SCHOOL BUS CHASSIS WORKSHOP MANUAL

Models: Type C SB
FS65

STI-347, S20 (10/10P)

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 *School Bus Chassis Maintenance Manual*.

IMPORTANT: Descriptions and specifications in this manual were in effect at the time of printing. Freightliner Custom Chassis Corporation reserves the right to discontinue models at any time, or change specifications and design 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.

© 1996–2010 Daimler Trucks North America LLC

All rights reserved. No part of this publication, in whole or in part, may be translated, reproduced, stored in a retrieval system, or transmitted in any form by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of Daimler Trucks North America LLC. Daimler Trucks North America LLC is a Daimler company.

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

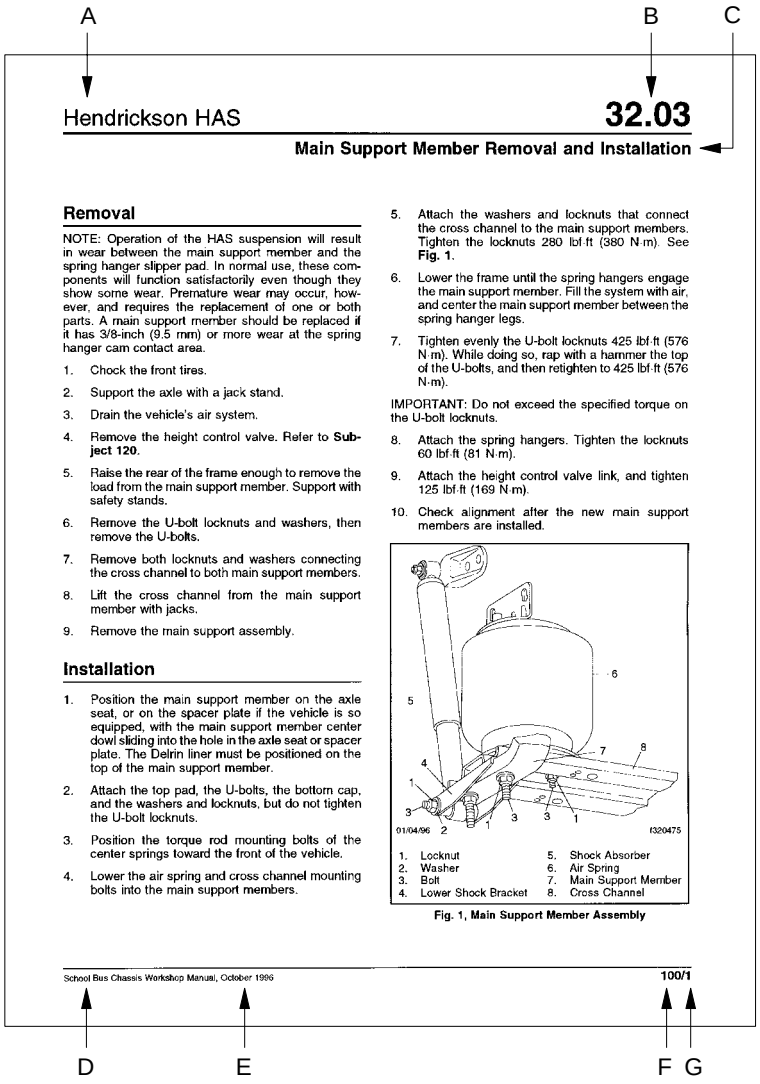
Warranty-related service information available on the AccessFreightliner.com website includes the following documentation.

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 a *School Bus Chassis Workshop Manual* page, see **Fig. 1**.



10/02/96 f020055

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

Fig. 1, Example of a School Bus 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
25	Clutch
26	Transmission
30	Throttle Control
31	Frame and Frame Components
32	Suspension
33	Front Axle
35	Rear Axle
40	Wheels and Tires
41	Driveline
42	Brakes
46	Steering
47	Fuel
49	Exhaust
54	Electrical, Instruments, and Controls
60	Cab
82	Windshield Wipers and Washer
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
ABS ..... antilock braking system
ABS ..... acrylonitrile-butadiene-styrene
A/C ..... air conditioner
AC ..... alternating current
ACPU ..... air conditioning protection unit
ADLO ..... auto-disengagement lockout
a.m. ..... *ante meridiem* (midnight to noon)
AM ..... amplitude modulation
amp(s) .... ampere(s)
AMU ..... air management unit
ANSI ..... American National Standards Institute
API ..... American Petroleum Institute
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
ATF ..... automatic transmission fluid
attn ..... attention
aux. ..... auxiliary
av ..... *avoirdupois* (British weight system)
AWG ..... American wire gauge
AWS ..... American Welding Society
BAT ..... battery
BBC ..... bumper-to-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
CCA ..... cold cranking amperes
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
CLS ..... coolant level sensor
cm ..... centimeters
cm^3 ..... cubic centimeters
CMVSS .... Canadian Motor Vehicle Safety Standard
Co. ..... company
COE ..... cab over engine
Corp. ..... corporation
CPU ..... central processing unit
cSt ..... centistokes (unit of measurement for describing the viscosity of general liquids)
cu ft ..... cubic feet
cu in ..... cubic inches
CUM ..... Cummins
CWS ..... collision warning system
DC ..... direct current
DDA ..... Detroit Diesel Allison
DDC ..... Detroit Diesel Corporation
DDE ..... Detroit Diesel Engines
DDEC ..... Detroit Diesel Electronic (engine) control
DDR ..... diagnostic data reader
DDU ..... driver display unit
DGPS ..... differential global positioning system
dia. ..... diameter
DIP ..... dual inline package (switch)
DLA ..... data link adaptor
DLU ..... data logging unit
DMM ..... digital multimeter
DOT ..... Department of Transportation
DRL ..... daytime running lights
DRM ..... dryer reservoir module
DSM ..... district service manager
DTC ..... discharge temperature control
DVOM ..... digital volt/ohm meter
ea. ..... each
EBS ..... electronic braking system
ECAP ..... electronic control analyzer programmer
ECAS ..... electronically controlled air suspension
ECI ..... electronically controlled injection
ECM ..... electronic control module
ECU ..... electronic control unit
EDM ..... electronic data monitor
EEPROM .. electrically erasable programmable read-only memory
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
etc. ..... *et cetera* (and so forth)
ETEC ..... electronic truck engine control
EUI ..... electronic unit (fuel) injectors
FAS ..... Freightliner air suspension
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
FM ..... frequency modulation
FMCSA .... Federal Motor Carrier Safety Administration
FMI ..... failure mode identifier
FMSI ..... Friction Materials Standards Institute
FMVSS .... Federal Motor Vehicle Safety Standard
FRP ..... fiberglass reinforced plastic
FSA ..... field service authorization
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

