2 Install the center bracket.
    - 17.3 Install the sun visors.
18. If so equipped, put the air horn lanyard through the opening in the headliner, then attach the lanyard to its anchor point on the cab roof structure.
19. If applicable, install the right- and left-side storage bins and the center bin.
20. Install the right- and left-side A-pillar covers.
21. Install the passenger-side grab handle.
22. Using new Christmas-tree type fasteners, attach the headliner to the roof bows.
23. Connect the wiring to the dome light, then install it into the headliner.
24. If so equipped, install the center seat belt anchor.
25. Connect the batteries.
26. Remove the chocks from the tires.

Rear Wall Upholstery Panel Replacement

NOTE: See **Fig. 1** for this procedure.

1. If not already done, park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. If not already done, drain the air tanks.
3. If not already done, disconnect the batteries at the negative terminals.
4. Remove the seat(s). For instructions on removing a bench seat, see **Group 91** in this manual.
5. Remove the interior grab handles.

Upholstery Panels Replacement



03/18/2002 f603009

1. Headliner
2. Christmas-Tree Type Fastener, small head (7 qty.)
3. Christmas-Tree Type Fastener, large head (4 qty.)
4. Rear Wall Upholstery Panel
5. Cab Structure

Fig. 1, Headliner and Rear Wall Upholstery Panels

6. Remove the tread plates from the doorways.
7. Remove the upper anchors for the seat belts.
   - 7.1 On one side of the vehicle, pry off the plastic cover.
   - 7.2 Remove the hexnut, rubber washer, and bushing
   - 7.3 Remove the seat belt anchor.
   - 7.4 Repeat the procedure on the other side of the vehicle.
8. If so equipped, remove the driver's and passenger's seat-belt height adjusters.
9. Remove the lower outboard seat belt anchors.
10. Remove the seals from the rear edge of each door opening.
11. Remove the headliner. For instructions, see "Headliner Replacement" in this subject.
12. Remove the four Christmas-tree type fasteners holding the upholstery panel to the cab structure.
13. Pull up the bottom edge of the rear wall upholstery panel from behind the lip at the rear of the floor mat.
14. Remove the rear wall upholstery panel from the cab.
15. Put the new rear wall upholstery panel in place in the cab.

16. Push the bottom rear edge of the panel down behind the lip on the floor mat.
17. Using new Christmas-tree type fasteners, attach the upholstery panel to the cab structure.
18. Install the headliner. For instructions, see "Headliner Replacement."
19. Install the door seals.
20. Connect the wiring and install the dome light.
21. Install the tread plates in the doorways.
22. Install the interior grab handles.
23. Install the upper center seat belt anchors.
24. If applicable, install the driver's and passenger's seat-belt height adjusters.
25. Remove the chocks from the tires.

Floor Mat Replacement

1. If not already done, park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.
2. If not already done, disconnect the batteries at the negative terminals.
3. Remove the seat(s) and seat belts. For instructions on removing a bench seat, see **Group 91** in this manual.
4. Remove the kick panels forward of the doors.
5. Remove the tread plates from the doorways.
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. 2**.

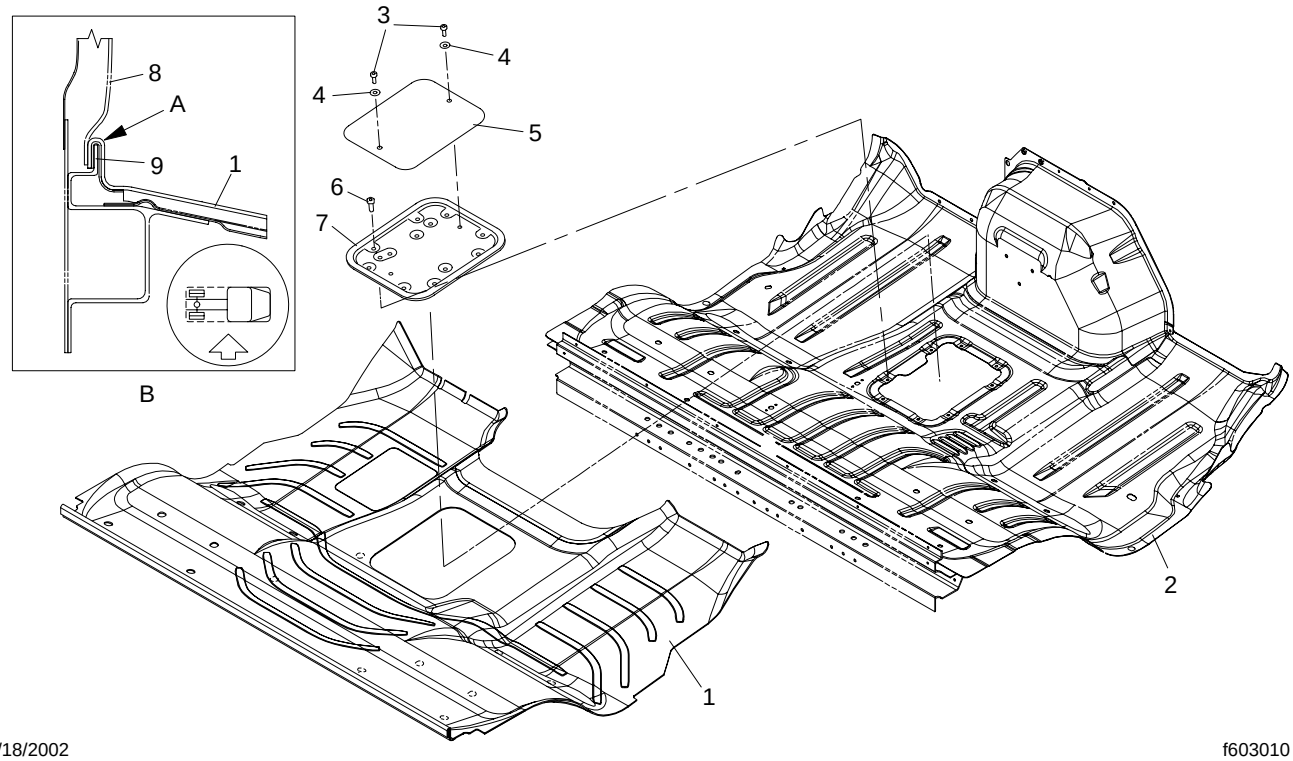
NOTE: The transmission electronic control unit (ECU) is attached to the underside of the metal transmission cover plate. Disconnect the wiring from the ECU before removing the cover plate.

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. 2**. 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.
9. Put the new 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.
10. 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 standard transmission, install the metal cover plate, the rubber mat, and then the shift lever boot.
11. Install the kick panels forward of the doors.
12. Install the treadplates in the doorways.
13. Install the seat(s) and the seat belts. For instructions on installing a bench seat, see **Group 91** in this manual.
14. Connect the batteries.
15. Remove the chocks from the tires.

Upholstery Panels Replacement



03/18/2002 f603010

A. Floor fits over this lip.

B. Cross-Sectional View (rear of cab)

1. Floor Mat
2. Cab Deck Structure
3. Torx-head Screw, 1/4–20
4. Washer
5. Rubber Mat
6. Torx-head Screw, M6 (8 qty.)
7. Cover Plate
8. Rear Wall Upholstery Panel
9. Steel Lip (plastic U-channel not shown)

Fig. 2, Floor Mat Installation (equipped with automatic transmission)

Dash Panels Removal and Installation

Removal

See **Fig. 1** for the removal and installation procedures.

1. Park the vehicle on a level surface, shut down the engine, set 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 holding it in place.
5. Remove the trim plate panel.
6. Remove the right-hand dash panel assembly.
   - 6.1 Remove the Torx-head screws holding the panel in place.
   - 6.2 Disconnect the wiring for the dome light switch.

   NOTE: The dome light switch is on the side of the panel assembly and is activated by the door.

   - 6.3 Pry up the upper edge of the dash panel to release the clips from the slots.
   - 6.4 Remove the right-hand dash panel assembly.
7. Remove the top cover by removing the Torx-head screws holding it in place.
8. Remove the cup holder assembly.
   - 8.1 Remove the screws holding the assembly in place.
   - 8.2 Lift the assembly out and disconnect the wiring from the back of the HVAC controls.
   - 8.3 Remove the cup holder assembly.

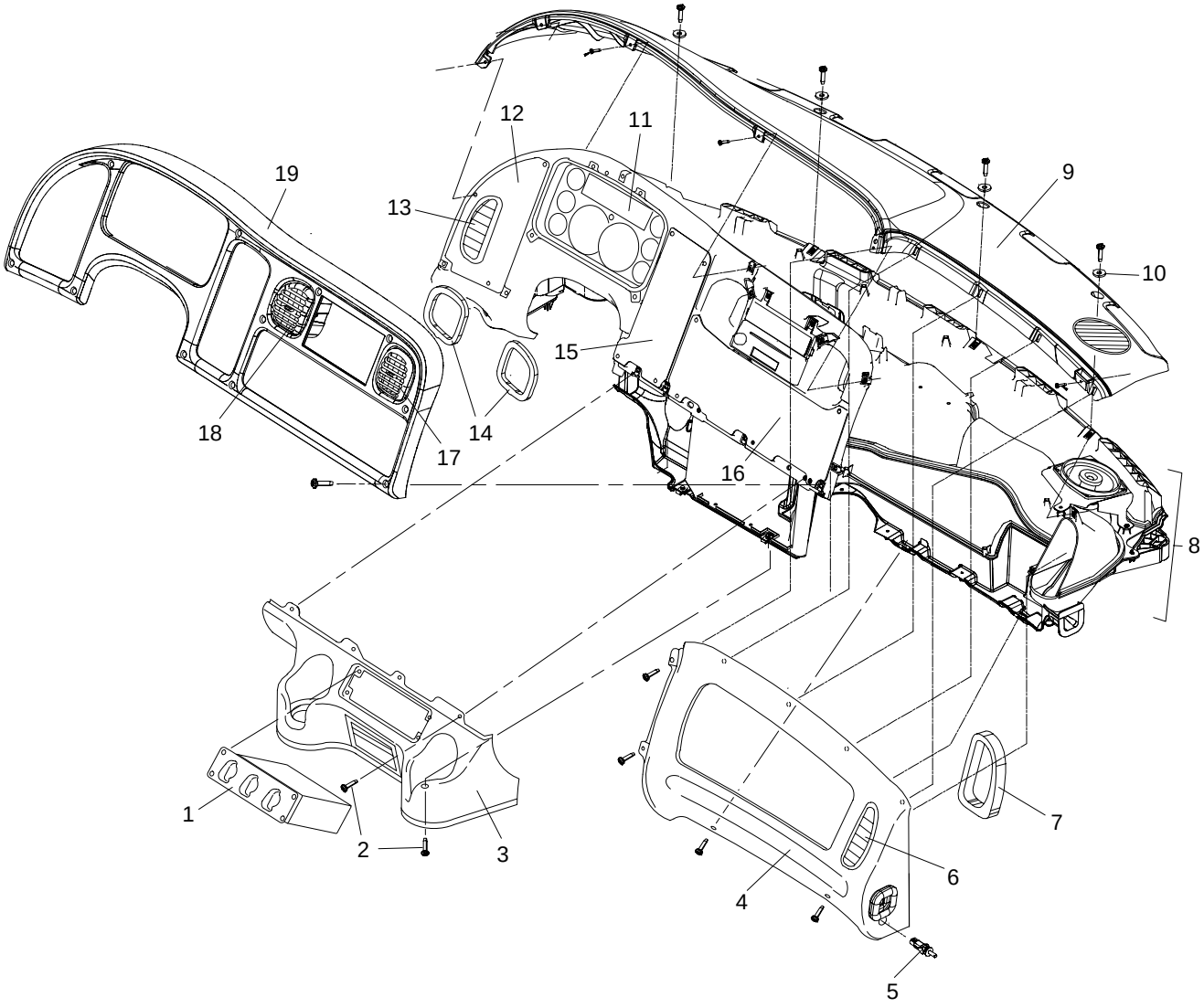
Installation

1. Install the cup holder assembly.
   - 1.1 Put the cup holder assembly in place and connect the wiring to the back of the HVAC controls.
   - 1.2 Install the Torx-head screws.
2. Install the top cover. Tighten the Torx-head screws firmly.
3. Install the right-hand dash panel assembly.
   - 3.1 Put the panel in place.
   - 3.2 Connect the wiring for the dome light switch on the side of the panel assembly.
   - 3.3 At the upper edge of the right-hand dash panel, push the clips into their slots.
   - 3.4 Install the Torx-head screws. Tighten firmly.

NOTE: The right-hand dash panel must be installed before you can install the trim plate panel.

4. Install the trim plate panel. Tighten the Torx-head screws firmly.
5. Install the lower HVAC panel. Tighten the Torx-head screws firmly.

Dash Panels Removal and Installation



12/13/2001 f610599

NOTE: HVAC lower cover not shown.

1. HVAC Control Head Assembly
2. Torx®-Head Screw
3. Cup Holder Assembly
4. Right-Hand Dash Panel Assembly
5. Dome Light Switch
6. Right-Hand Window Outlet Louver
7. Duct Seal
8. Tray Assembly with HVAC Ducting
9. Top Cover
10. Washer
11. Instrument Cluster, ICU 3
12. Gauge Panel
13. Left-Hand Window Outlet Louver
14. Duct Seal
15. Gauge Panel
16. Gauge Panel
17. Right-Hand Dash Outlet Louver
18. Left-Hand Dash Outlet Louver
19. Trim Plate Panel

Fig. 1, Dash Panels

Tray Assembly Removal and Installation

Removal

The tray assembly functions as a dash support, wiring harness carrier, and as the ducting assembly for the heater/air conditioning system. It is attached to the cab frontwall.

1. Park the vehicle on a level surface, shut off the engine, set the parking brakes, and chock the tires.
2. Remove all the dash panels. See **Subject 100** for instructions.
3. As applicable, remove or disconnect the dash gauges, instruments, and controls.
4. Remove the upper dash panel assembly framework.
   - 4.1 Disconnect the ignition wiring.
   - 4.2 Disconnect and remove the dome light switch.
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** for instructions.
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 holding the wiring or air lines in place.
10. Remove the left-hand 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 holding 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 two fasteners holding the tray assembly to the steering column mounting bracket.
14. Remove the one fastener attaching the tray assembly to the top of the HVAC unit.
15. Remove the Christmas tree-type fasteners holding the tray assembly to the wiring harness bracket.
16. Remove the two fasteners holding the tray assembly to the center bracket where the cup holder assembly was attached.
17. From the engine compartment, remove the four fasteners attaching the tray assembly to the frontwall.
    - 17.1 Remove the fasteners attaching the air cleaner to the mounting bracket and the rain tray. Remove the air cleaner.
    - 17.2 Remove the remaining fasteners attaching 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 attaching the assembly to the frontwall. Don't tighten them fully until they are all installed, then tighten them firmly.
3. Install the fasteners inside the cab (do not tighten fully until all are installed):
   - two at the steering column bracket
   - two at the edge of where the cup holder assembly was removed
   - one on top of the HVAC unit.
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 25 lbf·ft (34 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. Install the upper dash panel frame assembly.
   - 8.1 Connect the ignition wiring.

Tray Assembly Removal and Installation

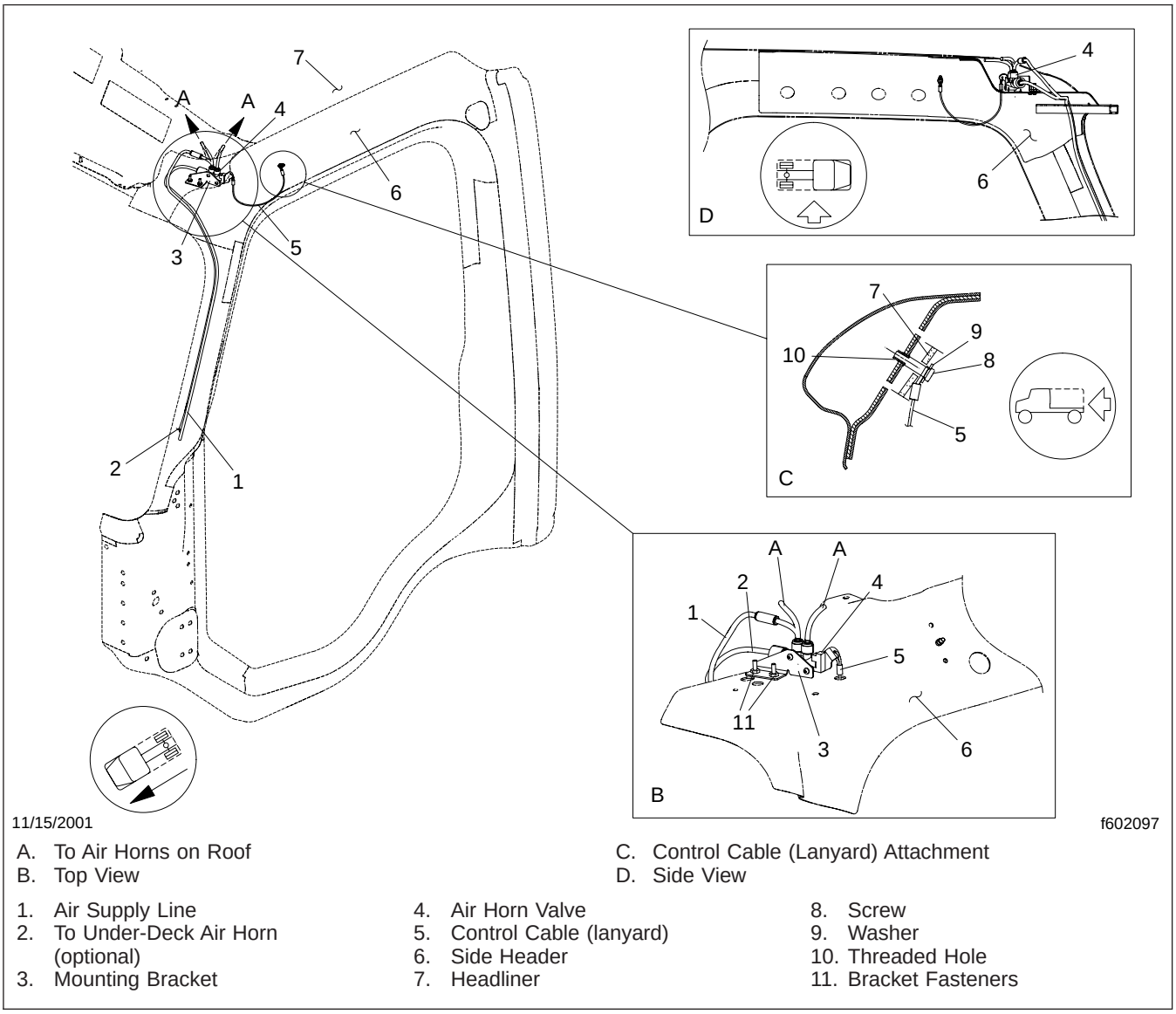
8.2 Install and connect the switch for the dome light.

9. As applicable, put 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** for instructions.
12. Install the left-hand kick panel and tread plate.
13. Install the upper and lower steering column covers.
14. Install the cup holder assembly.
15. From outside the vehicle, install the air cleaner. See **Section 09.01, Subject 110**, for instructions.
16. Install the surge tank. See **Group 20** for instructions.
17. Fill the radiator through the surge tank.
18. Lower the hood.
19. Connect the batteries.
20. Remove the chocks from the tires.

Replacement

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

Air Horn Valve Replacement



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

Removal

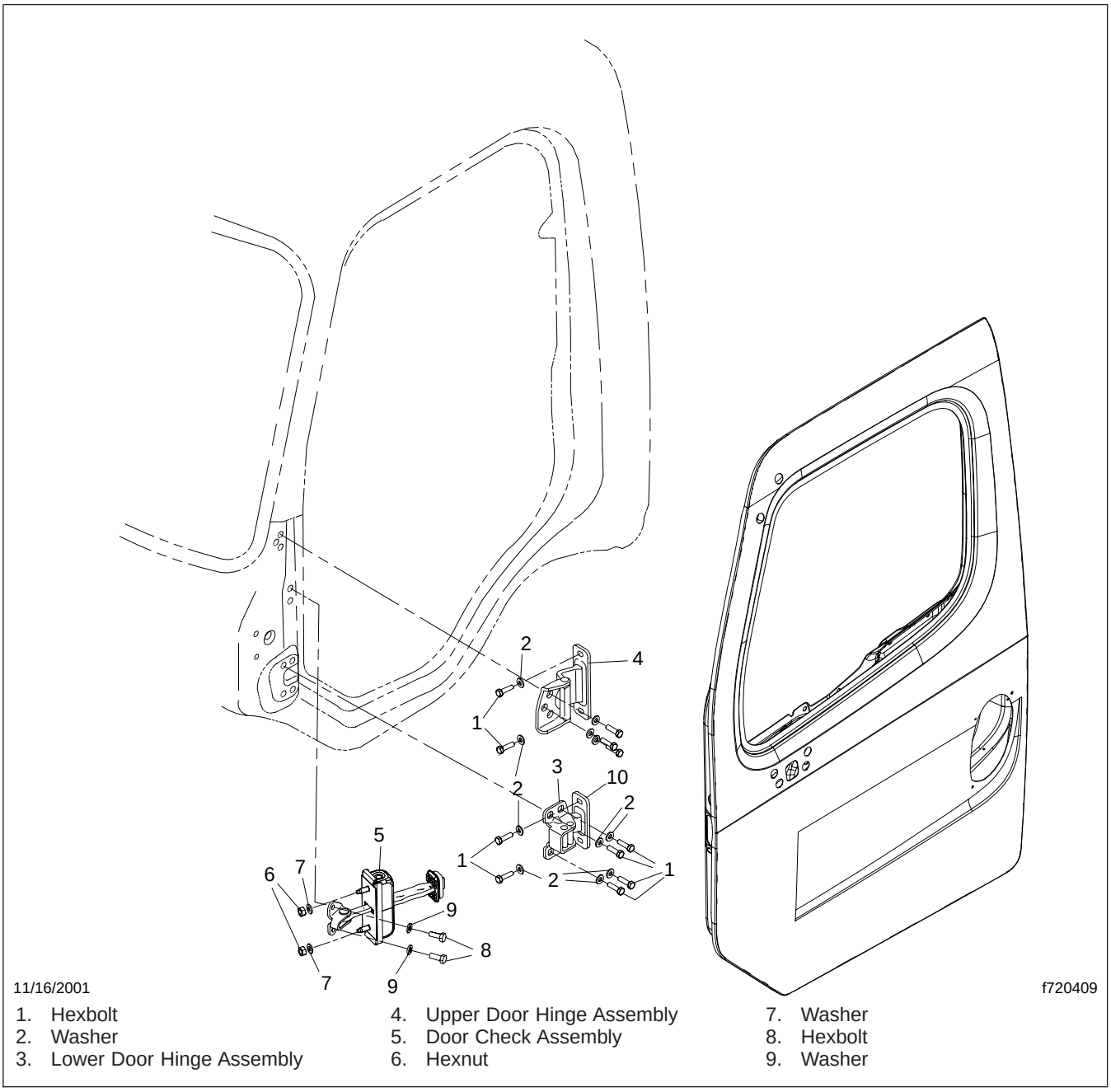
NOTE: This procedure is for removing doors with manual window regulators and manual mirrors.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Disconnect the batteries at the negative terminals.
3. Lower the window in the door you are removing.
4. Remove the cowl cover.
5. Open the door.
6. Remove the door check assembly. See **Fig. 1**.
   - 6.1 Remove the two hexbolts holding the door check clevis bracket to the cab.
   - 6.2 Remove the two nuts holding the door check in the edge of the door.
   - 6.3 Remove the inner door panel.
   - 6.4 Remove the door check assembly from the door.
7. Using a suitable hoist to support the door at its balancing point, remove the fasteners holding the hinges to the door. See **Fig. 2**.
8. Remove the door from the vehicle.

Installation

1. Position the door alongside the vehicle and align the holes in the hinges with those in the cab.
2. Install the hinge fasteners. Tighten the M8 hexbolts 15 lbf·ft (20 N·m). Tighten the M6 hexbolts 10 lbf·ft (14 N·m).
3. Close the door and check for alignment. Adjust the door if needed. See **Subject 140** for instructions.
4. Install the door check assembly.
   - 4.1 Install the door check into the edge of the door. Tighten the nuts 96 lbf·in (1085 N·cm).
   - 4.2 Install the inner door panel.
   - 4.3 Attach the clevis bracket to the cab. Tighten the hexbolts firmly.
5. Install the cowl cover.

Door Removal and Installation



1. Hexbolt
2. Washer
3. Lower Door Hinge Assembly
4. Upper Door Hinge Assembly
5. Door Check Assembly
6. Hexnut
7. Washer
8. Hexbolt
9. Washer

Fig. 1, Door and Door Check Removal and Installation

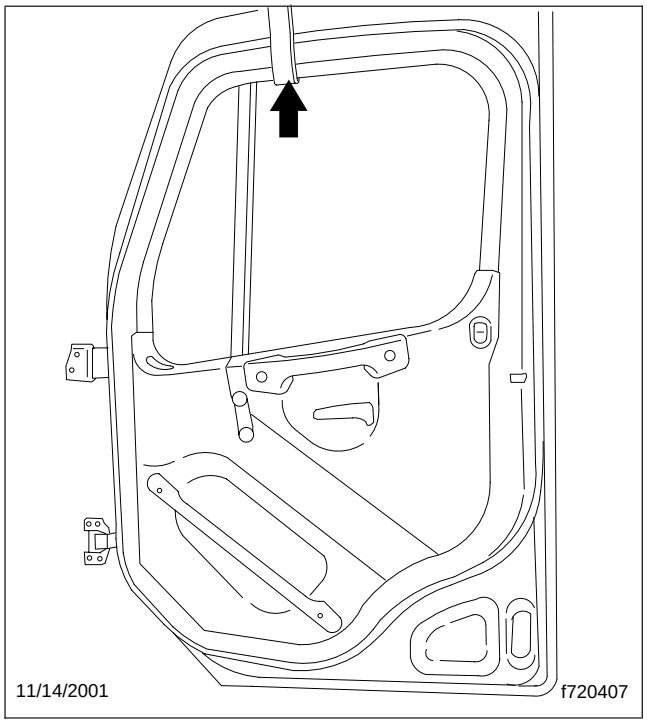


Fig. 2, Door Balancing Point

Replacement

There are four seals for the cab door:

- primary seal
- secondary seal
- lower seal
- rain gutter

See **Fig. 1** for an example of each seal.

Primary Seal Replacement

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 old seal from the door. It is held in place with double-sided tape and retainer clips. The retainer clips are integral with the seal.
4. Using alcohol, clean the surface of any old adhesive or dirt.
5. Install the new primary seal. 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 make sure the seal is seating. Adjust if necessary.
7. Remove the chocks from the tires.

Secondary Seal Replacement

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 tread plate at the bottom of the doorway and 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 and install the tread plate.
8. Close the door and check the seal. Adjust if necessary.
9. Remove the chocks from the tires.

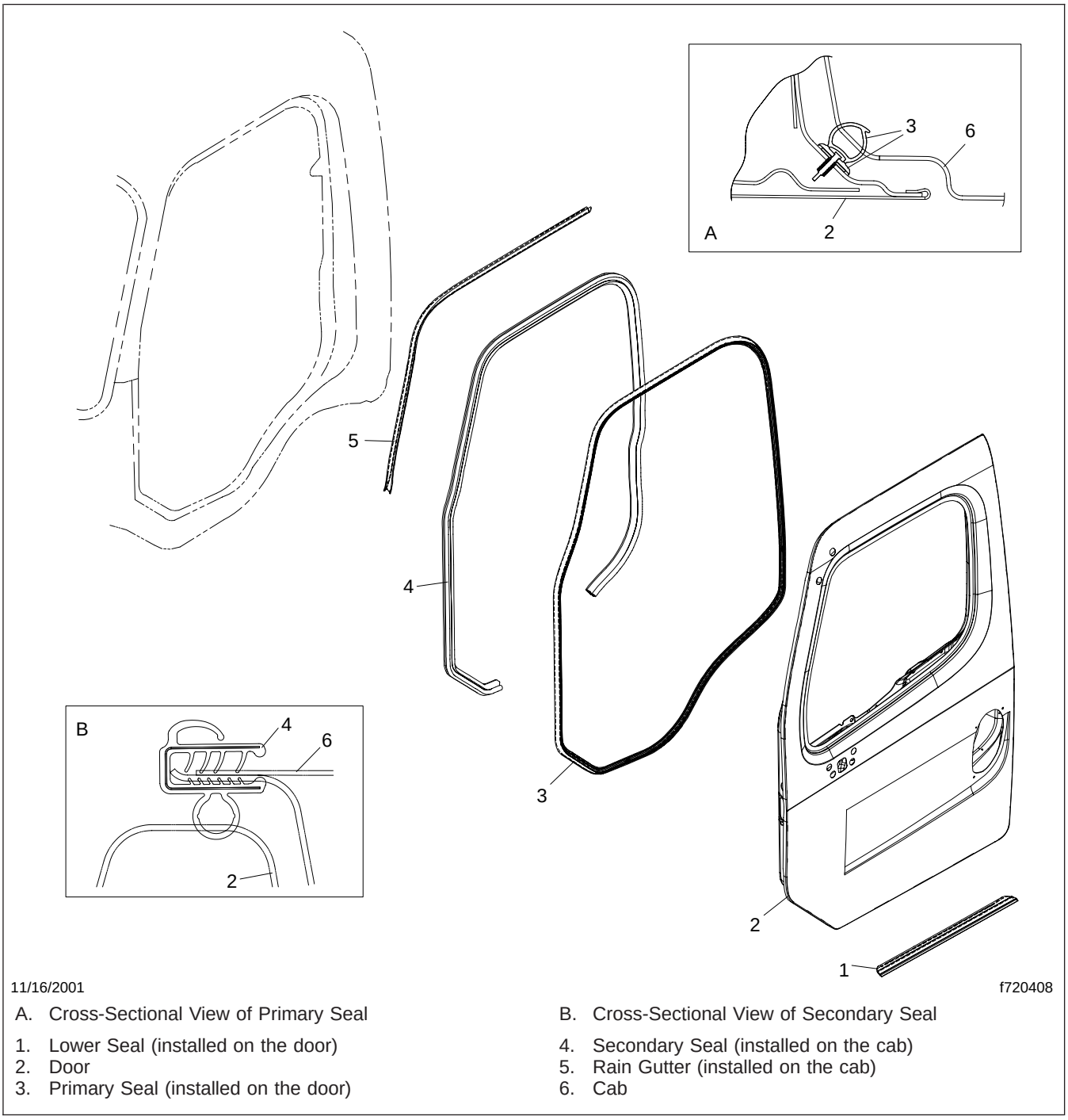
Lower Seal Replacement

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 old seal from the bottom of 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 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.
7. Remove the chocks from the tires.

Rain Gutter Replacement

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 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. 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.
7. Remove the chocks from the tires.

Door Seals Replacement



A. Cross-Sectional View of Primary Seal
B. Cross-Sectional View of Secondary Seal
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 (installed on the cab)
6. Cab

Fig. 1, Door Seals

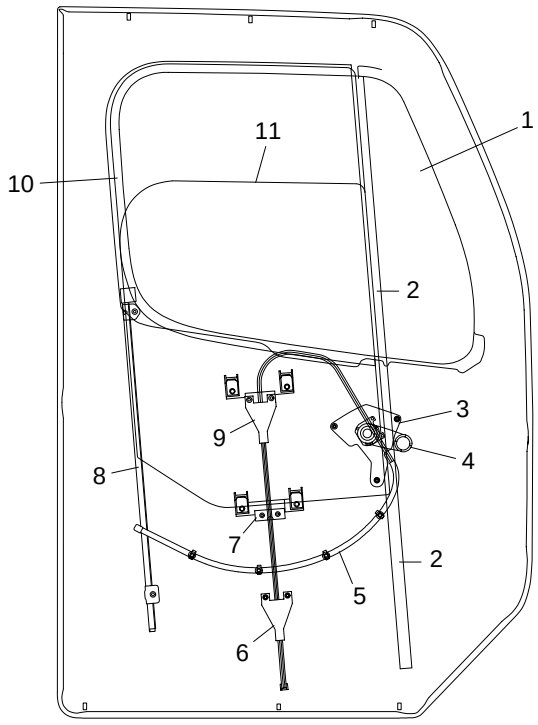
Replacement

NOTE: This procedure is for manual window regulators.

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. Lower the window all the way.
4. Remove the window crank and the inner door panel.
5. Remove the upper and lower screws holding the rear window track in place. Let the track rest at the bottom of the door. See **Fig. 1**.
6. Remove the window seal from the door window opening.
7. Raise the window half-way.
8. While supporting the glass, loosen the regulator clamps at the bottom edge of the window glass. See **Fig. 2**.
9. Remove the window glass by pulling it up and toward the inside of the door window opening.
10. Put the new window glass through the inside of the window opening. Support the glass until it rests on the regulator 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 roll up the window
13. Pull up the rear window channel, making sure the glass edge fits into it. Install the two fasteners that hold the channel in place.
14. Carefully tighten the regulator clamps at the bottom of the window glass. *Do not overtighten.*
15. Test the window regulator for smooth operation. The window should raise and lower with no binding.
16. Install the inner door panel.
17. Install the window crank.
18. Close the door.
19. Remove the chocks from the tires.

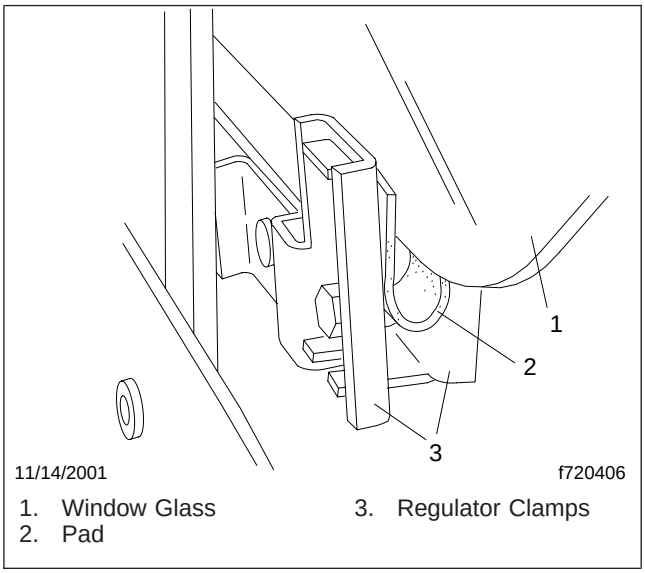


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1. Wing Window
2. Forward Window Glass Track
3. Crank Cover-Plate
4. Crank Handle
5. Run Channel Assembly
6. Lower Run Bracket
7. Window Regulator Clamp Assembly
8. Rear Window Channel
9. Upper Run Bracket
10. Window Seal
11. Window Glass

Fig. 1, Window Regulator Components

Door Window Replacement



1. Window Glass
2. Pad
3. Regulator Clamps

Fig. 2, Window Glass (bottom edge)

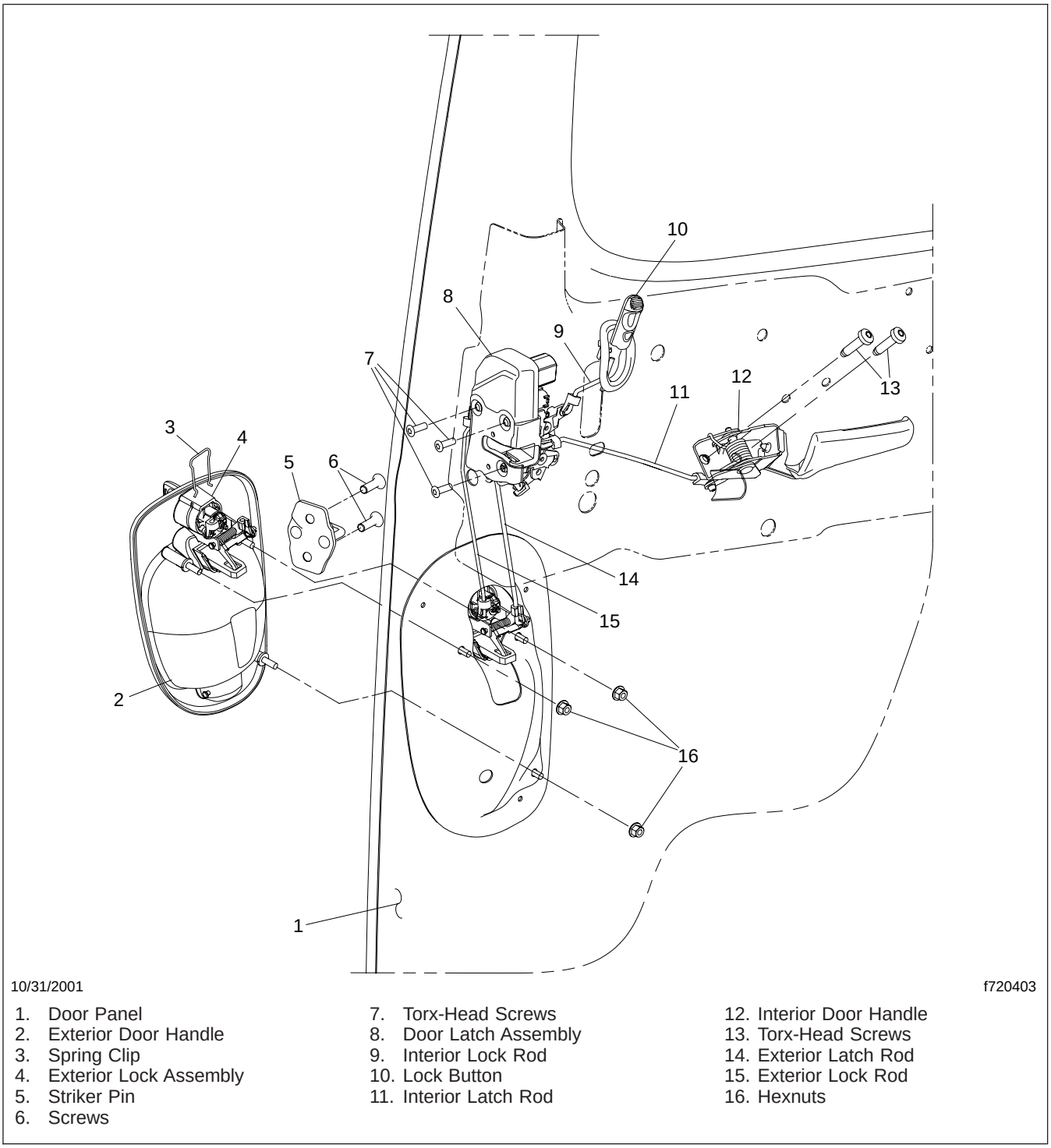
Replacement

NOTE: The door latches never require lubrication. They come from the manufacturer with lifetime lubrication.

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 window crank and the inner door panel.
4. Disconnect the latch rod from the interior door handle. See **Fig. 1**.
5. Disconnect the interior lock rod from the lock assembly.
6. Disconnect the exterior lock rod, and the interior and exterior latch rods.
7. At the edge of the door, remove the three Torx®-head screws holding the latch assembly in place.
8. Remove the latch assembly along with the exterior lock rod and the exterior and interior latch rods. Lift it through the opening in the interior door panel.
9. Install the rods on the new latch assembly.
10. Put the new latch assembly through the opening in the interior door panel.
11. Line up the holes in the latch assembly with those in the door edge. Install the three Torx-head screws and tighten them firmly.
12. Connect the interior lock rod to the latch assembly. Then connect all the remaining rods.

    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.
13. Check the rods for correct operation.
14. Install the inner door panel.
15. Install the window crank.
16. Close the door.
17. Remove the chocks from the tires.

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

General Information

When a door assembly is newly installed on a vehicle, it 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):

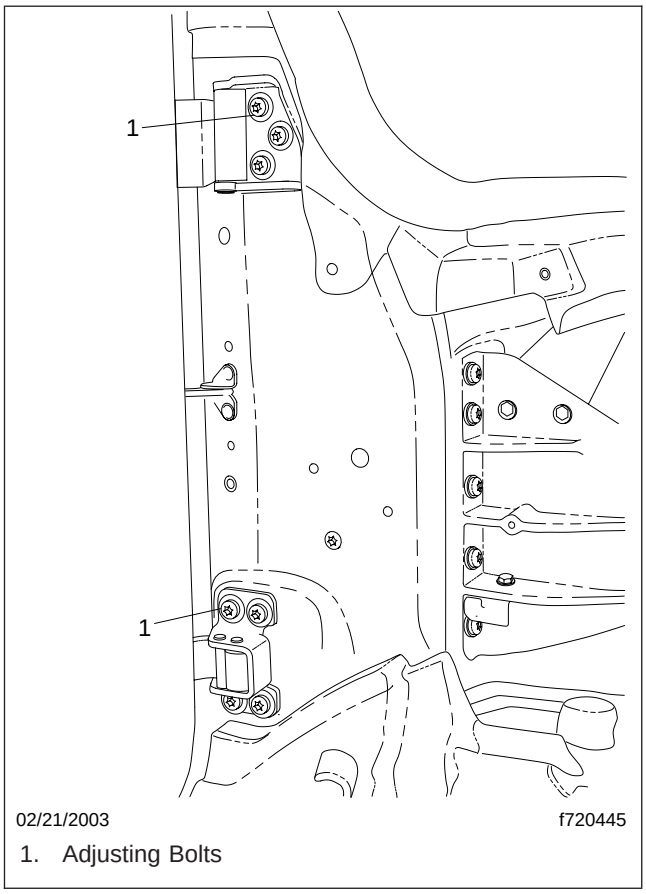
- wind or water leaks at the door opening frame
- premature wear of the door seal
- hard closing or opening of the door

The cab portion of the hinge has oversized holes, so that when the bolts attaching the hinge to the cab are loosened, the door can be adjusted forward or aft, and up and down within the door opening frame. See **Fig. 1**. Slotted holes on the door portion of the hinge, shown in **Fig. 2**, allow for in and out adjustment of the front of the door, and mounting slots for the striker, shown in **Fig. 3**, allow for in and out adjustment of the rear of the door.

Up-and-Down, Fore-and-Aft Adjustment

From outside the cab, visually check the alignment of the door with the cab door-opening frame. Check that the spaces around the top of the door are uniform.

1. Remove the cowl cover.
2. Mark both the vertical and horizontal positions of the latch striker and the hinge before loosening them for adjustment. This will greatly simplify the procedure.
3. Loosen the striker, then tighten it just enough to prevent unintentional movement.
4. Loosen the bolts that attach the hinge to the cab door-opening frame, but keep them tight enough to prevent unintentional hinge movement. See **Fig. 1**.
5. 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 (10 mm).