List of Abbreviations

gal ..... gallons
GAWR ..... gross axle weight rating
GL ..... gear lubricant
GND ..... ground
gpm ..... gallons per minute
GPS ..... global positioning system
GVWR ..... gross vehicle weight rating
HCU ..... hydraulic control unit
HD ..... heavy-duty
HEPA ..... high-efficiency particulate air (filter)
HFC ..... hydrogenated fluorocarbons (refrigerant-134a)
hp ..... horsepower
hp ..... high pressure
HRC ..... Rockwell "C" hardness
hr(s) ..... hour(s)
htr ..... heater
HVAC ..... heating, ventilating and air conditioning
H/W ..... hardware
ICU ..... instrumentation control unit
i.d. ..... inside diameter
ID ..... identification
IFI ..... Industrial Fasteners Institute
IGN ..... ignition
ILO ..... *in lieu of* (in the place of)
in ..... inches
in^3 ..... cubic inches
Inc. ..... incorporated
inH $_2$O ..... inches of water
inHg ..... inches of mercury
IP ..... instrument panel
ISO ..... International Organization for Standardization
k ..... kilo (1000)
kg ..... kilograms
km ..... kilometers
km/h ..... kilometers per hour
kPa ..... kilo Pascals
kW ..... kilowatts
L ..... liters
lb ..... pounds
lbf·ft ..... pounds force feet
lbf·in ..... pounds force inches
LCD ..... liquid crystal display
LED ..... light-emitting diode
LH ..... left-hand
LH DR ..... left-hand drive
LHK ..... liters per hundred kilometers
LHS ..... low hydrogen steel
LLC ..... limited liability company
L/min ..... liters per minute
LPG ..... liquefied petroleum gas
m ..... meters
max. ..... maximum
MESA ..... Mining Enforcement Safety Act
mfr. ..... manufacturer
mi ..... miles
MID ..... message identifier
MIL ..... military specification
min. ..... minutes
min. ..... minimum
misc. ..... miscellaneous
mL ..... milliliters
mm ..... millimeters
mod. ..... module
mpg ..... miles per gallon
mph ..... miles per hour
MSHA ..... Mining Safety and Health Administration
MVDA ..... Motor Vehicle Dealers Association
n ..... negative (front axle wheel alignment specification)
N/A ..... not applicable
N·cm ..... Newton-centimeters
NC ..... normally closed (terminal or switch)
NHTSA ..... National Highway Traffic Safety Administration
NIOSH ..... National Institute for Occupational Safety and Health
NLGI ..... National Lubricating Grease Institute
N·m ..... Newton-meters
NO ..... normally open (terminal or switch)
no. ..... number
NPT ..... national pipe thread
NPTF ..... national pipe thread fitting
NSBU ..... neutral start/backup
NT ..... nylon tube or nylon tubing
OCV ..... open circuit voltage
o.d. ..... outside diameter
O.D. ..... overdrive
OEM ..... original equipment manufacturer
OSHA ..... Occupational Safety and Health Administration
oz ..... ounces
ozf·in ..... ounces force inches
p ..... positive (front axle wheel alignment specification)
parm ..... parameter
PC ..... personal computer
PCB ..... printed circuit board
PDC ..... parts distribution center
PDM ..... power distribution module
PEEC ..... programmable electronic engine control
PID ..... parameter identifier
PLC ..... power line carrier
PLD ..... *Pumpe-Linie-Düse* (pump-line-nozzle)
p.m. ..... *post meridiem* (noon to midnight)
p/n ..... part number
PSA ..... pressure sensitive adhesive
psi ..... pounds per square inch
psia ..... pounds per square inch, atmosphere
psig ..... pounds per square inch, gauge
pt ..... pints
pt ..... points
PTCM ..... pressure time control module
PTO ..... power take-off
pvc ..... polyvinyl chloride
PWM ..... pulse width modulation
qt ..... quarts
qty. ..... quantity
R & O ..... rust inhibitors and oxidants
R–12 ..... refrigerant-12 (CFC)
R–134a ..... refrigerant-134a (HFC)
RAM ..... random access memory
recirc ..... recirculation
Ref(s). ..... reference(s)
RFI ..... radio frequency interference
RH ..... right-hand
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
RSG ..... road speed governor
RTV ..... room temperature vulcanizing

List of Abbreviations

RV ..... recreational vehicle
SAE ..... Society of Automotive Engineers
SB ..... service bulletin
SD ..... severe duty
SDU ..... step deployment unit
SEL ..... shutdown engine light
SI ..... service information
SI ..... *Système International*
SID ..... subsystem identifier
SMC ..... sheet molded compound
S/N ..... serial number
SPACE .... seat pretensioner activation for crash survival enhancement
SRT ..... standard repair time
SSD ..... side sensor display
SST ..... stainless steel
std. ..... standard
S/W ..... software
SW ..... switch
TAM ..... thermocouple amplifier module
TBS ..... turbo boost sensor
TCU ..... transmission control unit
TDC ..... top dead center
TDR ..... technician diagnostic routine
temp ..... temperature
TIG ..... tungsten inert gas
TPS ..... thermal protection switch
TPS ..... throttle position sensor
TRS ..... timing reference sensor
TSO ..... truck sales order
U.D. ..... underdrive
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
VDC ..... vehicle data computer
Vdc ..... volts, direct current
VIN ..... vehicle identification number
VIP ..... vehicle instrumentation and protection (Kysor)
VOC ..... volatile organic compounds
VOM ..... volt-ohmmeter
VSG ..... variable speed governor
VSS ..... vehicle speed sensor
WB ..... wire braid
WI ..... work instructions
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

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

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

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 may use metric fasteners (diameter and pitch are measured in millimeters).