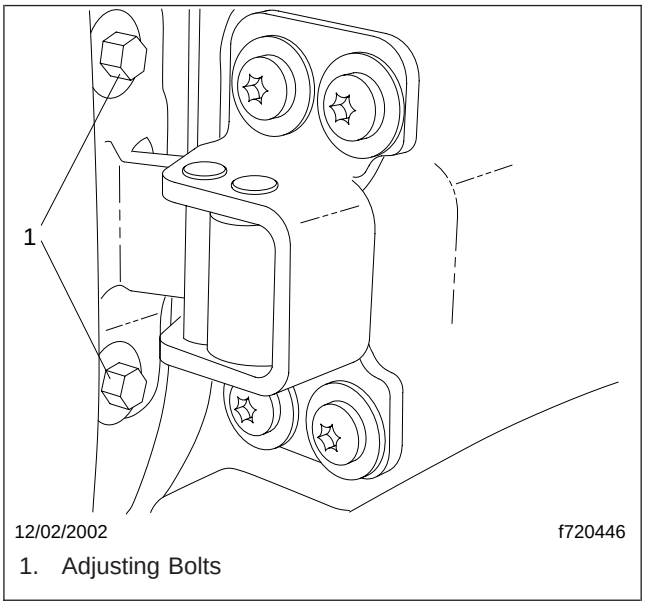


1. Adjusting Bolts

Fig. 1, Fore-and-Aft and Up-and-Down Adjusting Bolts on the Cab

6. Without disturbing the positions of the hinges or striker, carefully open and support the door, then tighten the hinge bolts to 15 to 18 lbf·ft (20 to 24 N·m).
7. 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 will be centered in the latch jaw when the door is closed. If needed, reposition the striker.
8. Tighten the striker 12 lbf·ft (16 N·m), then close the door and recheck the door alignment.
9. Install the cowl cover.

Door Adjustment



1. Adjusting Bolts

Fig. 2, In-and-Out Adjusting Bolts on the Door

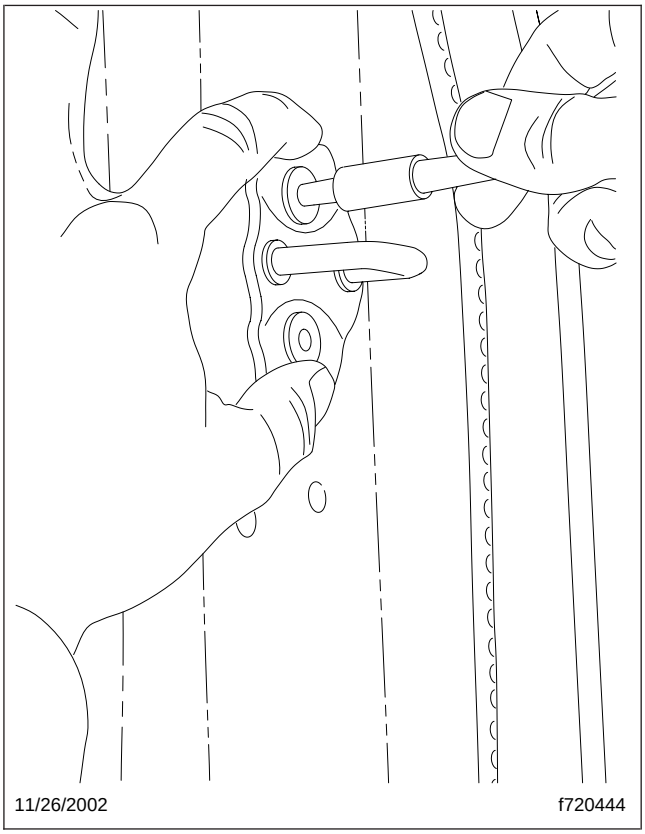


Fig. 3, Striker Adjustment

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. Move the door in or out until the outer surface is flush, within ±3/64 inch (±1 mm), with the surface of the cab skin at *both* the front and rear edges.

1. If the front edge of the door needs adjusting, mark the vertical and horizontal positions of the hinge before loosening them for adjustment. This will greatly simplify the procedure.
2. Loosen the bolts that attach the hinge to the door frame, but keep them tight enough to prevent unintentional hinge movement. See **Fig. 2**.
3. 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.

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.

4. Without disturbing the positions of the hinges, carefully open and support the door, then tighten the hinge bolts 15 to 18 lbf.ft (20 to 24 N·m).
5. If the rear edge of the door needs adjusting, mark the vertical and horizontal positions of the latch striker before loosening it for adjustment.
6. Loosen the striker, then tighten it just enough to prevent unintentional movement. See **Fig. 3**.
7. 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.
8. Without disturbing the position of the striker, carefully open the door, then tighten the striker 12 lbf·ft (16 N·m).

9. Close the door and recheck the door alignment.

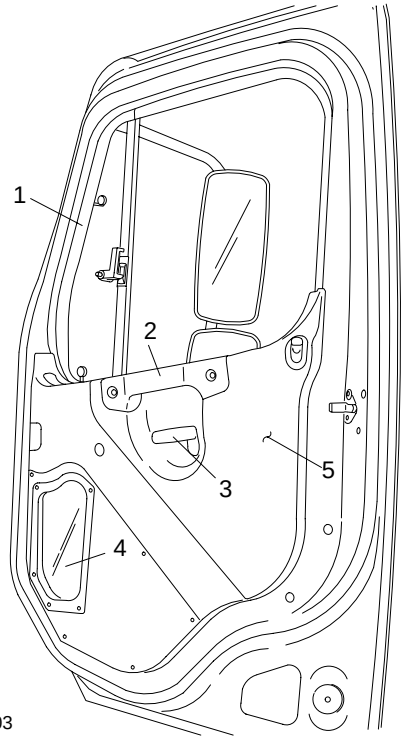
Striker Adjustment

1. As the door closes, watch to see if the striker is centered in relation to the latch jaws. The door should not move up or down when the door latch jaws engage the striker. Only the center of the striker must contact the latch jaws; the top or bottom of the striker should not contact any part of the latch jaw assembly.
2. 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.
3. Check that the latch jaws will just clear the striker head when the door is closed. If necessary, reposition the striker after loosening it with a number 40 Torx® recess driver.
4. Repeat the previous two steps. If the striker appears to be correctly positioned, tighten it 12 lbf·ft (16 N·m).
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.

Vent Window Seal Removal and Installation

Removal

1. Park the vehicle, set the parking brake, shut down the engine, and chock the tires.
2. Using a T40 Torx® screwdriver, remove the two mounting screws from the upper and/or lower door-pull handle. See **Fig. 1**.

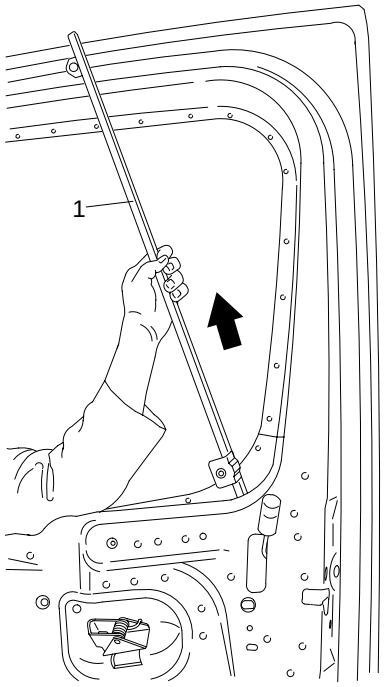


06/03/2003 f720483

1. Window Seal
2. Door Pull Handle
3. Door Latch
4. View Window
5. Door Trim Panel

Fig. 1, M2 Cab Door Trim

3. For vehicles with manual-crank windows, remove the window-regulator handle.
4. Using a T20 Torx screwdriver, remove the four attaching screws and the lower view-window trim ring.
5. Using a T40 Torx screwdriver, remove the interior door-latch handle.
6. Remove the door-trim panel.
   - 6.1 Using a T20 Torx screwdriver, remove the two screws from the forward flange.
   - 6.2 Pull the trim panel outward from the door to release the snaps, then lift it up and over the lock knob.
7. Remove the vapor barrier.
8. Lower the window.
9. Using a T30 Torx screwdriver, remove the two screws that attach the window rear run channel, then pull the channel up and through the window opening. See **Fig. 2**.



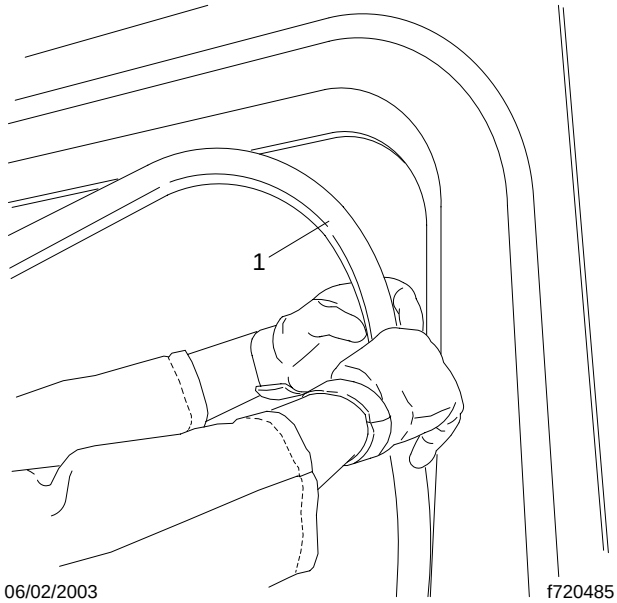
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1. Rear Channel Run

Fig. 2, Removing/Installing the Rear Run Channel

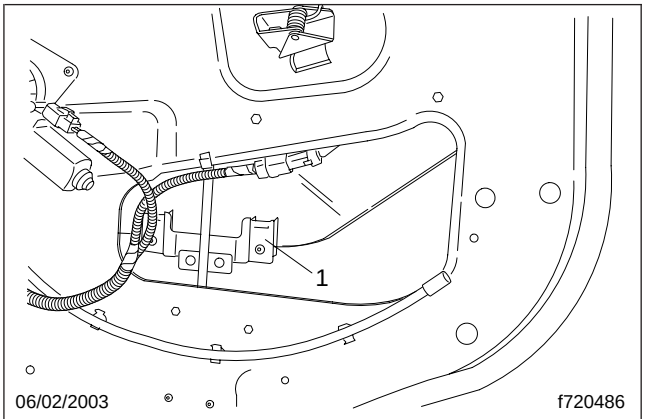
10. Remove the door-window seal.
    - 10.1 Peel back the vent-window seal where it overlaps the door-window seal.
    - 10.2 Pull the door-window seal down and back towards the rear of the cab to remove it. See **Fig. 3**.
11. Remove the door-window glass.
    - 11.1 Raise the window until the glass-clamp bolts can be accessed. See **Fig. 4**.
    - 11.2 Loosen the glass clamps that fasten the glass to the window regulator.

Vent Window Seal Removal and Installation



1. Window Seal

Fig. 3, Removing/Installing the Window Seal



1. Glass Clamp

Fig. 4, Removing/Installing the Cab-Door Glass

11.3 Lift the door-window glass up and in towards the cab to remove it.

12. Remove the vent-window glass.

12.1 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.

12.2 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.

13. Remove the vent-window frame assembly.

13.1 Using a T20 Torx screwdriver, remove the three screws between the door and the front of the vent-window frame assembly.

13.2 Using a T30 Torx screwdriver, remove the two screws that attach the run channel of the vent-window frame assembly to the door.

13.3 Pull the vent-window frame assembly up and out of the window opening. See **Fig. 5**.

14. Remove the seal from the vent-window frame assembly.

14.1 Stretch the top and bottom corners of the seal to release the locking tabs on the seal from the vent-window frame. See **Fig. 6**.

14.2 Remove the seal from the vent-window frame, carefully pulling it free from around the glass supports.

Installation

1. Install the seal onto the vent window.

1.1 Stretch the seal over the vent-window glass supports.

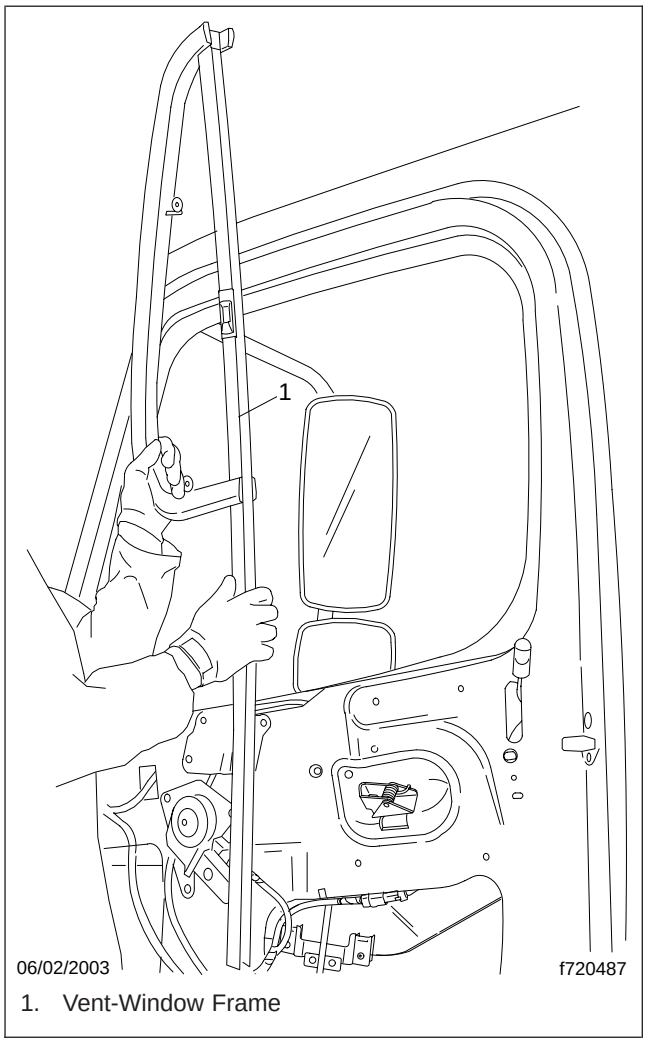
1.2 Apply soapy water to the window seal then press the top corner of the seal into the frame, locking the tabs on the seal into the frame. Work the seal around the frame, using the alignment tabs to position the seal properly. See **Fig. 7**.

1.3 Stretch the bottom edge of the seal and push the locking tabs into the slot in the frame. See **Fig. 6**.

2. Install the vent-window assembly.

2.1 Slide the run channel through the window opening and install the vent-window frame in the opening. See **Fig. 5**.

Vent Window Seal Removal and Installation



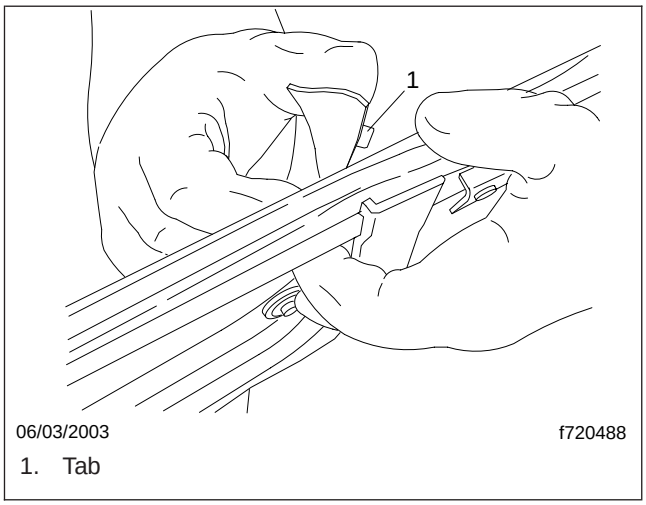
1. Vent-Window Frame

Fig. 5, Removing/Installing the Vent-Window Frame Assembly

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.

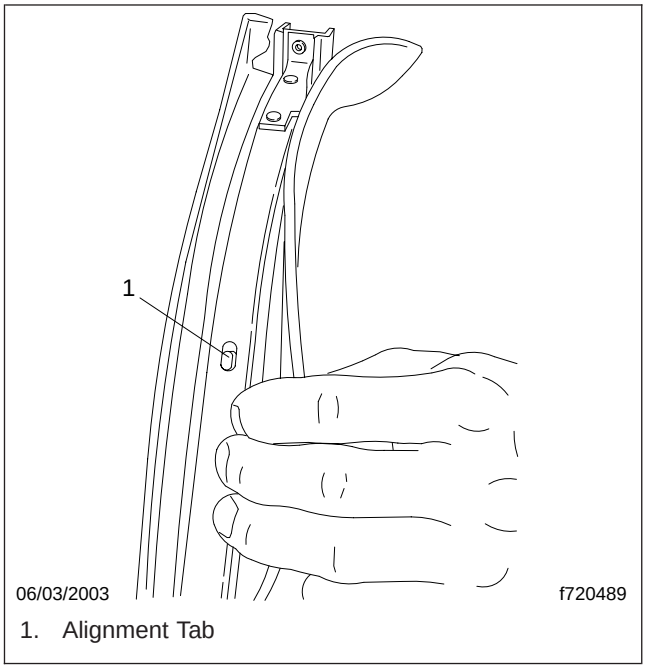
2.2 Install the three screws between the door and the vent-window frame, and tighten them 36 lbf·in (407 N·cm).

2.3 Using a T30 Torx screwdriver, install the two screws that attach the run channel to the door and tighten them 60 lbf·in (678 N·cm).



1. Tab

Fig. 6, Removing/Installing the Vent-Window Seal



1. Alignment Tab

Fig. 7, Installing the Vent-Window Seal

2.4 For an operable vent window, use the two glass-mounting screws to install the glass in the frame assembly. Tighten the screws 60 lbf·in (678 N·cm).

2.5 For a fixed vent window, lubricate the inside of the seal with soapy water. From the outside, slide the upper corner of the

Vent Window Seal Removal and Installation

glass into the seal, then while pushing in on the window, work the seal around the glass.

3. Install the door-window glass.
   - 3.1 Slide the door glass through the door-window opening and set it into the glass clamps.
   - 3.2 Slide the glass against the front window channel, then tighten the glass clamps 48 lbf·in (542 N·cm).
4. Lower the window.
5. Install the door window seal around the window opening, then apply 3M® Strip-Calk 08578 at the upper and lower sections where the vent window seal overlaps the door window seal, and press into place.
6. Install the door-window rear channel run in the door and tighten the attaching screws 60 lbf·in (678 N·cm).
7. Roll the window up and down to check for binding. Adjust as necessary.
8. Route the window-regulator cable through 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.

9. Install the door trim panel.
   - 9.1 Slide the trim panel over the door-lock knob.
   - 9.2 Firmly press the trim panel against the door to fasten the snaps.
   - 9.3 Using a T20 Torx screwdriver, install the two screws in the forward flange of the trim panel.
10. Using a T20 Torx screwdriver, install the four screws and the lower view-window trim ring.
11. Using a T40 Torx screwdriver, install the upper and/or lower door-pull handle and tighten the screws 12 lbf·ft (16 N·m).
12. Install the interior door-latch handle and tighten the screws 84 lbf·in (949 N·cm).
13. If the vehicle has manual-crank windows, install the window-regulator handle.
14. Remove the chocks from the tires.

General Information

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**.

Troubleshooting Tables

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

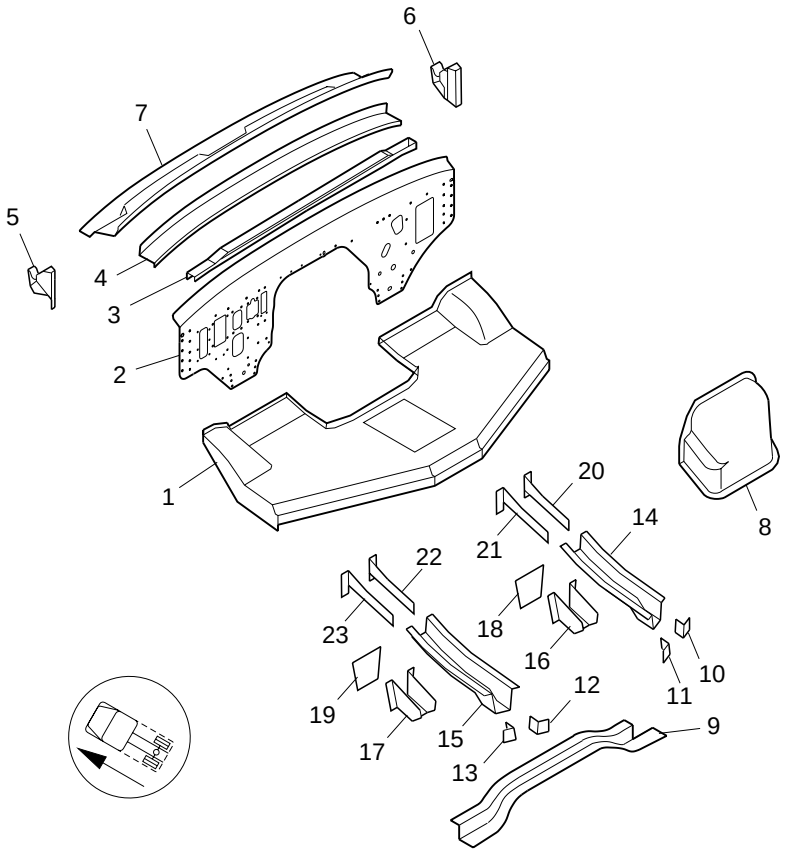
Manual Window Regulator Not Working or Noisy, Window Glass Binding			
Step	**Test Procedure**	**Test Result**	**Action**
1	Remove the interior door panel to gain access to the window regulator.	—	—
2	Are the regulator mounting screws tight, and is the glass secured to the regulator.	Yes	Go to **step 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 may also need to be 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

General Information

The cowling assembly provides support for the vehicle pedals, steering components, instrument panel assemblies, various electrical and electronic hardware, several fuel and cooling components, and the hood. See **Fig. 1**.

Cowling mounts are used to fasten the cowling to the frame rails. See **Fig. 2**. The cowling is also attached to the vehicle body when the body is mounted to the frame rails, by the body builder.

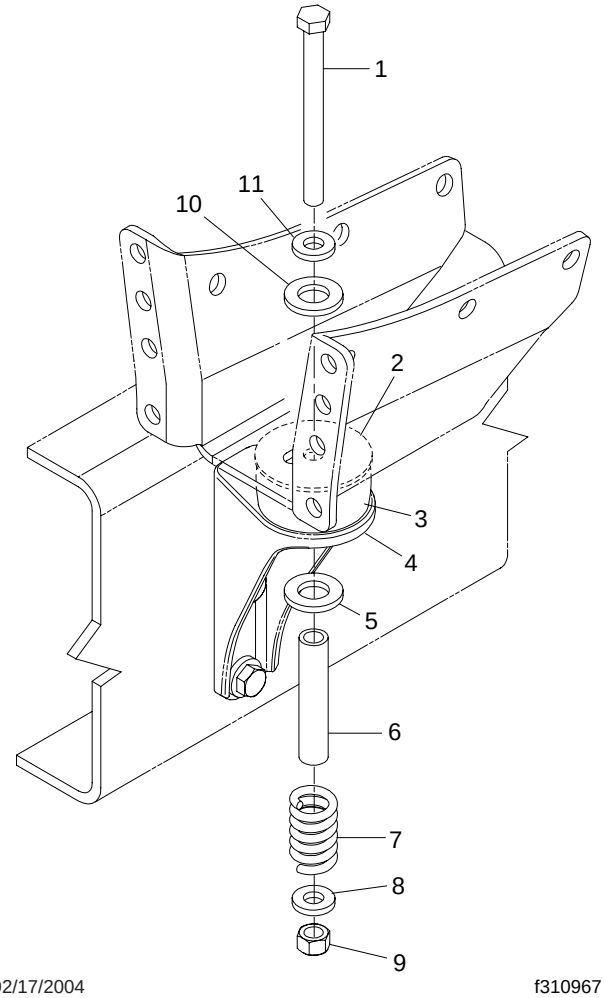


03/23/2007 f602301

1. Toe Board
2. Front Panel
3. Front Panel Reinforcement
4. Cowling Top Panel
5. Hood Support Bracket Assembly
6. Hood Support Bracket Assembly, Right
7. Cowling Top Support Panel
8. Engine Tunnel
9. Crossmember
10. Outer Gusset, Right
11. Inner Gusset, Right
12. Inner Gusset, Left
13. Outer Gusset, Left
14. Floor Mount, Right
15. Floor Mount, Left
16. Isolator Mount, Right
17. Isolator Mount, Left
18. Isolator Mount Reinforcement, Right
19. Isolator Mount Reinforcement, Left
20. Cab Mount Nut Plate, Right
21. Floor Mount Reinforcement, Right
22. Floor Mount Reinforcement, Left
23. Cab Mount Nut Plate, Left

Fig. 1, Cowling Assembly (exploded)

General Information



02/17/2004 f310967

1. Hexbolt
2. Flatwasher
3. Isolator
4. Cowling Mounting Bracket
5. Flatwasher
6. Cowling Mounting Spacer
7. Spring
8. Bearing Washer
9. Hexnut, 1/2–13
10. Washer
11. Bearing Washer

Fig. 2, Cowling Mount

Cowling Mount Isolator Replacement

Replacement

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

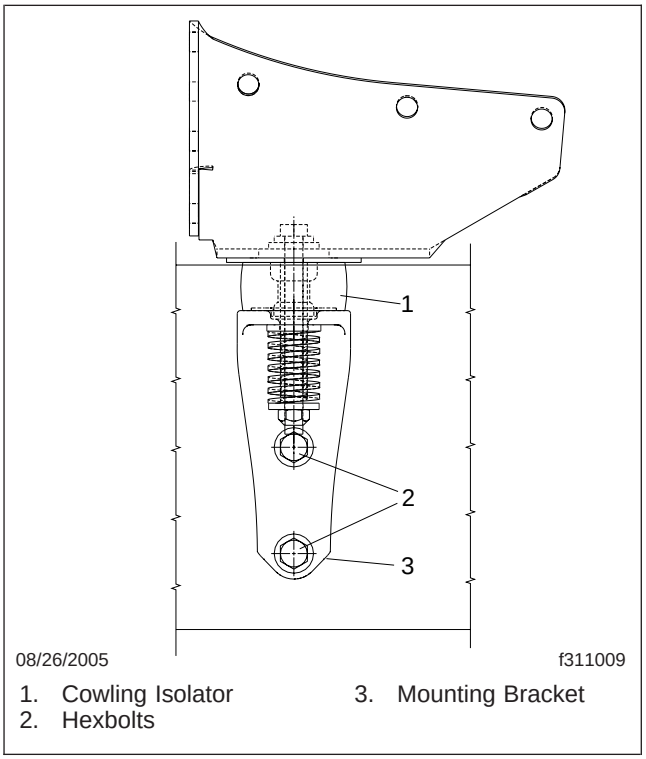
⚠ WARNING

Always use jack stands of sufficient strength, and position them according to the body manufacturer's recommendations. Failure to do so may cause the vehicle body to fall, resulting in personal injury and/or vehicle damage.

⚠ CAUTION

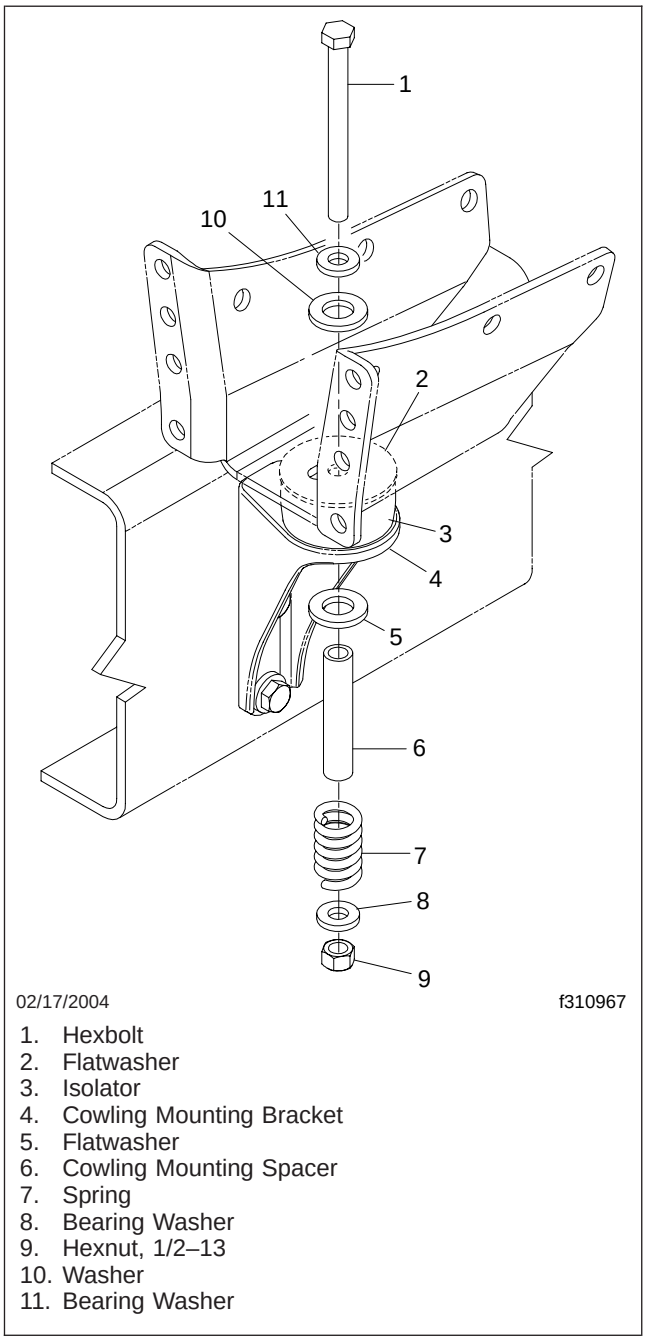
Do not raise the body higher than recommended. Doing so could damage the body tie downs.

2. The isolator is supported by a bracket mounted on the side of the rail on each side of the chassis. See **Fig. 1** and **Fig. 2**. Remove the two bolts that secure the bracket to the frame rail.



1. Cowling Isolator
2. Hexbolts
3. Mounting Bracket

Fig. 1, Cowling Mounting Bracket and Isolator, Side View



1. Hexbolt
2. Flatwasher
3. Isolator
4. Cowling Mounting Bracket
5. Flatwasher
6. Cowling Mounting Spacer
7. Spring
8. Bearing Washer
9. Hexnut, 1/2–13
10. Washer
11. Bearing Washer

Fig. 2, Cowling Mount

NOTE: To reach the nut on the inside of the frame rail, several harnesses and wiring may have to be moved. Carefully cut the tie straps that secure the harnesses and reposition them

Cowling Mount Isolator Replacement

as needed to get a 3/4-inch wrench or ratchet in place to hold the nut.

3. Using a bottle jack, raise the body approximately 1 inch (25 mm) to take the load off of the isolator and to support the body during isolator removal.

⚠ WARNING

Once the center-bolt nut is removed, the mounting bracket will be free to fall. Be careful when removing the center-bolt nut, making certain the mounting bracket is being held. The mounting bracket is heavy and could cause personal injury.

4. Remove the nut from the center-bolt, using a pair of 3/4-inch wrenches. Discard the isolator.
5. Position a new 60-durometer isolator over the center bolt, then position and support the mounting bracket.
6. Install the nut on the center bolt, using a pair of 3/4-inch wrenches. Tighten the nut slightly, leaving the center bolt loose for the following steps. See **Fig. 2**.
7. Make sure the assembly is installed in a vertical position with no lean toward the front or the rear of the vehicle. Misalignment will cause part wear and/or noise.
8. Attach the bracket to the side of the rail to support the isolator. Install the bolts and nuts that hold the bracket to the frame. Tighten the nut 56 lbf·ft (76 N·m). Using tie straps, secure any harnesses, hoses, or wiring that was moved.
9. Carefully lower the body onto the isolator and remove the bottle jack.
10. Tighten the nut on the center bolt 56 lbf·ft (76 N·m).
11. Repeat the process for the other side of the vehicle if needed.
12. Remove the chocks from the tires.

Dash Panels Removal and Installation

Removal

Refer to **Fig. 1** during the removal and installation procedures.

1. Park the vehicle on a level surface, shut down the engine, set the parking brakes, and chock the tires.
2. Disconnect the batteries at the negative terminal.
3. Remove the HVAC lower cover by removing the three Torx® screws that hold it in place.
4. Remove the trim plate panel.
5. Remove the right-hand dash endcap as follows:
   - 5.1 Remove the lower defroster grille.
   - 5.2 Remove the Phillips screw behind the lower defroster grille.
   - 5.3 Remove the two Phillips screws that secure the panel to the dash top cover.
6. Remove the Torx screws that hold the right-hand dash panel in place and remove the panel assembly as follows:
   - 6.1 Disconnect the wiring for the dome light switch.

   NOTE: The dome light switch is on the side of the panel assembly and is activated by the door.

   - 6.2 Pry up the upper edge of the dash panel to release the clips from the slots.
   - 6.3 Remove the right-hand dash panel assembly.
7. Remove the top cover by removing the Torx screws that hold it in place.
8. Remove the trim panel fastener that holds the left-hand dash cover to the dash top cover.
9. Remove the HVAC control and ignition switch panel as follows:
   - 9.1 Remove the screws that hold the assembly in place.
   - 9.2 Lift the assembly out and disconnect the wiring from the back of the HVAC controls.
   - 9.3 Disconnect the wiring from the back of the ignition switch.
   - 9.4 Remove the panel assembly.

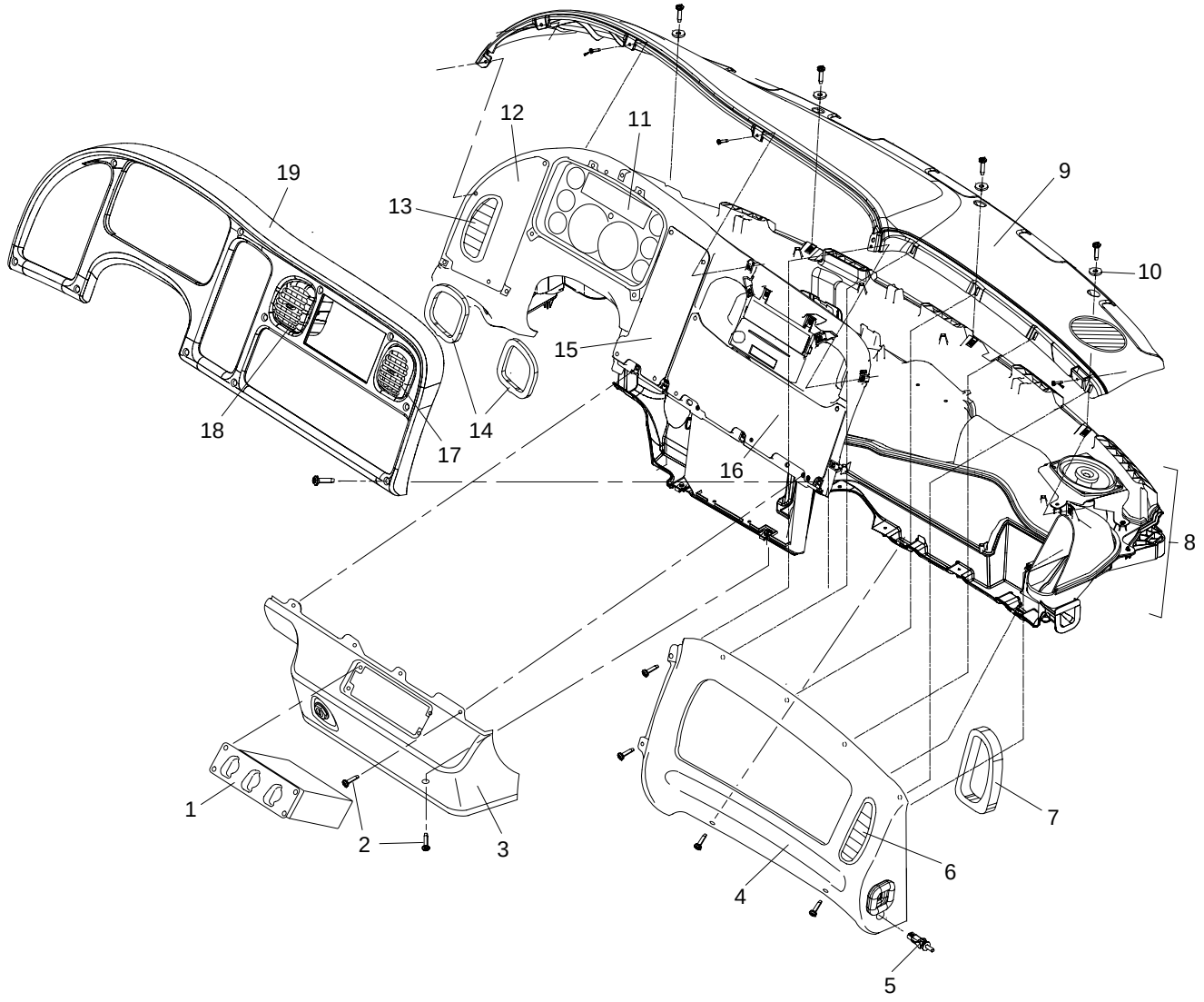
Installation

1. Install the HVAC control and ignition switch panel as follows:
   - 1.1 Position the HVAC control and ignition switch panel assembly, then connect the wiring to the back of the HVAC controls.
   - 1.2 Connect the wiring to the ignition switch.
   - 1.3 Install the Torx screws.
2. Install the top cover. Tighten the Torx screws firmly.
3. Install the trim panel fastener that holds the left-hand dash cover to the dash top cover.
4. Install the right-hand dash panel assembly as follows:
   - 4.1 Position the right-hand dash panel assembly.
   - 4.2 At the upper edge of the right-hand dash panel, push the clips into their slots.
   - 4.3 Install the Torx screws and tighten firmly.

NOTE: The right-hand dash panel must be installed before you can install the trim plate panel.

5. Install the trim plate panel. Tighten the Torx screws firmly.
6. Install the lower HVAC panel. Tighten the Torx screws firmly.
7. Install the right-hand dash endcap as follows:
   - 7.1 Install the two Phillips screws that hold the right endcap to the dash top cover.
   - 7.2 Install the Phillips screw in the lower defroster opening.
   - 7.3 Install the lower defroster grille.
8. Connect the batteries.
9. Remove the chocks from the tires.

Dash Panels Removal and Installation



02/19/2004 f610696

NOTE: HVAC lower cover not shown.

1. HVAC Control Head Assembly
2. Torx Screw
3. Ignition Panel Assembly
4. Right-Hand Dash Panel Assembly
5. Dome Light Switch
6. Right-Hand Window Outlet Louver
7. Duct Seal
8. Tray Assembly with HVAC Ducting
9. Top Cover
10. Torx Bolt and Washer
11. Instrument Cluster, ICU3
12. Gauge Panel
13. Left-Hand Window Outlet Louver
14. Duct Seal
15. Gauge Panel
16. Gauge Panel
17. Right-Hand Dash Outlet Louver
18. Left-Hand Dash Outlet Louver
19. Trim Plate Panel

Fig. 1, Dash Panels

Tray Assembly Removal and Installation

Removal

The tray assembly functions as a dash support, wiring harness carrier, and as the ducting assembly for the heater/air-conditioning system. It is attached to the cab frontwall.

1. Park the vehicle on a level surface, shut off the engine, set the parking brakes, and chock the tires.
2. Remove the passenger partition.
3. Remove the fasteners that secure the seat belt retractor to the sidewall.
4. Remove the driver's side switch panel from the side console.
5. Remove the driver's side console cover.
6. Remove the driver's side lower front cover.
7. Remove all the dash panels. See **Subject 100** for instructions.
8. As applicable, remove or disconnect the dash gauges, instruments, and controls.
9. Remove the upper dash panel assembly framework.
10. Disconnect the ignition wiring.
11. Disconnect and remove the dome light switch.
12. Tilt the hood.
13. Partially drain the radiator to below the level of the surge tank.
14. Remove the half fender.
15. Loosen the fasteners on the radiator surge tank as follows:
    - 15.1 Remove the fasteners that hold the surge tank to the HVAC intake plenum.
    - 15.2 Remove the nut and washer that secure the surge tank to the front wall.
    - 15.3 Remove the two screws that hold the surge tank to the air cleaner bracket on the underside of the surge tank.
    - 15.4 Disconnect the coolant level sensor.
    - 15.5 Disconnect the overflow tube from the surge tank.
    - 15.6 Disconnect the lower hose from the surge tank to the engine and plug the openings.
    - 15.7 Remove the three bolts that hold the air cleaner to the air cleaner bracket and move the air cleaner out of the way.
16. Remove the HVAC intake housing.
17. 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.
18. Remove the upper and lower steering column covers.
19. Remove the wiring harness from the dash tray assembly.
20. 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.
21. Remove the left-hand kick panel and the tread plate, then mark and disconnect the ground wires to the left of, and below the steering column.
22. 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.
23. Remove the three fasteners that hold the tray assembly to the steering column mounting bracket.
24. From the engine compartment, remove the four fasteners that attach the tray assembly to the frontwall.
25. 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. Don't tighten them fully until they are all installed, then tighten them firmly.
3. Install the fasteners inside the cab (do not tighten fully until all are installed).
4. Install the wiring harness in the dash tray.

Tray Assembly Removal and Installation

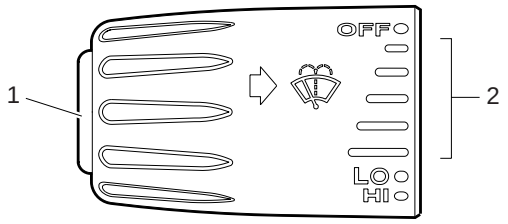
5. Install the bulkhead connector harness in the frontwall opening.

   As previously marked, connect the main harness plugs.
6. Attach the steering column to its bracket. Tighten the fasteners 25 lbf·ft (35 N·m).
7. Connect the ground wires to the stud below and to the left of the steering column.
8. Secure all the wiring with tie-straps.
9. Install the upper dash panel frame assembly.
10. As applicable, put all air lines and wiring through the openings in the dash panel frame assembly.
11. Install and connect the dash gauges, instruments, and controls.
12. Install the dash panels. See **Subject 100** for instructions.
13. Install the HVAC intake housing.
14. Install the radiator surge tank as follows:
    - 14.1 Place the surge tank into position.
    - 14.2 Install the air cleaner.
    - 14.3 Install the lower hose leading from the engine to the surge tank.
    - 14.4 Connect the overflow tube.
    - 14.5 Connect the coolant level sensor.
    - 14.6 Install the two screws on the underside of the surge tank.
    - 14.7 Install the nut and washer that connects the surge tank to the front wall.
    - 14.8 Install the fasteners that hold the surge tank to the HVAC intake plenum.
15. Install the half fender.
16. Install the upper and lower steering column covers.
17. Install the cup holder assembly.
18. Install the driver's side lower front console.
19. Install the driver's side console cover.
20. Install the driver's side switch panel.
21. Install the seat belt retractor.
22. Install the passenger partition.
23. Fill the radiator through the surge tank.
24. Lower the hood.
25. Connect the batteries.
26. Remove the chocks from the tires.