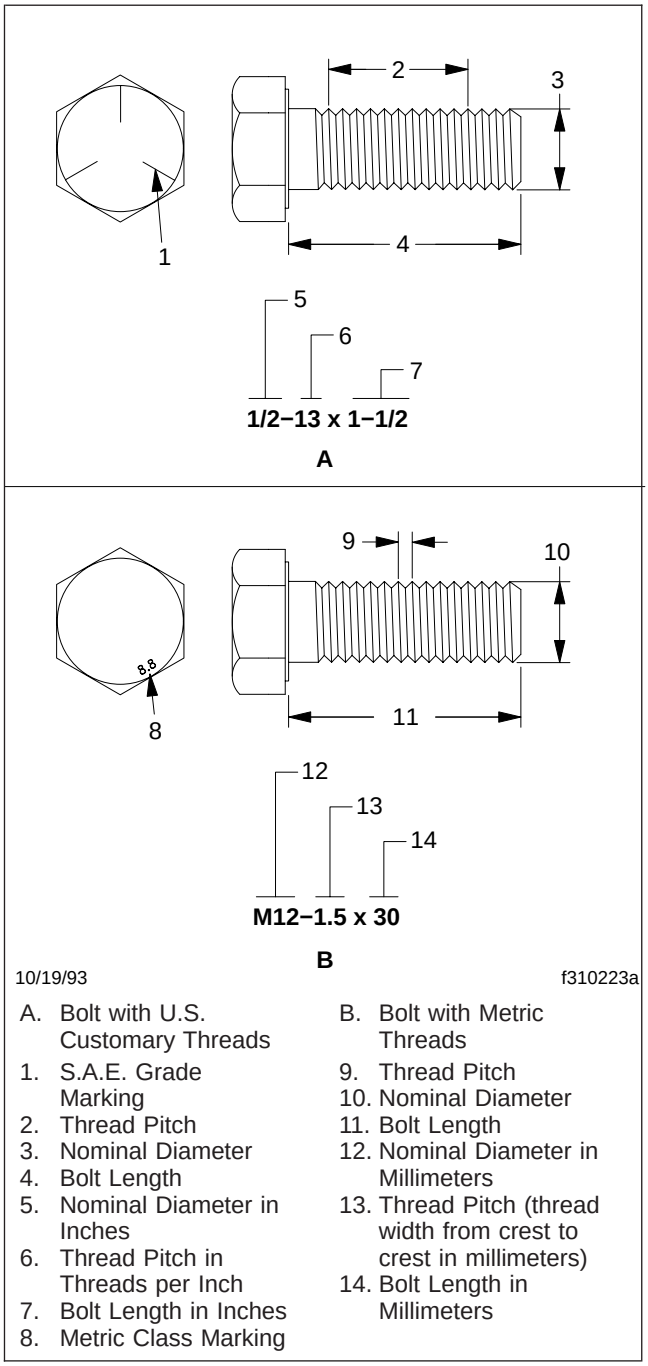
Most threaded fasteners used on the chassis that are 1/2-inch diameter or larger are plain hex-type fasteners (non-flanged); *all* metric fasteners are non-flanged. Special hardened flatwashers are used under the bolt head, and between the part being attached and the hexnut, to distribute the load, and 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.

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

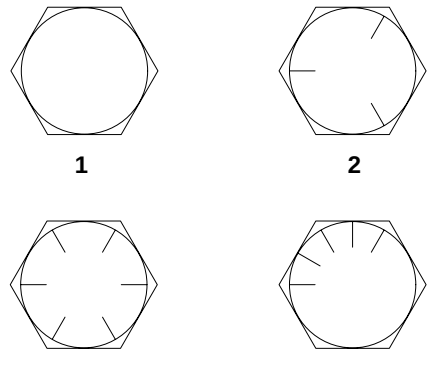


A. Bolt with U.S. Customary Threads
1. S.A.E. Grade Marking
2. Thread Pitch
3. Nominal Diameter
4. Bolt Length
5. Nominal Diameter in Inches
6. Thread Pitch in Threads per Inch
7. Bolt Length in Inches
8. Metric Class Marking

B. Bolt with Metric Threads
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

General Information

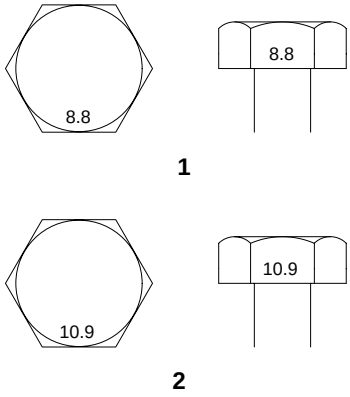


NOTE: Grade 2 bolts have no grade marking; grade 2 bolts are rarely used by Freightliner.

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



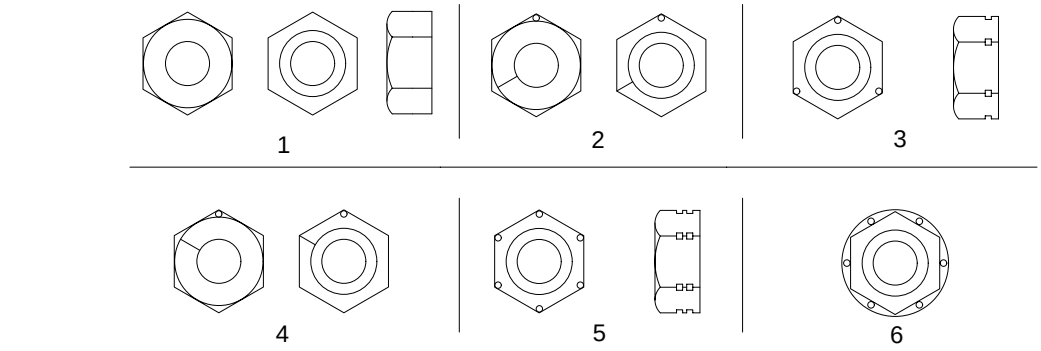
NOTE: In addition to the class markings, the bolt head must also carry the manufacturer's trademark or identification.

1. Class 8.8
2. Class 10.9

Fig. 4, Bolt Classes

Frame Fasteners

For components attached to the frame, grade 8 and

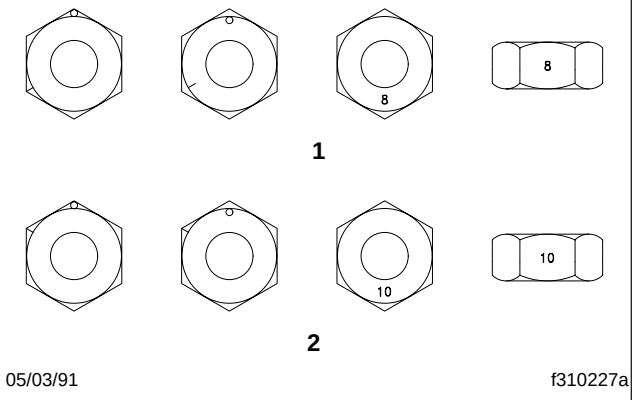


NOTE: Grade 2 (S.A.E.) and grade A (I.F.I.) nuts have no identification marks or notches; they are rarely used by Freightliner. Grade B (I.F.I.) nuts have three identification marks at 120 degrees, or 6 notches. Grade C (I.F.I.) nuts have three identification marks at 60 degrees, or 12 notches. Grade 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

8.2 phosphate-and oil-coated hexhead bolts and



1. Class 8 Nut
2. Class 10 Nut

Fig. 5, Nut Classes

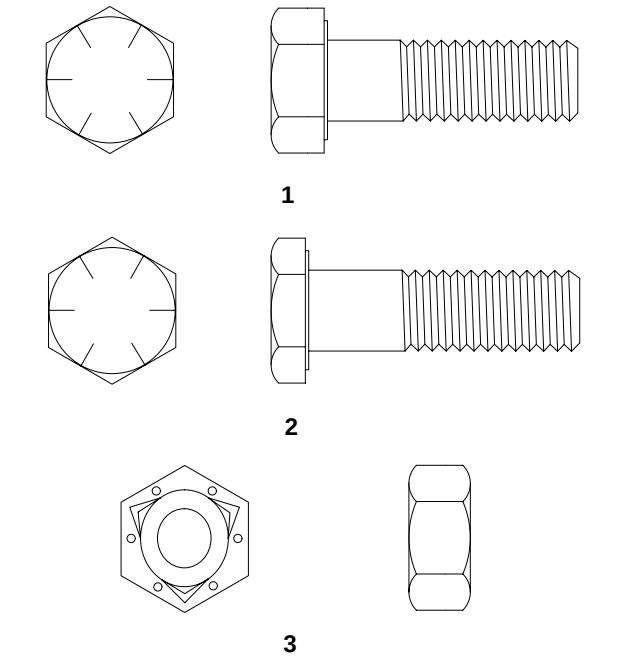
grade C cadmium-plated and wax-coated prevailing torque locknuts are used. The prevailing torque locknuts have distorted sections of threads to provide torque retention. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. See **Fig. 6**.

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.



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

Fig. 6, Frame Fastener Identification

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

General Information

is recommended for a fastener, the compound acts as a lubricant, and oil is not needed.

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® 244 or 271, or Perma-Lok® HM–128.

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

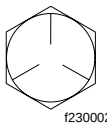
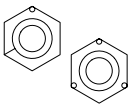
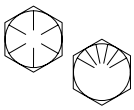
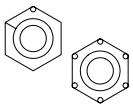
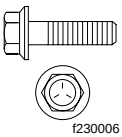
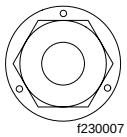
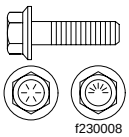
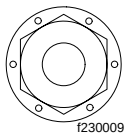
General Instructions

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 3 or 4 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.

IMPORTANT: Grade 8 regular hex zinc-yellow plated capscrews and cadmium- and wax-coated prevailing torque locknuts may be tightened to a lower torque value than the grade 8 regular hex fasteners described in **Table 1**. See **Table 2** for torque values for grade 8 regular hex zinc-yellow plated capscrews and cadmium- and wax-coated prevailing torque locknuts.

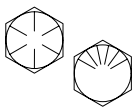
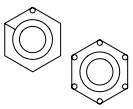
Torque Values for U.S. Customary Thread Fasteners With Lubricated* or Plated Threads†								
Thread Diameter–Pitch	Regular Hex				Flanged			
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 5 Bolt	Grade B Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft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

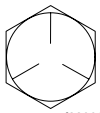
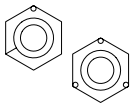
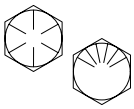
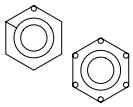
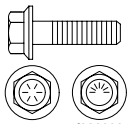
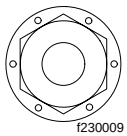
Table 1, Torque Values for U.S. Customary Thread Fasteners With Lubricated or Plated Threads

Specifications

Torque Values for Grade 8 Regular Hex Zinc-Yellow Plated Capscrews and Cadmium- and Wax-Coated Prevailing Torque Locknuts*		
Thread Diameter-Pitch	Regular Hex	
	Grade 8 or 8.2 Bolt	Grade 8 or C Nut
	Torque: lbf·ft (N·m)	
	 f230004	 f230005
1/4–20	6 (8)	
1/4–28	7 (9)	
5/16–18	13 (18)	
5/16–24	14 (19)	
3/8–16	23 (31)	
3/8–24	26 (35)	
7/16–14	37 (50)	
7/16–20	41 (56)	
1/2–13	56 (76)	
1/2–20	63 (85)	
9/16–12	81 (110)	
9/16–18	90 (122)	
5/8–11	112 (152)	
5/8–18	126 (171)	
3/4–10	198 (268)	
3/4–16	221 (300)	
7/8–9	319 (433)	
7/8–14	352 (477)	
1–8	479 (649)	
1–12	524 (710)	
1–14	537 (728)	

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

Table 2, Torque Values for Grade 8 Regular Hex Zinc-Yellow Plated Capscrews and Cadmium- and Wax-Coated Prevailing Torque Locknuts

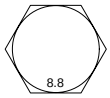
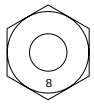
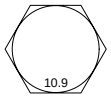
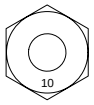
Torque Values for U.S. Customary Thread Fasteners With Dry (Unlubricated)* Plain (Unplated) Threads†						
Thread Diameter–Pitch	Regular Hex				Flanged	
	Grade 5 Bolt	Grade 5 or B Nut	Grade 8 or 8.2 Bolt	Grade 8 or C Nut	Grade 8 or 8.2 Bolt	Grade G Nut
	Torque: lbf·ft (N·m)		Torque: lbf·ft (N·m)		Torque: 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 **Table1** or **Table2**. Freightliner recommends that all plated and unplated fasteners be coated with oil before installation.

Table 3, Torque Values for U.S. Customary Thread Fasteners With Dry (Unlubricated) Plain (Unplated) Threads

Specifications

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).

Table 4, Torque Values for Metric Thread Fasteners With Lubricated or Plated Threads

VIN for Vehicles Built through April 30, 2000

IMPORTANT: See **Subject 060** for the vehicle identification numbering system for vehicles built May 1, 2000, or later.

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, 4UZ33FAD3VC345678.

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.

IMPORTANT: A new VIN-code structure will be used for all vehicles built after April 30, 2000.

Character positions 1 through 4 and 9 through 17 are nearly the same in both versions, but positions 5 through 8 have been assigned slightly different parameters. As a result, the build date of a vehicle must be determined before the VIN can be decoded.

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**	**3**	**3**	**F A**	**D**	**3**	**V**	**C**	**3 4 5 6 7 8**
Character Position	**1, 2, 3**	**4**	**5**	**6, 7**	**8**	**9**	**10**	**11**	**12 thru 17**
Decoding Table *	**Table 2**	**Table 3**	**Table 4**	**Table 5**	**Table 6**	**—**	**Table 7**	**Table 8**	**—**
Code Description									
Manufacturer, Make, Vehicle Type									
Chassis, Front Axle Position, Brakes									
Vehicle Model Series, Cab									
Engine Model, Horsepower Range									
Gross Vehicle Weight Rating (GVWR)									
Check Digit									
Vehicle Model Year									
Plant of Manufacture									
Production Number									

* 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 for Vehicles Built through April 30, 2000

VIN Position 4 (Chassis, Front Axle Position, Brakes)			
Code	**Chassis**	**Front Axle Position**	**Brakes**
A	4 x 2 Truck	Forward	Hydraulic
H	4 x 2 Truck	Forward	Air
1	4 x 2 Truck	Forward	Air/Hydraulic
3	4 x 2 Truck	Setback	Hydraulic
6	4 x 2 Truck	Setback	Air
9	4 x 2 Truck	Setback	Air/Hydraulic