General Information

The windshield wipers are operated by a switch at the end of the turn signal lever. See **Fig. 1**. To turn the windshield wipers on, turn the switch to the low speed, high speed, or any of the intermittent speeds.

The windshield washer is operated by pressing the windshield washer button on the end of the windshield wiper switch. When the washer button is pressed less than 0.5 of a second, the wiper/washer provides one dry wipe or mist. When the washer button is pressed for 0.5 to 1.0 second, the wiper/washer provides three wipes and a wash. When the washer button is held in, the wash cycle will continue until the washer button is released.



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1. Windshield Washer Button
2. Intermittent Wiper Speeds

Fig. 1, Windshield Wiper Switches

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

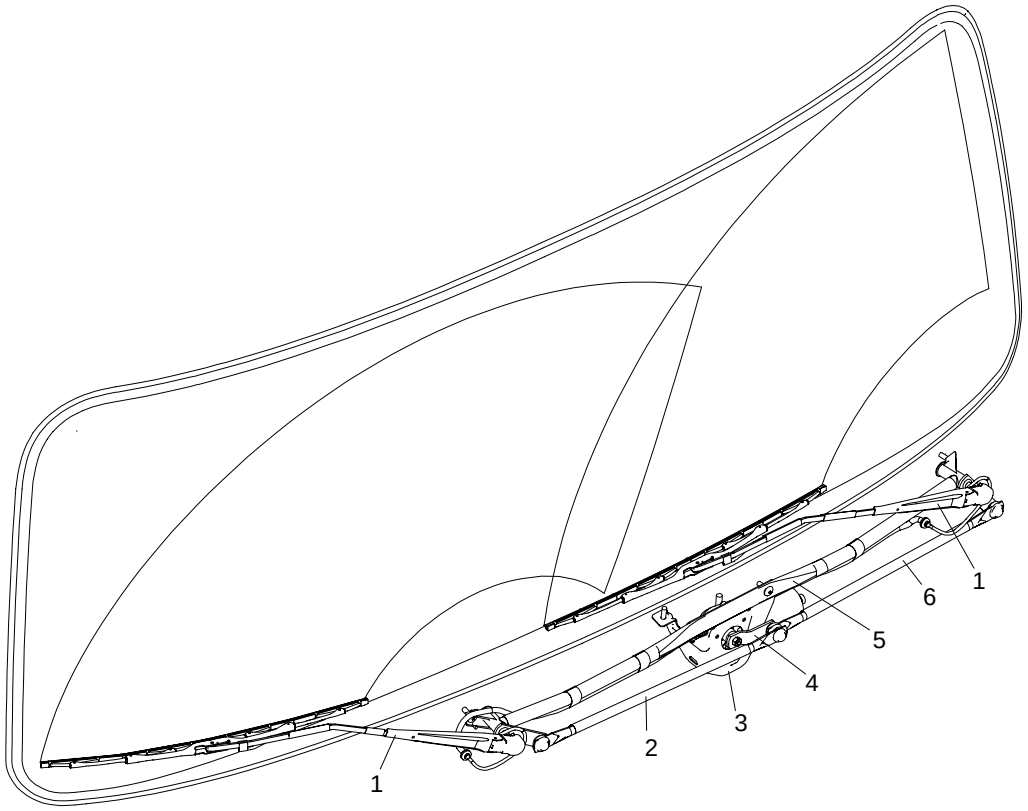
Disconnect the batteries before working on the wiper assembly. This will prevent the windshield wiper motor from cycling. The motor could cycle if the wiper linkage driveshaft is forced out of the parked position, which could result in personal injury.

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. Remove the wiper motor. Refer to **Subject 120** for instructions.
7. Remove the washer fluid supply line and any wiring attached to the unitizing tube.
8. Remove the fasteners that attach the unitizing tube to the cab. See **Fig. 1**.
9. Remove the unitizing tube.
10. Use fasteners to attach the unitizing tube to the cab.
11. Install the wiper motor. Refer to **Subject 120** for instructions.
12. Attach the washer fluid line and any loose wiring to the unitizing tube.
13. Attach the wiper arms to the wiper pivot shafts.
14. Connect the batteries.
15. Lower the hood.
16. Remove the chocks from the tires.

Unitizing Tube Replacement



10/02/2001 f820380

1. Wiper Arm
2. Right-Side Connecting Arm
3. Wiper Motor
4. Motor Lever
5. Unitizing Tube
6. Left-Side Connecting Arm

Fig. 1, Wiper Assembly

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.

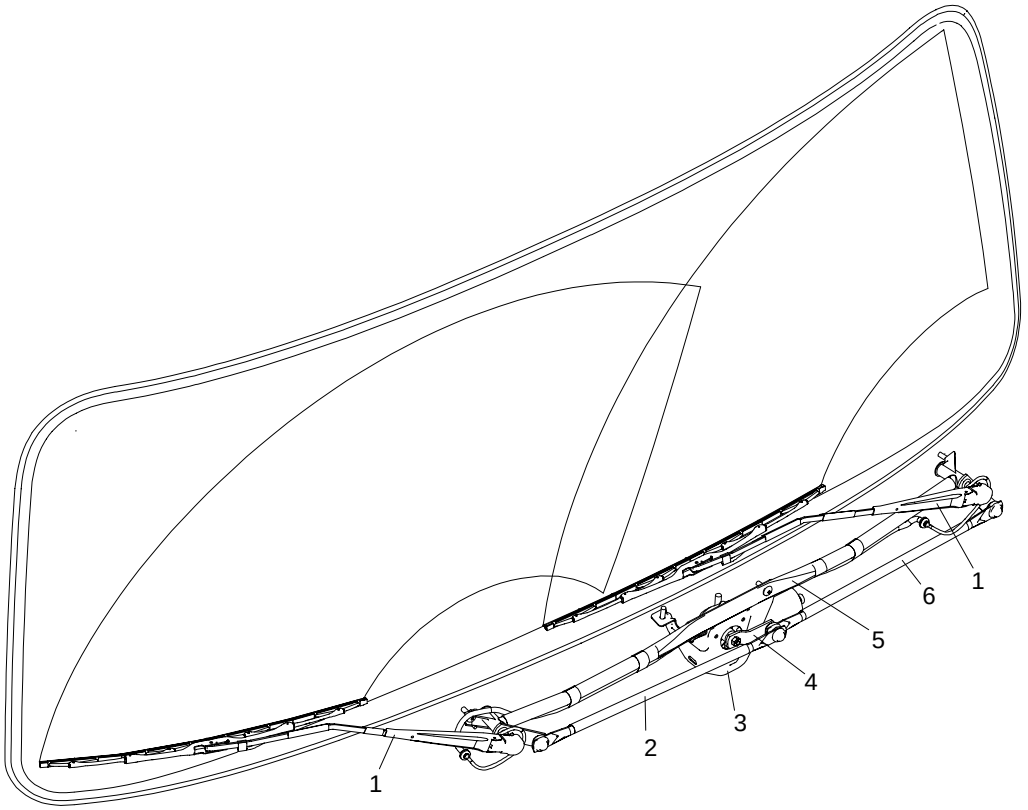
NOTE: If the connecting arms need to be replaced, the unitizing tube must be replaced as well.

4. Remove the connecting arm from the pivot ball studs, as follows. See **Fig. 1**.

   4.1 Mark the left and right connecting arms so that they are positioned properly when reinstalled.

   NOTE: Use care when inserting the screwdriver in between the linkage arms on the double ball stud to avoid damaging the rubber seal.

   4.2 Use a screwdriver to pry the right outer linkage arm off of the double ball stud.



10/02/2001 f820380

1. Wiper Arm
2. Right-Side Connecting Arm
3. Wiper Motor
4. Motor Lever
5. Unitizing Tube
6. Left-Side Connecting Arm

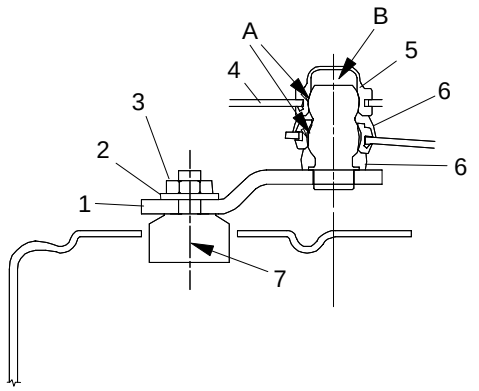
Fig. 1, Wiper Assembly

Connecting Arm Replacement

4.3 Rotate the arm towards the front of the vehicle to release the arm from the end of the ball stud.

4.4 Repeat the procedure for the left outer linkage arm.

5. Use grease to lubricate the inner diameter of the open socket on the connecting arm. See **Fig. 2**.



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A. Grease the inner diameter of the open socket before assembly.
B. Fill the ball stud and socket interface with grease.

1. Motor Lever
2. Lockwasher
3. Nut
4. Connecting Arm
5. Double Ball Stud
6. Seal
7. Centerline of Motor Output Shaft

Fig. 2, Wiper Motor Output Shaft Detail

6. Fill the ball stud and socket interface with grease.
7. Install the right and left connecting arms on the pivot ball studs, as follows.

7.1 Seat the closed end of the connecting arms onto the ball studs with a pair of adjustable pliers.

7.2 Seat the connector arm with the open-ended socket on the double ball stud.

7.3 Place the rubber seal on the double ball socket.

7.4 Seat the connector arm with the closed-end socket on the double ball stud.

8. Lower the hood.
9. Connect the batteries.
10. Remove the chocks from the tires.

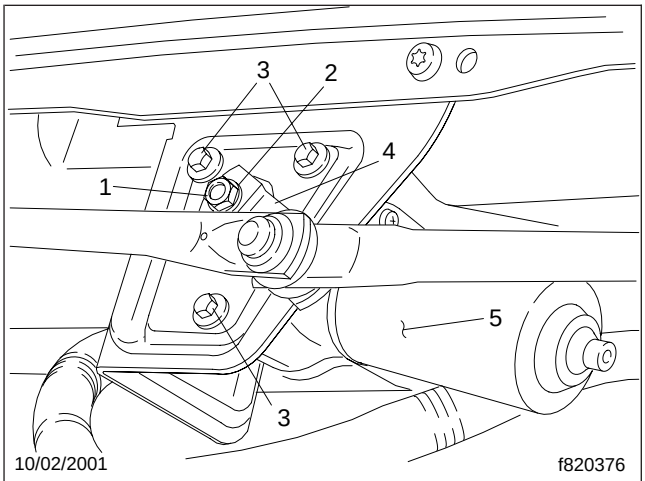
Replacement

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.
5. 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

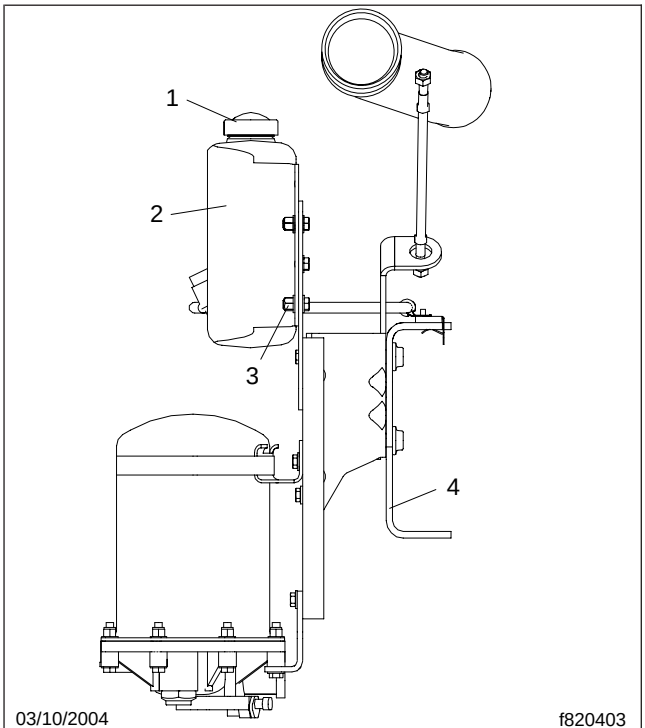
Fig. 1, Wiper Motor Assembly

6. Remove the capscrews that attach the wiper motor to the mounting bracket.
7. Disconnect the wiring harness from the wiper motor. Remove the wiper motor.
8. Connect the wiring harness to the new wiper motor.
9. Using capscrews, attach the wiper motor to the mounting bracket.
10. Using a nut and lockwasher, attach the motor lever to the wiper motor. Tighten the nut 9 to 12 lbf·ft (12 to 16 N·m).
11. Connect the batteries.
12. Lower the hood.
13. Remove the chocks from the tires.

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, as follows. See **Fig. 1**.



1. Washer Reservoir Cap
2. Washer Reservoir
3. Mounting Bolts
4. Frame Rail

Fig. 1, Washer Reservoir Assembly

4.1 Remove the washer reservoir cap.

4.2 Place a container under the washer reservoir.

4.3 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 pump from the washer reservoir.
7. Remove the bolts, washers, and nuts that hold the washer reservoir to the washer bottle bracket.
8. Position the reservoir on the washer bottle bracket and install the bolts, washers, and nuts. Tighten the bolts securely.
9. Attach the pump to the new washer reservoir.
10. Attach the washer fluid line to the washer reservoir.
11. Attach the wiring harness to the pump.
12. Fill the new reservoir with washer fluid. Install the washer reservoir cap.
13. Lower the hood.
14. Connect the batteries.
15. Remove the chocks from the tires.

General Information

The Blend Air heating, ventilating, and air conditioning (HVAC) system uses a brushless blower motor. The rate of airflow is controlled by an eight-speed fan switch. Air outlets are located in the instrument panel, along the bottom of the dash, at the windshield, and at the side windows.

The temperature in the driver's area can be controlled by the temperature control switch on the climate control panel.

The air selection switch on the control panel is used to select the direction of warm or cool air through the driver's area.

On vehicles with air conditioning, a recirculation button on the control panel allows the driver to recirculate the air in the driver's area and prevent fresh or outside air from entering the system. Press the recirculation button to start the recirculation mode. After 20 minutes in recirculation mode, the system will go in to partial recirculation mode. 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 full or partial recirculation mode, the recirculation mode will be canceled. The driver may notice a slight change in the sound within the vehicle as the system goes in to and out of partial recirculation mode. The change in the sound is normal.

Description of Components

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.

The climate control panel is controlled by a microprocessor and backlit with LEDs (light-emitting diodes).

Refrigerant

Refrigerant absorbs heat from the air in the vehicle and releases it to the air outside the vehicle.

In an open container, refrigerants boil at temperatures below the freezing point of water. Sealing and pressurizing refrigerant in the air conditioning system raises its boiling-point temperature.

During compressor operation, refrigerant constantly changes from a liquid to a gas. It absorbs heat (boiling) in the low-pressure evaporator and it changes from a gas to a liquid as it releases absorbed heat in the high-pressure condenser.

Expansion Valve

The expansion valve is a dividing point between the high- and low-pressure parts of the refrigerant system. High-pressure liquid refrigerant from the condenser passes through the expansion valve and moves into the low-pressure area of the evaporator.

An expansion valve controls the flow rate of refrigerant in proportion 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 diaphragm in the expansion valve to react, which causes an orifice in the valve to open or close. Through the orifice, liquid refrigerant is metered into the evaporator as needed.

Evaporator

Because the evaporator is an area of low pressure in the system, the boiling point of refrigerant lowers, which causes it to absorb heat from the tubing walls and fins. As it absorbs heat, liquid refrigerant quickly boils and turns into a gas.

As heat is absorbed from 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; the air becomes dehumidified.

Refrigerant Compressor

Heat in the low-pressure gas of the evaporator is not heat that can be noticed by 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 evaporator is very cold.

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.

General Information

Another function of the compressor is to move refrigerant through the system.

Condenser

A condenser turns hot refrigerant gas coming from the compressor into liquid. The condenser is mounted below the radiator. Because of its location, the condenser transfers heat to air that is drawn in by the engine fan and by air that is forced into the engine compartment as the vehicle moves forward.

Receiver-Drier

Used as a reservoir and filter for liquid refrigerant from the condenser, a receiver-drier also removes water and acids from the refrigerant. The water-absorbing material, or desiccant, in the unit helps stop blockages from forming in the expansion valve and in other parts of the system.

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).

Actuator

The actuator is a combined motor and gearbox and is used to drive 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.

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 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 ±69 kPa). The fan turns off when the pressure drops below 250 ±10 psi (1725 ±69 kPa).

Binary Switch

The binary switch disengages the refrigerant compressor to protect it from harmful operating conditions. It performs two functions:

1. If the refrigerant system pressure is too low, the binary switch will keep the compressor from operating. The switch disengages the compressor when the pressure on the high pressure side of the system falls between 27 to 35 psi (186 to 241 kPa). Normal compressor operation resumes when the rising pressure reaches 28 to 36 psi (193 to 248 kPa) above the shutoff pressure. This occurs when the ambient temperature falls to around 36°F (2°C) or when refrigerant has leaked out of the system.

NOTE: Since the binary switch is on the high-pressure side, the compressor may continue to operate (trying to cool the vehicle) if most, but not all, of the refrigerant leaks out of the system until the air conditioner is turned off or the vehicle is shut down for a short time. Continuing to run the compressor with a low charge can lead to a lack of lubrication and high temperatures in the compressor.

2. If the refrigerant system pressure on the high-pressure side increases to between 426.5 to 483.5 psi (2941 to 3334 kPa), the binary switch shuts off the compressor clutch. Too much pressure may be caused by excess refrigerant in the system or anything that causes poor condenser performance such as poor air flow through the condenser. When the system pressure has decreased to 313 to 426 psi (2158 to 2937 kPa), the compressor resumes operation.

Heater Core

When the engine is on, coolant flows through the heater core tubes heating the tubes and fins. The heat is absorbed by air that is forced through the heater core by the blower motor.

Blower Motor

The brushless blower motor forces air through the HVAC assembly and through the ductwork.

Definition of Terms

Refer to the following terms for a better understanding of the heater and air-conditioning system.

Actuator The actuator is a combined motor and gearbox used to drive the temperature blend, recirculation, and air distribution levers and doors within the HVAC assembly.

Air Conditioner A system used to control the temperature, humidity, and movement of air in the driver's area.

Ambient Air Temperature The temperature of air around an object or the outside temperature.

Binary Switch Disengages the refrigerant compressor to protect it from harmful operating conditions.

Blower Motor A brushless blower motor forces air through the HVAC assembly and through the duct work.

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 in the air conditioning system.

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 the refrigerant, changing it from a high-pressure hot gas to a high-pressure warm liquid.

Condensing Pressure Pressure as read from the gauge at the discharge service valve. Pressure from the discharge side of the compressor into the condenser.

Contaminants Anything other than refrigerant or refrigerant oil in the system. Usually means water in the system. When water and refrigerant mix, corrosive hydrochloric acid forms.

Cycling Clutch System A system which controls compressor clutch operation in order to raise or lower the temperature in the cab.

Dehumidify To remove water from the air at the evaporator.

Dehydrate To remove all traces of moisture from the refrigerant system. Normally called evacuation.

Desiccant A drying agent used in the receiver-drier to remove water and create an extremely dry condition.

Discharge Line Connects the refrigerant compressor outlet to the condenser inlet.

Discharge Pressure High-side pressure or condensing pressure being discharged from the compressor.

Drive Pulley A V-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 area to another.

Evacuate To place a high vacuum in the air-conditioning system and dehydrate or remove all traces of moisture.

Evaporate To change 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. It also removes some moisture from the air.

Expansion Valve A device that causes a pressure-drop of the refrigerant and also regulates its flow.

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 grit.

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 in which hot engine coolant flows to provide heat to the driver's area or to adjust the temperature produced by the air conditioner.

High-Side Service Valve A device located on the liquid line. It allows high-side pressure to be checked and other service operations to be performed.

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.

General Information

Liquid Pressure Pressure of refrigerant in the liquid line from the receiver-drier to the thermostatic expansion valve.

Low-Air Pressure Switch An air-operated electrical switch that is normally open, but closes when the system pressure rises to 65 to 75 psi (450 to 515 kPa). Its purpose is to prevent the refrigerant compressor from turning on if the air system pressure is too low to activate the cooling fan.

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 A device 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. The unit of measure used to measure vacuum drawn from a refrigerant system by a vacuum pump.

Nitrogen A colorless, odorless, dry, inert gas.

Opacity A condition that is used to describe 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.

psia Pounds per square inch atmospheric pressure. Pressure exerted by the air at sea level. Atmospheric pressure is usually measured with a mercury barometer.

psig Pounds per square inch gauge pressure. Any pressure above normal atmospheric pressure (14.7 psi) is referred to as gauge pressure.

Receiver-Drier A combination desiccant, filter, and storage container for liquid refrigerant.

Recovery Removal of the refrigerant from air conditioning systems.

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. Another purpose of the compressor is to move refrigerant through the system.

Refrigerant Oil A highly refined synthetic oil used in R–134a air conditioning systems.

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 vapor the air can hold at a given temperature.

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.

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, internal system vacuum levels 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.

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 place 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 is always directed through the evaporator. If the refrigerant compressor is engaged, the air is cooled. 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 achieve the selected temperature. The temperature blend, air distribution, and recirculation levers and doors are controlled by actuators.

Heater

Moving the temperature control switch toward maximum heat allows more airflow through the heater core fins.

Air Conditioner

When the air conditioner is on, the motion of 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 moves 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 and causes it to change into 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 driver's area 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.

R–134a refrigerant 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 (38 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

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the air cleaner. For instructions, see **Section 09.01, Subject 110**.
4. Remove the surge tank. For instructions, see **Section 20.01, Subject 130**.

IMPORTANT: If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

5. Remove the Torx® capscrew that attaches the coolant lines to the heater core. Remove the coolant lines from the heater core.
6. Remove the following dash panels inside the vehicle. See **Fig. 1**. For instructions, see **Section 75.01**.
   - lower HVAC cover
   - trim plate panel
   - lower dash panel
   - end cap
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.

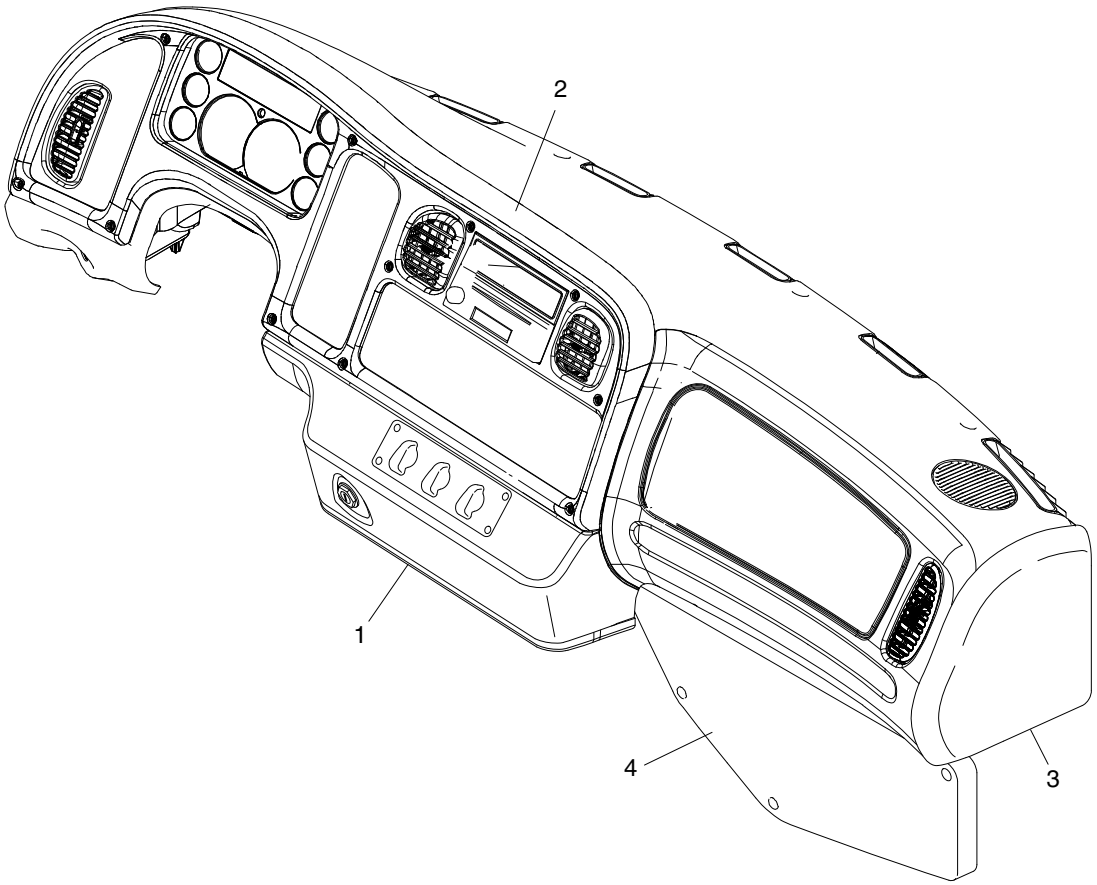
⚠ WARNING

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.

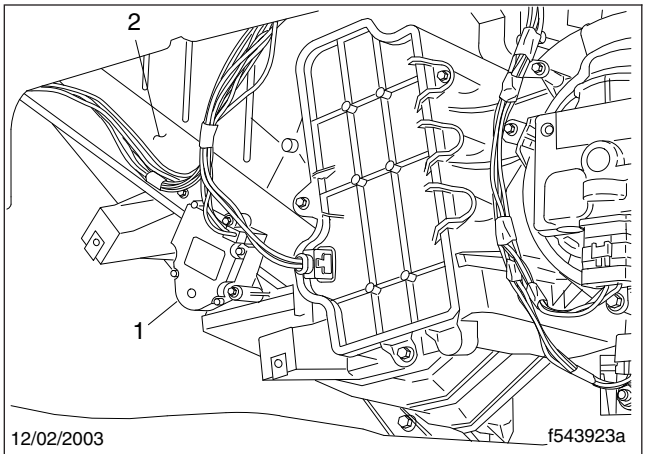
10. Wearing protective gloves, remove the heater core and drain any remaining coolant from the heater core.
11. Remove any debris or coolant that may be in the heater core housing.
12. Wearing protective gloves, install a new heater core in the HVAC assembly.
13. Using a Torx capscrew, attach the coolant lines to the heater core.
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 75.01**.
18. Install the surge tank. For instructions, see **Section 20.01, Subject 130**.
19. Install the air cleaner. For instructions, see **Section 09.01, Subject 110**.
20. Connect the batteries.
21. Fill the engine cooling system with the heater valves closed.
22. If the heater circuit was drained, open only the supply valve and the heater circuit vent, near the return valve, to bleed air from the heaters without sending it through the engine. If the heater circuit was not drained, open both valves.
23. Turn the ignition ON and set the heater control to hot; do not start the engine. If so equipped, turn the heater circuit booster pump on.
24. Start the engine and maintain the coolant level in the surge tank, filling to the full mark as needed.
25. If bleeding air from the heaters, close the vent when coolant is present and open the return valve.
26. Continue running the engine until the thermostat opens, then shut down the engine.
27. Once the engine has cooled, top off the coolant to the full mark and reinstall the radiator cap.
28. Bleed the cooling system.

Heater Core Replacement



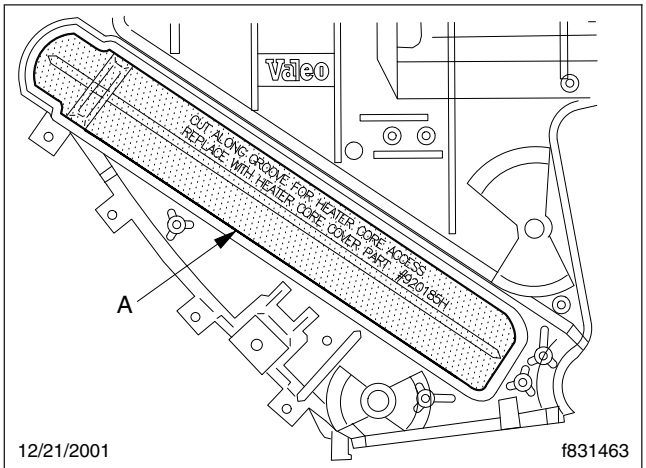
1. Lower Dash Panel
2. Trim Plate Panel
3. End Cap
4. Lower HVAC Cover

Fig. 1, Dash Panels



1. Temperature Blend Actuator
2. Heater Core Service Cover

Fig. 2, HVAC Assembly



A. Cut within the groove on the heater core access panel.

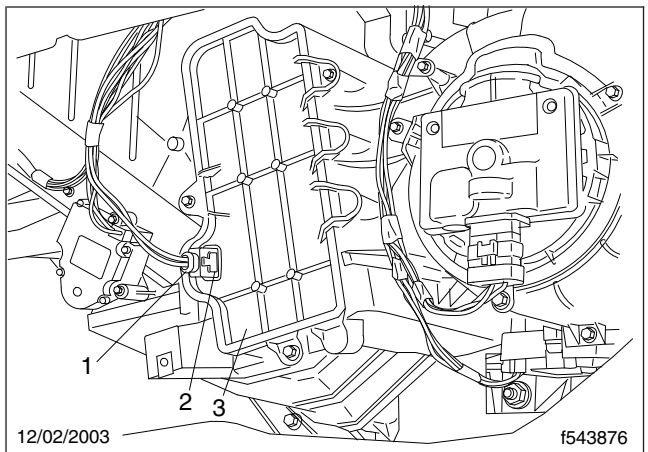
Fig. 3, Heater Core Access Panel

Replacement

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

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 vehicle. For instructions, see **Group 75**.
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.
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. Torque the capscrews 35 lbf·in (395 N·cm).
17. Install the evaporator in the HVAC assembly.



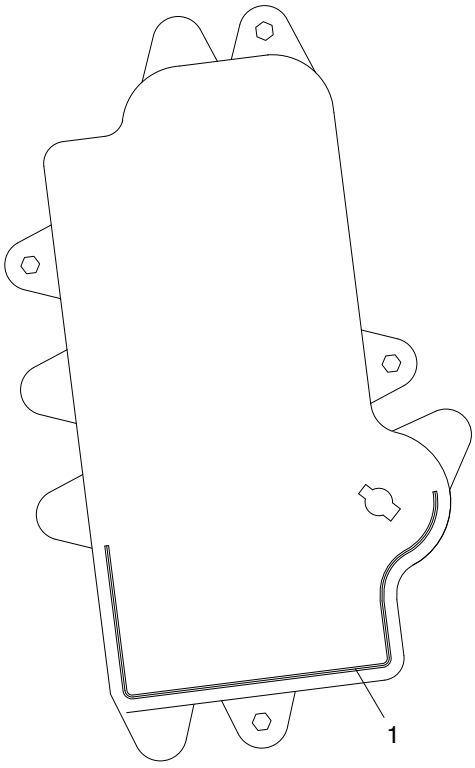
1. Evaporator Probe Wiring Harness
2. Evaporator Probe
3. Evaporator Service Cover

Fig. 1, Evaporator Probe and Service Cover

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. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 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**.
23. Install the evaporator probe in the evaporator service cover.
24. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 75**.
25. Install the surge tank. For instructions, see **Section 20.01, Subject 130**.
26. Install the air cleaner. For instructions, see **Section 09.01, Subject 110**.

Evaporator Replacement

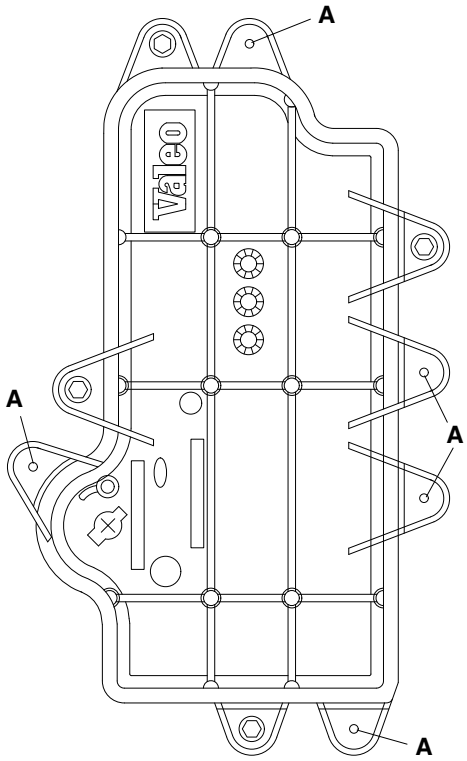


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1. Condensate Seal

Fig. 2, Evaporator Service Cover

27. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**. 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.
29. Remove the chocks from the tires.



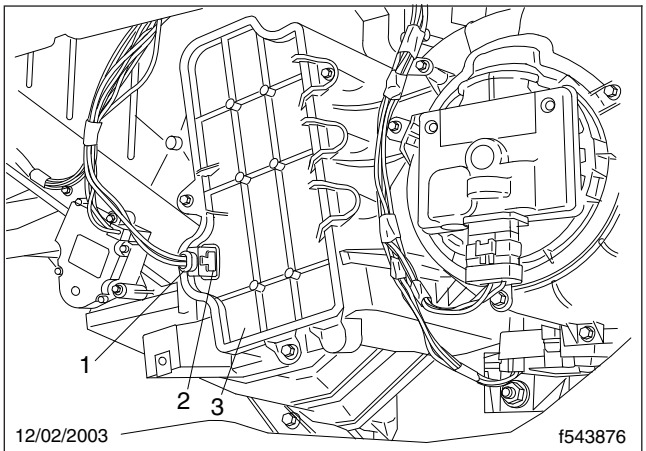
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A. Drill a tapped hole in any of these alternative mounting locations.

Fig. 3, Evaporator Service Cover

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 75**.
3. Press the metal retainer on the wiring harness connector to disconnect the wiring harness from the evaporator probe. See **Fig. 1**.



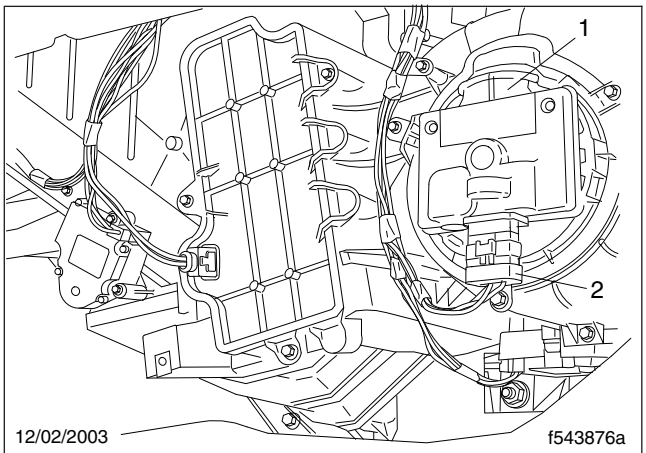
1. Evaporator Probe Wiring Harness Connector
2. Evaporator Probe
3. Evaporator Service Cover

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 75**.
8. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Disconnect the batteries.
3. Remove the lower HVAC cover. For instructions, see **Group 75**.
4. Disconnect the wiring harness from the blower motor. See **Fig. 1**.



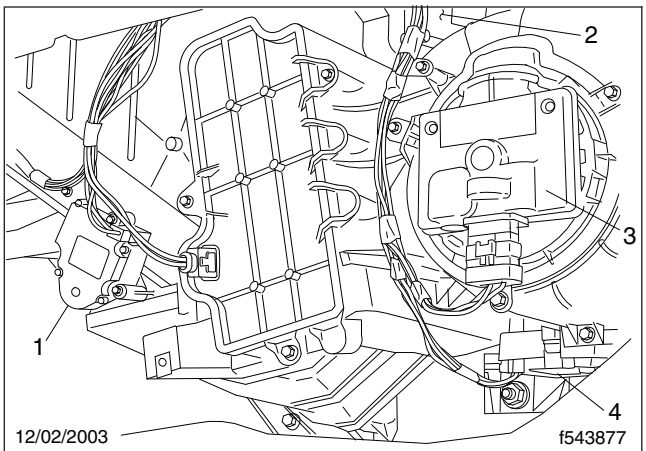
1. Blower Motor
2. Blower Motor Wiring Harness

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 75**.
9. Connect the batteries.
10. Remove the chocks from the tires.

Temperature Blend Actuator Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 75**.
3. Disconnect the wiring harness from the temperature blend actuator. See **Fig. 1**.



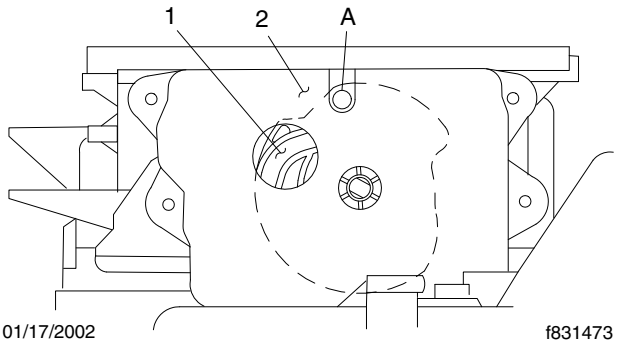
1. Temperature Blend Actuator
2. Air Distribution Actuator
3. Blower Motor
4. Recirculation Actuator

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 75**.
8. Remove the chocks from the tires.

Air Distribution Actuator Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 75**.
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 75**.
9. Remove the chocks from the tires.

Actuator Replacement

Recirculation Actuator Replacement

NOTE: The recirculation actuator is equipped only on vehicles with air conditioning.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the lower HVAC cover. For instructions, see **Group 75**.
3. Disconnect the wiring harness from the recirculation actuator. See **Fig. 1**.
4. Remove the capscrews that attach the actuator to the HVAC assembly and remove the actuator.
5. Using capscrews, install the actuator on the HVAC assembly. Make sure that the actuator is correctly aligned on the door extension.
6. Attach the wiring harness to the recirculation actuator.
7. Attach the lower HVAC cover to the dash panel. For instructions, see **Group 75**.
8. Remove the chocks from the tires.

Heater and Air Conditioner Assembly or Heater Assembly Replacement

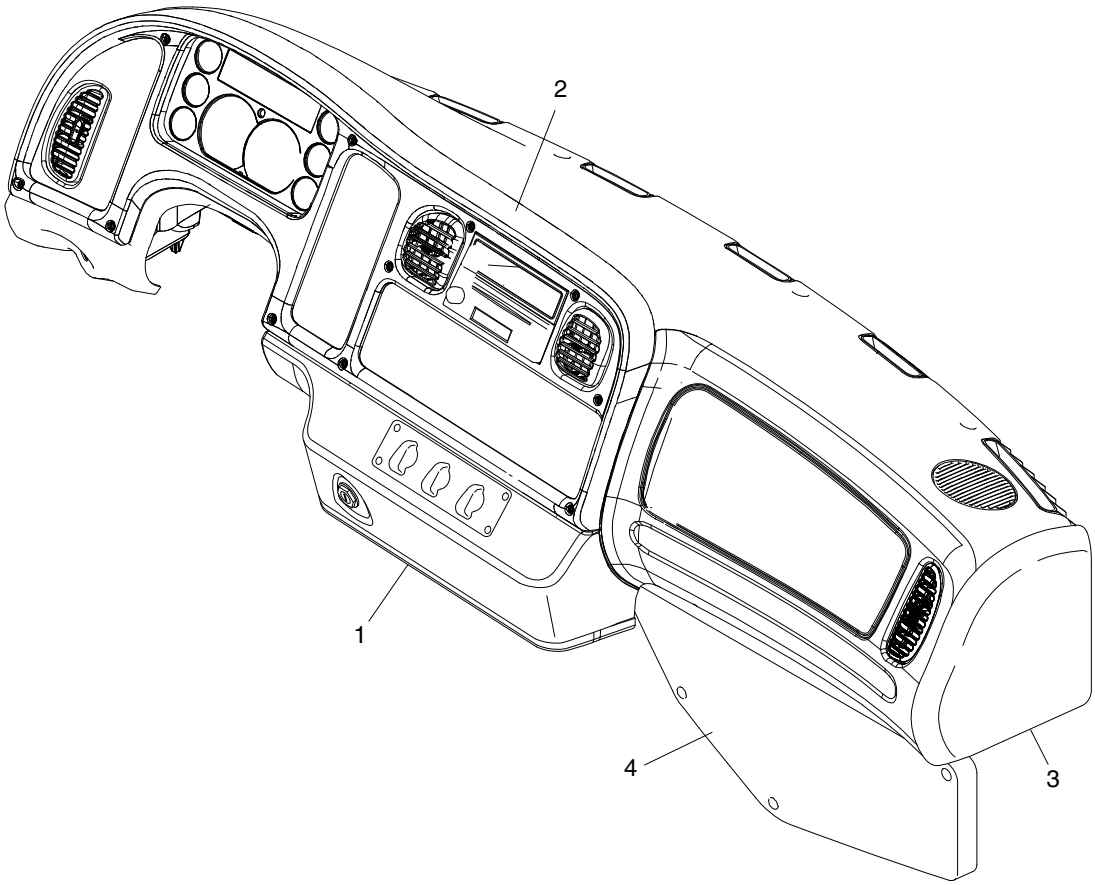
Replacement

1. Turn off the engine, apply the parking 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**.
5. If equipped with an air conditioner, recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**, in this section.
6. Remove the Torx® capscrew that attaches the coolant lines 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 vehicle. See **Fig. 1**. For instructions, see **Section 75.01**.
    - lower HVAC cover
    - trim plate panel
    - lower dash panel
    - end cap
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.
11. Using capscrews, nuts, and washers, attach the new heater and air conditioner assembly or heater assembly to the dash and frontwall. Torque the capscrews 72 to 96 lbf·in (810 to 1080 N·cm). Torque the nuts 18 to 19 lbf·ft (24 to 26 N·m).
12. Connect the two HVAC wiring harnesses.
13. 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.
14. Using a capscrew, attach the refrigerant lines to the expansion valve. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
15. Using a Torx capscrew, attach the coolant lines to the heater core.
16. Install the dash panels. For instructions, see **Section 75.01**.
17. Install the surge tank. For instructions, see **Section 20.01, Subject 130**.
18. Install the air cleaner. For instructions, see **Section 09.01, Subject 110**.
19. Connect the batteries.
20. Remove the chocks from the tires.

Heater and Air Conditioner Assembly or Heater Assembly Replacement



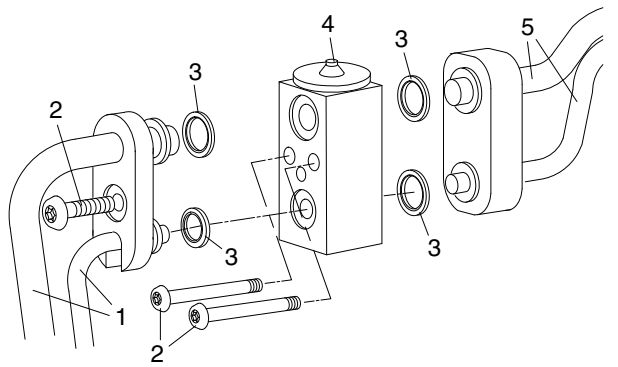
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1. Lower Dash Panel
2. Trim Plate Panel
3. End Cap
4. Lower HVAC Cover

Fig. 1, Dash Panels

Replacement

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

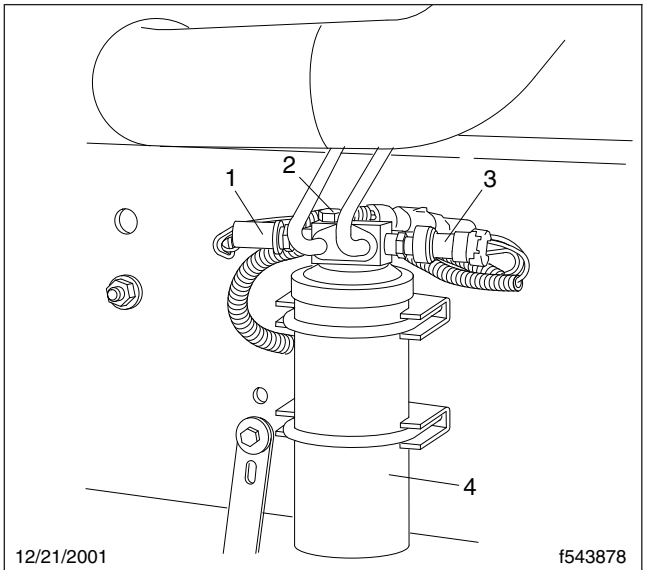
Fig. 1, Expansion Valve

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. Torque 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. Torque the capscrew on the retaining plate 11 to 15 lbf·ft (15 to 20 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**.
16. 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**.
17. Return the hood to the operating position.
18. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Recover the refrigerant from the air conditioning system. For instructions, see **Subject 220**.
4. Disconnect the wiring harness from the fan cycling switch and disconnect the wiring harness from the binary switch. See **Fig. 1**.



1. Fan Cycling Switch
2. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

5. Remove the fan cycling switch and the binary switch from the receiver-drier.
6. Disconnect the refrigerant lines from the receiver-drier. 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).

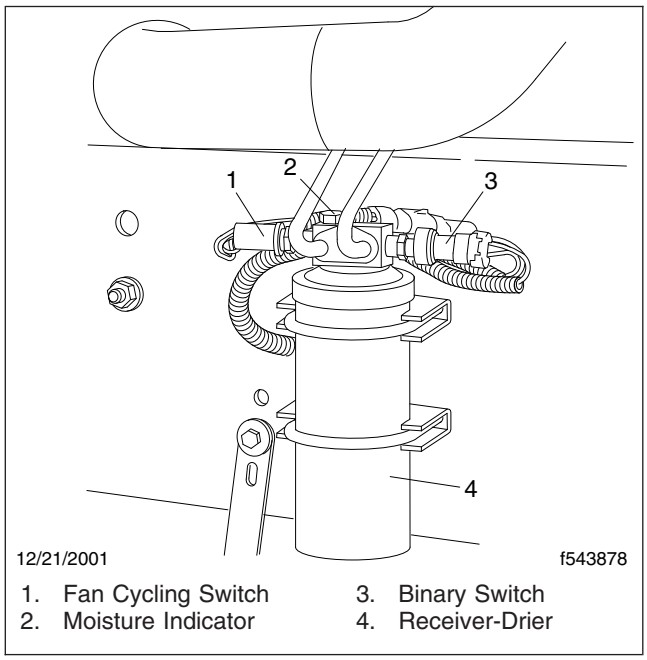
7. Remove the nuts and washers that attach the U-bolts and mounting brackets to the frame rail. Remove the receiver-drier.

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.

8. Using U-bolts, mounting brackets, nuts, and washers, install a new receiver-drier on the frame rail.
9. Uncap the refrigerant lines.
10. Using only Mini Stat-O-Seals, replace the Mini Stat-O-Seals on the refrigerant lines. Do not lubricate Mini Stat-O-Seals prior to installation.
11. Connect the refrigerant lines to the receiver-drier. Torque the bolt on the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
12. Attach the fan cycling switch and the binary switch to the receiver-drier.
13. Attach the fan cycling wiring harness to the fan cycling switch and attach the binary switch wiring harness to the binary switch.
14. Evacuate and charge the air conditioning system with refrigerant. For instructions, see **Subject 220**.
15. 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**.
16. Return the hood to the operating position.
17. Remove the chocks from the tires.

Replacement

1. Turn off the engine, apply the parking 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. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

4. Remove the binary switch.
5. Install a new binary switch on the receiver-drier.
6. Connect the wiring harness to the binary switch.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Climate Control Panel Replacement

Replacement

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Remove the capscrews that attach the climate control panel to the lower dash panel. Pull the control panel away from the lower dash 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 lower dash panel.
6. Remove the chocks from the tires.

Recovery

⚠ WARNING

Before doing any of the work below, read the information in 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.

The recovery process removes most of the refrigerant charge in the system.

1. Turn off the engine, apply the parking brakes, and chock the tires.
2. Open the hood.
3. Remove the caps from the suction and discharge service valves.
4. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery/charge station hoses to the valves, as follows.

   IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

   4.1 Make sure that the refrigerant recovery/charge station valves are closed.

   4.2 Connect the red high-side hose to the discharge service valve.

   4.3 Connect the blue low-side hose to the suction service valve.

   4.4 Turn the knob clockwise on each coupler to open the Schrader valves.
5. Follow the refrigerant recovery/charge station manufacturer's instructions and recover all of the refrigerant from the system.

IMPORTANT: Always comply with all local regulations regarding refrigerant disposal. You may be subject to substantial penalties for improper disposal.

6. Measure the oil recovered during this procedure. The compressor will have to be refilled 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.
7. Return the hood to the operating position.

Evacuating (recycling)

Moisture in a Refrigerant System

Water forms ice crystals at the thermostatic expansion valve. Ice crystals retard or stop the flow of refrigerant, causing a reduction or complete loss of cooling. As the expansion valve warms due to the lack of refrigerant, the ice melts and passes through the expansion valve. Then refrigerant will flow again until the ice crystals re-form. The result is intermittent cooling.

Refrigerant oil has an extremely high moisture absorption capacity. This reduces the lubricating ability of the oil, which could damage the compressor and other system components.

Effects of Pressure on the Boiling Point of Water

Water boils at 212°F (100°C) at an atmospheric pressure of 14.7 psi (101 kPa) (sea level). At higher elevations the atmospheric pressure is lower, which allows water to boil at lower temperatures. See **Table 1** for boiling temperatures of water at converted pressures.

Similarly we 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 the lowest at the pump, water vapor is pulled out of the system. See **Fig. 1**. This process is called evacuation or dehydration. Also, most refrigerant recovery/charge stations automatically recycle refrigerant during this process to ensure the system will be charged with the cleanest refrigerant possible.

Boiling Temperatures of Water at Converted Pressures		
Boiling Temperature of Water: °F (°C)	**Absolute Pressure: psi (microns Hg)**	**Vacuum: inHg (mmHg)**
212 (100)	14.696 (759993.4)	0 (0)
205 (96)	12.770 (660400.0)	3.92 (99.6)
194 (90)	10.169 (523881.6)	9.22 (234.2)
176 (80)	6.8699 (355269.8)	15.93 (404.6)
158 (70)	4.5207 (233786.7)	20.72 (526.3)
140 (60)	2.8900 (14958.7)	24.04 (610.6)
122 (50)	1.7987 (92555.1)	26.28 (667.5)
104 (40)	1.0700 (55336.4)	27.74 (704.6)
89 (32)	0.61540 (31826.2)	28.67 (728.2)
86 (30)	0.57010 (26220.4)	28.89 (733.8)
76 (24)	0.44435 (22979.9)	29.02 (737.1)
72 (22)	0.38856 (20094.7)	29.13 (739.9)
69 (21)	0.35084 (18143.7)	29.21 (741.9)
64 (18)	0.29505 (15258.5)	29.32 (744.7)
59 (15)	0.24720 (12783.8)	29.42 (747.3)
53 (12)	0.19888 (10285.0)	29.52 (749.8)
45 (7)	0.14746 (7625.8)	29.62 (752.3)
32 (0)	0.08858 (4579.6)	29.74 (755.4)
21 (–6)	0.05293 (2738.1)	29.81 (757.2)
6 (–14)	0.02521 (1304.0)	29.87 (758.7)
–24 (–31)	0.004905 (253.7)	29.911 (759.74)
–35 (–37)	0.002544 (131.6)	29.915 (759.84)
–60 (–51)	0.0004972 (25.7)	29.9200 (759.968)
–70 (–57)	0.0002443 (12.69)	29.92050 (759.9807)
–90 (–68)	0.0000526 (2.72)	29.92089 (759.9906)

Table 1, Boiling Temperatures of Water at Converted Pressures

Vacuum Pump Selection

The purpose of a high-vacuum pump is to reduce and hold a vacuum in the air conditioning system so moisture can be boiled at ambient temperature. For example, a vacuum pump capable of pulling a vacuum of 28.89 inHg (734 mmHg) is able to boil water at 86°F (30°C). There are various types of vacuum pumps available. Only some types are recommended for truck air conditioning evacuation.

Air pump-type vacuum pumps are designed to remove large volumes of air but do not develop high vacuum. They cannot pull more than 28 inHg (711 mmHg) which boils water at 100°F (38°C).

Compressor-type vacuum pumps come in two designs: piston-type and rotary-vane type. A piston-type compressor can typically pull a vacuum of 28.2 inHg (716 mmHg) which boils water at 96°F (36°C). A rotary-vane type compressor may pull a vacuum of 29.82 inHg (757 mmHg) which boils water at 21°F

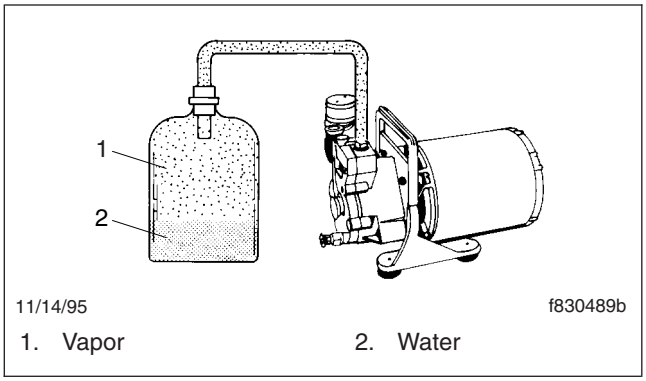


Fig. 1, Water to Vapor

(–6°C), but it is limited to pumping 0.4 to 0.8 cfm, which is too slow to handle truck air conditioners.

High-vacuum pumps are available in single-stage and two-stage models. A single-stage pump is adequate, but a two-stage pump is recommended to save time and assure complete evacuation. See **Fig. 2**.

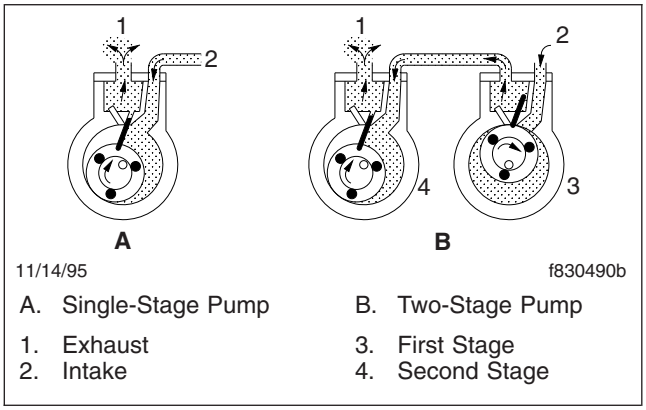


Fig. 2, Single- and Two-Stage Vacuum Pumps

Most single-stage high-vacuum pumps with a gas ballast will pull down to about 29.88 inHg (758.95 mmHg) which boils water at 4°F (–16°C).

A two-stage high-vacuum pump features a second pump to reach a higher vacuum than a single-stage pump. In a two-stage pump, the exhaust of the first pump discharges into the intake of the second pump. The second stage pumps at a lower pressure and therefore pulls a higher vacuum on the system than the first pump can by itself.

Two stage high-vacuum pumps are capable of pulling down to 29.9192 inHg (759.95 mmHg) of vacuum for prolonged periods, which boils water at –60°F (–51°C).

The discharge line restriction is a factor affecting pump-down time. Pump-down time can be significantly reduced by use of larger diameter hoses, as short in length as possible.

Pumping capacity affects pump-down time. It is perfectly acceptable to use a large vacuum pump on a small system. Using too small of a pump on a large system could cause premature pump wear or require excessive time to pull a vacuum, even though the pump may be able to draw adequate vacuum.

The suggested minimum cfm for pumps on different size air conditioners are listed in **Table 2**.

Minimum CFM for Pumps on Different Size Air Conditioners	
System Size	**Suggested High-Vacuum Pump Size**
Panel Trucks Large Window Units	2.2 cfm
Tractor/Trailers, Buses Rooftop A/C Systems	3.0 cfm
Refrigeration Van	15.0 cfm

Table 2, Minimum CFM for Pumps on Different Size Air Conditioners

Measuring Vacuum

Gauges

Vacuum can be measured with:

- A standard compound gauge;
- A closed-end manometer;
- An electronic thermistor vacuum gauge.

A standard compound gauge reads low pressures in inches of mercury. It is not suitable for measuring high vacuum.

A closed-end U-tube mercury manometer can be read with good accuracy. High vacuum readings can only be read from laboratory-style U-tube manometers, which are not practical for service shops.

An electronic thermistor vacuum gauge is designed for use with high vacuum pumps and can accurately

read as low as 100 microns. This gauge can use an analog scale or a digital (LED) display.

Procedure

The location of the vacuum gauge will affect the reading. The closer to the vacuum source, the lower will be the reading.

Isolate the vacuum pump with a good vacuum valve and allow the pressure in the system to stabilize before taking a final reading.

If the pressure will not stabilize, it is an indication of a leak. If it does stabilize at a vacuum which is too high (for example, 1500 microns Hg), it is an indication of moisture and more evacuation is required.

Maintaining the Vacuum Pump

Maintenance is important for high-vacuum pumps. The oil must be changed at regular intervals to prevent moisture buildup which will cause eventual pump failure.

Pumping down for extremely wet air conditioning systems can completely saturate the pump oil.

⚠ CAUTION

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.

Vacuum pump oil is water soluble. This aids the pump in reaching a high vacuum by absorbing water and sealing the pump.

Only vacuum pump oil should be used 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 must have been recovered and the compressor filled with the correct amount of refrigerant oil. Replace the receiver-drier if the system is opened.
2. Wearing protective goggles and nonleather gloves, attach the refrigerant recovery/charge station hoses to the valves, as follows.

   IMPORTANT: Push down firmly on the hose connectors until a clicking sound is heard. This will ensure that the coupler is locked.

   2.1 Make sure that the refrigerant recovery/charge station valves are closed.

   2.2 Connect the red high-side hose to the discharge service valve.

   2.3 Connect the blue low-side hose to the suction service valve.

   2.4 Turn the knob clockwise on each coupler to open the Schrader valves.
3. Follow the refrigerant recovery/charge station manufacturer's instructions and evacuate/recycle the refrigerant system.

Flushing

⚠ WARNING

Before doing any of the work below, read the information in 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.

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.

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 change the oil in the compressor, and replace 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 inspect the compressor.

Do not flush the receiver-drier or the compressor.

Flush the system in segments to lessen the chance of blowing deposits against a port.

Flush the system in the opposite direction of refrigerant flow.

Flushing parts with refrigerant, requires a refrigerant recovery and charging machine.

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.

Charging

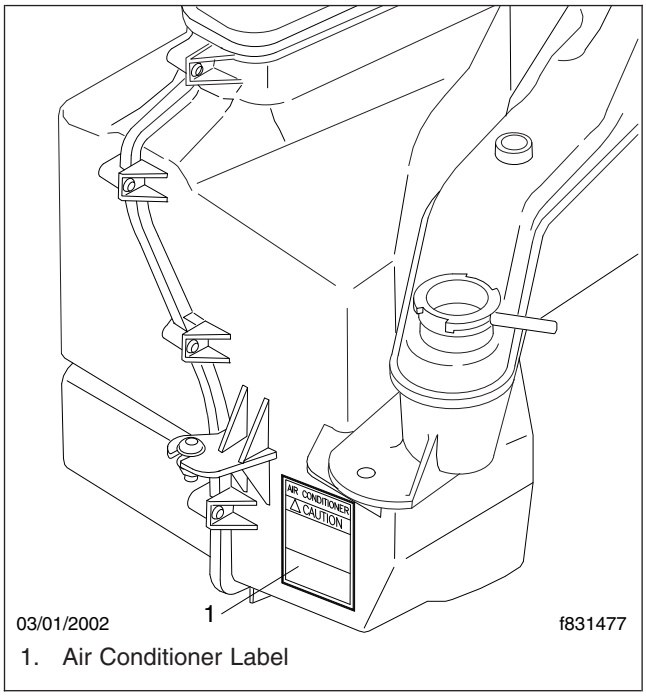
⚠ WARNING

Before doing any of the work below, read the information in 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.

NOTE: Before charging, the system must be recovered and evacuated with the refrigerant recovery/charge station connected to the service and discharge port connections.

1. The amount of refrigerant needed to fully charge the air conditioning system is printed on the "Air Conditioner" label on the air intake plenum located under the hood. See **Fig. 3**.

   Set the tank on a scale and weigh it so that the correct amount of refrigerant enters the system. This prevents overcharging, which could damage the compressor.



1. Air Conditioner Label

Fig. 3, Air Intake Plenum

2. Charge the refrigerant system, as follows.

   NOTE: If equipped with a refrigerant recovery/charge station, charge the system on the high side following the manufacturer's instructions. If charging from a bulk container, do the following.

   2.1 Turn the tank (bulk container) upside down. With the engine off, open the high-side hand valve. **Do not** open the low-side hand valve.

   2.2 Allow refrigerant to enter the system until the correct charge, by weight, has entered. Then close the high-side hand valve.

   2.3 Start the engine and run it at 1500 rpm. Set the cab air conditioner controls at maximum cooling and fan speed. The refrigerant compressor must engage.

   2.4 If a full charge did not enter the system, place the tank (bulk container) in the upright position, then open the low-side valve to draw vapor into the system. Leave the valve open until the correct weight of refrigerant has entered the system, then close the low-side valve.

   NOTE: If refrigerant is slow to enter the system because of low outside temperatures, vaporization can be quickened by placing the refrigerant tank in a tub of warm water no warmer than 125°F (52°C).

3. While the compressor is engaged, check the operating pressures at the suction and discharge ports. If the operating pressures are not acceptable, see **Troubleshooting 300** for possible causes.

4. Disconnect the high-side hose. With the engine running, open the low-side and high-side hose valves to recover the refrigerant from the lines.

5. Shut down the engine.

Leak Testing

General Information

⚠ WARNING

Before doing any of the work below, read the information in 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.

Refrigerant is odorless. As a result, all of it may leak away and not be noticed until the system stops cooling. All vehicle refrigerant systems lose some refrigerant depending on the condition of the system. Higher loss rates signal a need to locate and repair the leaks.

Leaks are most often found at the compressor hose connections and at the various fittings and joints in the system. If unapproved replacement hoses are installed, refrigerant can be lost through hose permeation.

Leak Detection

When checking for leaks, move the probe all the way around the fitting or suspected leak.

NOTE: Do not try to use a leak tester right after connecting or disconnecting service hoses. Traces of refrigerant at the fittings can falsely signal a leak. Always verify a leak by blowing

shop air in to the area of the suspected leak and checking the area again.

Freightliner Trucks recommends using only the Heated Diode type of electronic leak detector. This type of detector can be identified by its construction and power supply. It has a heated element which requires periodic replacement and uses either a 12V DC or 120V AC power supply, or has a rechargeable battery. The Heated Diode type detector is sensitive only to gases containing halogen such as R–134a and R–12 refrigerants. It will not detect other substances and is more likely to detect all of the leaks in a system. This type has both visual and audio indicators and self-tests to confirm operation.

Recommended electronic Heated Diode type leak detectors are available from their manufacturers. See **Table 3**.

Another type of detector, the Corona Discharge type, is the kind most commonly found in service and repair shops. This detector requires very little power and can operate on as few as four AA alkaline batteries. The Corona Discharge detector is not sufficiently sensitive and will create false alarms by detecting moisture and antifreeze or solvent vapors. This type of detector is specifically **not recommended**.

Use the following procedures to locate A/C system refrigerant gas leaks using a heated diode type electronic leak detector.

1. Operate the electronic leak detector in accordance with the manufacturer's instructions.
2. Leak test with the engine turned off.
3. Charge the air conditioning system with sufficient refrigerant to indicate a gauge pressure of at least 50 psi (345 kPa) with the system not operating. It may not be possible to produce this amount of pressure and measure leakage if the ambient temperature is less than 59°F (15°C).
4. Be careful not to contaminate the detector probe tip if the part being tested is not clean. Wipe the part off with a dry shop towel or blow it off with shop air. Do not use cleaners or solvents as many detectors are sensitive to their chemical ingredients.

Electronic Leak Detectors		
Designation	**Manufacturer**	**Comments**
D-TEK	Leybold Inficon 2 Technology Place East Syracuse NY 13057 (315) 434-1144	• Rechargeable battery • Hand-held design • Simple to operate
H–10 Professional	Bacharach Inc. c/o Yokogawa Corp. of America 2 Dart Road Newnan GA 30265 (800) 850-0044	• Rechargeable battery • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Most sensitive available
J 39400	SPX Kent-Moore 28635 Mound Road Warren MI 48092-3499 (800) 328-6657	• 12V DC or 120V AC • Carrying case with strap • Calibration leak bottle • Manual sensitivity control • Manual balance control

Table 3, Electronic Leak Detectors

Refrigerant Service Operations

5. Visually inspect the entire refrigerant system. Look for air conditioning lubricant leakage and corrosion or damage to lines, hoses, and all other components. Inspect each questionable location carefully with the detector probe. Check all fittings, couplings, refrigerant controls, service ports (with caps installed), brazed or welded areas, and areas around attachment points and hold-downs.
6. Follow the path of the refrigerant system methodically so that no leaks are missed. If a leak is found, continue to test the rest of the system.
7. Inspect an area of possible leakage slowly and close to the part, moving completely around the part. Move the probe no faster than one to two inches (25 to 50 mm) per second and no farther away than 1/4 inch (6 mm) from the part.
8. If a large leak is present in either the system being serviced or the service equipment, the surrounding air will be saturated with refrigerant gas. In this situation the leak detector operates erratically and will indicate leakage without being near a possible leak source. Place a large fan so that a light breeze blows through the work area. Verify a leak by blowing shop air into the area and repeating the inspection. Pinpoint a large leak by blowing out the area often.
9. You may test the evaporator core while it is in its housing. Turn on the blower motor for a minimum of 15 seconds. Shut off the blower and wait for refrigerant gas to accumulate in the housing. Follow the detector instructions for the specific length of time to wait for the gas to accumulate. Insert the detector probe into the blower resistor block or condensate drain tube if no water is present. If this is not possible, insert the probe into the closest opening to the evaporator such as a heater or vent duct.

NOTE: The presence of water in the condensate drain tube can be determined by inserting the eraser end of a pencil in the drain tube. Inserting the pencil will break the surface tension of any water near the opening of the drain tube and allow the water to drain out before inserting the probe tip. It is only necessary to break the plane of the drain tube with the probe tip. It doesn't need to be inserted far into the tube.

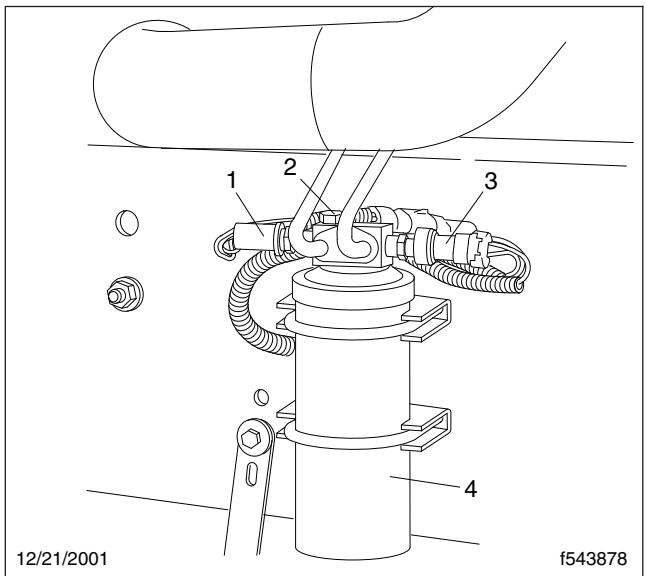
10. Leak test the front seal area of the compressor. Blow shop air into the cavities in and around the clutch for at least 15 seconds. Let the compressor stand for one minute and then test for leakage. Inspect the compressor by placing the probe near the holes at the front of the clutch.

IMPORTANT: Be careful not to damage the clutch bearing seal with high pressure shop air.

11. Leak test repaired areas of the system after repairs have been performed. Leak test the service ports with the caps installed after any service that disturbs the refrigerant system.

Replacement

1. Turn off the engine, apply the parking 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. Moisture Indicator
3. Binary Switch
4. Receiver-Drier

Fig. 1, Receiver-Drier

4. Remove the fan cycling switch.
5. Install a new fan cycling switch on the receiver-drier.
6. Connect the wiring harness to the fan cycling switch.
7. Return the hood to the operating position.
8. Remove the chocks from the tires.

Preliminary Checks

Before testing the operation of the air conditioning system, check the following items:

1. Make sure the drive belt on the refrigerant compressor is not damaged. Make sure the compressor mounting capscrews are tight. The capscrews should be torqued 15 to 19 lbf·ft (20 to 26 N·m).
2. Using a feeler gauge, check the refrigerant compressor for correct clutch clearance. For instructions, see **Section 83.01, Subject 140**.
3. Check for broken or cut hoses. Check for loose fittings on all parts.
4. 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.
5. If there is not enough airflow, make sure that leaves or other debris have not entered the fresh air ports under the windshield. If debris is present, it could clog the air inlet and block airflow. Remove the debris carefully.

   Be sure that all ducts are connected to the dash outlets.

Air Conditioning System Performance Test

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.

1. Park the vehicle out of direct sunlight, shut down the engine, and chock the tires.
2. Open the hood.
3. Record the ambient temperature and the relative humidity in **Table 1**.

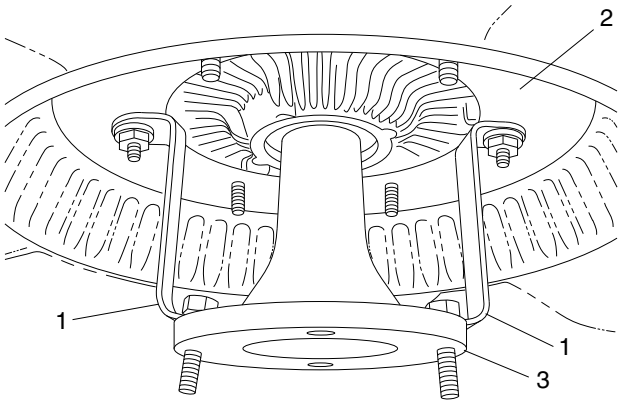
⚠ WARNING

Use two brackets to lock the fan. If two brackets are not used, the bolts could shear or the fan could become unbalanced resulting in personal injury or damage to the fan.

4. Make sure the engine fan is engaged. If equipped with a viscous fan, the fan must be manually locked before testing the A/C system.

NOTE: To lock the fan, make two Z-shaped brackets similar to those shown in **Fig. 1**, and mount them to the fan and hub 180 degrees apart. It is important to use two brackets to prevent vibration when testing. Brackets can be made by bending 3/4-inch x 1/8-inch (19 mm x 3 mm) mild steel strap in a vise.

5. Open the driver and passenger doors.



1. Z-Shaped Bracket
2. Fan
3. Hub

Fig. 1, Viscous Fan

6. Connect the A/C test gauges to the refrigerant system service ports.
7. Place a thermometer in the center dash outlet.
8. Start the engine and warm it to operating temperature.
9. Set the engine speed to 1500 rpm.
10. Set the control panel to normal A/C, the recirculation to off, and the fan to the highest speed.
11. Allow the system time to stabilize (at least 5 minutes or until the dash outlet temperature is at minimum) then record the values in **Table 1** under the "Actual Readings" column.
12. Refer to the appropriate temperature/pressure table in **Subject 400**. Using the recorded ambient temperature and relative humidity readings, locate the values in the temperature/pressure

table and record them in **Table 1** under the "Published Readings" column.

13. If the actual dash outlet temperature is within the range of the published values, then the system is performing satisfactorily. If the actual temperature is not within the published value, use the other readings such as high side or low side pressures and compressor cycling information to begin diagnosing the system.
14. If Z-shaped brackets were used to lock the viscous fan, remove the brackets.

	Published Readings (see step 12)	Actual Readings
Ambient Temperature Relative Humidity (RH)		_____°F (°C) _____% RH
Center Dash Outlet Temperature	_____°F (°C) to _____°F (°C)	_____°F (°C)
High Side Pressure	_____ psi (kPa) to _____ psi (kPa)	_____ psi (kPa)
Low Side Pressure	_____ psi (kPa) to _____ psi (kPa)	_____ psi (kPa)
Compressor Cycling	yes/no	yes/no
Compressor On/Off Time (only if cycling)	on _____ sec off _____ sec	on _____ sec off _____ sec

Table 1, A/C Performance Test Data

Fault Analysis Flow Chart

See **Fig. 2** for the fault analysis flow chart.

System 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" for diagnosis.
The control head is not working.	
The blower motor is in protection mode.	Refer to "Blower Motor Circuit Tests" for diagnosis.

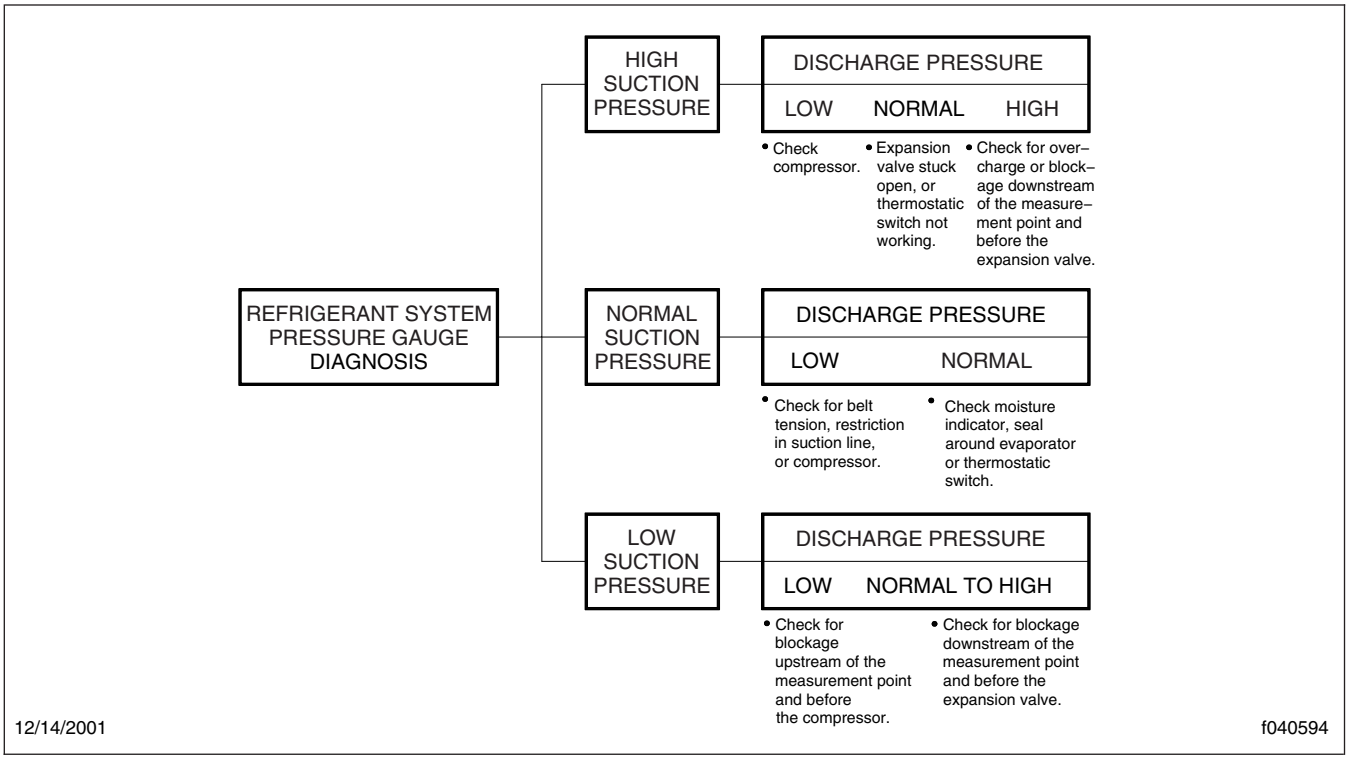


Fig. 2, Fault Analysis Flow Chart

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 this subject.
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 this subject for diagnosis.
	Mechanical problem with temperature blend door actuator.

Troubleshooting

Problem—Warm Airflow When the Air Conditioner is On, A/C is Not Working, or Poor Performance of A/C	
Possible Cause	**Remedy**
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" 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.
There are line or component restrictions.	Remove the line 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."

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" for diagnosis.
The control head 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" for diagnosis.
The recirculation door actuator is not working.	
The control head 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" for diagnosis.
The control head is not working.	

Not able to control where the air is directed.

Troubleshooting

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" for diagnosis.
The control head is not working.	

Problem—No Backlighting on the Control Head

Problem—No Backlighting on the Control Head	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Backlighting Circuit Tests" for diagnosis.
The control head is not working.	

Problem—Blower Not Working

Problem—Blower Not Working	
Possible Cause	**Remedy**
Problem with the wiring.	Refer to "Blower Motor Circuit Tests" for diagnosis.
The control head is not working.	
A fuse is blown.	
The blower motor is not working.	

Component and System Tests

Use the following component and system tests to diagnose an HVAC problem.

Receiver-Drier

To the touch, the entire length of the receiver-drier should be the same temperature. If the receiver-drier is not the same temperature, it may indicate a blockage or low charge. Any blockage can cause high head pressures.

Cooling System

Although they are not physically connected, there is a close tie between the air conditioner and the cooling system. Poor air conditioner cooling can be the result of a problem in the cooling system.

If the cooling system does not work correctly, the heat of the engine will rise to abnormal levels. The added heat will transfer to the air conditioner, other underhood parts, and maybe make its way into the vehicle. The added heat makes it necessary for the air conditioner to work harder and reduces the ability of the air conditioner to cool down the air in the driver's area.

See **Group 20** for cooling system troubleshooting and to the engine manufacturer's service manual for other details about cooling system problems.

Expansion Valve

Problems with the expansion valve may be caused by the valve being stuck closed or open. When the valve is stuck closed, the evaporator coil and the expansion valve will be at outside temperature. When the valve is stuck open, both the coil and the valve will be extremely cold with frost or ice buildup.

Because the expansion valve channels are very small, blockages in the system tend to be found here. The valve is very sensitive to contamination. The contaminant is usually water. Less than a drop of water is all it takes to make the valve stop work-

ing. When water reaches the valve, the extreme cold that results from the pressure drop freezes the water, forming a block of ice in the valve. After the system shuts down and the valve warms up, the ice melts and the valve operates again only to freeze up when the moisture returns.

On-and-off operation of the expansion valve means that the receiver-drier is not removing moisture from the system.

Refrigerant Compressor

Compressor problems usually show in one of four ways:

- abnormal noise
- seizure
- leakage
- low suction and discharge pressures

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.

Low discharge pressure may be caused by not enough refrigerant, not enough belt tension, or a blockage somewhere in the system. These things should be checked before servicing the compressor.

Evaporator

The evaporator coils are basically trouble-free when airflow over the fins is not blocked. The filter next to the evaporator removes debris. If the filter is installed, no blockage can occur.

If a leak exists in the system and it cannot be traced to other parts or fittings, suspect damage to one of the evaporator coils.

Condenser

The condenser is usually trouble-free. Normally, the temperature of the condenser outlet line is noticeably cooler than the inlet line. However, when road debris such as leaves or dirt build up, the airflow over the condenser fins is blocked. Air is not able to absorb enough heat to turn the hot refrigerant gas into a liquid. High head pressures will result. In these cases, carefully clean off the outer surfaces of the condenser with compressed air or a soap and water solution. Be careful not to bend the fins.

High head pressures will also occur if the condenser tubing is abnormally bent, blocking the flow of refrigerant. Frost will appear at the point where the flow is restricted.

Less common internal blockages, such as bits of foreign material or metallic grit buildup, will stop the flow of refrigerant.

When troubleshooting a suspected condenser problem, remember that the problem may be caused by the radiator transferring high levels of heat to the condenser. See **Group 20** of this manual for cooling system troubleshooting and to the engine manufacturer's service manual for other information about cooling system problems.

Line Restrictions

A restricted suction line causes low suction pressure at the compressor and little or no cooling. A restriction in a line between the compressor and the expansion valve can cause high discharge and low suction pressure, and insufficient cooling.

Areas of ice or frost buildup usually mean a blockage. Parts that often freeze-up are probably corroded or inoperative and should be replaced. Parts, such as the expansion valve, that freeze-up once in a while may do so because of moisture in the system. If this happens, recover the refrigerant charge, evacuate/recycle the system refrigerant, replace the receiver-drier, and recover, evacuate, and charge the system with refrigerant.

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 head (climate control panel). The control head 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 head to the sensor.

The target position is based on the temperature control switch setting and internal control head 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 2** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified. If the temperature blend door actuator passes the tests in **Table 2** and the actuator still does not operate properly, check for mechanical problems with the actuator.

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 head (climate control panel). The control head 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 head to the sensor.

The target position is based on the air selection switch setting and internal control head 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 3** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified. If the air distribution door actuator passes the tests in **Table 3** 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.

Temperature Blend Door Actuator Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check 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).	9V+ for about 1 second	measured across pins 5 and 6 of the temperature blend door actuator connector	Check wiring between control head and temperature blend door actuator. If wiring is okay, replace the control head.
Actuator position sensor reference voltage circuit	key on, engine off temperature blend door actuator connector removed	5V	measured between pin 7 of the temperature blend door actuator connector and the battery negative post	
Actuator position sensor reference ground circuit	key on, engine off temperature blend door actuator connector removed	12V	measured between pin 8 of the temperature blend door actuator connector and the battery positive post	
Actuator position sensor feedback signal circuit	key on, engine off all connectors connected	0.50V (full hot) to 4.00V (full cold)†	backprobe pins B11 and B5 at control head connector	Check wiring between control head 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 2, Temperature Blend Door Actuator Circuit Tests

Air Distribution Door Actuator Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check 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 digital multimeter (DMM).	9V+ for about 1 second	measured across pins 5 and 6 of the air distribution door actuator connector	Check wiring between control head and air distribution door actuator. If wiring is okay, replace the control head.
Actuator position sensor reference voltage circuit	key on, engine off air distribution door actuator connector removed	5V	measured between pin 10 of the air distribution door actuator connector and the battery negative post	
Actuator position sensor reference ground circuit	key on, engine off air distribution door actuator connector removed	12V	measured between pin 8 of the air distribution door actuator connector and the battery positive post	

Air Distribution Door Actuator Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check if Test Fails**
Actuator position sensor feedback signal circuit	key on, engine off all connectors connected	0V (far right) to 5V (far left)	backprobe pins B10 and B5 at control head connector	Check wiring between control head 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 3, 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 vehicle. The recirculation door actuator is controlled by the recirculation button on the control head (climate control panel).

The S2 chassis has partial recirculation. For information on this feature, see **Subject 050**.

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. After 20 minutes, 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 head 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 head to the sensor.

The target position is based on the recirculation button setting and internal control head 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 4** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified. If the recirculation 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, 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.

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 head (climate control panel). The control head 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 5** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified. If the blower motor passes the tests in **Table 5** 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.

Recirculation Door Actuator Circuit Tests

Test	Conditions	Good Result	Test Point	What to Check 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 digital multimeter (DMM).	9V+ for about 1 second	measured across pins 5 and 6 of the recirculation door actuator connector	Check wiring between control head and recirculation door actuator. If wiring is okay, replace the control head.
Actuator position sensor reference voltage circuit	key on, engine off recirculation door actuator connector removed	5V	measured between pin 10 of the recirculation door actuator connector and the battery negative post	
Actuator position sensor reference ground circuit	key on, engine off recirculation door actuator connector removed	12V	measured between pin 8 of the recirculation door actuator connector and the battery positive post	

Troubleshooting

Recirculation Door Actuator Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check if Test Fails**
Actuator position sensor feedback signal circuit	key on, engine off all connectors connected	0.8V (recirc. on) to 4.7V (recirc. off)	backprobe pins A11 and B5 at control head connector	Check wiring between control head 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 4, Recirculation Door Actuator Circuit Tests

Blower Motor Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check if Test Fails**
Main power to blower motor	battery switch on (if equipped) key off blower motor connector removed	12V	measured between pin 4 of blower motor connector and negative battery post	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 open in circuit 98F.
Blower motor ground circuit	battery switch on (if equipped) key off blower motor connector removed	12V	measured between pin 3 of blower motor connector and the positive battery post	Check for open in blower motor ground circuit.
PWM signal from control head	battery switch on (if equipped) key on, engine off blower motor connector connected Change the fan (blower) speed setting on the control head and observe frequency using digital multimeter (DMM).	0 Hz fan off 0 Hz fan on high 2000 Hz all other speeds	backprobe pins 4 and 5 of the blower motor connector, harness side (DMM set to measure frequency)	check circuit 338H check control head
Voltage drop (power circuit)	battery switch on (if equipped) key on, engine off all connectors connected fan (blower) speed on high	less than 0.5V	backprobe pin 4 at the blower motor connector, other lead on positive battery post	Locate high resistance or open in circuit 98F.

Blower Motor Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check if Test Fails**
Voltage drop (ground circuit)	battery switch on (if equipped) key on, engine off all connectors connected fan (blower) speed on high	less than 0.5V	backprobe pin 3 at the blower motor connector, other lead on negative battery post	Locate high resistance or open in blower motor ground circuit.
Blower motor current draw	battery switch on (if equipped) keys on, engine off all connectors connected fan (blower) speed on high	less than 23.5A	Use current clamp around circuit 98F or blower motor ground wire.	check blower motor

The voltage should be approximately the same as the battery voltage.

Table 5, Blower Motor Circuit Tests

Evaporator Probe Circuit Tests

The evaporator temperature sensor is a resistive element where the resistance increases as the temperature decreases. The control head (climate control panel) uses this sensor to determine the evaporator temperature. The control head 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 head will shut off the compressor when the evaporator temperature is near the point where freezing may occur. See **Table 6** for the evaporator probe temperature versus resistance values.

Perform the tests in **Table 7** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified.