Table 3, VIN Position 4 (Chassis, Front Axle Position, Brakes)

VIN Position 5 (Vehicle Model Series, Cab)	
Code	**Freightliner Custom Chassis Corporation**
B	MB Chassis (Shuttle Bus, front engine)

VIN Position 5 (Vehicle Model Series, Cab)	
Code	**Freightliner Custom Chassis Corporation**
C	FS65 Chassis (School Bus, front engine)
F	SBFD Chassis (School Bus, front engine)
L	VCL Chassis (RV, luxury, rear engine)
M	MC Chassis (RV, front engine)
R	SBRD Chassis (School Bus, rear engine)
V	VC Chassis (RV, hiline, rear engine)
X	XC Chassis (RV, midline, rear engine)
2	XB Chassis (Shuttle Bus, rear engine)
3	MT35 Chassis (Walk-In Van, front engine)
4	MT45 Chassis (Walk-In Van, front engine)
5	MT55 Chassis (Walk-In Van, front engine)

Table 4, VIN Position 5 (Vehicle Model Series, Cab)

VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)			
Code	**Engine Manufacturer**	**Engine Model**	**HP Range**
EB	Caterpillar	C10 / 3176J	225–275
EC	Caterpillar	C10 / 3176J	276–335
ED	Caterpillar	C10 / 3176J	336–407
FA	Cummins	6BT 5.9 (diesel) / ISB	185–224
FB	Cummins	6BT 5.9 (diesel) / ISB	225–275
FF	Cummins	6BT 5.9/ ISB	153–184
FH	Cummins	6BT 5.9–195G (natural gas)	185–224
FV	Cummins	6BT 5.9–195G (natural gas)	126–152
HB	Detroit Diesel	S–50	225–275
HC	Detroit Diesel	S–50	276–335
JA	Caterpillar	CFE / 3126 (diesel)	185–224
JB	Caterpillar	CFE / 3126 (diesel)	225–275
JC	Caterpillar	CFE / 3126 (diesel)	276–335
JF	Caterpillar	CFE / 3126 (diesel)	153–184
KY	Cummins	L10	225–275
LA	Cummins	6C 8.3 (diesel) / ISC	185–224
LB	Cummins	6C 8.3 (diesel) / ISC	225–275
LC	Cummins	6C 8.3 (diesel) / ISC	276–335
LD	Cummins	L10	336–407
LE	Cummins	ISC	336–407
LY	Cummins	L10	276–330

VIN for Vehicles Built through April 30, 2000

VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)			
Code	**Engine Manufacturer**	**Engine Model**	**HP Range**
MC	Cummins	M11 / ISM	276–335
MD	Cummins	M11 / ISM	336–407
NT	Cummins	4B 3.9–130 hp (diesel)	126–152
RY	Caterpillar	3406	270–330
SY	Caterpillar	3406	233–407
TY	Caterpillar	3408	383–467
UY	Caterpillar	3306	225–275
VY	Caterpillar	3406	225–269
WD	Caterpillar	C12 / 3176L	336–407
WE	Caterpillar	C12 / 3176L	408–495
WY	Caterpillar	3306	276–335
XY	Caterpillar	3406	408–495
XZ	Caterpillar	3406	496–605
0Y	No Engine	—	—

Table 5, VIN Positions 6 and 7 (Engine Manufacturer, Model, Horsepower Range)

VIN Position 8 (Gross Vehicle Weight Rating)		
Code	**lb**	**kg**
A	26,001–33,000	11 794–14 968
B	33,001 or over	14 969 or over
C	19,501–26,000	8846–11 793
D	16,001–19,500	7258–8845
2	6001–10,000	2722–4536
3	10,001–14,000	4537–6350
4	14,001–16,000	6351–7257

Table 6, VIN Position 8 (Gross Vehicle Weight Rating)

VIN Position 10 (Vehicle Model Year)	
Code	**Model Year**
N	1992
P	1993
R	1994
S	1995
T	1996
V	1997
W	1998

VIN Position 10 (Vehicle Model Year)	
Code	**Model Year**
X	1999
Y	2000

Table 7, VIN Position 10 (Vehicle Model Year)

VIN Position 11 (Plant of Manufacture)	
Code	**Plant of Manufacture**
C	Gaffney, South Carolina

VIN for Vehicles Built through April 30, 2000

VIN Position 11 (Plant of Manufacture)	
Code	**Plant of Manufacture**
D	Mercedes-Benz, Mexico, Santiago
M	Mercedes-Benz, Mexico, Monterrey

Table 8, VIN Position 11 (Plant of Manufacture)

VIN for Vehicles Built from May 1, 2000

IMPORTANT: See **Subject 050** for the vehicle identification numbering system for vehicles built before May 1, 2000.

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.

IMPORTANT: A revised VIN-code structure will be used for all vehicles built after April 30, 2000. As a result, the build date of a vehicle must be determined before the VIN can be decoded.

Character positions 1 through 4 and 9 through 17 are nearly the same in both versions, but positions 5 through 8 have been assigned slightly different parameters.

Another new feature is that 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 or trailer.

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

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 †
		None	
AC	MB55 Chassis	None	Class 6 ‡
AD	MB55 Chassis	None	Class 7 §

VIN for Vehicles Built from May 1, 2000

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
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

VIN Positions 5 and 6 (Model, Cab, Class/GVWR)			
Code	**Model**	**Cab**	**Class (GVWR)**
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

* 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.

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

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**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
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

VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**Brakes**
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 C8.3	Natural Gas	8.3	I–6	Air
B6	Cummins C8.3	Natural Gas	8.3	I–6	Hydraulic
B7	Cummins C8.3	Natural Gas	8.3	I–6	Air/Hydraulic
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

VIN for Vehicles Built from May 1, 2000

VIN Positions 7 and 8 (Engine, Brakes)					
Code	**Engine**	**Fuel**	**Displace-ment (L)**	**Config-uration**	**Brakes**
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	8.3	I–6	Air
CZ	Cummins ISL	Diesel	8.3	I–6	Hydraulic
C1	Cummins ISL	Diesel	8.3	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
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

Table 6, VIN Position 10 (Model Year)

VIN Position 11 (Build Location)	
Code	**Plant of Manufacture**
C	Gaffney, South Carolina

VIN Position 11 (Build Location)	
Code	**Plant of Manufacture**
D	Mercedes-Benz, Mexico, Santiago

Table 7, VIN Position 11 (Build Location)

Engine Port Diagrams

Use the following diagrams to identify engine ports:

- For a Caterpillar CFE Engine, see **Fig. 1**.