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

The A/C compressor clutch is controlled by the control head (climate control panel). When the control head determines that the A/C compressor is required, it grounds the A/C request input to the bulkhead module (BHM). The BHM acts as a relay; when it receives the A/C request ground input from the control head, it sends +12V of power through its output to the A/C compressor through the binary switch. If the refrigerant pressure is too high or too low, the binary switch will break the circuit between the bulkhead module and the A/C compressor to prevent damage to the A/C system.

When **all** of the following conditions are met, the control head 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.

Evaporator Probe Temperature Versus Resistance					
Temperature: °F	**Temperature: °C**	**Resistance: ohms**	**Temperature: °F**	**Temperature: °C**	**Resistance: ohms**
5	–15	36,780	75	24	5189
14	–10	27,830	77	25	4964

Troubleshooting

Evaporator Probe Temperature Versus Resistance					
Temperature: °F	Temperature: °C	Resistance: ohms	Temperature: °F	Temperature: °C	Resistance: ohms
23	–5	21,250	79	26	4751
32	0	16,360	81	27	4548
41	5	12,690	82	28	4354
50	10	9927	84	29	4170
59	15	7823	86	30	3995
61	16	7466	88	31	3828
63	17	7125	90	32	3669
64	18	6805	91	33	3518
66	19	6500	93	34	3373
68	20	6210	95	35	3236
70	21	5935	97	36	3104
72	22	5673	99	37	2979
73	23	5426	100	38	2860

Table 6, Evaporator Probe Temperature Versus Resistance

Evaporator Probe Circuit Tests				
Test	Conditions	Good Result	Test Point	What to Check 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. 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.	16,000 to 16,730Ω at 32°F (0°C)	across pins on the temperature probe	Replace temperature probe
Evaporator temperature probe circuit test	battery switch on (if equipped) key on, engine off sensor probe installed, but connector is disconnected	5V	across temperature probe connector terminals	Check for open in circuits 338K and 338GP. If wiring is okay, replace the control head.

Table 7, Evaporator Probe Circuit Tests

- The fan switch is on any setting other than off.
- The evaporation sensor temperature is above 40.1°F (4.5°C).
- The countdown timer has expired, which prevents the A/C compressor from cycling more than four times per minute.

When these conditions exist, the control head sends the A/C request signal to the bulkhead module. See **Fig. 3**.

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 8** for the A/C clutch circuit tests. Perform the tests in **Table 8** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified.

Backlighting Circuit Tests

See **Table 9** for the backlighting circuit tests. Perform the tests in **Table 9** in the sequence presented. The directions under the column "What to Check if Test Fails" are sometimes dependent on good results from previous tests. If any of the tests fail, stop and perform the repair or check specified. If all of the tests pass and the backlighting at the control head still does not operate properly, check the control head.

Fault Codes

If the A/C clutch is not working, use ServiceLink to check for fault codes. See **Table 10** and **Table 11** for a description of the fault codes.

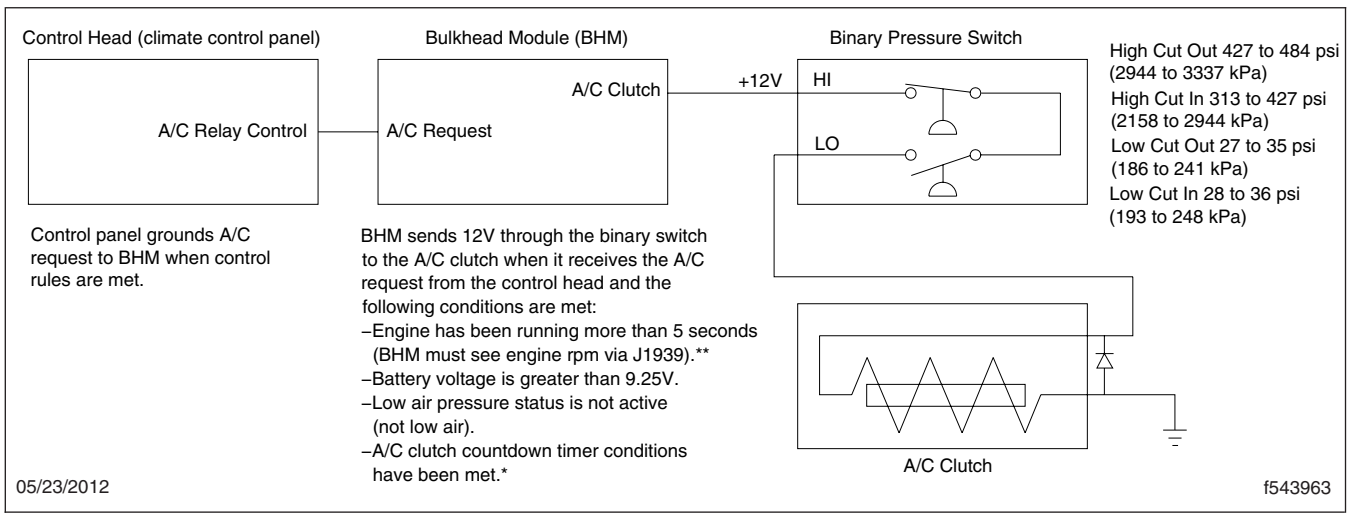


Fig. 3, A/C Clutch Control Circuit

Troubleshooting

A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement				
Test	**Conditions**	**Good Result**	**Test Point/Method**	**What to Check 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.	A/C request is received by the BHM.	ServiceLink/Datalink Monitor NOTE: Make sure the Datalink Monitor template is **not** in Test Mode. The control head 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 head before proceeding with "What to Check if Test Fails."	Perform the "Evaporator Probe Circuit Tests." Check wiring between the control head and the bulkhead module. Check for open circuit. Check the control head. 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.	A/C clutch should engage.	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.	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. faulty wiring faulty A/C clutch ground circuit faulty A/C clutch coil (Coil resistance should be 3Ω ±0.5Ω). faulty BHM (See note in Test Point/Method column)

Circuit faults with the A/C clutch output may generate bulkhead module fault codes.

Table 8, A/C Clutch Circuit Tests for Diagnosing No A/C Clutch Engagement

Backlighting Circuit Tests				
Test	**Conditions**	**Good Result**	**Test Point**	**What to Check if Test Fails**
Backlighting circuit ground test	battery switch on (if equipped) key off, engine off control head connector disconnected	12V	measured between pin B8 of the control head connector and the positive battery post	Check for open in the control head ground circuit.
Backlighting power test	battery switch on (if equipped) key off, engine off control head connector disconnected headlight switch on	Voltage should be about 1.2V at full dim and 10.8V at full bright.	Measure voltage between pins A2 (positive lead) and B8 (negative lead) on the control head connector while toggling the dimmer switch between full dim and full bright.	Check circuit 29A for 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 head connector disconnected headlight switch on	400 Hz	Measure frequency between pins A2 and B8 on the control head connector.	Check circuit 29A for open/ short. If okay, refer to **Group 54** for further diagnosis.

The voltage should be approximately the same as the battery voltage.

Table 9, 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 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 open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for short to ground.

Table 10, J1587 Fault Codes, HVAC (bulkhead module related) MID 164

Troubleshooting

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 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 open circuit.
		06	A/C clutch output shorted to ground (high current)	Check circuit 98A for short to ground.

Table 11, J1939 Fault Codes, HVAC (bulkhead module related) Source Address (SA) 33

Refrigerant recovery/charge stations can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
(800) 328-6657

See **Fig. 1** and **Fig. 2** for the HVAC wiring diagram.

Refrigerant Charge Specification
The amount of refrigerant needed to fully charge the air conditioning system is printed on the "Air Conditioner" label on the air intake plenum located under the hood. See **Fig. 3**.

Table 1, Refrigerant Charge Specification

Refrigerant Oil Specification	
Refrigerant Oil	**Capacity**
Sanden SP–15	10 fl oz (300 mL)

Table 2, Refrigerant Oil Specification

Stat-O-Seal Assembly Bolt Torque Specs	
HVAC Component	**Torque: lbf·ft (N·m)**
Refrigerant Compressor	11 to 15 (15 to 20)
Condenser	
Receiver-Drier	
Expansion Valve	
Evaporator	
Junction Block	

Torque the two small screws that attach the expansion valve to the evaporator lines at the frontwall 35 lbf·in (395 N·cm).

Table 3, Stat-O-Seal Assembly Bolt Torque Specs

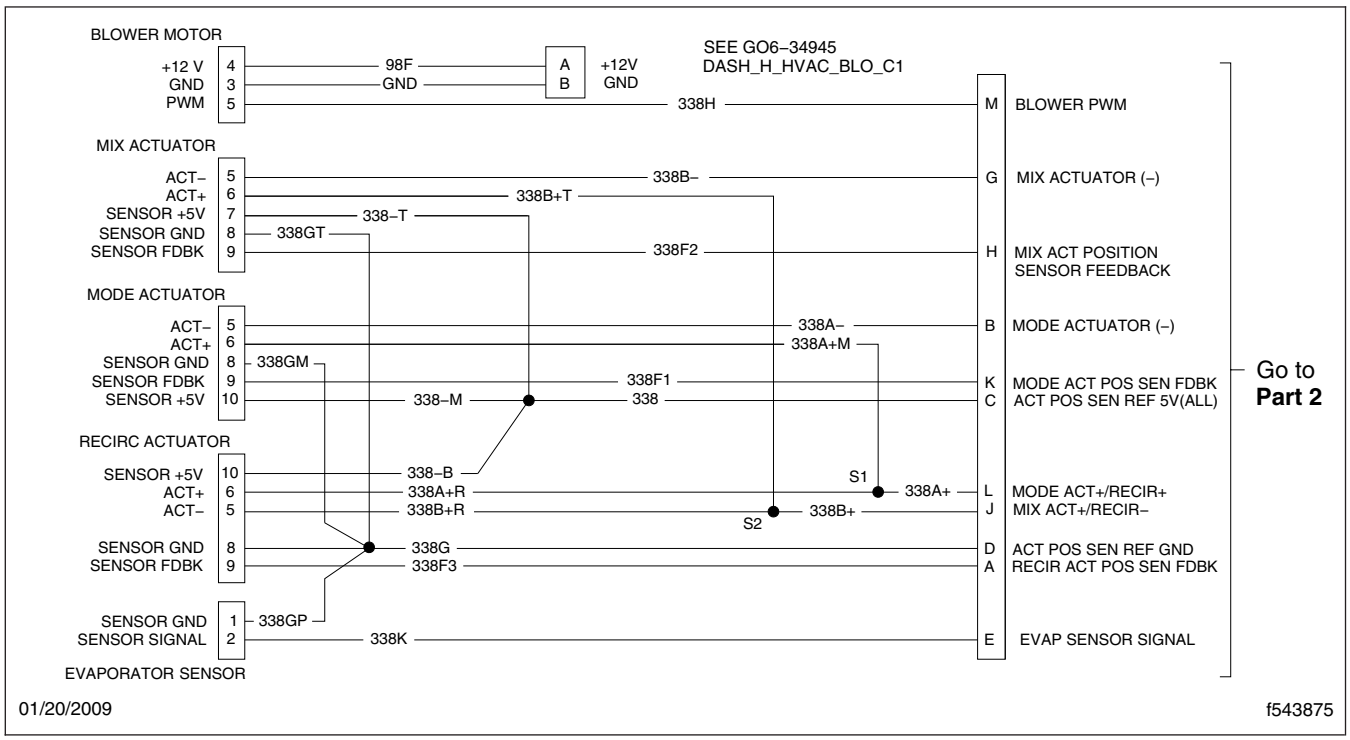


Fig. 1, HVAC Wiring Diagram, Part 1

Specifications

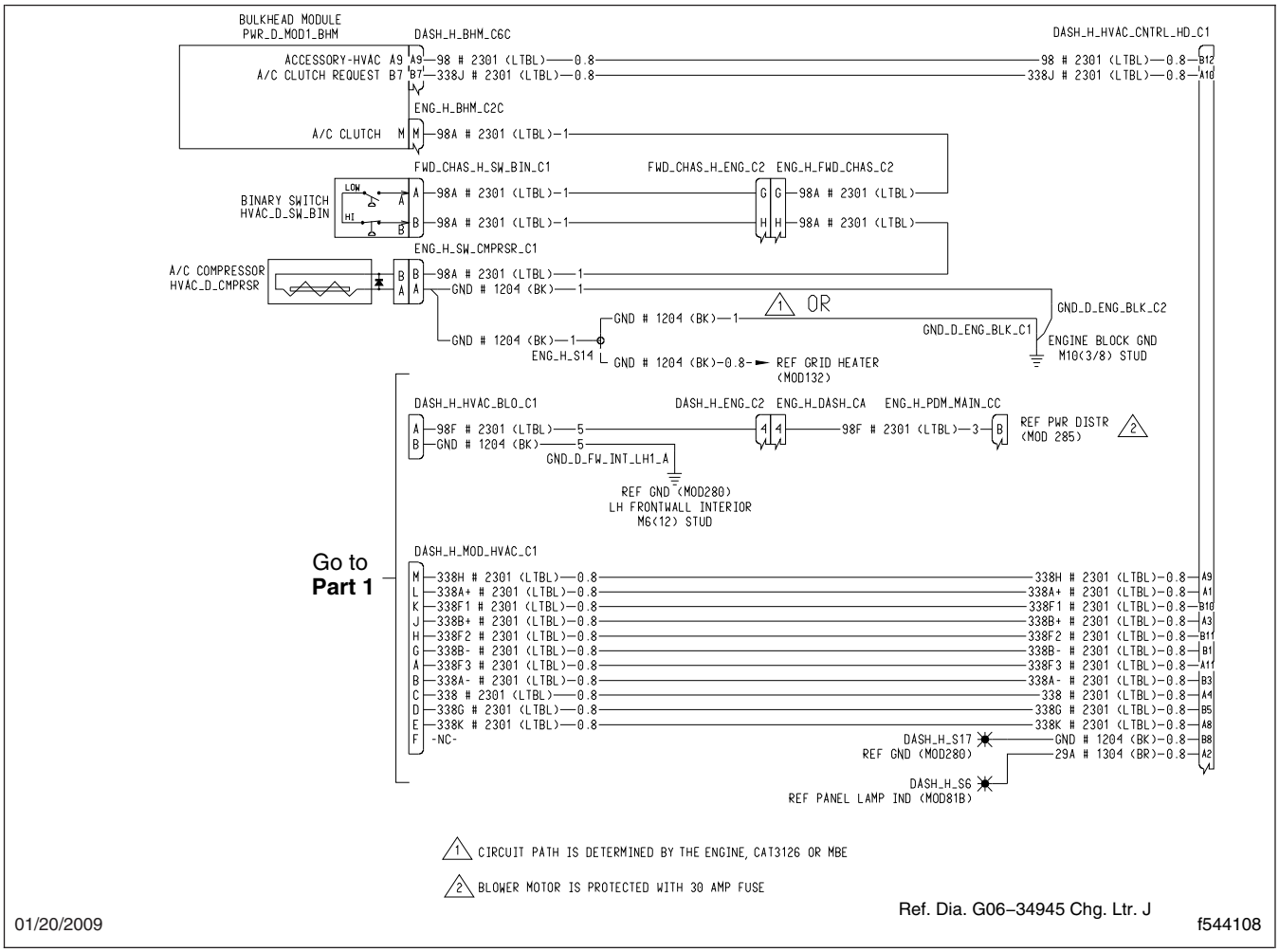
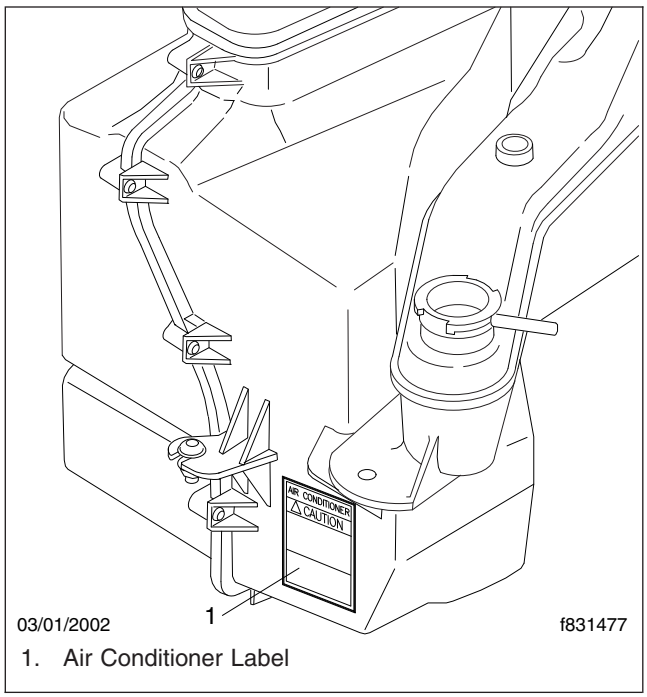


Fig. 2, HVAC Wiring Diagram, Part 2



1. Air Conditioner Label

Fig. 3, Air Intake Plenum

General Information

The primary purpose of the refrigerant compressor is to draw refrigerant gas from the evaporator and compress it into high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid so that it can be used for cooling again. The secondary 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.

R–134a refrigerant 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 (38 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.

Pre-Service Checks

⚠ WARNING

Before doing any work, read the information in 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.

Compressor problems usually show in one of four ways:

- abnormal noise
- seizure
- leakage
- low suction and discharge pressures

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 with the engine shut off and see if the drive plate can be turned. If it can't be turned, the compressor has seized.

Do the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Be sure to check the moisture indicator to see if moisture is the cause of the problems. The air conditioner should be on when checking the indicator. It is better to check it at the end of the day.
2. Check the drive belt and mounting, as follows.
   - 2.1 On the drive belt look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. See **Group 01** for instructions.
   - 2.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the correct torque specification. Repair or replace cracked or damaged brackets.
3. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.
4. Check for road debris buildup on the condenser coil fins. Using air pressure and a whisk broom or a solution of soap and water, carefully clean the condenser. Be careful not to bend the fins.
5. Check the refrigerant charge in the air conditioner system. For instructions, see **Section 83.00, Subject 220**.

NOTE: For other possible causes of air conditioner problems, see **Section 83, Subject 300**.

Refrigerant Compressor Removal and Installation

Removal

WARNING

Before doing any work, read the information in 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.

1. Turn off the engine, apply the brakes, and chock the tires.
2. Recover the refrigerant from the air conditioning system. See **Section 83.00, Subject 220** for instructions.
3. Remove the serpentine belt. Do not pry or roll the belt off the pulleys.
4. Disconnect the wiring harness from the compressor.
5. Disconnect the discharge and suction lines from the compressor. Quickly cap the discharge and suctions ports and the refrigerant lines.

IMPORTANT: 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).

6. 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 quantity is printed on a label attached to the compressor. When installing a new compressor on the vehicle, do all of the steps below. If installing a used compressor, disregard the first two steps.

1. Prepare a new compressor, as follows.
   - 1.1 Gently release the nitrogen gas from the discharge side of the compressor, as follows. Be careful not to let the oil flow out.
   - 1.2 Turn the compressor shaft several times by hand to distribute oil which has settled in the cylinder.
2. If installing a new compressor, adjust the refrigerant oil level in the new compressor. For instructions, see **Subject 130**.
3. Using capscrews and washers, install the compressor on the mounting bracket. Torque the capscrews 15 to 19 lbf·ft (20 to 26 N·m).
4. 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.
5. 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.
6. Connect the refrigerant lines to the compressor. Torque the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
7. Connect the wiring harness to the compressor.
8. Install the serpentine belt.
9. 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 83.00, Subject 180**.
10. Evacuate, charge, and leak test the refrigerant system. See **Section 83.00, Subject 210** for instructions.
11. Lower the hood.
12. Remove the chocks from the tires.

Oil Check and Adding Oil to the Compressor

General Information

Compressors are charged with 10 fl oz (296 mL) of refrigerant oil. When the air conditioning system is operating, some refrigerant oil leaves the compressor and is circulated 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 may cause damage to the compressor.

IMPORTANT: Whenever the air conditioning system is discharged or recovered, the recovered oil 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. Oil must be from a container that has not been opened or that has been tightly sealed since its last use.

Order Sanden PAG oil SKI 7803 1997 (type SP–15) for an 8.45-ounce (250-mL) can of refrigerant oil from your local Freightliner parts distribution center. Tubing, funnels, or other equipment used to transfer the oil should 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.

Checking and Adding Refrigerant Oil

There are two methods of checking and adding refrigerant oil:

- oil recovery method
- dipstick method

The oil recovery method is the preferred method. The dipstick method can be used when there is a sudden release of refrigerant or when it is not possible to measure the quantity of oil recovered from the system.

Oil Recovery Method

WARNING

Do not remove the oil fill plug on the refrigerant compressor without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue causing serious injury or blindness.

1. Before beginning the refrigerant recovery process, make sure that the oil accumulator and oil drain bottle on the recovery/recycle machine are emptied of oil from previous repairs.
2. Recover all of the refrigerant from the system. For instructions, see **Section 83.00, Subject 210**.
3. Drain the recovered oil into the calibrated drain bottle of the recovery/recycle machine. Record the amount of oil recovered and properly dispose of the recovered oil.
4. Inspect the refrigerant oil. If the oil has any of the following characteristics, flush and charge the system with 10 fl oz (296 mL) of oil.
   - silver or black oil—indicates metal in the air conditioning system due to compressor wear
   - milky oil—may indicate moisture in the system
   - grit or debris in the oil
5. 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 [1]] = [Quantity Added to the System]

   Table 1 provides the quantities of oil that need to be added to the system for each component that

[1] The total quantity of oil for the replaced components should not exceed 6 fl oz (17 mL).

Oil Check and Adding Oil to the Compressor

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.

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	1 (30)
Low Pressure Line	2 (59)
Condenser	1 (30)
Evaporator	3 (89)
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

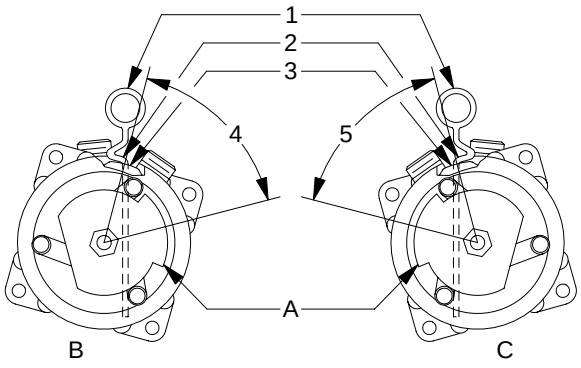
6. Remove the oil fill plug on the refrigerant compressor and add the refrigerant oil. Never add more than 8 fl oz (237 mL) to the system unless the system has been flushed.
7. Evacuate, charge, and leak test the refrigerant system. See **Section 83.00, Subject 210** for instructions.

Dipstick Method

⚠ WARNING

Do not remove the oil fill plug on the refrigerant compressor without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue causing serious injury or blindness.

1. Recover all of the refrigerant from the system. For instructions, see **Section 83.00, Subject 210**.
2. After repairs are finished, remove the oil fill plug on the refrigerant compressor. Using a socket wrench on the armature retaining nut, turn the shaft clockwise until the counterweight is positioned correctly. See **Fig. 1**.



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A. Position of counterweight.
B. Mounting angle right.
C. Mounting angle left.

1. Dipstick
2. Dipstick Stop
3. Oil Fill Hole
4. 2 o'Clock
5. 10 o'Clock

Fig. 1, Checking the Oil Level

3. Check the refrigerant oil level with a dipstick. Make sure the angle of the dipstick stop is in the correct orientation. See **Fig. 1**.

NOTE: A dipstick can be made locally or purchased from a special tools supplier. For information, see **Specifications 400**.

4. Remove the dipstick and count the number of notches covered by the oil. If the number of notches covered by oil does not match the specifications for the appropriate mounting angle in **Table 2**, add or subtract oil to the midrange value. For example, if the mounting angle is zero degree, add oil until six notches on the dipstick are covered by oil.

NOTE: If the compressor shaft is rotated more than one-half turn between adding oil and checking, it may cause the dipstick reading to be low.

5. Now that the oil level matches the specification for the compressor, refer to **Table 1** to determine how much oil to add for each component that was replaced. The total quantity of oil for the replaced components should not exceed 6 fl oz (177 mL). Replace the oil fill plug and begin the evacuating procedure as soon as possible to remove air. Evacuate, charge, and leak test the

refrigerant system using the instructions in **Section 83.00, Subject 210**.

Oil Specifications at Various Mounting Angles	
Mounting Angle	**Number of Notches Covered by Oil**
0°	5 to 7
10°	6 to 8
20°	7 to 9
30°	8 to 10
40°	9 to 11
50°	10 to 12
60°	11 to 13
90°	16 to 18

Table 2, Oil Specifications at Various Mounting Angles

Adjusting the Refrigerant Oil Level in a New Compressor

Sanden refrigerant compressors are charged with 10 fl oz (296 mL) of refrigerant oil. If the air conditioning system has been flushed, the compressor will need a 10-ounce charge. If the system has not been flushed, use the following procedure to adjust the oil level in the compressor.

Use the worksheet on the following page to adjust the refrigerant oil level in a new compressor. See **Fig. 2**.

Oil Check and Adding Oil to the Compressor

Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

1. Drain the oil from the old compressor.
   - 1.1 Remove the oil plug and drain as much oil as possible into a clean, calibrated container.
   - 1.2 If there are caps on the suction and discharge ports, remove them.
   - 1.3 Drain the oil from the suction and discharge ports into the container while turning the shaft clockwise using a socket wrench on the armature retaining nut.
   - 1.4 Enter the amount of oil that was drained from the compressor. 1. ☐
2. See Table 1 in Section 83.01, Subject 130, of the *S2 Chassis Workshop Manual* to determine the total amount of refrigerant oil that is needed for each component that was replaced. Enter the amount, up to 6 fl oz (177 mL), here. 2. ☐
3. Add the amounts from steps 1 and 2 and enter the total. 3. ☐
4. Subtract the total in step 3 from 10 and enter that number. For example, if the total in line 3 was six, the calculation would be 10 − 6 = 4. 4. ☐
5. Refer to the table below for the amount of oil that must be drained from the new compressor.

If the number in step 4 is:	Drain this amount from the new compressor:
a negative number(−)	2 fl oz (59 mL)
0	2 fl oz (59 mL)
1	2 fl oz (59 mL)
2	2 fl oz (59 mL)
3	3 fl oz (89 mL)
4	4 fl oz (118 mL)
5	4 fl oz (118 mL)
6	4 fl oz (118 mL)
7	4 fl oz (118 mL)
8	4 fl oz (118 mL)
9	4 fl oz (118 mL)
10	4 fl oz (118 mL)

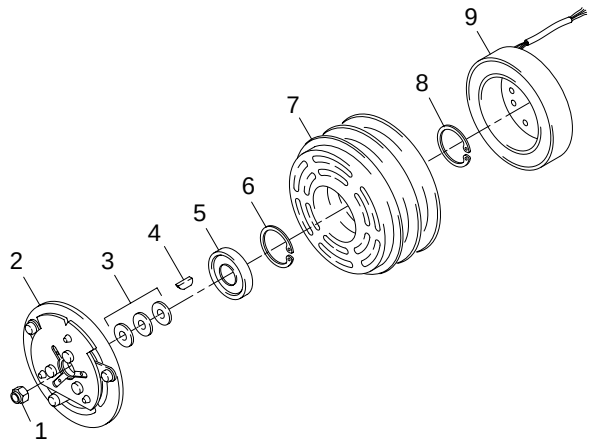
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Fig. 2, Worksheet for Adjusting the Refrigerant Oil Level in a New Compressor

Clutch Assembly Removal, Inspection, and Installation

Removal

See **Fig. 1** for an illustration of the clutch assembly components.

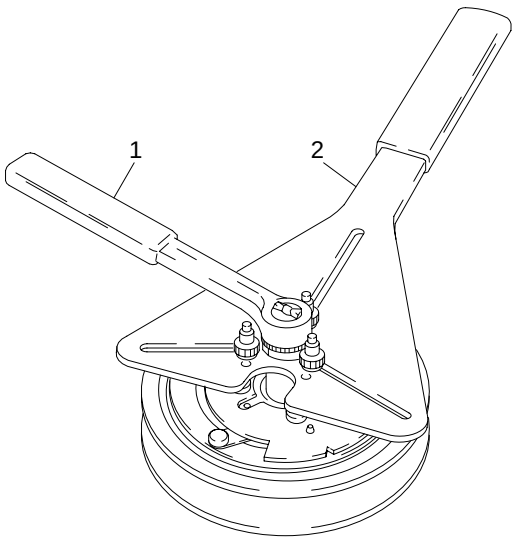


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1. Shaft Nut
2. Drive Plate
3. Clutch Shims
4. Shaft Key
5. Rotor Bearing Dust Cover
6. Rotor Snap Ring
7. Rotor Assembly
8. Field Coil Assembly Snap Ring
9. Field Coil Assembly

Fig. 1, Clutch Assembly

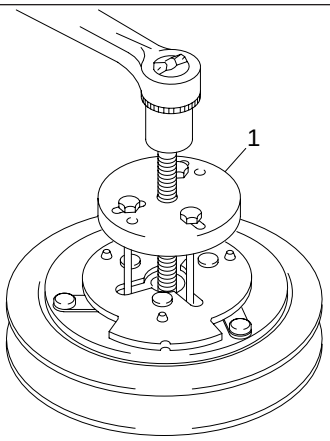
1. Remove the compressor from the vehicle. For instructions, see **Subject 120**.
2. Insert the pins of the drive plate spanner into the threaded holes of the drive plate assembly. Hold the drive plate assembly securely while removing the retaining nut. See **Fig. 2**.
3. Using the drive plate puller, install the three puller bolts into the drive plate assembly. Turn the center screw clockwise to loosen and remove the drive plate. See **Fig. 3**.
4. If equipped with a rotor bearing dust cover, remove it. Be careful not to distort the cover when removing it.
5. Use a slotted screwdriver and hammer to remove the shaft key. See **Fig. 4**.



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1. Socket Wrench
2. Drive Plate Spanner

Fig. 2, Removing the Retaining Nut



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1. Drive Plate Puller

Fig. 3, Removing the Drive Plate

6. Remove the clutch shims. Use a pointed tool and a small screwdriver to prevent the shims from binding on the shaft.
7. Using snap ring pliers, remove the rotor assembly snap ring.
8. Remove the rotor assembly, as follows.

   8.1 Insert the lip of the rotor puller jaws into the snap ring groove. See **Fig. 5**.

Clutch Assembly Removal, Inspection, and Installation

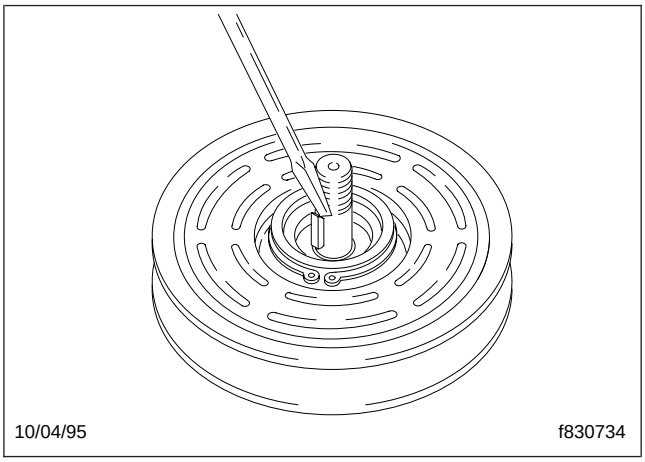
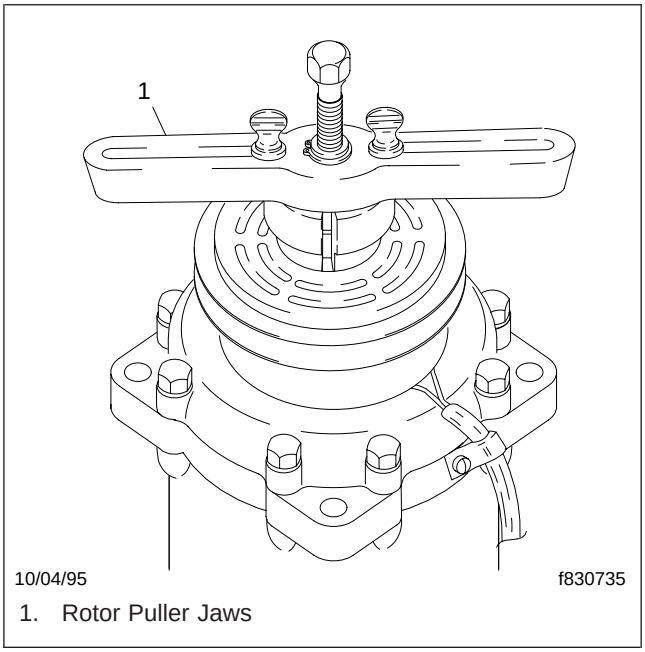


Fig. 4, Removing the Shaft Key



1. Rotor Puller Jaws

Fig. 5, Positioned Rotor Puller Jaws

8.2 Place the rotor puller shaft protector over the exposed shaft.

8.3 Align the thumb screws to the rotor puller jaws. Tighten the screws finger-tight.

8.4 Using a socket wrench, turn the puller center bolt on the rotor puller jaws clockwise and remove the rotor assembly, as follows.

9. Remove the field coil assembly, as follows.

9.1 Remove the field coil assembly lead wire from the clamp on the compressor.

9.2 Disconnect the wiring harness.

9.3 Remove the snap ring. Then remove the field coil assembly.

Inspection

1. Inspect the drive plate assembly. If the frictional surface shows signs of damage due to too much heat, replace the drive plate assembly and the rotor assembly.
2. Check the appearance of the rotor assembly. If the frictional surface of the rotor shows signs of too much grooving due to slippage, replace both the rotor assembly and the drive plate assembly. Clean the frictional surfaces of the rotor assembly before installing it.
3. Check the field coil assembly for a loose connector and for cracked insulation. Replace it if necessary.

Installation

NOTE: When supporting the compressor in a vise, clamp only on the mounting ears, never on the body of the compressor.

1. Install the field coil assembly, as follows.

1.1 Position the coil assembly on the compressor.

1.2 Install the snap ring.

1.3 Attach the field coil assembly lead wire to the clamp on the compressor.

1.4 Connect the wiring harness.

2. Install the rotor assembly, as follows.

2.1 Position the rotor over the boss of the front housing.

2.2 Place the rotor installer ring into the bearing bore. Make sure that the edge rests only on the inner race of the bearing, not on the seal, rotor pulley, or outer race of the bearing.

2.3 Place the driver into the ring. Using a hammer or an arbor press, drive the rotor

Clutch Assembly Removal, Inspection, and Installation

pulley down against the front housing step. See **Fig. 6**.

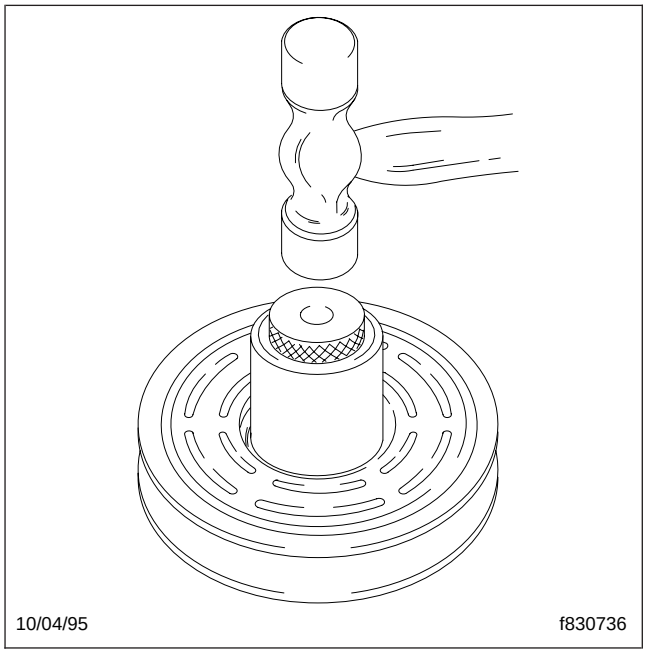


Fig. 6, Driving the Rotor Pulley Down Against the Front Housing Step

2.4 Using snap ring pliers, install the rotor bearing snap ring.

2.5 Using snap ring pliers, install the rotor retaining snap ring. If a bevel is present on the snap ring, make sure that it is facing away from the body of the compressor.

2.6 If equipped with a rotor bearing dust cover, install the cover by gently tapping it into place.

3. Install the drive plate assembly, as follows.

3.1 Using pliers, install the shaft key. See **Fig. 7**.

3.2 Install the shims.

3.3 Align the keyway in the drive plate assembly with the shaft key. Using a driver and a hammer or an arbor press, drive the assembly down over the shaft until it bottoms on the shims. See **Fig. 8**.

3.4 Install the retaining nut. If the nut is 1/2–20, tighten it 20 to 25 lbf·ft (27 to 34 N·m).

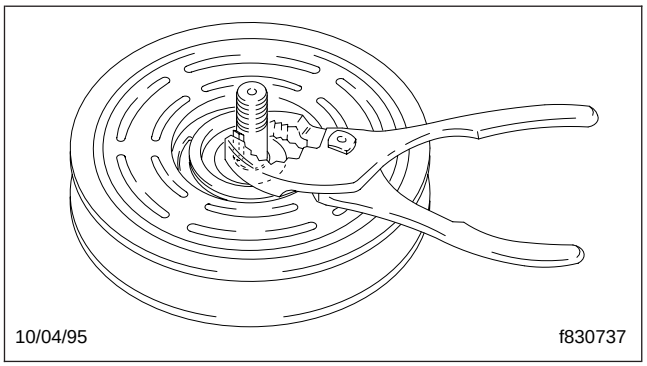


Fig. 7, Installing the Shaft Key

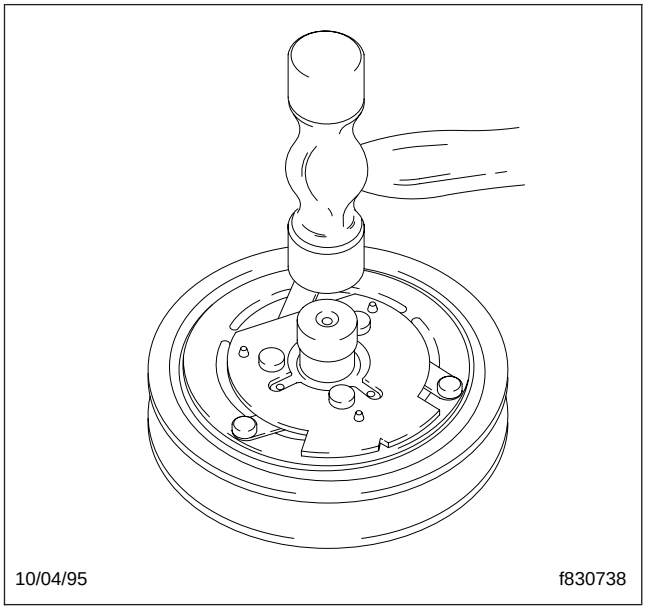


Fig. 8, Installing the Drive Plate Assembly

If the nut is M8, tighten it 11 to 15 lbf·ft (15 to 21 N·m).

4. Using a feeler gauge, check that the clutch clearance is 0.016 to 0.031 inch (0.4 to 0.8 mm). See **Fig. 9**. If the gap is not even around the clutch, gently tap down at the high areas. If the overall gap is out of spec, remove the drive plate assembly and change the shims as necessary.

5. Install the compressor on the vehicle. For instructions, see **Subject 120**.

Clutch Assembly Removal, Inspection, and Installation

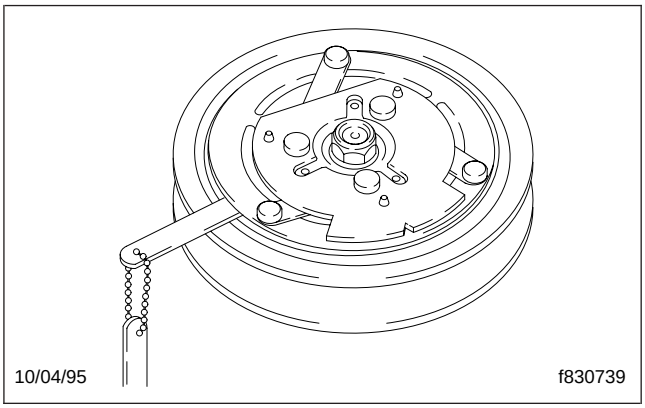


Fig. 9, Checking the Clutch Clearance

Specifications

Special tools can be purchased from:

SPX Kent-Moore
28635 Mound Road
Warren, Michigan 48092-3499
800-328-6657

Mini Stat-O-Seal Assembly Bolt Torque Specifications	
HVAC Component	**Torque: lbf·ft (N·m)**
Refrigerant Compressor	11 to 15 (15 to 20)
Condenser	
Receiver-Drier	
Expansion Valve*	
Evaporator	
Junction Block	

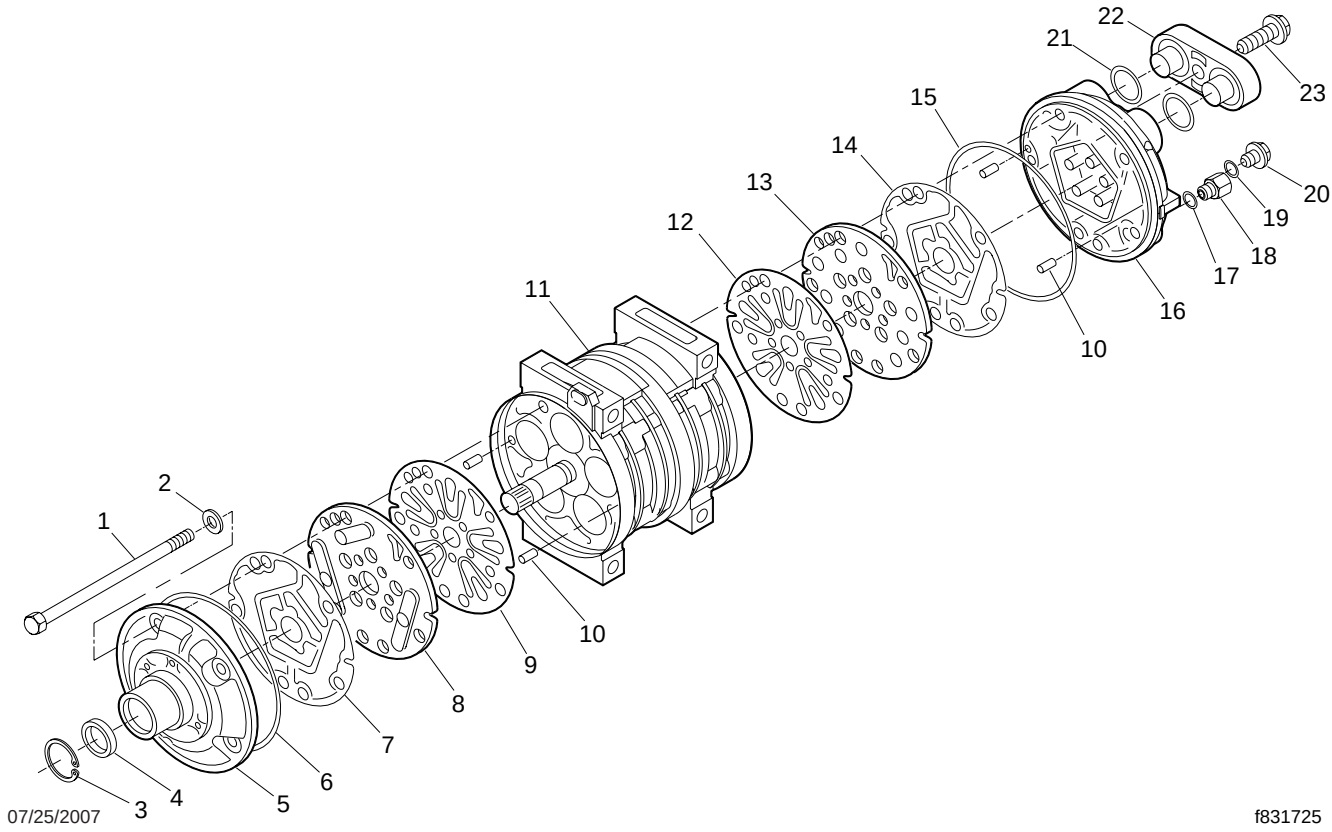
* Torque the two small screws that attach the expansion valve to the evaporator lines at the frontwall 35 lbf·in (395 N·cm).

Table 1, Mini Stat-O-Seal Assembly Bolt Torque Specifications

General Information

The primary purpose of the refrigerant compressor is to draw refrigerant gas from the evaporator and compress it into high-pressure gas. High pressure raises the condensation point of refrigerant gas, which allows the condenser to change it to a liquid so that it can be used for cooling again. The secondary purpose of the compressor is to move refrigerant through the air conditioning system.

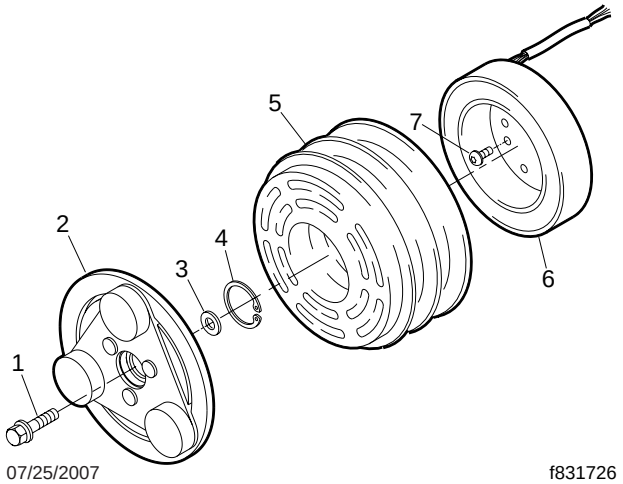
Figure 1 shows an exploded view of the TM-21 compressor. See **Fig. 2** for an exploded view of the refrigerant compressor clutch assembly.



1. Body Bolt (5)
2. Washer (5)
3. Snap Ring
4. Shaft Seal
5. Front Cylinder Head
6. O-ring, Body
7. Front Gasket
8. Front Valve Plate
9. Front Suction Valve
10. Guide Pins (4)
11. Cylinders/Shaft Assembly
12. Rear Suction Valve
13. Rear Valve Plate
14. Rear Gasket
15. O-ring, Body
16. Rear Cylinder Head
17. Pressure Relief Valve O-ring
18. Pressure Relief Valve
19. Oil Drain Plug O-ring
20. Oil Drain Plug
21. Rear Port O-ring (2)
22. Shipping Plug
23. Bolt

Fig. 1, TM-21 Compressor (exploded view)

General Information



1. Armature Bolt
2. Armature Plate
3. Shim
4. Snap Ring
5. Pulley and Bearing Assembly
6. Field Coil
7. Field Coil Screws (3)

Fig. 2, Refrigerant Compressor Clutch Assembly (exploded view)

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.

R–134a refrigerant 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 (38 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. The air conditioning system may be safely pressurized with dry nitrogen.

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.

Pre-Service Checks

⚠ WARNING

Before doing any work, read the information in 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.

Compressor problems usually show in one of four ways:

- abnormal noise
- seizure
- leakage
- low suction and discharge pressures

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 with the engine shut off and see if the drive plate can be turned. If it can't be turned, the compressor has seized.

Do the following checks whenever the air conditioner system is not cooling enough and the causes are unknown.

1. Be sure to check the moisture indicator to see if moisture is the cause of the problems. The air conditioner should be on when checking the indicator.
2. Check the drive belt and mounting, as follows.
   - 2.1 On the drive belt look for wear, damage, or oil. If worn, oil-soaked, or damaged, remove it and install a new one. See **Group 01** for instructions.
   - 2.2 Check the compressor mounting parts for loose fasteners, cracks, or other damage. Tighten loose fasteners to the correct torque specification. Repair or replace cracked or damaged brackets.
3. Check the wiring and connections to the compressor clutch. Replace damaged wiring and tighten loose connections.
4. Check for road debris buildup on the condenser coil fins. Using air pressure and a whisk broom or a solution of soap and water, carefully clean the condenser. Be careful not to bend the fins.
5. Check the refrigerant charge in the air conditioning system. For instructions, see **Section 83.00, Subject 210**.

NOTE: For other possible causes of air conditioner problems, see **Section 83.00, Subject 300**.

Removal

⚠ WARNING

Before doing any work, read the information in 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.

1. Turn off the engine, apply the parking brake, and chock the tires.
2. Recover the refrigerant from the air conditioning system. See **Section 83.00, Subject 210** for instructions.
3. Remove the serpentine belt. Do not pry or roll the belt off the pulleys.
4. Disconnect the wiring harness from the compressor.
5. Disconnect the discharge and suction lines from the compressor. Quickly cap the discharge and suctions ports and the refrigerant lines.

IMPORTANT: 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).

6. 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 quantity is printed on a label attached to the compressor. When installing a new compressor on the vehicle, do all of the steps below. If installing a used compressor, disregard the first step.

1. Prepare a new compressor, as follows.

   1.1 Gently release the nitrogen gas from the discharge side of the compressor, as follows. Be careful not to let the oil flow out.

   1.2 Slowly rotate the magnetic clutch several times by hand to distribute oil which has settled in the cylinders. See **Fig. 1**.

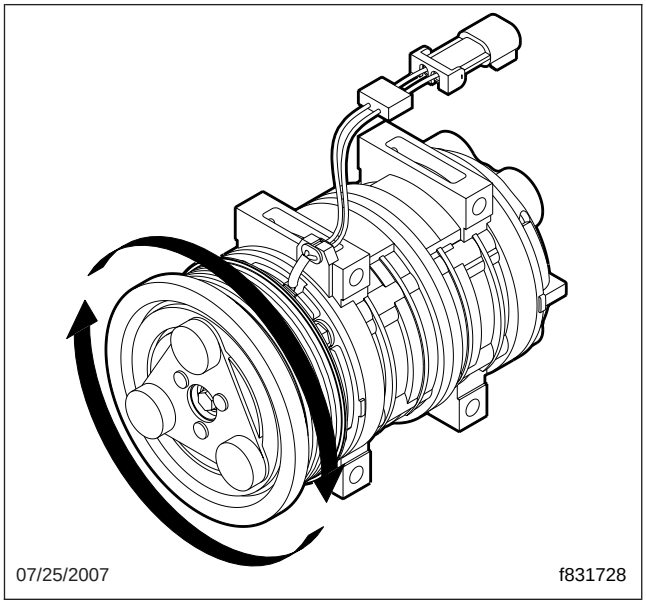


Fig. 1, Magnetic Clutch Rotation

2. If installing a new compressor, adjust the refrigerant oil level in the new compressor. For instructions, see **Subject 130**.
3. Using capscrews and washers, install the compressor on the mounting bracket. Tighten the capscrews 15 to 19 lbf·ft (20 to 26 N·m).

   The compressor should be installed on the vehicle within the range shown in **Fig. 2**. The compressor is equipped with a pressure feed lubrication system, which cannot function properly if the compressor is installed outside the indicated range.

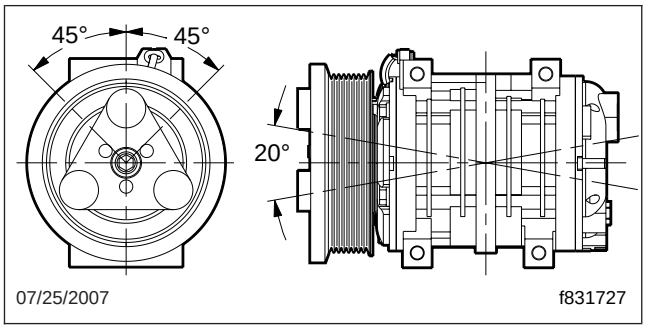


Fig. 2, Compressor Position

Refrigerant Compressor Removal and Installation

4. 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.
5. 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.
6. Connect the refrigerant lines to the compressor. Tighten the retaining plate 11 to 15 lbf·ft (15 to 20 N·m).
7. Connect the wiring harness to the compressor.
8. Install the serpentine belt.
9. 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 83.00, Subject 180**.
10. Evacuate, charge, and leak test the air conditioning system. See **Section 83.00, Subject 210** for instructions.
11. Lower the hood.
12. Remove the chocks from the tires.

General Information

Compressors are factory-charged with 16.9 oz (500 mL) of refrigerant oil. Some refrigerant oil is circulated through the system with the refrigerant, and cannot leave the system except through a leak, when the system is recovered, or when a system part is replaced.

IMPORTANT: Add the same amount of oil that is removed when the system is discharged or recovered, or when a system part is replaced. Oil must be from a container that has not been opened, or that has been tightly sealed since its last use.

For R–134a systems, order Seltec PAG oil ZXL 100PG (DH-PS) from your local Freightliner parts distribution center. Tubing, funnels, or other equipment used to transfer the oil should be very clean and dry.

The list below contains approximate refill amounts for R–134a air conditioning systems.

A. Refrigerant charge—0.7 fl oz (20 mL): This amount of oil may be lost from the system each time the system loses its charge due to routine recovery or due to a slow leak and no other parts of the system have been replaced.

IMPORTANT: The items below list oil quantities that include the amounts that are lost during recovery. Do not add an additional 0.7 fl oz (20 mL)—the amount described in the item above—to the quantities listed.

B. Receiver-drier—2.7 fl oz (80 mL);

IMPORTANT: A new receiver-drier does not contain any refrigerant oil.

C. Condenser—1.0 fl oz (30 mL);

D. Evaporator coil—0.7 fl oz (20 mL);

E. Entire system with or without an auxiliary heater/air-conditioner—16.9 fl oz (500 mL). Add the appropriate amount of oil to the compressor if the entire system (including the compressor) has been recovered of refrigerant and oil, and if the system has been evacuated.

When handling refrigerant oil:

- The oil should be free of water, dust, metal powder, and other foreign substances.
- Don't mix refrigerant oil with other types or viscosities of oil.
- Refrigerant oil absorbs moisture when exposed to the air for any period. After use, quickly seal the oil container.

IMPORTANT: Check the compressor oil level at the time of installation and whenever a loss of refrigerant oil has occurred.

⚠ WARNING

Do not remove the oil fill plug without first recovering the system. Failure to recover the system could cause uncontrolled release of high-pressure refrigerant, which can freeze skin and eye tissue, causing serious injury or blindness.

1. Open the doors and windows.
2. Operate the blower at maximum speed and the compressor for at least 20 minutes with the engine at idle. Shut down the engine.
3. Recover all of the refrigerant from the system. For instructions, refer to **Section 83.00, Subject 210**.
4. Remove the compressor from the vehicle. For instructions, see **Subject 120**.
5. Remove the oil fill plug from the side of the compressor.
6. Drain the oil through the oil fill opening and the high and low pressure connections into a clean container.
7. Using a graduated cylinder, measure the amount of refrigerant oil recovered.
8. Check the oil for contamination:
   - Increased opacity of the oil.
   - Color change to red.
   - Presence of foreign matter, metal filings, etc.

IMPORTANT: Use only ZXL 100PG (DH-PS) refrigerant oil.

9. Fill the compressor with the specified amount found in **Table 1**.

Oil Check and Adding Oil to the Compressor

System Full-Charge Compressor Oil Capacity Specifications		
Specified Capacity	**Amount Recovered from System**	**Amount to Remove from New Compressor**
16.9 fl oz (500 mL)	11.9 fl oz (350 mL) or more	16.9 fl oz (500 mL) minus amount recovered
	less than 11.9 fl oz (350 mL)	4.4 fl oz (130 mL)

Table 1, System Full-Charge Compressor Oil Capacity Specifications

NOTE: The oil filler plug O-ring is not re-usable. Be sure not to twist the new O-ring while installing it on the filler plug.

10. Install a new O-ring. Insert the plug in the oil fill opening. Tighten the plug 10 to 12 lbf·ft (14 to 16 N·m).
11. Evacuate, charge, and leak test the air conditioning system. For instructions, refer to **Section 83.00, Subject 210**.

Magnetic Clutch Removal, Inspection, and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Remove the center armature bolt. See **Fig. 1**.

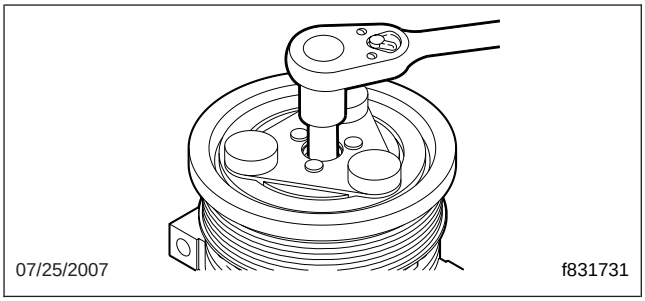


Fig. 1, Armature Bolt Removal

3. Using an armature plate puller, remove the armature plate. Then remove the shims from either the armature shaft or the armature plate. See **Fig. 2**.

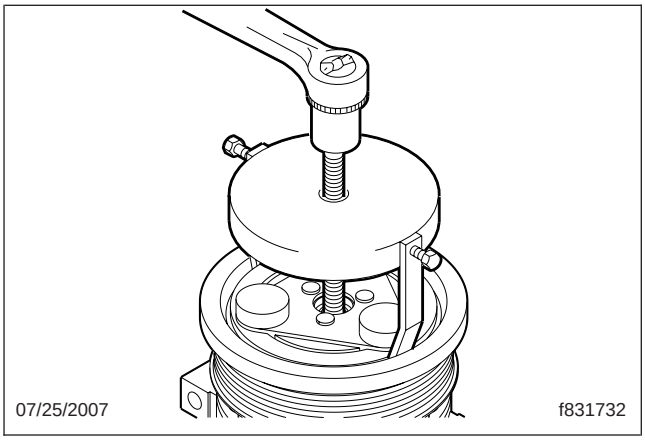


Fig. 2, Armature Plate Removal

4. Using external snap ring pliers, remove the snap ring. Remove the cover, if so equipped. See **Fig. 3**.

⚠ CAUTION

To avoid damaging the pulley groove, the puller claws should be hooked into (not under) the pulley groove. Use the correct tools and do not push directly on the shaft.

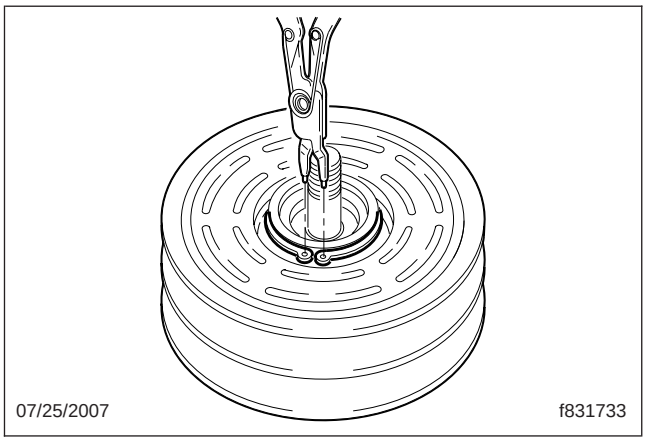


Fig. 3, Snap Ring Removal with External Pliers

5. Using a pulley puller, remove the pulley assembly and the spacer positioned on the cylinder head hub. See **Fig. 4**.

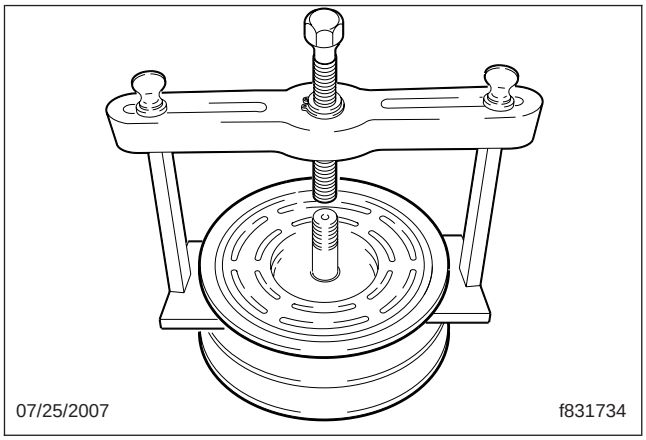


Fig. 4, Pulley Assembly Removal

IMPORTANT: Do not hold the coil by the lead wire.

6. Remove the coil lead wire from the wire holder on the compressor. Next, remove the three screws, and finally the coil.

Inspection

1. Inspect the armature plate contact surface. If the contact surface is scorched, replace the armature plate and pulley.
2. Check the appearance of the pulley assembly. If the pulley's contact surface is excessively

Magnetic Clutch Removal, Inspection, and Installation

grooved due to slippage, replace the coil, pulley assembly, and armature plate. There should not be any foreign material, such as oil or dirt, lodged between the clutch plate and the pulley. Using a suitable solvent, clean the contact surfaces before installing the clutch plate and pulley.

3. Check the coil for a loose connector or cracked insulation.

Installation

⚠ CAUTION

To prevent smashing the lead wire during installation, the lead wire should not protrude from the guiding groove of the compressor.

1. Install the lead wire in the wire holder on the compressor.
2. Install the coil on the compressor and tighten the mounting screws 3 to 4 lbf·in (34 to 45 N·cm).
3. Using the installer and a hand press, install the pulley assembly.
4. Using snap ring pliers, install the snap ring. The chamfered inner edge of the snap ring should face upward.
5. Install the armature plate and the original shim(s) on the drive shaft. Press the armature plate down by hand.
6. Tighten the armature bolt 9 to 10 lbf·in (100 to 110 N·cm), using the holder to prevent armature plate rotation. After tightening the bolt, make sure the pulley rotates smoothly.
7. Ensure that the clutch has a clearance of 0.01 to 0.02 inch (0.3 to 0.5 mm). If necessary, adjust the clearance using shims.
8. Remove the chocks from the tires.

Replacement

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

IMPORTANT: The refrigerant must be recovered before replacing the shaft seal. See **Section 83.00, Subject 210** for instructions.

2. Remove the center armature bolt. See **Fig. 1**.

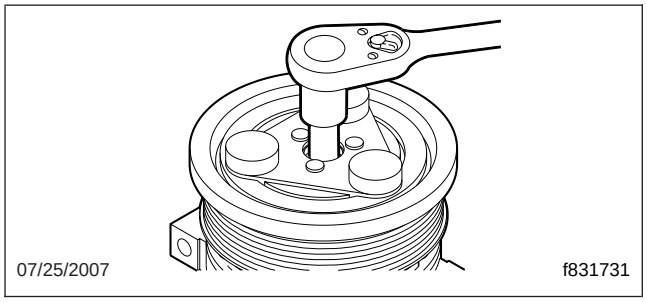


Fig. 1, Armature Bolt Removal

3. Using an armature plate puller, remove the armature plate. Then remove the shims from either the armature shaft or the armature plate. See **Fig. 2**.

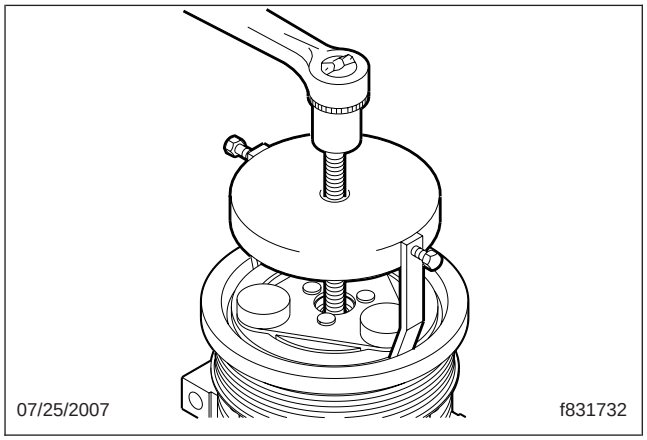


Fig. 2, Armature Plate Removal

4. Using internal snap ring pliers, remove the snap ring. See **Fig. 3**.
5. Using a shaft seal removal tool, remove the shaft seal. Engage the tool's hook with the shaft seal hook, then slowly draw the shaft seal out of the housing. See **Fig. 4**.

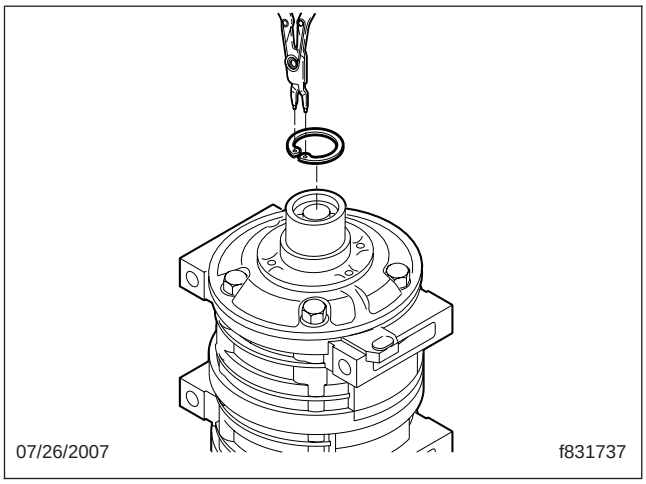


Fig. 3, Snap Ring Removal with Internal Pliers

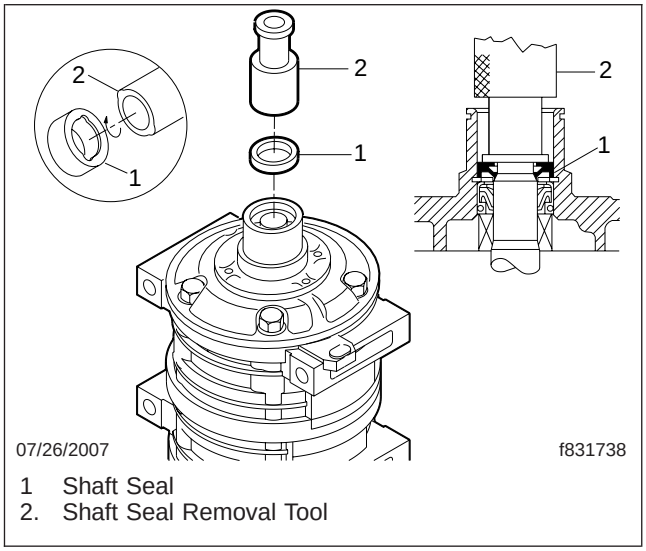


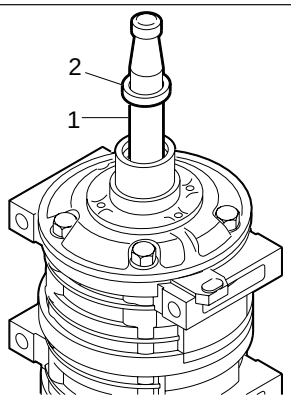
Fig. 4, Shaft Seal Removal

IMPORTANT: The shaft seal should not be used again. Always use a new shaft seal when reassembling the compressor. Be very careful to ensure that the lip of the new shaft seal being installed is not scratched or damaged in any way. Make certain that the shaft seal is free from lint and dirt that could damage the shaft seal surface.

6. Clean the seal section of the front cylinder head.
7. Apply clean compressor oil to the new shaft seal and to the front cylinder head.

Shaft Seal Replacement

8. Fit the guide over the end of the spline shaft.
9. Insert the shaft seal over the guide and into the front cylinder head.
10. Using the installation end of the removal tool, install the shaft seal as far as possible into the front cylinder head. See **Fig. 5**. Remove the guide from the spline shaft.

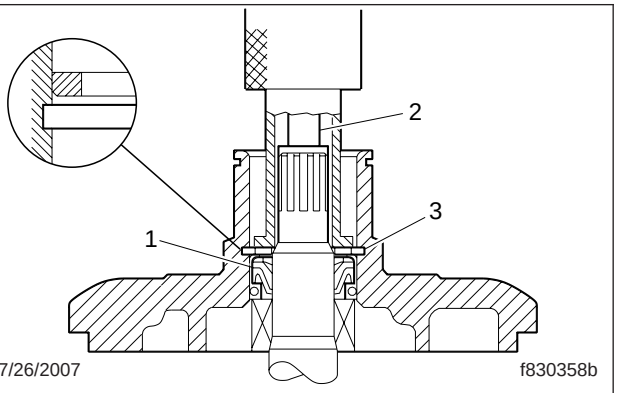


1. Guide
2. Shaft Seal

Fig. 5, Shaft Seal Installation

NOTE: When installing the snap ring, the chamfered edge of the snap ring must face upward. See **Fig. 6**.

11. Using internal snap ring pliers, install the snap ring. Press the snap ring with the installation end of the shaft seal removal tool, until a "click" is heard.



1. Shaft Seal
2. Guide
3. Snap Ring

Fig. 6, Snap Ring Installation

12. Install the armature plate and the original shim(s) on the drive shaft. Press the armature plate down by hand.
13. Tighten the armature bolt 9 to 10 lbf·in (100 to 110 N·cm), using the holder to prevent armature plate rotation. After tightening the bolt, make sure the pulley rotates smoothly.
14. Evacuate, charge, and leak test the refrigerant system. For instructions, see **Section 83.00, Subject 210**.
15. Remove the chocks from the tires.

Front and Rear Cylinder Head Disassembly, Inspection, and Assembly

Disassembly

1. Park the vehicle on a level surface, shut down the engine, apply the parking brake, and chock the tires.
2. Recover the refrigerant from the system. See **Section 83.00, Subject 210**.
3. Remove the compressor. See **Subject 120**.
4. Remove the magnetic clutch assembly. See **Subject 140**.
5. Remove the drain plug, then drain the oil.
6. Remove the shaft seal. See **Subject 150**.
7. Using a socket wrench, remove the five body bolts that secure the head. See **Fig. 1**.
8. Remove the front cylinder head. Alternately tap the two projections on the circumference of the front cylinder head with a screwdriver and a mallet. See **Fig. 2**.
9. Remove the O-ring and all of the gasket material from the front cylinder head.
10. Remove the valve plate and suction valve from the cylinder shaft assembly. Remove all of the gasket material from the valve plate.
11. Remove the rear cylinder head. Alternately tap the projections on the circumference of the rear head with a screwdriver and a mallet.
12. Remove the O-ring and all of the gasket material from the rear cylinder head.
13. Remove the valve plate and suction valve from the cylinder shaft assembly. Remove all of the gasket material from the valve plate.

Inspection

Check the front and rear valve plates for scratched, bent, or damaged parts. Inspect both cylinder heads and both valve plate assemblies for nicks and/or burrs on the sealing surfaces. Clean or replace them if damaged. Ensure that all passages in the valve plate are unobstructed. If either the cylinder head or valve plate is cracked, replace it.

Assembly

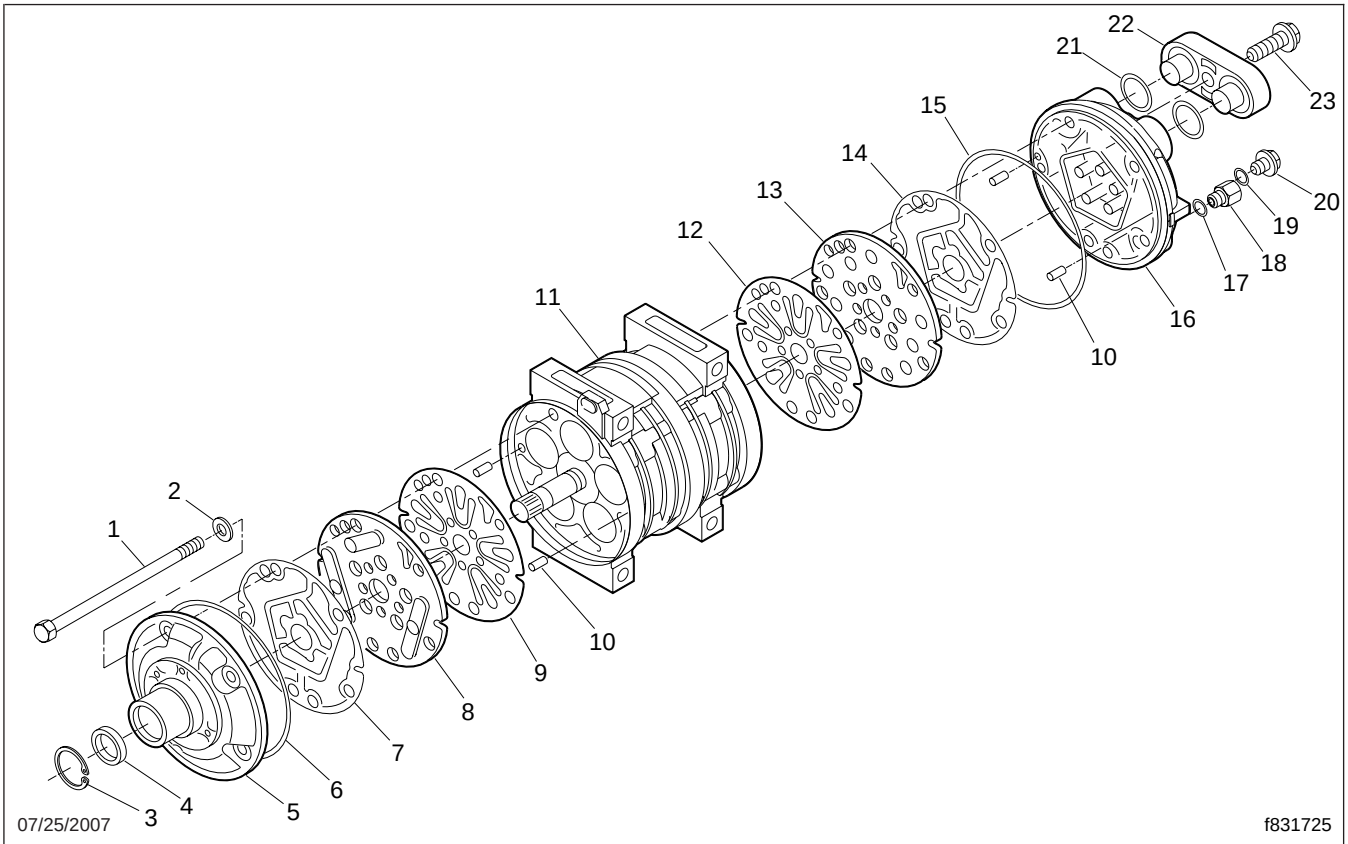
Rear Cylinder Head

1. Place the cylinder shaft assembly on a bench with the rear side up.
2. Install the rear suction valve so that it is aligned with the alignment pin.
3. Install the rear valve plate on the rear suction valve. Do not mistake the rear valve plate for the front valve plate. Ensure that each valve is aligned with the valve escape groove of each cylinder.
4. Coat the new gasket with clean compressor oil, then install it on the rear valve plate.
5. Thinly coat the new O-ring with clean compressor oil, then install it on the rear cylinder head.
6. Install the rear cylinder head. If the rear cylinder head is difficult to install, tap it lightly with a mallet.

Front Cylinder Head

1. Place the cylinder shaft assembly on a bench with the front side up.
2. Install the front suction valve so that it is aligned with the front alignment pin.
3. Install the front valve plate on the front suction valve. Do not mistake the rear valve plate for the front valve plate. Ensure that each valve is aligned with the valve escape groove of each cylinder.
4. Coat the new gasket with clean compressor oil, then install it on the front valve plate.
5. Thinly coat the new O-ring with clean compressor oil, then install it on the front cylinder head.
6. Install the front cylinder head. If the front cylinder head is difficult to install, tap it lightly with a mallet.
7. Install new gaskets on the body bolts. There should not be any oil on the bolts or the bolt seating area. Install the five body bolts on the front cylinder head side and tighten them 15 to 17 lbf·ft (20 to 23 N·m). Tighten the bolts in the order shown in **Fig. 3**.
8. Turn the driveshaft 2 to 3 times by hand to make sure that the shaft rotates smoothly.

Front and Rear Cylinder Head Disassembly, Inspection, and Assembly



1. Body Bolt (5)
2. Washer (5)
3. Snap Ring
4. Shaft Seal
5. Front Cylinder Head
6. O-ring, Body
7. Front Gasket
8. Front Valve Plate
9. Front Suction Valve
10. Guide Pins (4)
11. Cylinders/Shaft Assembly
12. Rear Suction Valve
13. Rear Valve Plate
14. Rear Gasket
15. O-ring, Body
16. Rear Cylinder Head
17. Pressure Relief Valve O-ring
18. Pressure Relief Valve
19. Oil Drain Plug O-ring
20. Oil Drain Plug
21. Rear Port O-ring (2)
22. Shipping Plug
23. Bolt

Fig. 1, TM-21 Compressor (exploded view)

9. Install the oil drain plug with a new O-ring, thinly coated with clean compressor oil. Tighten the plug 9 to 11 lbf·ft (12 to 15 N·m).
10. Install the compressor.
11. Fill the compressor, through the suction side connector, with the specified amount of clean compressor oil.
12. Evacuate, charge, and leak test the refrigerant system. For instructions, see **Section 83.00, Subject 210**.
13. Install the magnetic clutch. See **Subject 140**.
14. Remove the chocks from the tires.

Front and Rear Cylinder Head Disassembly, Inspection, and Assembly

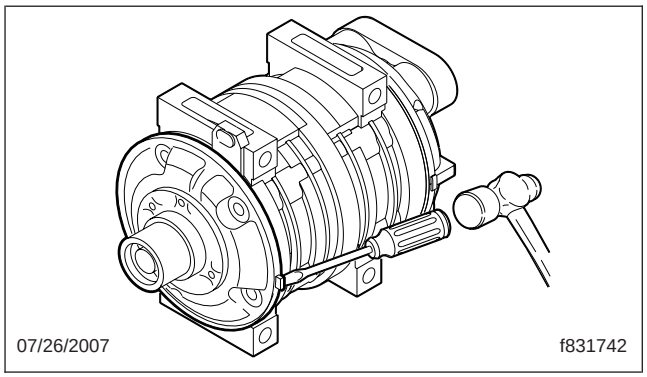


Fig. 2, Front Cylinder Head Removal

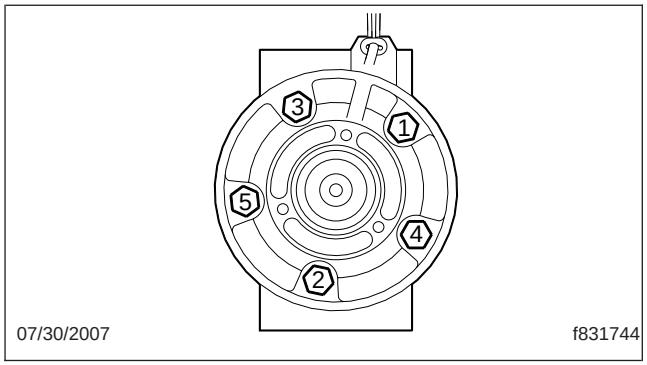


Fig. 3, Bolt Tightening Sequence

Specifications

Compressor Torque Values		
Description	**Size**	**Torque**
Armature Bolt	M6 x 1.0	9–10 lbf·in (100 to 110 N·cm)
Field Coil Screw	M5 x 0.8	3–4 lbf·in (34 to 45 N·cm)
Body Bolt	M8 x 1.25	13–16 lbf·ft (18 to 22 N·m)
Oil Drain Plug	M8 x 1.25	9–11 lbf·ft (12 to 15 N·m)
Pressure Relief Valve	3/8–24	6–7 lbf·in (70 to 80 N·cm)
Connector Bolt	M8 x 1.25	15–17 lbf·ft (20 to 23 N·m)
Compressor Capscrews	—	15–19 lbf·ft (20 to 26 N·m)
Retaining Plate	—	11–15 lbf·ft (15 to 20 N·m)

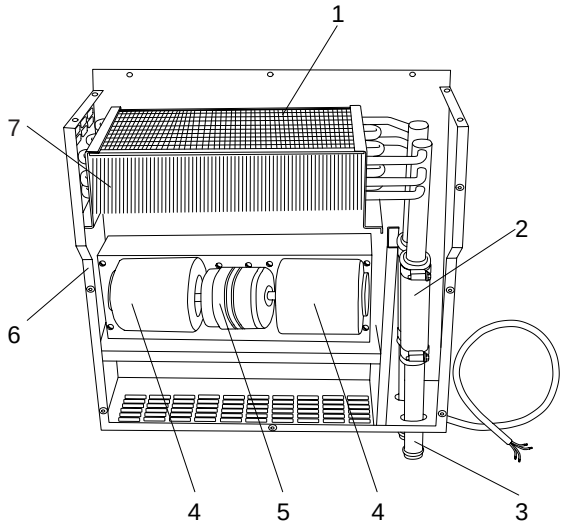
Table 1, Compressor Torque Values

Compressor Oil Capacity—System Full-Charge		
Specified Capacity	**Amount Recovered from System**	**Amount to Remove from New Compressor**
16.9 fl oz (500 mL)	11.9 fl oz (350 mL) or more	16.9 fl oz (500 mL) minus amount recovered
	less than 11.9 fl oz (350 mL)	4.4 fl oz (130 mL)

Table 2, Compressor Oil Capacity—System Full-Charge

General Information

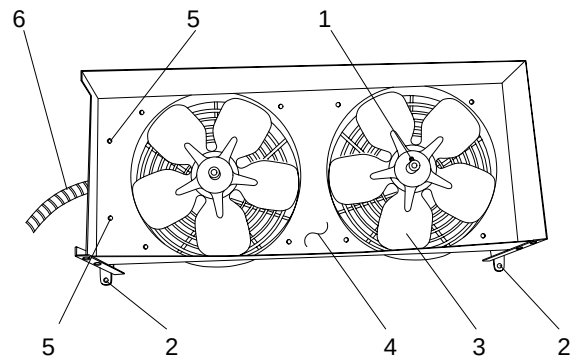
Auxiliary heaters are self-contained units that consist of a housing, heater core, and blower motor. The heater core is a series of fins through which tubing is routed. When the water valve is open, engine coolant flows through the heater core tubes, heating the tubes and fins. The heat is absorbed by air that is forced through the heater core by the blower motor. Auxiliary heater assemblies can be mounted on the walls, under the seats, or in the stepwells. See **Fig. 1**, **Fig. 2** and **Fig. 3**.



05/04/2004 f831630

1. Filter
2. Connecting Hose
3. Heater Core Extension Pipes
4. Blower Fan
5. Blower Motor
6. Housing
7. Heater Core

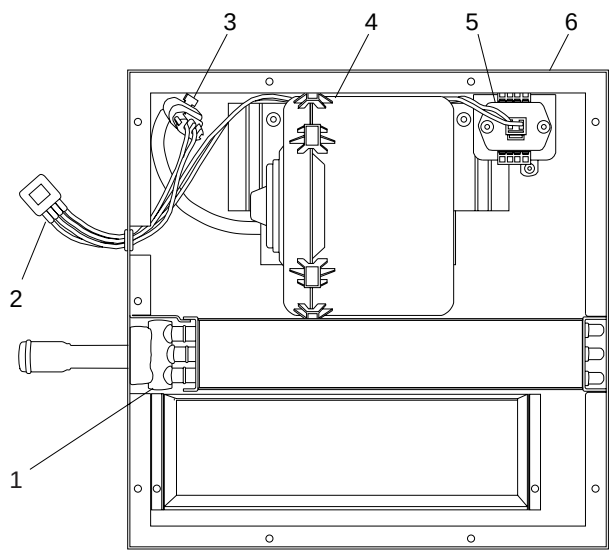
Fig. 1, Rear Wall Heater



04/30/2004 f831628

1. Setscrew
2. Mounting Bracket
3. Heater Fan
4. Housing
5. Heater Core Fastener Location
6. Wire Harness

Fig. 2, Under-Seat Heater (heater core removed)



06/02/2004 f831637

1. Heater Core
2. Harness Connector
3. Blower Motor Connector
4. Blower Motor
5. Restrictor Block
6. Housing

Fig. 3, Stepwell Heater

Rear Wall Heater Core Replacement

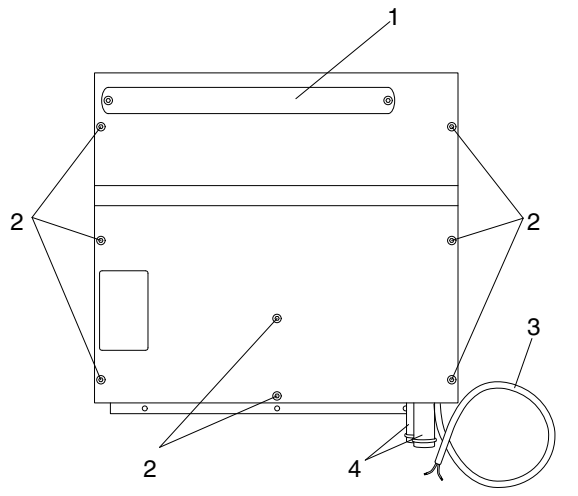
Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the rear door and place a protective cover on the rear floor area.

IMPORTANT: A small amount of coolant may be present in the heater core. Protect the interior of the bus to prevent damage from coolant spillage.

If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

3. Mark the coolant hose connection positions for assembly reference. Loosen the clamps and disconnect the heater core supply and return lines. Clamp off the lines to prevent coolant loss.
4. Remove the screws that attach the cover to the rear wall heater housing. See **Fig. 1**.

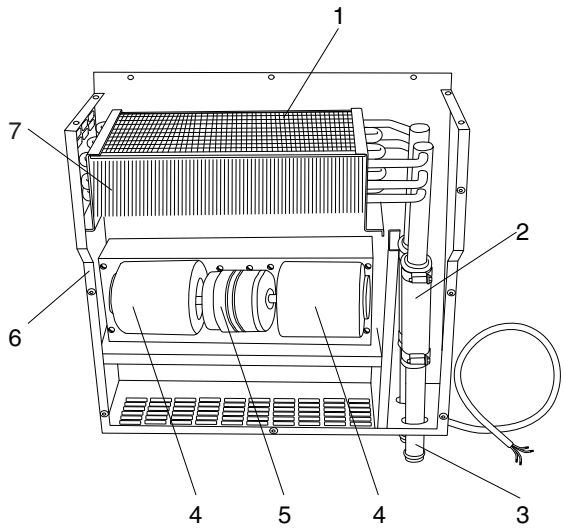


04/28/2004 f831629

1. Filter Cover
2. Cover Mounting Screws
3. Blower Motor Wire Harness
4. Heater Core Extension Pipes

Fig. 1, Rear Wall Heater

5. Slide the air filter screen out of the retaining tabs in front of the heater core.
6. Lift the heater core out of the rear wall heater housing. See **Fig. 2**.