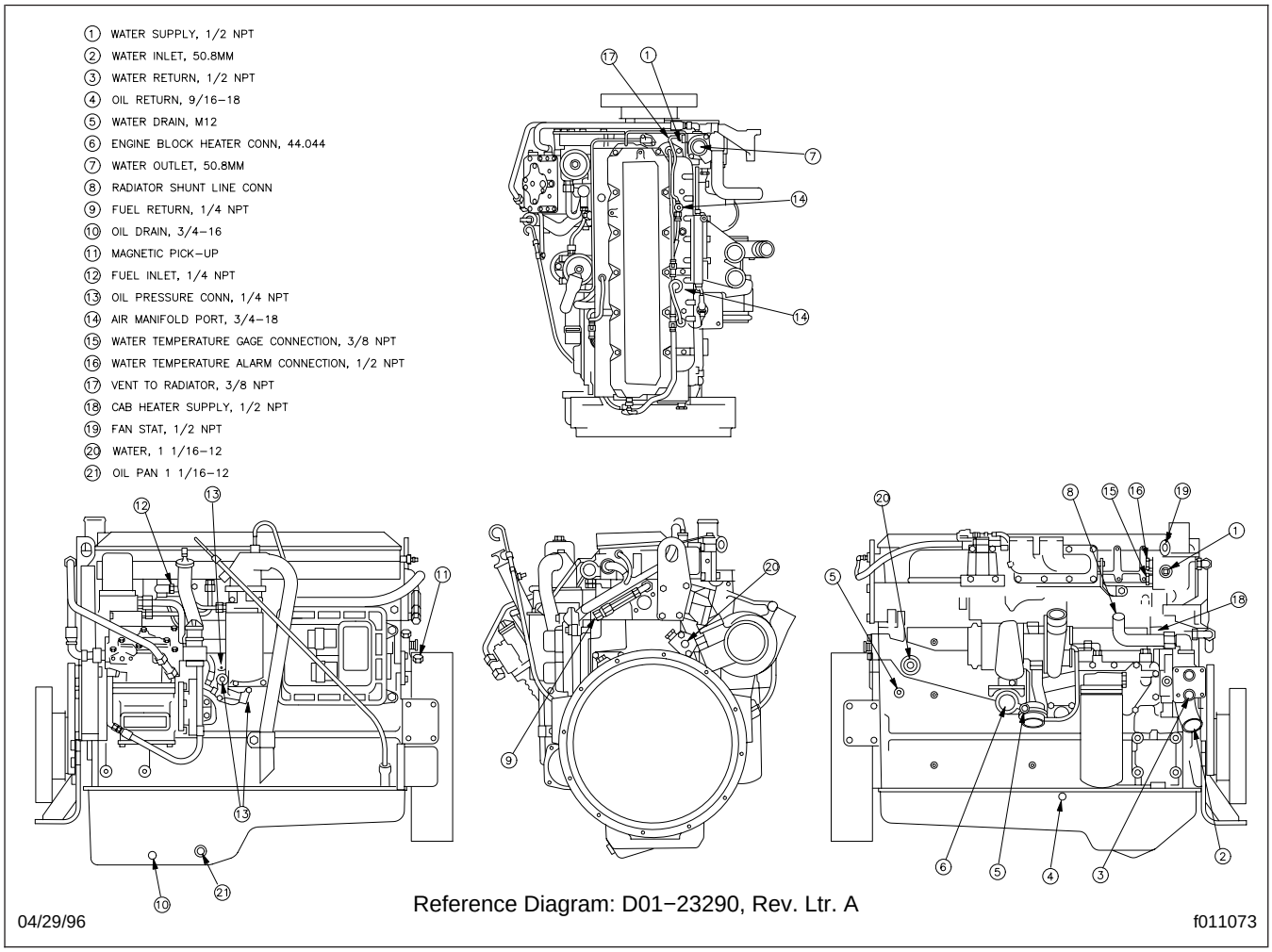
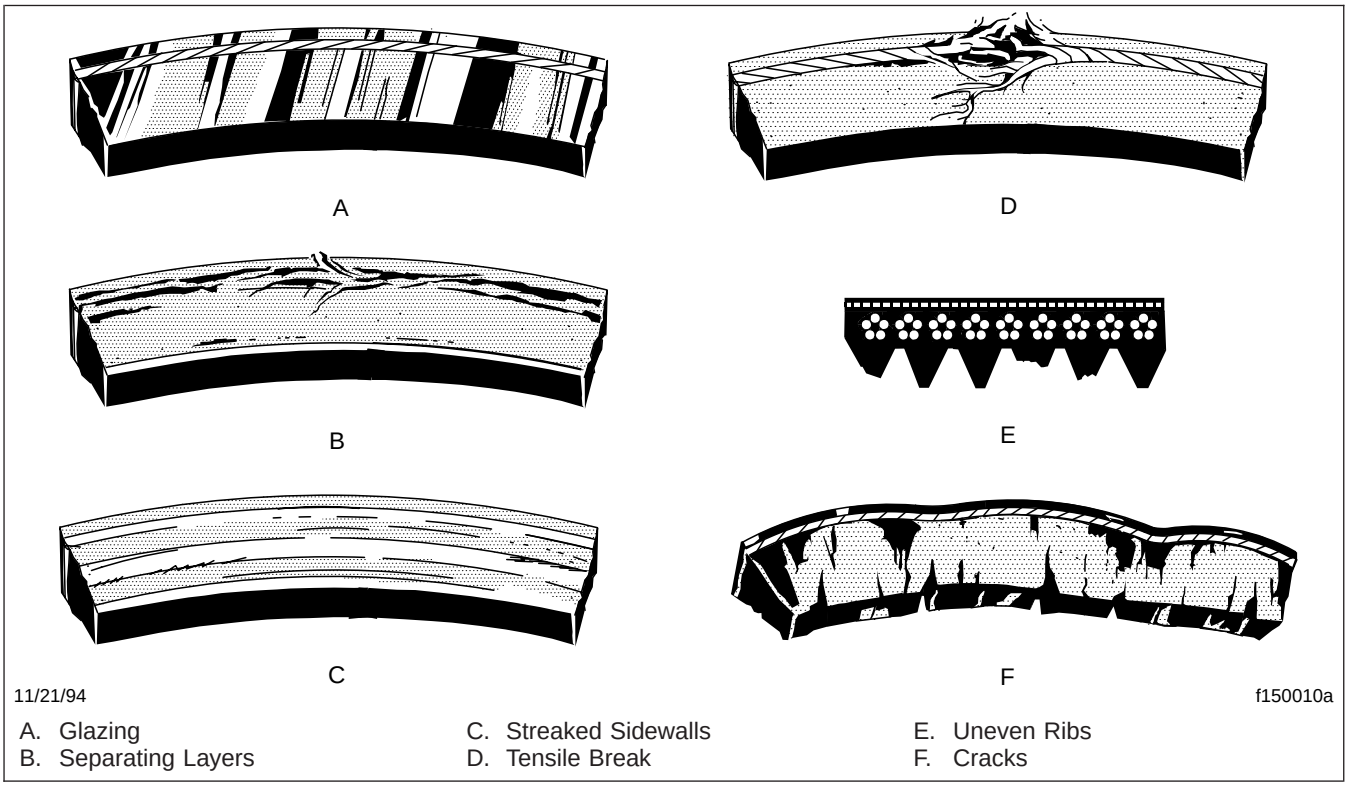


Fig. 1, Caterpillar CFE Engine Ports

Pulley and Drive Belt Inspection, Caterpillar Engines

Inspection

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



A. Glazing
B. Separating Layers
C. Streaked Sidewalls
D. Tensile Break
E. Uneven Ribs
F. Cracks

Fig. 1, Drive Belt Problems

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.