05/04/2004 f831630

1. Filter
2. Connecting Hose
3. Extension Pipe
4. Blower Fan
5. Blower Motor
6. Housing
7. Heater Core

Fig. 2, Heater Components

7. Remove the four clamps and the connecting hoses from the extension pipes and heater core.
8. Using new connecting hoses, connect the extension pipes to the new heater core. Tighten the clamps.
9. Position the heater core inside the heater housing.
10. Slide the air filter under the tabs in front of the heater core.
11. Position the cover onto the heater housing. Install and secure the 12 mounting screws.
12. Connect the coolant hoses to the previously marked heater core extension pipes. Tighten the coolant hose clamps.
13. Fill the engine cooling system with the heater valves closed.
14. If the heater circuit was drained, open only the supply valve and the heater circuit vent, near the return valve, to bleed air from the heaters without

Rear Wall Heater Core Replacement

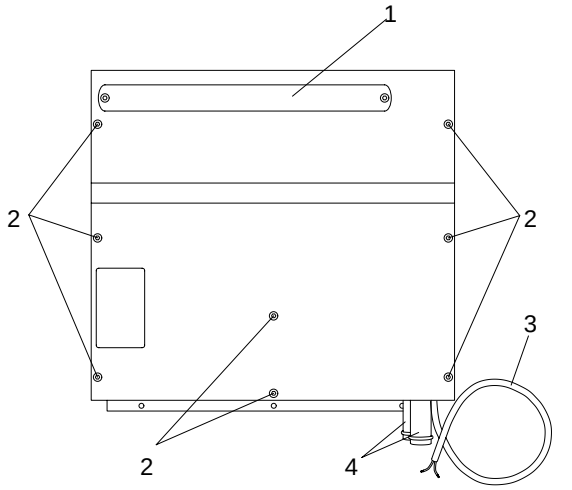
sending it through the engine. If the heater circuit was not drained, open both valves.

15. Turn the ignition ON and set the heater control to hot; do not start the engine. If so equipped, turn the heater circuit booster pump on.
16. Start the engine and maintain the coolant level in the surge tank, filling to the full mark as needed.
17. If bleeding air from the heaters, close the vent when coolant is present and open the return valve.
18. Continue running the engine until the thermostat opens, then shut down the engine.
19. Once the engine has cooled, top off the coolant to the full mark and reinstall the radiator cap.
20. Bleed the cooling system.

Rear Wall Heater Blower Motor Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Open the rear door and place a protective cover on the rear floor.
3. Remove the 12 screws that fasten the rear wall heater housing cover. See **Fig. 1**.

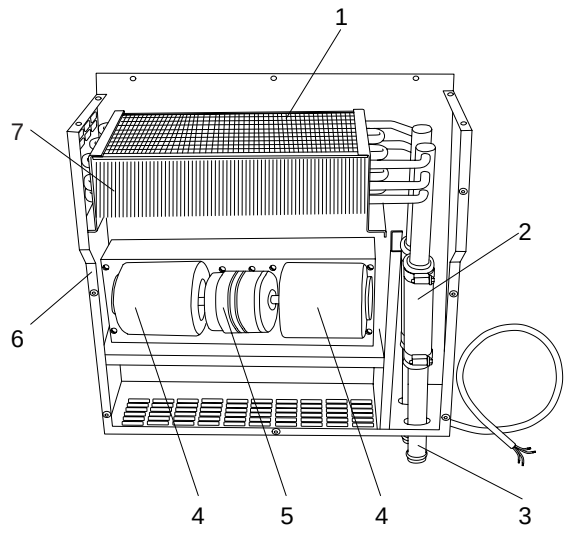


04/28/2004 f831629

1. Filter Cover
2. Cover Mounting Screws
3. Blower Motor Wire Harness
4. Heater Core Extension Pipes

Fig. 1, Rear Wall Heater

4. Lift the blower motor assembly from the mounting slots in the rear wall heater housing. See **Fig. 2**.
5. Disconnect the wire harness from the blower motor.
6. Connect the wire harness to the new blower motor.
7. Slide the blower motor assembly into the housing mounting slots.
8. Position the cover on the wall heater housing. Secure the cover with the 12 mounting screws.



05/04/2004 f831630

1. Filter
2. Connecting Hose
3. Extension Pipe
4. Blower Fan
5. Blower Motor
6. Housing
7. Heater Core

Fig. 2, Heater Components

Under-Seat Heater Core Replacement

Replacement

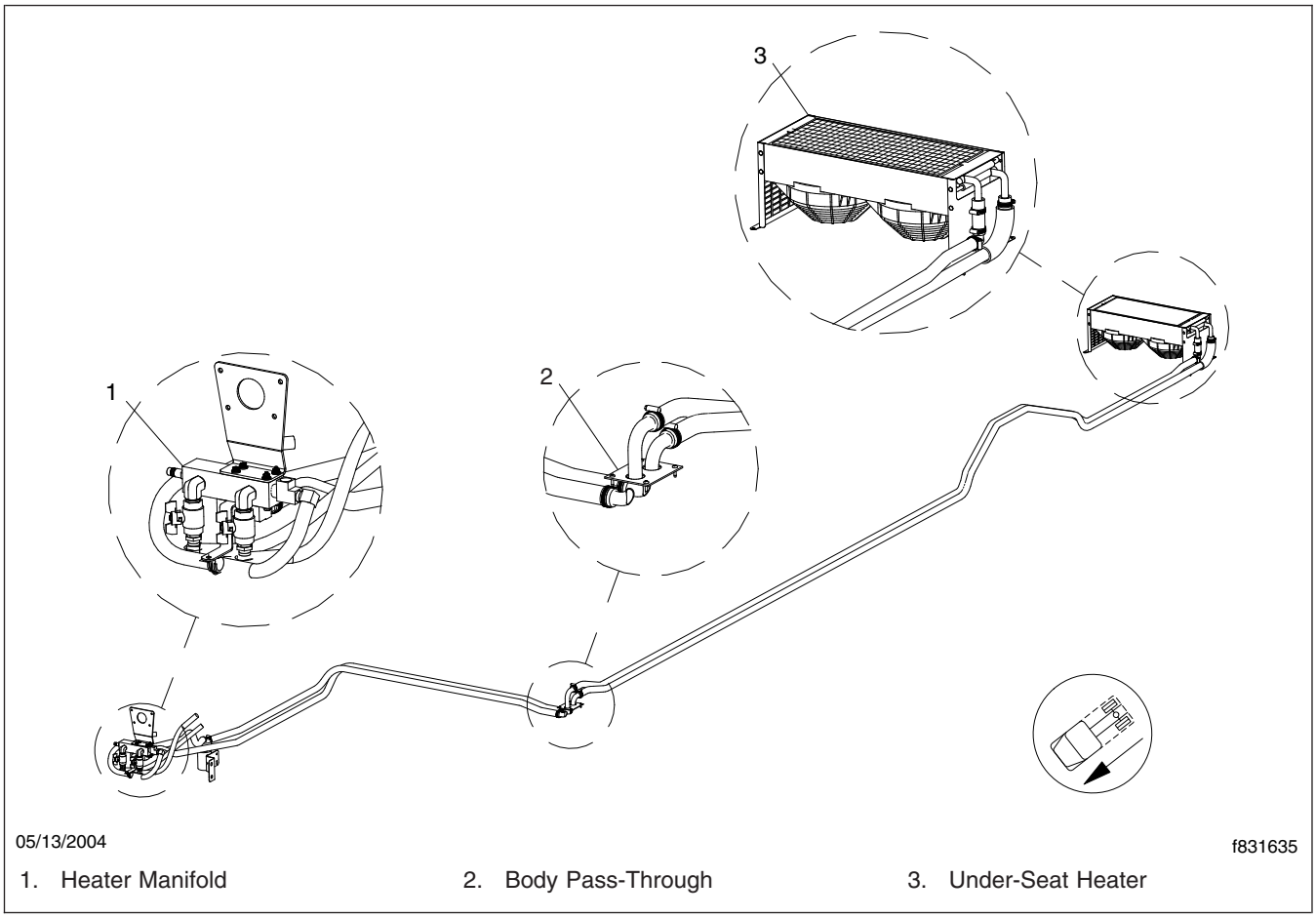
1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. Remove the applicable seat to gain access to the under-seat heater.

IMPORTANT: A small amount of coolant may be present in the heater core. Protect the interior of the bus to prevent damage from coolant spillage.

If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

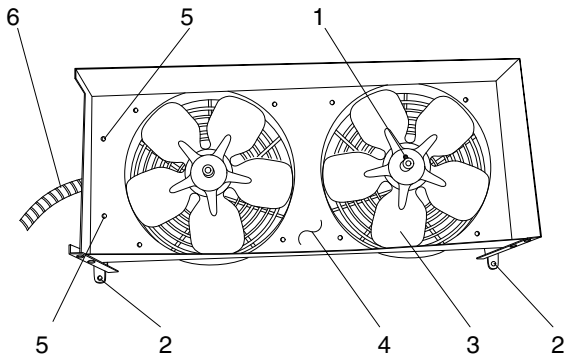
3. Mark the coolant hose connection positions for assembly reference. Loosen the clamps and disconnect the heater core supply and return lines. Clamp off the lines to prevent coolant loss. See **Fig. 1**.
4. Disconnect the wire harness connector from the fan motors.
5. Remove the four screws that attach the under-seat heater housing to the floor. Remove the under-seat heater assembly from the bus. See **Fig. 2**.
6. Slide the air filter out of the tabs on the front of the heater core.
7. Remove the two screws that fasten the heater core to the under-seat heater housing.
8. Slide the heater core flange out of the flap in the under-seat heater housing. See **Fig. 3**.
9. Position the new heater core into the under-seat heater housing. Slide the heater core flange under the housing flap. Attach the heater core to the housing using the two mounting screws.
10. Slide the air filter into the tabs at the front of the heater core.
11. Place the under-seat heater housing on the floor. Align the mounting holes. Install and tighten the mounting screws.
12. Connect the wire harness to the fan motors.
13. Connect the heater core coolant hoses to the previously marked heater core pipes. Install and tighten the hose clamps.
14. Fill the engine cooling system with the heater valves closed.
15. If the heater circuit was drained, open only the supply valve and the heater circuit vent, near the return valve, to bleed air from the heaters without sending it through the engine. If the heater circuit was not drained, open both valves.
16. Turn the ignition ON and set the heater control to hot; do not start the engine. If so equipped, turn the heater circuit booster pump on.
17. Start the engine and maintain the coolant level in the surge tank, filling to the full mark as needed.
18. If bleeding air from the heaters, close the vent when coolant is present and open the return valve.
19. Continue running the engine until the thermostat opens, then shut down the engine.
20. Once the engine has cooled, top off the coolant to the full mark and reinstall the radiator cap.
21. Bleed the cooling system.

Under-Seat Heater Core Replacement



1. Heater Manifold
2. Body Pass-Through
3. Under-Seat Heater

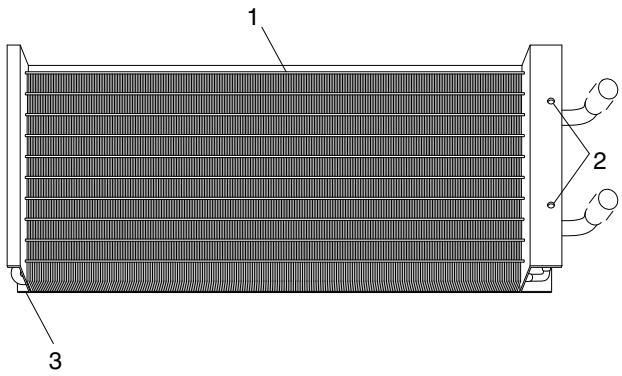
Fig. 1, Hose Routing



04/30/2004 f831628

1. Setscrew
2. Mounting Bracket
3. Heater Fan
4. Housing
5. Heater Core Fastener Location
6. Wire Harness

Fig. 2, Under-Seat Heater (heater core removed)



05/12/2004 f831633

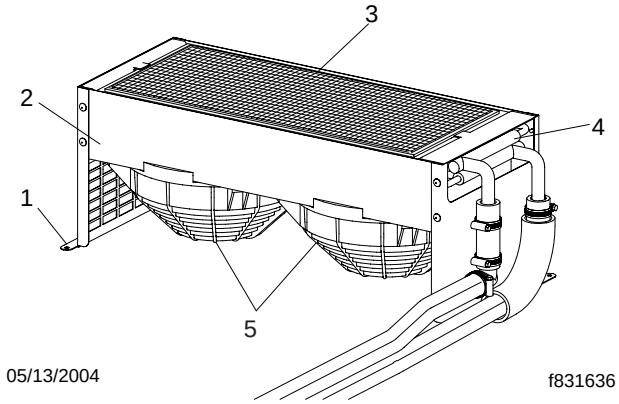
1. Core
2. Housing Fastener Mounting Hole
3. Flange

Fig. 3, Under-Seat Heater Core

Under-Seat Heater Fan Motor Replacement

Replacement

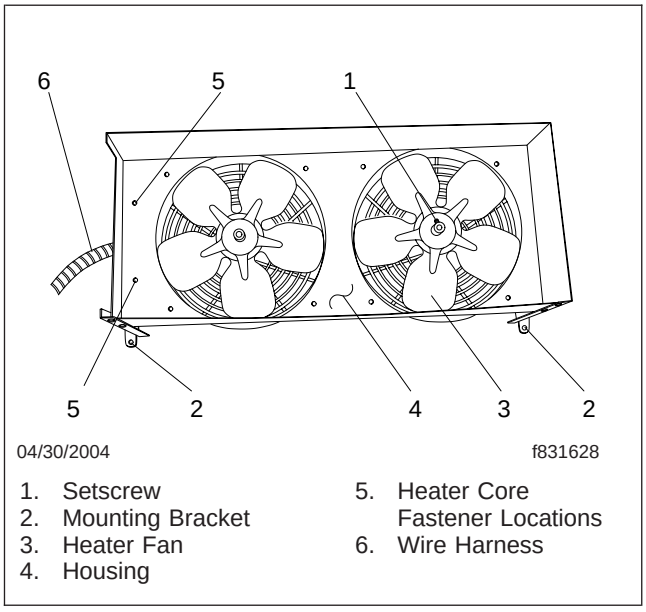
1. Park the vehicle on a level surface, shut down the engine, and set the parking brakes. Chock the tires.
2. Remove the applicable seat to gain access to the under-seat heater.
3. Disconnect the wire harness connector from the fan motors.
4. Remove the four screws that attach the under-seat heater housing to the floor. See **Fig. 1**.



1. Mounting Bracket
2. Housing
3. Filter
4. Heater Core
5. Fan Cage

Fig. 1, Under-Seat Heater

5. Tilt the under-seat heater housing up enough to access the two heater core mounting screws. Support the under-seat heater housing with a block of wood.
6. Remove the two screws that fasten the heater core to the under-seat heater housing.
7. Slide the heater core flange out of the flap in the under-seat heater housing. Separate the heater core from the under-seat heater housing.
8. Carefully support the heater core in a position that will not kink the heater hoses.
9. Remove the under-seat heater housing from the bus.
10. Remove the setscrew from the heater fan. Remove the heater fan from the motor shaft. See **Fig. 2**.



1. Setscrew
2. Mounting Bracket
3. Heater Fan
4. Housing
5. Heater Core Fastener Locations
6. Wire Harness

Fig. 2, Heater Fans (heater core removed)

11. Cut the wire ties that attach the wire conduit to the housing.
12. Carefully pull the wire harness out of the conduit.
13. Identify the wires that connect to the fan motor that needs replacing. Locate the splice connections for that fan motor and cut the wires.
14. Remove the two 1/4-inch fan motor mounting nuts from the fan cage. Remove the fan motor.
15. Position the new fan motor on the fan cage. Install and tighten the two 1/4-inch fan motor mounting nuts.
16. Match the wire colors on the replacement fan motor to the harness splice of the same color wire. Splice and tape the fan motor wires to the harness.
17. Insert the wire harness into the wire conduit.
18. Secure the harness conduit to the housing with new wire ties.
19. Return the under-seat heater housing to the bus.
20. Carefully align and slide the heater core flange under the flap in the under-seat heater housing. Attach the heater core to the housing using two mounting screws.

Under-Seat Heater Fan Motor Replacement

21. Align the under-seat heater housing mounting holes with the floor holes. Install and tighten the mounting screws.
22. Connect the wire harness connector to the fan motors.
23. Install the seat.

Replacement

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

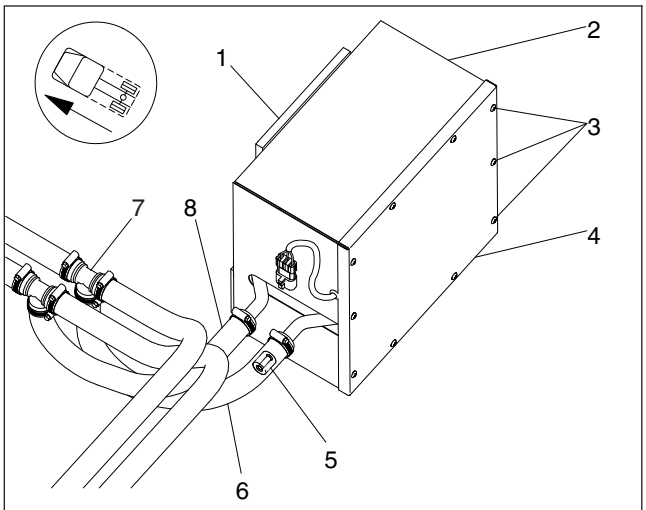
NOTE: A flow restrictor is trapped in the supply hose.

2. Mark the coolant hose connection positions for assembly reference. Loosen the clamps and disconnect the heater core supply and return hoses. Clamp off the hoses to prevent coolant loss.

IMPORTANT: A small amount of coolant may be present in the heater core. Place a pan under the stepwell heater housing to catch the coolant spillage.

If the vehicle is equipped with heater circuit valves, the valves should be closed to prevent the loss of coolant.

3. Remove the 10 screws that attach the cover to the stepwell heater housing. See **Fig. 1**.

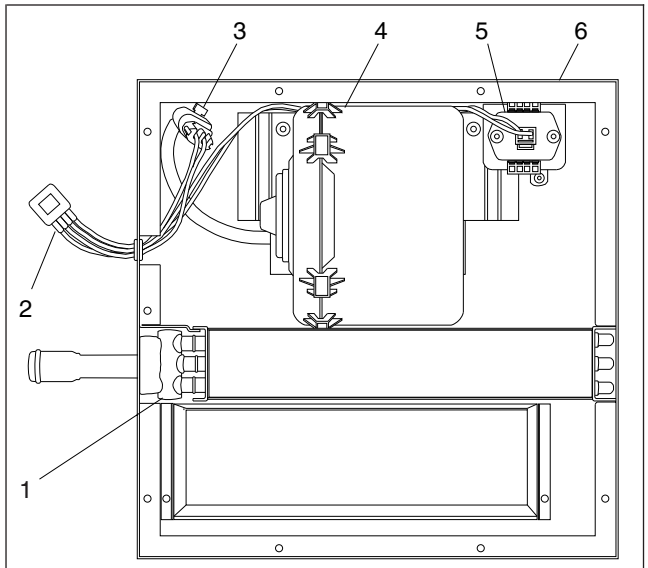


05/14/2004 f831634

1. Heater Outlet Vent
2. Housing
3. Cover Mounting Screws
4. Cover
5. Flow Restrictor
6. Supply Hose
7. Hose Tee
8. Return Hose

Fig. 1, Stepwell Heater

4. Slide the heater core out of the stepwell heater housing slots. See **Fig. 2**.



06/02/2004 f831637

1. Heater Core
2. Harness Connector
3. Blower Motor Connector
4. Blower Motor
5. Restrictor Block
6. Housing

Fig. 2, Stepwell Heater

5. Slide the new heater core into the slots in the stepwell heater housing.
6. Position the cover on the stepwell heater housing. Install and tighten the 10 mounting screws.
7. Connect the coolant hoses to the previously marked supply and return pipes. Tighten the coolant hose clamps.
8. Fill the engine cooling system with the heater valves closed.
9. If the heater circuit was drained, open only the supply valve and the heater circuit vent, near the return valve, to bleed air from the heaters without sending it through the engine. If the heater circuit was not drained, open both valves.
10. Turn the ignition ON and set the heater control to hot; do not start the engine. If so equipped, turn the heater circuit booster pump on.
11. Start the engine and maintain the coolant level in the surge tank, filling to the full mark as needed.
12. If bleeding air from the heaters, close the vent when coolant is present and open the return valve.

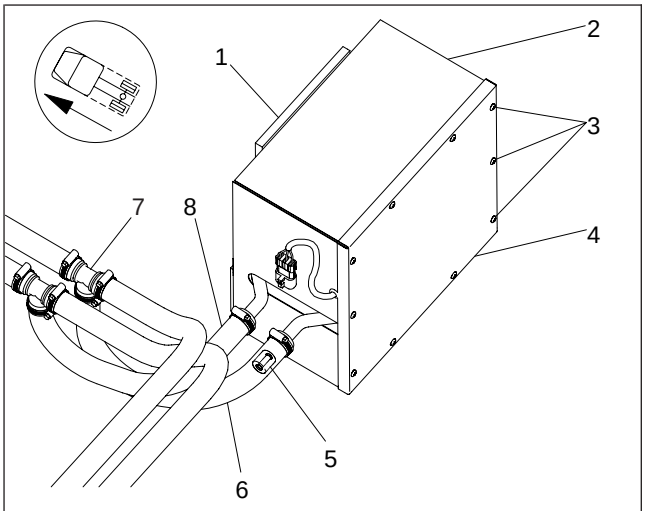
Stepwell Heater Core Replacement

13. Continue running the engine until the thermostat opens, then shut down the engine.
14. Once the engine has cooled, top off the coolant to the full mark and reinstall the radiator cap.
15. Bleed the cooling system.

Stepwell Heater Blower Motor Replacement

Replacement

1. Shut down the engine, apply the parking brakes, and chock the tires.
2. Remove the 10 screws that attach the cover to the stepwell heater housing. See **Fig. 1**.

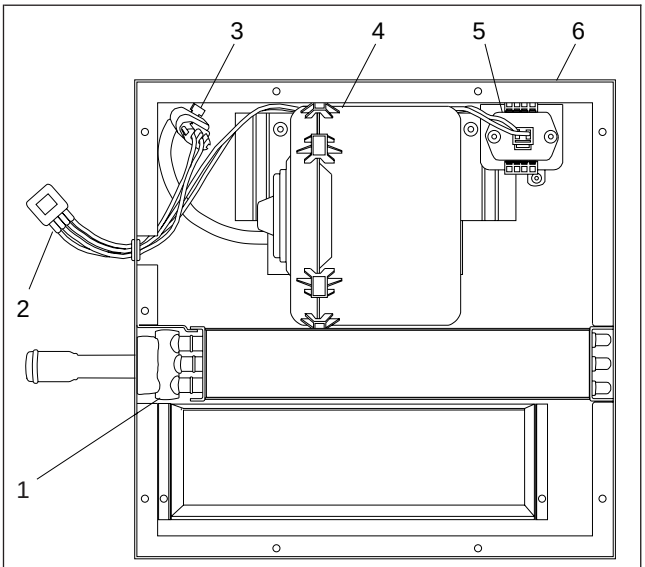


05/14/2004 f831634

1. Heater Outlet Vent
2. Housing
3. Cover Mounting Screws
4. Cover
5. Flow Restrictor
6. Supply Hose
7. Hose Tee
8. Return Hose

Fig. 1, Stepwell Heater

3. Disconnect the blower motor electrical connector. See **Fig. 2**.
4. Remove the four screws that attach the blower motor assembly to the stepwell heater housing. Lift the blower motor assembly out of the housing.
5. Install the replacement blower motor assembly into the housing.
6. Install and tighten the four screws that attach the blower motor assembly to the stepwell heater housing.
7. Place the cover on the stepwell heater housing. Install and tighten the 10 mounting screws.
8. Connect the blower motor electrical connector.
9. Remove the chocks from the tires.



06/02/2004 f831637

1. Heater Core
2. Harness Connector
3. Blower Motor Connector
4. Blower Motor
5. Restrictor Block
6. Housing

Fig. 2, Stepwell Heater

General Information

S2 Chassis have a molded, fiberglass-reinforced-plastic (FRP) hood, and sheet-molded compound (SMC) half-fenders that mount to the sides of the body. Several reinforcing members (also made of SMC) are bonded to the engine side of the hood. The front grille is made of injection-molded plastic.

A recess in the hood, above the grille, provides the handle for hood tilting.

The hood is compression molded using the preform molding process. The first step in this process is to produce a preform by spraying chopped glass fibers and resin binder in a controlled manner onto a screen that's the same shape as the male molding die. The preform is then heated to cure the resin binder. Next, the preform is moved to a compression molding press. The preform is placed onto the male half of a matched metal mold. As the halves of the mold close, resin is distributed throughout the part, and is cured under heat and pressure.

After molding, the hood is trimmed. Then the fiber-glass reinforcements and metal parts are bonded to the hood.

When in the operating position, the hood is supported at the front by the hood-hinge pivots and at the rear by hood support brackets which are attached to the cab. A groove in each bracket mates with pins attached to the inside of the hood, near each upper rear corner. The hood is held down with two rubber over-center latches, with part of the latch attached to the hood, and the other part attached to each half-fender. To prevent warm, under-hood air from entering the body through the air conditioner/heater air-inlet, a hood seal attaches to the cowl panel, ahead of the windshield.

The front hood-hinge pivots are adjustable fore and aft and left and right. The rear hood support brackets are adjustable up and down only.

The tilt-assist assembly consists of two torsion bars attached to a bracket bolted to the frame rail front closing crossmember. The outboard ends of the torsion bars fit into slots in the hood hinges.

Splash shields under the hood extend to the inboard side of the tires.

On the underside of the hood are several 1-inch (25-mm) thick polyester polyurethane foam hood liners, with a polymer-film facing. The liners reduce engine noise emissions.

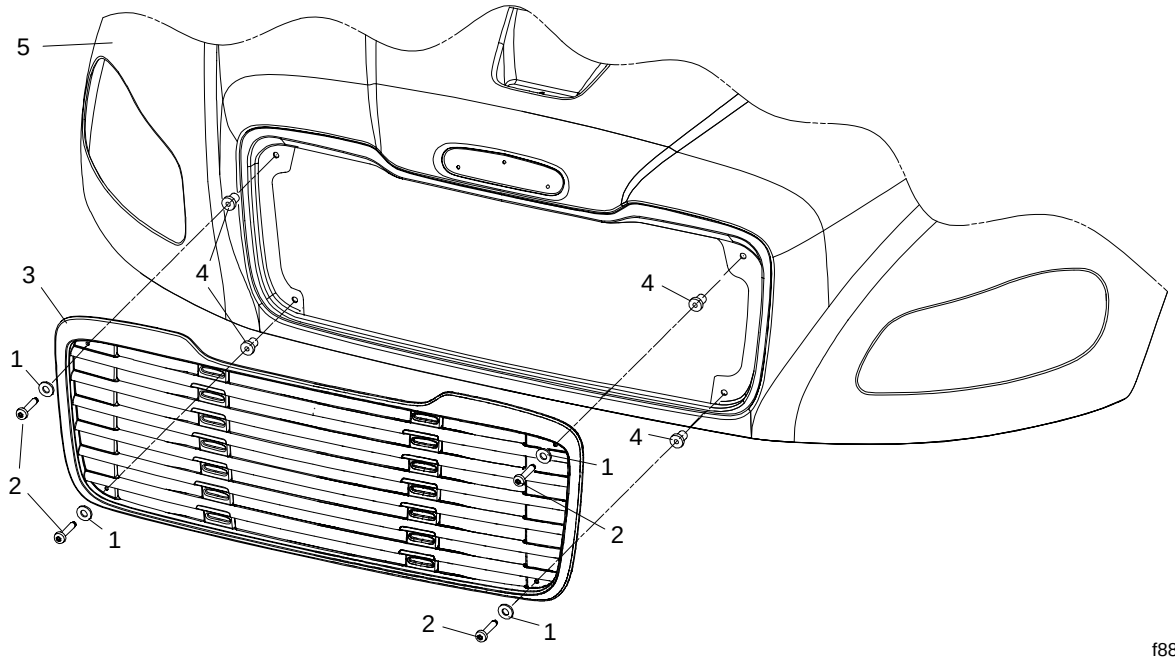
Grille Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the rear tires.
2. With the hood in the operating position, use a Torx® screwdriver (T30) to remove the grille-to-hood screws. See **Fig. 1**.
3. Remove the grille.

Installation

1. Place the grille in the hood opening and align the screw holes.
2. Using a Torx screwdriver (T30) install the screws and tighten them 15 lbf·ft (20 N·m).



1. Washer
2. T30 Torx Screw
3. Grille
4. Well Nut
5. Hood

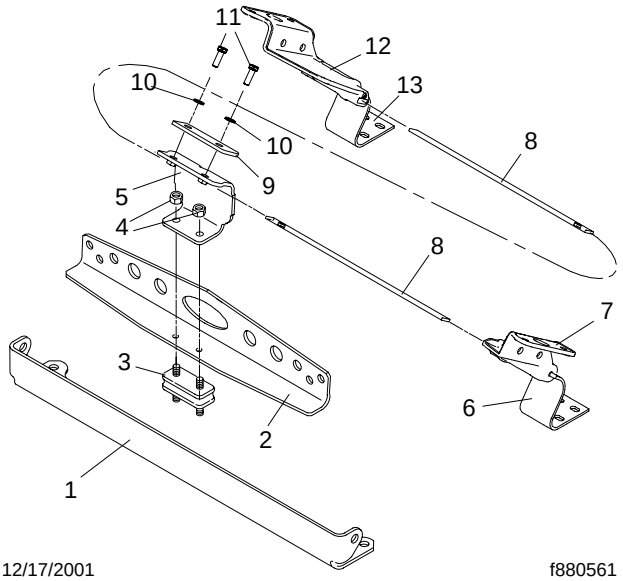
Fig. 1, Grille Installation

Hood Removal and Installation

Removal

1. Park the vehicle on a level surface, shut down the engine, apply the parking brakes, and chock the rear tires.
2. Remove the grille. See **Subject 100** for instructions.
3. Tilt the hood.
4. Remove the tilt-assist torsion bars, as follows.
   - 4.1 Tilt the hood slightly closed, until the torsion bars are not twisted, to take the tension off them.
   - 4.2 Reach through the grille opening and remove the two hexbolts that hold the torsion bars to the center mounting bracket. See **Fig. 1**.
   - 4.3 Remove the outboard ends of the torsion bars from the slots in the upper hood hinges.
5. 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.
6. Disconnect the hood damper from the hood. See **Fig. 3**.
7. Disconnect the wiring harness. Cut the zip ties holding the wiring harness to the headlamp assemblies. Release the harness mounting clips then disconnect the harness from the headlamps and turn signals on both sides of the vehicle. Place the harness on the chassis out of the way.
8. Return the hood until it is balanced over the pivots to relieve tension on the stop cables. Have a co-worker hold the hood in this position.
9. Disconnect the stop cables from the brackets on the radiator. See **Fig. 4**.
10. Carefully tilt the hood onto the support.
11. Using a T40 Torx® screwdriver, remove the hood-hinge pivot bolts. See **Fig. 5**.
12. 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.



12/17/2001 f880561

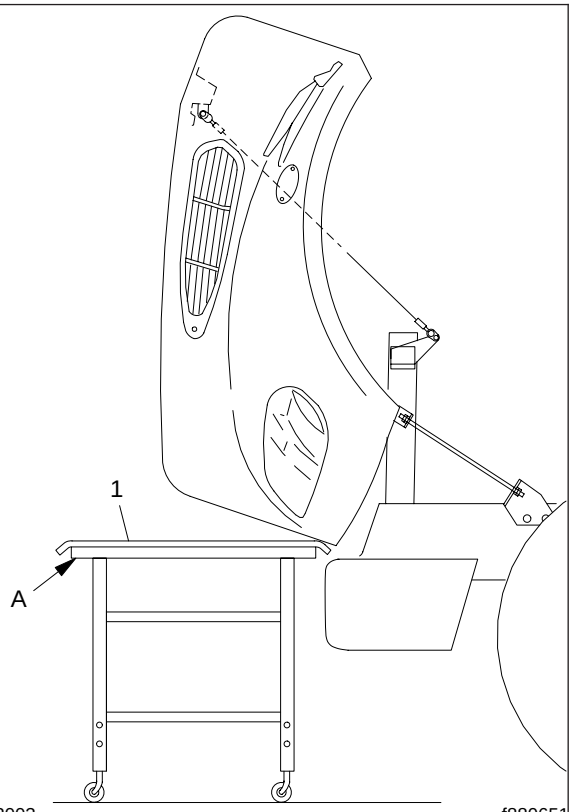
1. Crossmember Closing Bracket
2. Radiator Support Bracket
3. Radiator Isolator Assembly
4. Hexnuts
5. Center Mounting Bracket
6. Lower Hood Hinge, Left Side
7. Upper Hood Hinge, Left Side
8. Torsion Bar
9. Mounting Plate
10. Washer
11. Hexbolt, 3/8–16
12. Upper Hood Hinge, Right Side
13. Lower Hood Hinge, Right Side

Fig. 1, Torsion Bar Removal/Installation

Installation

1. 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 hinge brackets with those in the lower hood hinges. Using a T40 Torx screwdriver, install the hood-pivot bolts from the inboard side. Install the locknuts. Tighten 25 lbf·ft (34 N·m). See **Fig. 5**.
3. Lower the hood until it is balanced over the pivots, then have a co-worker hold the hood in this position.
4. Connect the stop-cable assemblies to the brackets on top of the radiator. Tighten the flanged hexnuts firmly.

Hood Removal and Installation

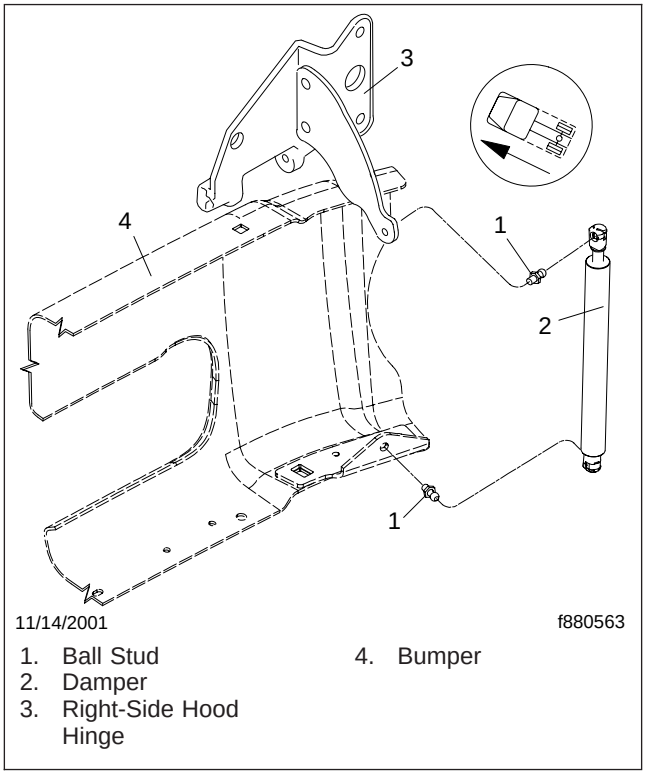


A. The top of support should be at the same height as the lowest edge of the hood.

1. Cardboard, Carpet, or Furniture Pad

Fig. 2, Supporting the Hood (typical hood shown)

5. Remove the hood support from the front of the vehicle and lower the hood. Check the hood adjustment, and adjust the hood if needed. See **Subject 120** for instructions.
6. Tilt the hood all the way open.
7. Attach the hood damper to the hood bracket. See **Fig. 3**.
8. Connect the tilt-assist torsion bars, as follows.
   - 8.1 With the hood tilted slightly closed, insert the outboard end of each torsion bar into the slot in the hood hinge.
   - 8.2 Place the inboard ends of the torsion bars on top of the mounting bracket. Install the mounting bracket plate on top of the torsion bars.

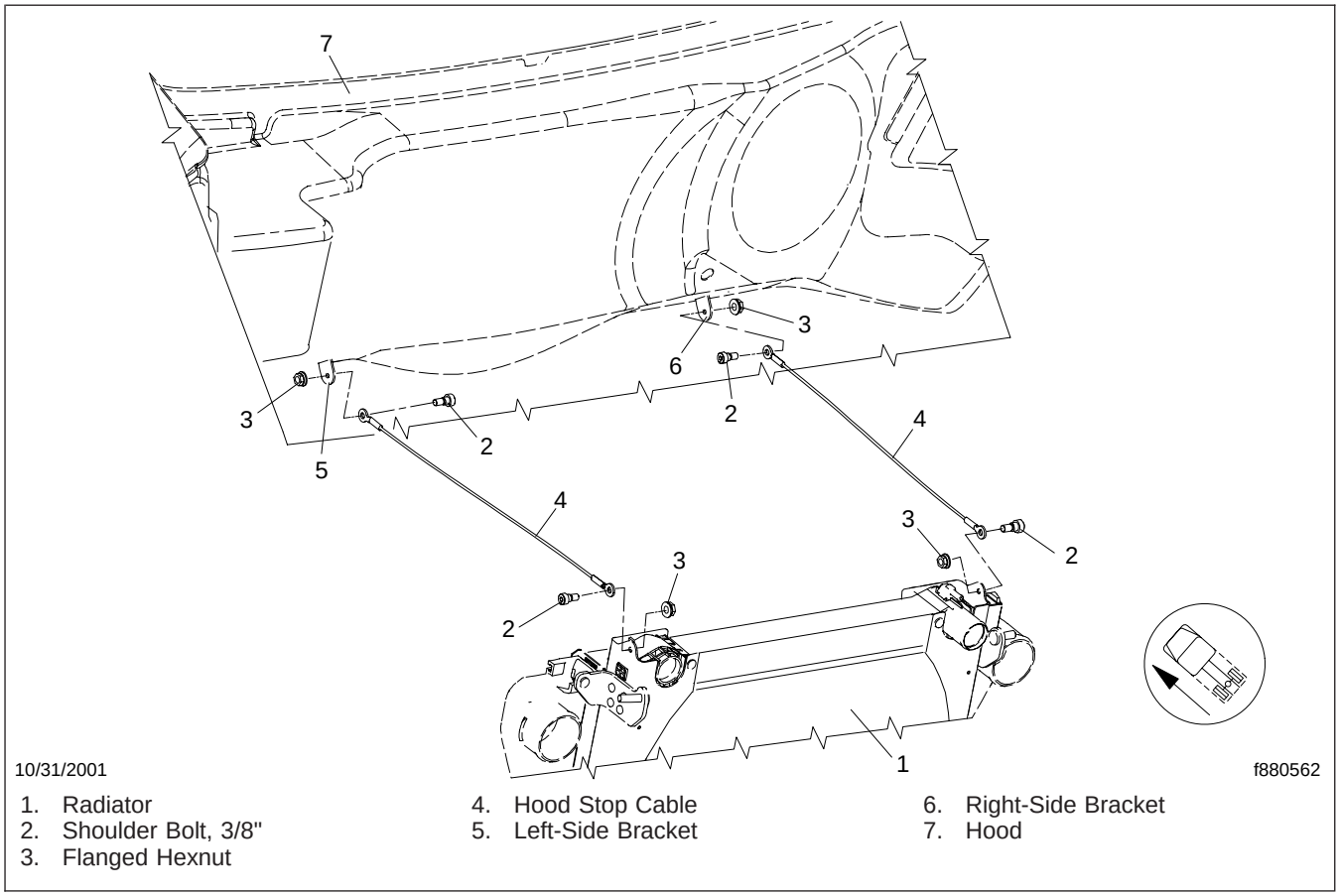


1. Ball Stud
2. Damper
3. Right-Side Hood Hinge
4. Bumper

Fig. 3, Bumper-Mounted Hood Damper Installation

   - 8.3 Install the 3/8–16 hexbolts and tighten them 28 lbf·ft (38 N·m).
9. Connect the wiring harness to the headlamps and turn signal assemblies on both sides of the vehicle. Fasten the harness in the mounting clips then use zip ties to attach the wiring harness to the headlamp assemblies.
10. Install the grille. See **Subject 100** for instructions.
11. Remove the chocks from the tires.

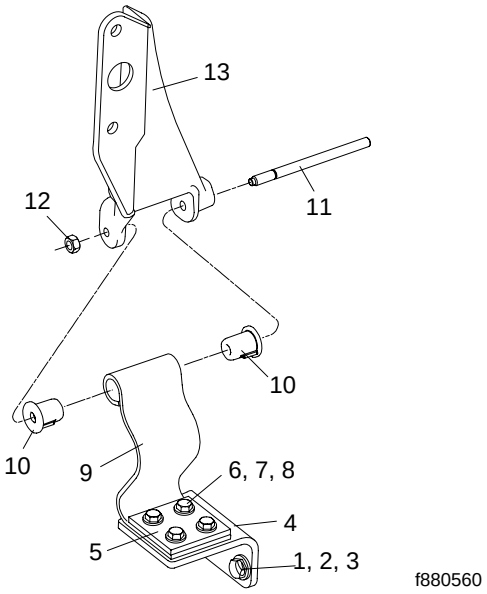
Hood Removal and Installation



1. Radiator
2. Shoulder Bolt, 3/8"
3. Flanged Hexnut
4. Hood Stop Cable
5. Left-Side Bracket
6. Right-Side Bracket
7. Hood

Fig. 4, Hood Stop Cables

Hood Removal and Installation



NOTE: Do not remove the bushings unless they are damaged.

1. Hexbolt, 5/8–11
2. Hexnut, 5/8–11
3. Washer
4. Mounting Bracket
5. Mounting Plate
6. Hexbolt, 3/8–16
7. Hexnut, 3/8–16
8. Washer
9. Lower Hood Hinge
10. Bushing
11. Hood-Pivot Bolt
12. Locknut, M10
13. Upper Hood Hinge

Fig. 5, Hood-Pivot Bolt Removal/Installation

Adjustment

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.
2. With the hood in the operating position, and both hood latches latched, measure the gap between the rear vertical edge of the hood and the front outer vertical edge of the cowl at both sides of the vehicle. See **Fig. 1**. The recommended gap should be between 1-3/8 and 1-5/8 inches (29 to 35 mm).

   If the gap is *not* within specifications on one or both sides, adjust the fore-and-aft position of the hood, as follows.

   2.1 Determine the amount that the hood must be moved at one or both sides, to correct the gap.

   2.2 Unlatch and tilt the hood.

   2.3 At the side(s) of the hood that must be moved, loosen the four fasteners that attach the hood hinge to the support bracket just enough to allow the hood to slide fore and aft for adjustment.

   Slide that side(s) of the hood fore or aft the amount determined earlier.

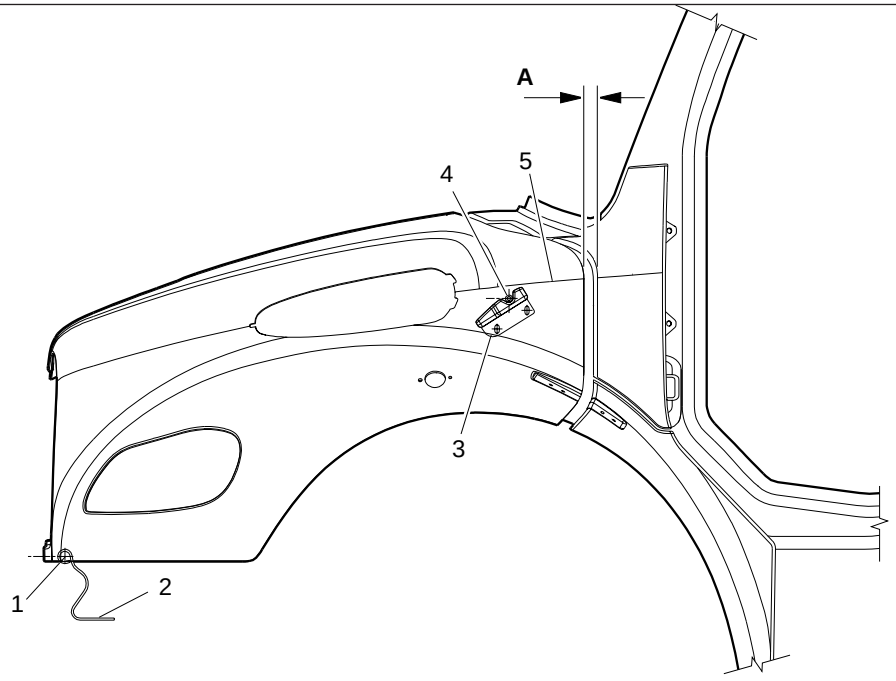
   Tighten the fasteners 28 lbf·ft (38 N·m).

   2.4 Close the hood and fasten the latches.

   2.5 Again, check the gap at both sides of the hood.

   If the gap is *not* within specifications, repeat the above procedure.

   When the gap is within specifications at both sides of the hood, go to the next step.



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A. Between 1-3/8 and 1-5/8 inches (29 to 35 mm)

1. Hood-Pivot Bolt
2. Hood Lower Hinge
3. Hood Support Isolator
4. Hood Rear Locator Pin
5. Hood Character Line

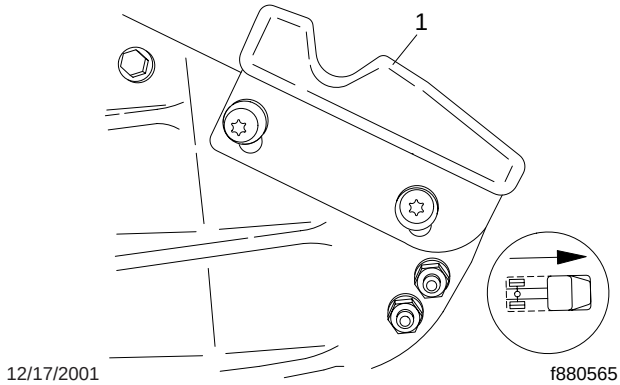
Fig. 1, Hood Fore-and-Aft and Rear Height Measurements

Hood Adjustment

3. If there is misalignment, adjust the up-and-down position of the rear of the hood, as follows.

   3.1 Unlatch and tilt the hood.

   3.2 If not already done, at the side(s) of the hood that must be moved, loosen the two fasteners that attach the rear hood support isolator assembly to the hood, just enough to allow the hood support assembly to move up or down for adjustment. See **Fig. 2**.



1. Rear Hood Support Isolator Assembly

Fig. 2, Rear Hood Support Isolator

NOTE: Complete the steps for up-and-down adjustment of one side, before doing the other side.

   3.3 Return the hood to the operating position, but latch only the side that is *not* being adjusted. Raise the mount to its highest position.

   3.4 At the side of the hood that is being adjusted, push down on the top of the hood until the character lines (or paint stripes) are aligned.

   3.5 Carefully tilt the hood, without changing the position of the hood support isolator assembly. Tighten the isolator fasteners firmly.

   If the other side of the hood needs to be adjusted, repeat the procedure.

4. Close the hood and latch it.

5. Remove the chocks from the tires.

Hood Repair Safety Precautions

Precautions

Before performing any fiberglass repairs, read the following precautions. Observe any additional precautions given by the manufacturers of the repair materials used.

1. 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 splash contacting your eyes.
2. Wear protective gloves, as some people may have skin sensitivity to resin. Also, do not allow the hardener to contact your skin. The hardener can be a skin irritant.

IMPORTANT: In case the hardener or resin contacts your skin, wash with soap and water. If the hardener or resin should contact your eyes, rinse with plenty of water (15 minutes), and call a doctor.

3. When working with fiberglass materials, wear old clothing, since the resin may damage garment material. Wash the clothing before wearing again.
4. Most of the liquids involved in fiberglass repair and cleanup (especially when using acetone as a solvent) are flammable; some are also toxic. Do not perform repairs in areas where exposed (or stored) flammable liquids may contact an open flame or any burning material, such as a cigarette. Do not perform repairs in areas that are not well-ventilated.

⚠ WARNING

Do fiberglass repairs in a safe workshop area to prevent severe personal injury due to explosion of flammable liquids or breathing of toxic fumes.

5. Do not use electric tools when the fumes of flammable solvents are present. The heat or sparks generated by the tools could create a fire hazard.
6. When grinding or sanding fiberglass surfaces, wear goggles or other protective eye shields, and also an air purifying respirator, either a throwaway type or one with a replaceable particulate filter(s). Do not breath grinding dust or particles, otherwise irritation may occur. Also, during grinding and sanding operations, wear a disposable (paper) shop coat to keep dust and fiber slivers off your clothing.
7. Because fiberglass dust can shorten the life of electrical units, air-powered tools are preferred (for frequent use).
8. Unless fiberglass repairs are done on a regular (daily) basis, do not save leftover liquids. If liquids must be saved, store them in cool, dark areas, away from direct sunlight.

General Information

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 large damaged areas, see "Structural Damage Repair."

For section replacement or to rebond parts, see "Hood Component Rebonding."

Before performing any fiberglass repairs, read the precautions listed in **Subject 130**. Observe any additional precautions given by the manufacturers of the repair materials used.

Surface Damage Repair

Surface damage refers to scratches, chips, or nicks on the outer surface of the hood. Use the following instructions to repair surface damage:

1. Inspect the damaged area. If the cracks go all the way through the hood, see "Structural Damage Repair" for instructions.
2. Clean the area with 3M™ General Purpose Adhesive Cleaner. Inspect the area closely.
3. 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).
4. Clean the area with dry compressed shop air.
5. Apply 3M Automix 8275 (400 ml syringe) or 8266 (600 ml syringe) adhesive 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 dispensing 3M Automix two-part adhesives, the first few inches to come from the cartridge will be discolored; discard this adhesive. Continue to dispense the adhesive, producing a continuous bead of uniform size and uniform color.

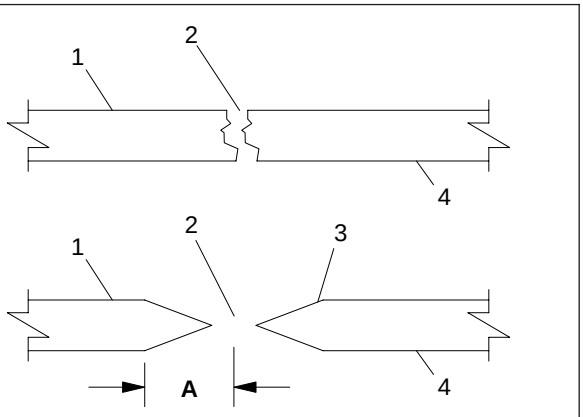
6. After the adhesive dries (about 35 minutes), sand it with a hand-held disc pad. Use 320-grit or finer sandpaper. Feather the edges of the fill so there are no visible sharp edges.
7. Clean the area with dry compressed shop air. Mask the area, then spot prime and paint it. Primer can be applied immediately after sanding. See **Group 98** for spot-painting instructions.

Structural Damage Repair

Structural damage refers to any type of damage, from hairline cracks to large fractures or punctures, that penetrate through the laminate and affect the structural soundness of the damaged part. For large damaged areas it may be easier to replace the panel. In such cases see "Hood Component Rebonding."

1. If a sound absorbent liner is present on the underside of the damaged area, remove the panel(s) to provide an adequate working area.
2. Clean both sides of the damaged area with 3M General Purpose Adhesive Cleaner. Inspect the area closely; all dirt, water, grease, and oils must be removed.
3. Inspect the area to determine the extent of the damage by pushing on the surfaces immediately surrounding and underneath the damaged area. All ragged edges, cracks, and unsound fragments will need to be removed. Using a marking pen mark a circle on both sides of the hood, 3 to 4 inches (76 to 102 mm) around the damaged area.
4. Using a grinder on both sides of the hood, grind through the hood at the point of damage, and taper out to the marked circle. In some cases it will be necessary to greatly enlarge the hole in order to grind back to sound material. See **Fig. 1**.
5. Using dry compressed shop air, blow off the area and inspect for any remaining cracks. If cracks

Hood Repair



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A. Grind a recess one-half the depth of the laminate and extending 3 to 4 inches outward in all directions from the damaged area.

1. Laminate
2. Crack
3. Taper
4. Engine Side of Hood

Fig. 1, Tapered Hole

still exist, grind the area tapering out towards sound material.

6. Sand the surface of the tapered area around the hole, using a DA sander with 80-grit or less sandpaper, to even out the tapers and leave a rough bonding surface.
7. Clean the sanded areas using dry compressed shop air and wipe the area with a clean cloth.
8. Cut a series of patches for the underside of the hood out of fiberglass mat. The first patch should be about 2 inches larger than the hole, but still able to fit in the sanded area. Cut additional sections from the mat cutting each section progressively smaller.
9. On the outside of the hood, tape over the damaged area using aluminum panel repair tape.
10. Apply 3M Automix 08277 to the under side of the area to be repaired.

When dispensing 3M Automix 08277, the first few inches to come from the cartridge will be discolored. Discard this adhesive. Continue to dispense the adhesive until a continuous bead of uniform size and color is produced.

11. Use a plastic squeegee applicator to spread a thin layer of the 3M Automix 08277 adhesive over the damaged area.
12. Lay the largest piece of fiberglass matting on a piece of clean cardboard and work a generous amount of 3M Automix 08277 into the matting. On the underside of the hood, center the matting over the repair area and apply the adhesive embedded matting over the work area working out any air bubbles.
13. Apply adhesive to the next smaller section of fiberglass matting using the same technique as the larger piece.
14. Apply the next smaller section of fiberglass matting to the larger piece, again working out any air bubbles.
15. Add a final thin layer of adhesive to the embedded sections of matting until the damaged area is even with the surrounding surfaces. The adhesive should be hard enough in 50 minutes to allow sanding.
16. Remove the tape backing from the outside surface.
17. Re-wipe the outside surface of the repair area with 3M General Purpose Adhesive Cleaner.
18. Using a DA sander with 80-grit sandpaper, sand the adhesive on the outside of the hood.
19. Clean the sanded area using dry compressed air, and wipe with a clean cloth.
20. Use a plastic squeegee applicator to spread a thin layer of the adhesive over the scuffed area.
21. Add a generous amount of 3M Automix 08275 over the entire repair area, building it up slightly above the level of the hood panel surface.
22. Allow the hood to dry for 30 minutes before sanding.
23. After the adhesive dries, sand the repaired area to a smooth flat surface. Prime and paint the surfaces on both sides of the hood.

NOTE: Open time is affected by temperature only. The open time is cut in half for every 20°F over 72°F (6°C over 22°C). The time doubles for every 20°F below 72°F (6°C below 22°C). The adhesive is not recommended for use when the temperature is less than 62°F (16°C).

Hood Component Rebonding

1. If rebonding a joint that has separated, or if replacing a damaged part, completely separate each part, using a heat gun and putty knife. Remove all of the old adhesive. The heat gun will soften the adhesive and allow it to be peeled from the fiberglass.

NOTICE

To release the adhesive, the bond area should be heated to 260°F (126°C). Heating the area above this temperature will damage the fiberglass panel.

2. Clean the surfaces to be bonded with 3M General Purpose Adhesive Cleaner. Inspect the area closely to be sure all of the old adhesive, dirt, water, grease, and oils are removed.
3. Scuff the surfaces with 80- to 220-grit sandpaper.
4. Before applying adhesive, test fit the parts by clamping the replacement part in position. Remove the replacement part for application of the adhesive.
5. Select a 3M Automix adhesive based on the desired working time and apply the adhesive to the areas to be bonded. See **Table 1** for open times.
6. Clamp the parts together and remove any excessive adhesive that squeezes out.
7. Let the adhesive dry for 5 times the specified open time. For example, if using 3M Automix 08277 adhesive: Open time X 5 = Clamping time, so 10 minutes open time is 50 minutes clamping time.

NOTE: When dispensing 3M Automix two-part adhesives, the first few inches to come from the cartridge will be discolored; discard this adhesive. Continue to dispense the adhesive until a continuous bead of uniform size and color is produced.

NOTE: When clamping parts together there should be a gap between parts for the adhesive to bond properly. The gap should be about the spacing of a paper clip. If necessary, cut a paper clip in half and place the paper clip sections at two places along the bond seam to act as a spacer.

3M Adhesives Open Time			
3M Part Number	**Syringe Size (ml)**	**Open Time (min.)**	**Use**
08270	400	1.5	Minor crack repair and small part replacement
08271	400	3.5	Inner hood structure replacement
08267	600	3.5	Inner hood structure replacement
08277	400	10.0	Inside crack repair (self-leveling)
08272	400	10.0	Fender replacement
08268	600	10.0	Fender replacement
08273	400	35.0	Large part replacement
08269	600	35.0	Large part replacement
08275	400	10.0	Permanent adhesive (not for removable sections)

Table 1, 3M Adhesives Open Time

Specifications

Torque Specifications	
Fastener Description	**Torque Value**
Hood Pivot Bolt Locknuts	25 lbf·ft (34 N·m)
Torsion Bar Mounting Hexbolts	28 lbf·ft (38 N·m)
Tilt-Assist Spring Strut Fasteners	15 to 19 lbf·ft (20 to 26 N·m)

Table 1, Torque Specifications

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.

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. For inspection instructions, 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.

Seat Belt and Tether Belt Inspection

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 and tether 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, extreme dirt and dust, or for severe fading from exposure to sunlight, especially near the buckle latch plate and in the D-loop guide area.
2. Check operation of the buckle, latch, Komfort Latch or Sliding Komfort Latch (if equipped), web retractor, and upper seat belt mount on the door pillar. Check all visible components for wear or damage.
3. Check the seat belt and tether belt connection points, and tighten any that are loose.

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.

NOTE: The following replacement procedure is for nonsuspension seats only.

1. Park the vehicle on a level surface, shut down the engine, and set the parking brake. Chock the tires.
2. On the driver and passenger side of the vehicle, remove the tread plate and the cover that protects the seat belt retractor. See **Fig. 1**.

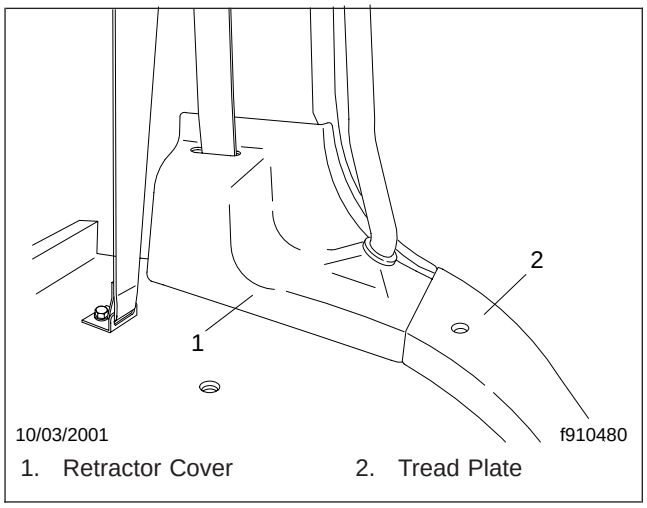


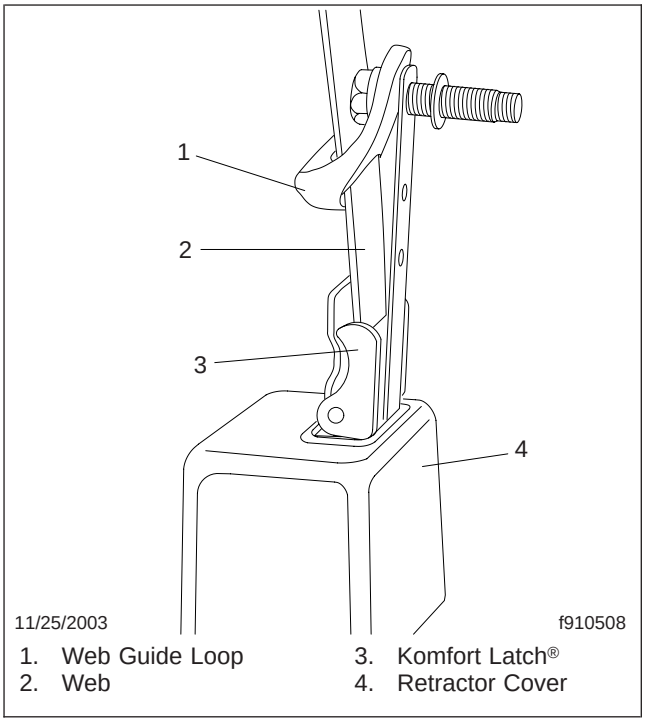
Fig. 1, Seat Belt Retractor Cover

3. Remove the three capscrews that attach the seat belt to the cab. Remove the seat belt.
4. Remove the bolt, spacer, and nut that attach the buckle assembly to the cab. Remove the buckle assembly.
5. Using a bolt, spacer, and nut, attach the buckle assembly to the cab. Tighten the bolt 35 to 45 lbf·ft (47 to 61 N·m).
6. Using three capscrews, attach the seat belt to the cab. Tighten the capscrews 35 to 45 lbf·ft (47 to 61 N·m).
7. Install the retractor cover and the tread plate.

Unlocking an Installed Retractor

Seat belt retractors are locking up and preventing the webbing from being extracted. This condition is known as reverse lock-up and is caused by excessive webbing spooling into the retractor before installation in the vehicle.

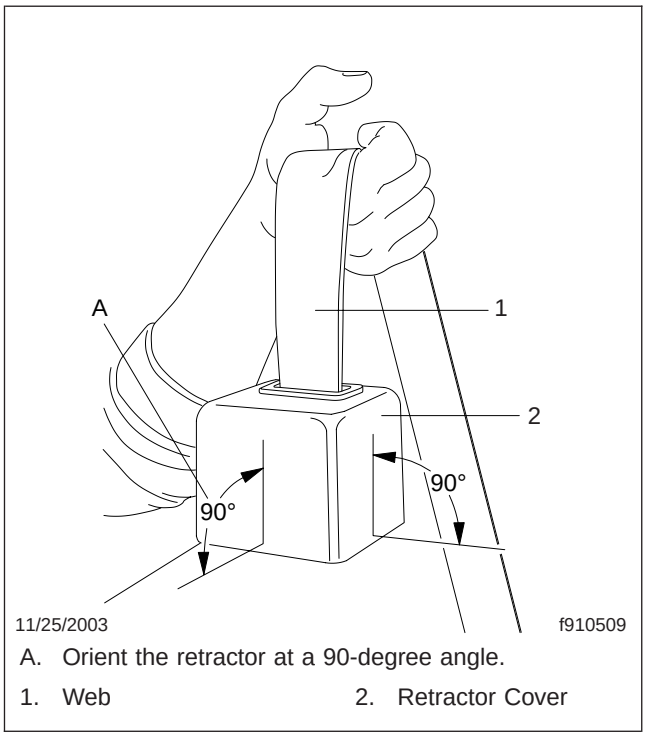
1. Park the vehicle, apply the parking brake, shut down the engine, and chock the front and rear tires.
2. Verify that the retractor is mounted in the 90-degree position. See **Fig. 1**.
3. Firmly grasp the web close to the retractor. See **Fig. 2**.



1. Web Guide Loop
2. Web
3. Komfort Latch®
4. Retractor Cover

Fig. 1, Retractor in the 90-Degree Position

4. Pull on the web with enough force to tighten the web onto the spool until the webbing locks back onto the retractor. The retractor should unlock when tension is released.
5. Remove the chocks from the tires.



A. Orient the retractor at a 90-degree angle.

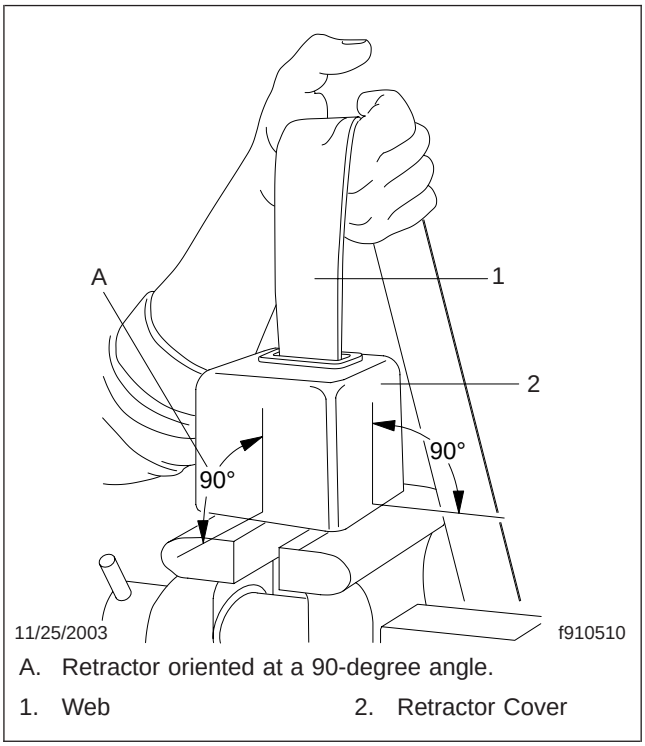
1. Web
2. Retractor Cover

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 (305 to 381 mm) to retract. Lock the Komfort Latch on the web. See **Fig. 4**.

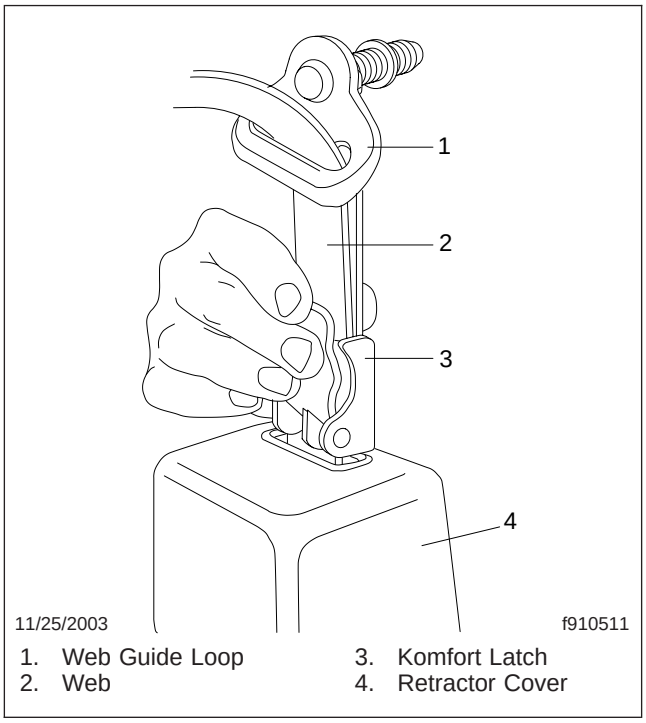
Seat Belt Retractor Unlocking



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

Troubleshooting

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.

Replace the entire seat belt system if:

- the shoulder harness or lap belt is cut, frayed, or showing signs of extreme wear;
- the buckle and latch do not engage with a solid sounding click or do not release freely when the button is pressed;
- the retractor locks up at improper times or the lap belt or shoulder harness does not move freely to and from the retractor when the vehicle is not moving. Whether the seat belt is fastened or not, the retractor should not lock unless the seat belt is jerked;
- the shoulder harness or lap belt has been exposed to extreme sun light, dust, or dirt, causing the webbing color to fade and deteriorate the strength of the webbing;
- the plastic around the buckle is deformed, cracked, or broken exposing the internal mechanism;
- the retractor cover is cracked or broken exposing the internal mechanism or stored webbing;
- the metal or plastic area of the latch is deformed, cracked, corroded, or broken;
- the D-loop is deformed, cracked, or broken.

For seat belt replacement instructions, see **Subject 110**.

Replace, adjust, or tighten as necessary if:

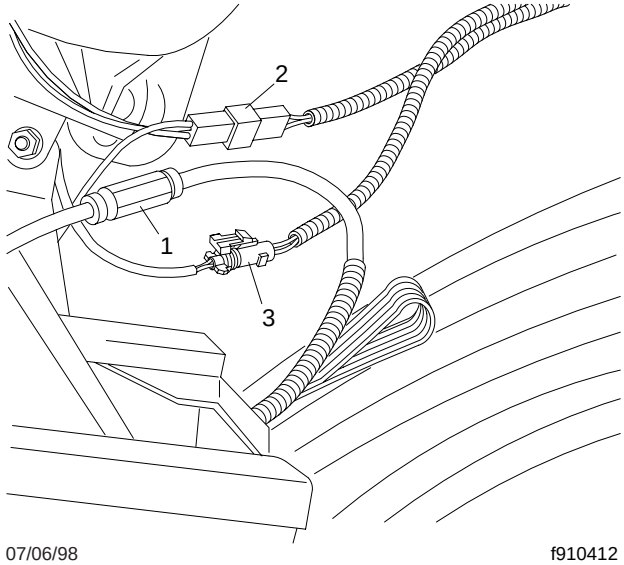
- the tethers are missing, extremely loose, or are not attached to the seat;
- the D-loop webbing guide does not rotate freely;
- the hardware is missing, rusted, corroded, or damaged;
- the hardware is not tight.

When replacing hardware, use only Freightliner authorized parts.

Air Suspension Seat

Removal

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Pull out on the seat height adjustment valve knob until all air is exhausted from the air spring.
3. Disconnect the air line from the air spring assembly by pushing in the collar of the fitting while pulling the air line out of the fitting. See **Fig. 1**.



1. Air Line Fitting (air suspension seat only)
2. Seat Occupancy Detector Electrical Connector
3. Seat Belt Switch Electrical Connector

Fig. 1, Rear of Air Suspension Seat (non-suspension seat similar)

4. Mark and disconnect the electrical connectors for the seat occupancy detector and the seat belt switch. See **Fig. 1**.
5. Remove the seat-belt straps and tether straps. For instructions, see **Section 91.00, Subject 110** in this manual.
6. Remove the mounting nuts and the flatwashers attaching the seat to the seat base assembly. Remove the seat from the cab.

Installation

1. Place the seat in position on the seat base assembly. Install the mounting nuts and the flatwashers. Tighten the nuts 27 lbf·ft (37 N·m).
2. Attach the brackets of the seat-belt straps and tether straps. Tighten the capscrews 40 lbf·ft (54 N·m).
3. Connect the air line to the fitting in the air spring assembly by pushing the tube into the fitting.
4. Connect the electrical connectors for the seat occupancy detector and the seat belt switch.
5. Remove the chocks from the tires.

Non-Suspension Seat

Removal

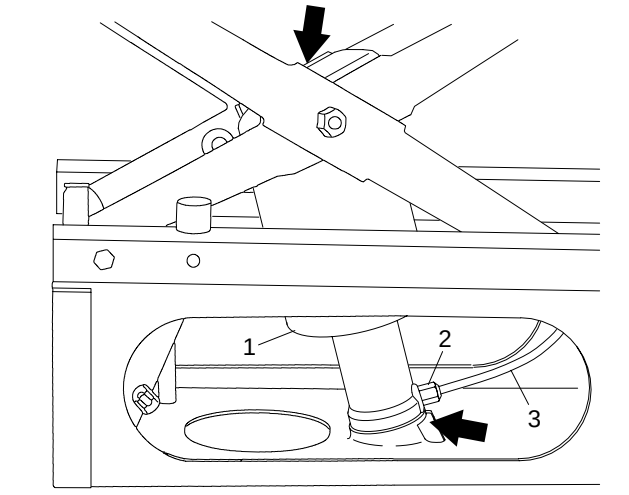
1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Mark and disconnect the electrical connectors for the seat occupancy detector and the seat belt switch. See **Fig. 1**.
3. Remove the mounting nuts and the flatwashers attaching the seat to the seat base assembly. Remove the seat from the cab.

Installation

1. Place the seat in position on the seat base assembly. Install the mounting nuts and the flatwashers. Tighten the nuts 27 lbf·ft (37 N·m).
2. Connect the electrical connectors for the seat occupancy detector and the seat belt switch.
3. Remove the chocks from the tires.

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Remove the seat using the instructions in **Subject 100**.
3. Disconnect the air line from the air spring, and remove the air line fitting from the air spring.
4. Remove the fasteners from the top and bottom of the air spring. The fasteners are indicated with arrows in **Fig. 1**.



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1. Air Spring
2. Air Line Fitting
3. Air Line

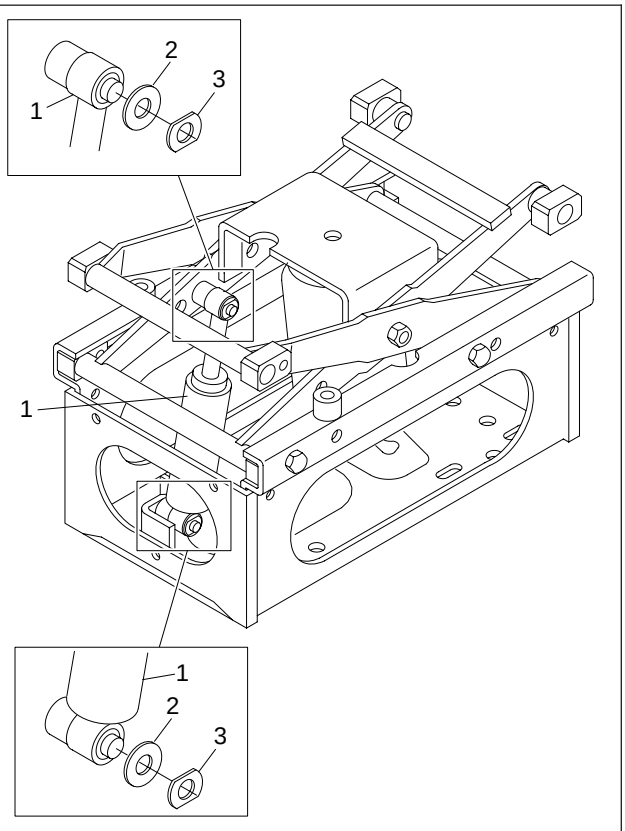
Fig. 1, Air Spring Assembly Mounting

5. Remove the air spring from the seat base.
6. Place the new air spring in position in the seat base.
7. Install the single fastener at the top and the single fastener at the bottom of the air spring. Tighten them securely.
8. Install the air line fitting in the new air spring and connect the air line to the air spring fitting.
9. Install the seat using the instructions in **Subject 100**.
10. Test the operation of the new air spring and ensure that it works properly.
11. Remove the chocks from the tires.

Replacement

NOTE: The seat assembly does not need to be removed.

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Fill the air spring so that the seat is at its maximum height.
3. Move the channel assembly to the full rearward position to gain working room.
4. Remove the push nuts securing the top and the bottom of the damper. See **Fig. 1**.



1. Damper
2. Bushing
3. Push Nut

Fig. 1, Damper Assembly

5. Remove the bushings and the damper.
6. Install the new damper and bushings.
7. Install the push nuts at the top and bottom of the damper. Make sure that they are secure.
8. Test the operation of the new damper and ensure that it works properly.
9. Remove the chocks from the tires.

Seat Height Adjustment Valve Replacement

Replacement

1. Park the vehicle on a level surface, shut down the engine, set the parking brake, and chock the tires.
2. Push in on the seat height adjustment valve knob until the seat is adjusted to its maximum height.
3. Disconnect the air suspension seat air line by pushing in the collar of the fitting while pulling the air line out of the fitting.
4. Mark and disconnect both the supply and the delivery air lines at the valve.
5. Remove the seat height adjustment valve.
   - 5.1 Remove the fastening nut and the lockwasher from the front of the valve.
   - 5.2 Remove the valve from the mounting tab on the seat base.
6. Install the new seat height adjustment valve.
   - 6.1 Place the valve in position in the mounting tab.
   - 6.2 Install the lockwasher and the fastening nut on the front of the valve and tighten the nut securely.
7. Connect both the supply and the delivery air lines (marked previously) to the valve.
8. Connect the air suspension seat air line by pushing in the collar of the fitting while pushing the air line into the fitting.
9. Test the valve and ensure that it operates properly.
10. Remove the chocks from the tires.

General Information

Freightliner LLC currently applies DuPont® Imron Elite EA high-solids polyurethane enamel on the vehicle hood at the factory.

Black Standard Urethane or Imron Elite EA is used on the vehicle chassis. The chassis includes the frame, spoke spider, running gear, and any components attached to the frame.

To meet the federal air quality regulations imposed by the EPA and local jurisdictions, this product contains lower levels of volatile organic compounds (VOCs) than earlier types (916Y, Centari®, and Imron), and is 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:

- Body—use Imron Elite EA
- Chassis—use only Imron Elite EA

To ensure proper gloss, durability, and color-matching of the enamel, repair panels with the same product originally applied to the vehicle.

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 vehicle driver's manual for the location of this decal.

NOTE: The high-solids Standard Urethane applied to the chassis at the factory is sold to original equipment manufacturers (OEMs) only, and is not available for aftermarket sale. Use Imron Elite EA, N0001 Black, for repainting.

General Guidelines

This section provides instructions for preparing large panels or the entire hood and cowl 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.

⚠ CAUTION

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.

1. Wash the entire vehicle with a mild that which does not contain lanolin or additives. Before the solution dries, rinse the vehicle with fresh water. Dry the vehicle.
2. Cover the area around the repair area to prevent damage to surrounding objects from solvent overspray or drips.

⚠ WARNING

Solvents are flammable. Keep them away from heat, sparks, and open flame. Keep the container closed. Use only with adequate ventilation. Avoid breathing the vapor, or headache, nausea, and impaired reaction time and coordination may result. Failure to follow this warning may result in serious personal injury.

3. Wipe all surfaces to be painted, using 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.

   3.1 Work on small areas at a time, wetting the surface liberally.

   3.2 Quickly wipe the surface with a clean cloth before the solvent or cleaner has a chance to dry. Change cloths frequently.
4. Feather the edge of all repaired areas, chipped surfaces, and scratches.

   4.1 Cut down the edges of broken spots with no. 220 sandpaper.

   4.2 Feather the edges by hand, using a sanding block with no. 400 sandpaper.
5. Sand the entire area to be painted. Using a sanding block and no. 400 sandpaper, or a DA sander and no. 240 sandpaper, remove the gloss to improve adhesion of the primer.
6. Using a clean cloth soaked with cleaner, remove any sanding dust.
   - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
   - Fiberglass—use a solution of one part water and one part isopropyl alcohol (IPA).
7. Treat bare metal and rusted areas.
   - Steel—use DuPont 5717 S metal conditioner.
   - Aluminum—use DuPont 225 S aluminum cleaner.

   7.1 Mix one part of the cleaner with two parts of water in a plastic bucket.

Preparing for Topcoating

7.2 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.

7.3 While the metal is still wet, wipe thoroughly with a clean, dry cloth. Allow the surface to dry before applying a conversion coating.

8. Apply a conversion coating to all bare metal.
   - Steel—use DuPont 5718 S metal conversion coating.
   - Zinc casings or galvanized surfaces (iron or steel)—use DuPont 5718 S metal conversion coating.
   - Aluminum—use DuPont 226 S aluminum conversion coating.

   8.1 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.

   8.2 Leave the coating on the surface for 2 to 5 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.

   8.3 Wipe the surface dry with a clean cloth, or air dry.

9. With paper and tape, mask all areas that are not to be painted.

Prime Coat

⚠ CAUTION

The material, substrate, or ambient temperature should be above 50°F and below 110°F.

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 primer.
   - Steel and aluminum—use Corlar 824 S epoxy primer.
   - Fiberglass—use Corlar 825 S epoxy primer.

   3.1 Stir the primer thoroughly.

   3.2 Mix two parts Corlar epoxy 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 Set the air pressure at the spray gun at 45 psi (310 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.

   3.6 Hold the spray gun about 10 to 12 inches (25 to 30 cm) from the surface.

   3.7 Spray one full wet coat to give a dry film thickness of 0.7 to 1.0 mil (18 to 25 µm).

   3.8 Clean the equipment immediately after use, using DuPont 3602 S lacquer thinner.

   3.9 Allow to dry for 2 to 4 hours before application of topcoat.

4. Wet sand the primer with no. 400 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.
    - Metal or plastic—use DuPont 3939 S lacquer and enamel cleaner.
    - Fiberglass—use a solution of 1 part water and 1 part isopropyl alcohol (IPA).

NOTE: See **Subject 110** for topcoating instructions.

General Guidelines

This section provides instructions for applying a topcoat of DuPont® enamel to full panels or the entire hood and cowl. For spot repairs or touch-ups, see **Subject 120**.

⚠ CAUTION

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 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), while spraying Imron Elite EA, and until the work area has been exhausted of all vapor and spray mist. Breathing paint vapor or spray mist can cause personal injury.

Mixing

1. Stir the Imron Elite EA enamel thoroughly.
2. Mix three parts Imron Elite EA enamel with one part of DuPont 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).

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.

Application

1. Set the air pressure at the spray gun to 60 to 65 psi (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 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 Apply a second medium-wet coat in an east-to-west direction.
3. To air dry, allow 6 to 8 hours.

   To force dry, wait 7 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, using DuPont 3602 S lacquer thinner or 8685 S reducer.

Recoating or Decorating

Two-toning, striping, or lettering may be applied in 10 to 12 hours.

Decals may be applied in 24 hours.

Topcoating

For topcoats cured over 72 hours, scuff-sand with no. 400 sandpaper and wipe with a clean tack cloth before recoating, striping, lettering, or applying decals.

General Guidelines

This section 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. Preparation materials specified for one type of surface should not be used for any other type of surface. See **Specifications 400** for a summary of the materials used in this section.
2. Limit intermediate coatings, such as primers, to 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).

⚠ CAUTION

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 them away from heat, sparks, and open flame. Keep the container closed. Use only with adequate ventilation. Avoid breathing the vapor, or headache, nausea, and impaired reaction time and coordination may result. Failure to follow this warning may result in serious personal injury.

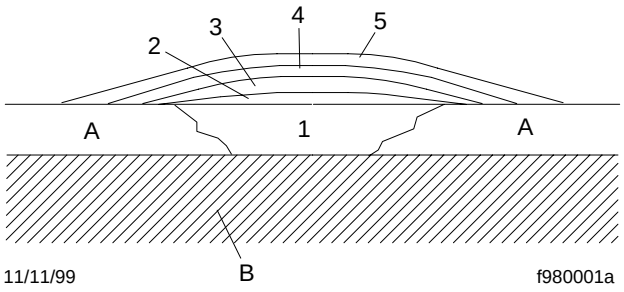
3. Clean the area to be repaired, using DuPont 3939 S solvent, then quickly wipe the surface with a clean, lint-free cloth before the solvent dries. Remove all traces of wax, polish, grease, and silicones.
4. Sand or grind all dents and scratches.
5. Wet sand the area being repaired, using no. 320 grit 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 primer, 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 (350 to 470 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, using DuPont 3602 S lacquer thinner.

10.9 Air dry 2 to 4 hours or force dry 20 minutes.

11. Wet sand the primer with no. 400 or finer sandpaper. Feather the edge into the surrounding area.
12. Remove the sanding dust. Use the same solvent and wipe-on, wipe-off method used earlier to clean the area.
13. Wipe the repair area with a tack cloth.
14. If the finish is old, apply one coat of DuPont 222 S adhesion promoter over the entire repair area.

    14.1 Set the air pressure to 35 psi (240 kPa) at the spray gun.

    14.2 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), while spraying topcoat, and until the work area has been exhausted of all vapor and spray mist. Breathing topcoat vapor or spray mist can cause personal injury.

Imron Elite EA Topcoating

1. Mix the Imron Elite EA polyurethane enamel.
   1.1 Stir the Imron Elite EA enamel thoroughly.
   1.2 Mix three parts Imron 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 (410 to 450 kPa). For pressure feed systems, set the fluid delivery at 12 to 16 ounces (350 to 470 mL) per minute.
3. For metallic topcoats only, apply one coat of DuPont 500 S urethane clear.
   3.1 Mix eight parts of 500 S urethane with one part 193 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 Imron 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 (100 to 140 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, using DuPont 3602 S lacquer thinner or 8685 S reducer.

Equipment Application Parameters		
Parameter	**English Units**	**Metric Units**
Atomizing Air		
Primer	45 psi	310 kPa
Enamel	60–65 psi	410–450 kPa
Fluid Delivery	12–16 oz/min	350–470 mL/min
Booth Temperature	75°F	23°C
Spray Gun Distance	10–12 in	25–30 cm

Table 1, Equipment Application Parameters

DuPont Surface Preparation Materials				
Step	**Steel**	**Aluminum**	**Plastic**	**Fiberglass**
Wash and dry	Mild detergent (such as dish washing detergent)			
Wipe with cleaner	Prep-Sol 3919 S	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	5717 S metal conditioner	225 S aluminum cleaner	—	—
Apply conversion coating to bare metal	5718 S metal conversion coating	226 S aluminum 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		Mix: - 2 parts Corlar 825 S primer with 1 part DuPont 826 S activator - reduce 3 parts of mixture with 1 part DuPont 3602 S lacquer thinner	

Table 2, DuPont Surface Preparation Materials

DuPont Imron Elite EA Topcoating and Spot Repair Materials	
Step	**Instruction**
Mix enamel	Mix: - 3 parts Imron Elite EA - 1 part 194 S activator
Pressure at gun	60–65 psi (414–448 kPa)
Equipment cleanup	3939 S lacquer and enamel cleaner or 8685 S reducer

Table 3, DuPont Imron Elite EA Topcoating and Spot Repair Materials