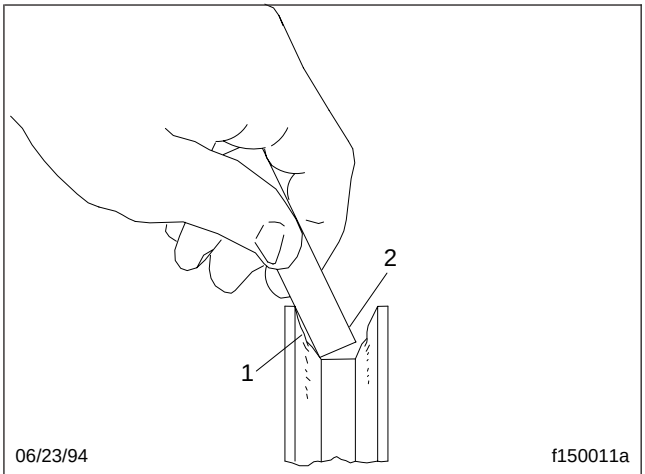
2. Check all pulley bearings for roughness. Replace the bearings if they're rough.

3. Inspect all pulleys for foreign objects, oil, or grease in the grooves. Use a nonflammable

Pulley and Drive Belt Inspection, Caterpillar Engines

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

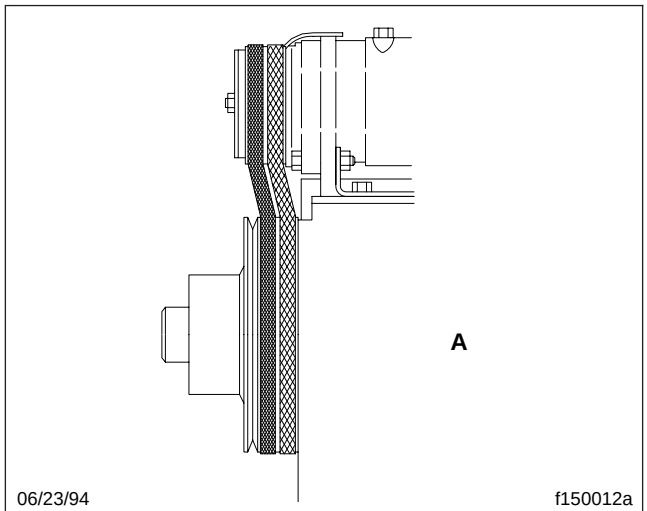
Fig. 2, Check for Pulley Wear

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.



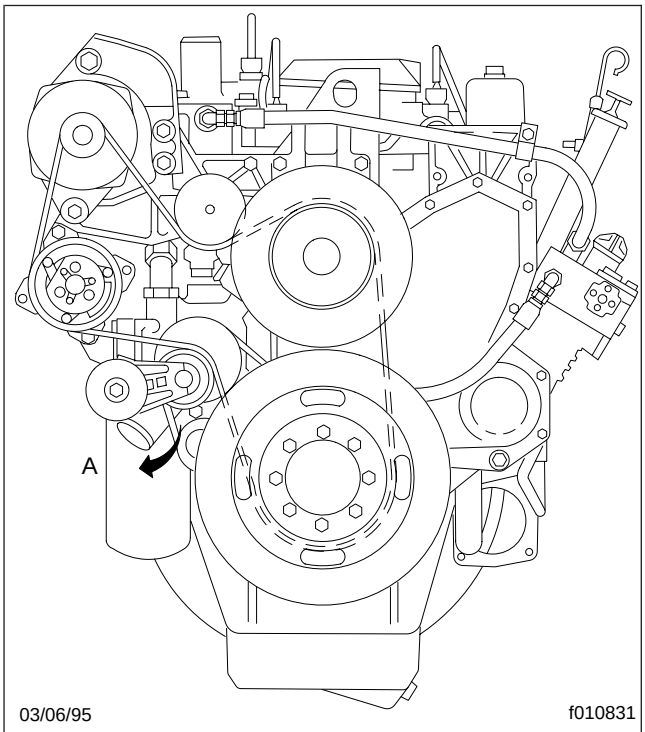
A. Side View of Misaligned Pulleys.

Fig. 3, Check for Misaligned Pulleys

Accessory Drive Belt Replacement, Caterpillar CFE Engines

Replacement

1. Insert a 1/2-inch rachet drive into the square hole in the belt tensioner, and turn the tensioner clockwise. See **Fig. 1**.



A. Turn the belt tensioner clockwise, off the belt.

Fig. 1, Accessory Drive Belt, Caterpillar CFE Series Engine

2. Remove the engine accessory drive belt.
3. Inspect the pulleys and the drive belt (even if installing a new belt) as instructed in **Subject 100**.

CAUTION

When installing a serpentine drive belt, route the belt correctly. If the belt is not routed correctly, the water pump pulley may rotate in the wrong direction, allowing the engine to overheat.

4. Position the drive belt over all the pulleys *except the drive belt tensioner.* For the correct belt routing, see **Fig. 1**.
5. Insert a 1/2-inch rachet drive into the square hole in the belt tensioner, and turn the tensioner clockwise. See **Fig. 1**.
6. Position the tensioner against the belt, and remove the rachet drive from the tensioner.

Engine Removal and Installation, Caterpillar CFE

Removal

NOTE: For engine wiring diagrams, refer to the applicable section in **Group 54**. For trouble-shooting procedures, refer to **Group 54** for the Kysor Warning and Engine-Shutdown System.

1. Apply the parking brakes, chock the tires, and drain the air system.

   If the vehicle is equipped with hydraulic brakes, release the parking brake, and disconnect the parking brake cable from the parking brake.

2. Disconnect the batteries.

   2.1 Disconnect the battery ground cable at the vehicle frame.

   2.2 Disconnect the positive battery cable from the batteries.

3. Remove the right fender splash shield.

4. Remove the hood and bumper. For instructions, refer to **Group 88**.

WARNING

Do not drain coolant from a hot engine. Opening the cooling system when the engine and coolant are hot can cause severe personal injury due to scalding by the hot, pressurized coolant.

5. Drain the radiator. For instructions, refer to the vehicle maintenance manual.

6. Remove the air cleaner housing. For instructions, refer to **Group 09**.

7. Remove the radiator. For instructions, refer to **Section 20.01**.

8. Label and disconnect the wiring. See **Fig. 1.**

   8.1 Disconnect the wiring from the starter.

   8.2 Disconnect the ground strap from the alternator.

   8.3 Disconnect the wiring from the alternator.

   8.4 Disconnect the wiring from the coolant temperature sensors.

   8.5 Unplug the lower wiring harness connector from the electronic control module.

9. If equipped, disconnect the ether start tube and sensor wire.

10. Disconnect the power steering components. For instructions, refer to **Group 46**.

11. If applicable, disconnect the air lines from the air governor on top of the air compressor.

12. At the fuel/water separator, disconnect the fuel delivery line that runs to the engine.

13. Disconnect the clutch cable. For instructions, refer to **Group 25**.

14. Disconnect the transmission shift cable. For instructions, refer to **Group 26**.

15. Remove the exhaust ducting.

    15.1 Loosen the V-band clamp that holds the forward end of the exhaust ducting to the rear of the turbocharger.

    15.2 Under the cab, disconnect the exhaust pipe from the saddle clamp mounted on the flywheel housing.

16. Disconnect the driveline from the transmission. For instructions, refer to **Group 26**.

17. While under the vehicle, disconnect all other engine and transmission components.

    17.1 Disconnect the wiring from the speedometer sensor at the transmission output.

    17.2 Disconnect the wiring harness connectors from the back-up alarm switch and the neutral start switch on the transmission top cover.

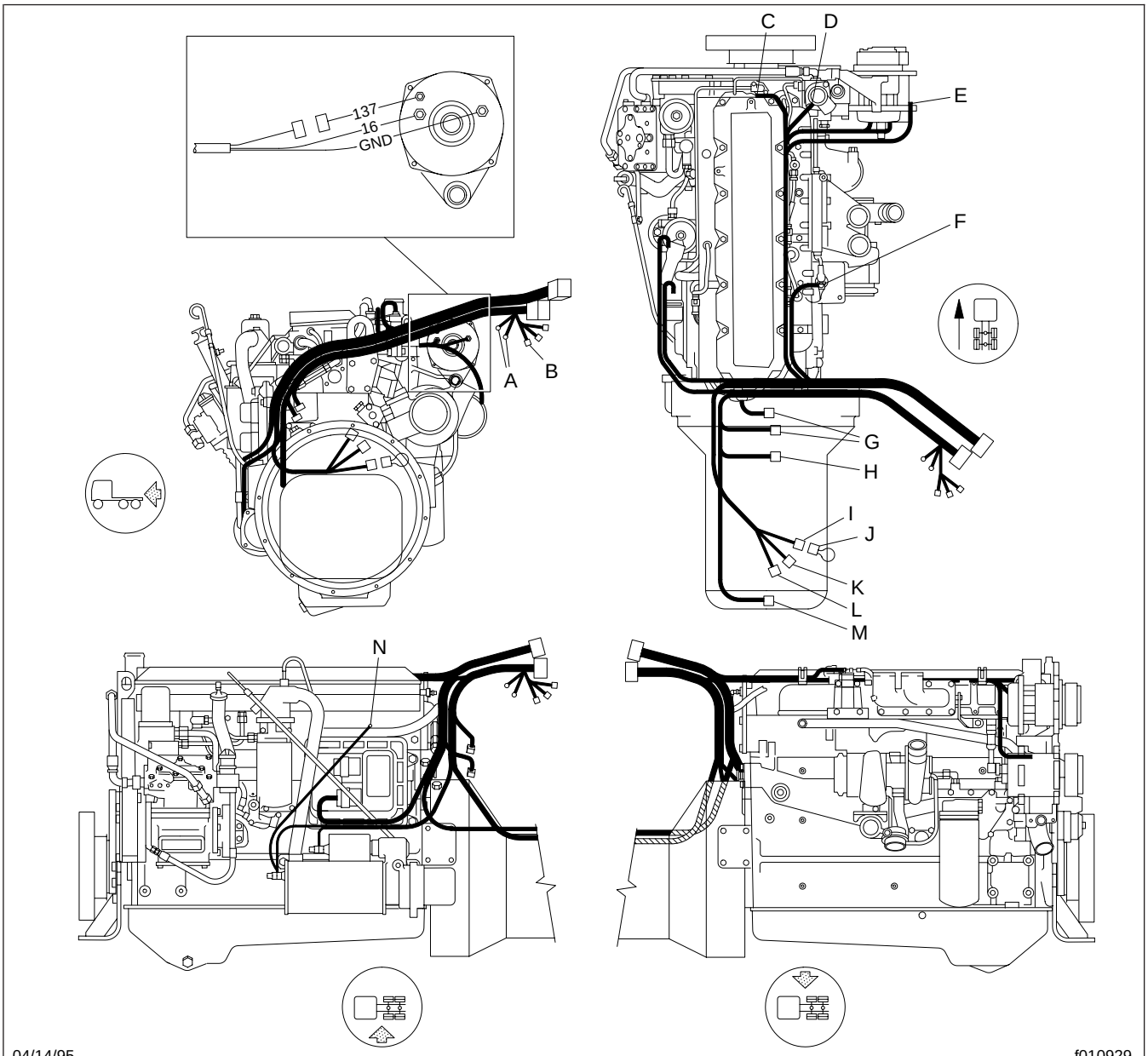
    17.3 Disconnect the fuel return line from the back of the engine block.

    17.4 If applicable, disconnect the wire-braid air compressor outlet line from the chassis air supply line.

WARNING

WARNING: The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are disconnected, do not get under the engine until it is securely supported on en-

Engine Removal and Installation, Caterpillar CFE



A. To Cab Studs
B. To Mag Switch
C. To Fan Clutch Solenoid
D. To Coolant Temperature Switch
E. To Refrigerant Compressor
F. To Grid Heater (Intake Air Heater)
G. To Tachometer Sensor
H. To Back Up Switch Wiring Harness
I. To Neutral Start Switch
J. Jumper Assembly
K. To Vehicle Speed Sensor
L. To Speedometer
M. To Vehicle Speed Sensor
N. To Ground Stud

Fig. 1, Wiring Harnesses

gine stands. An unsecured engine may fall, causing personal injury or death, and component damage.

18. Remove the engine from the vehicle.

    NOTE: Because the transmission is supported entirely by the engine, removing them as an assembly (as described below) is easier than disconnecting them and removing the engine only.

    18.1 Attach the chain to the existing lifting eyes at the front and the rear of the engine.

    18.2 With the engine lifting eyes connected by chain to the crane, raise the crane enough to tighten the chains, but not enough to lift the front of the vehicle.

    18.3 With the engine securely supported by the crane and lifting chains, disconnect the rear engine legs from the engine mounts on the frame rails.

    On each engine leg, remove the nut from the bolt that runs down through the engine leg, rubber isolators, and engine mount. Save the fasteners and isolators.

    18.4 Remove the nuts from the bolts that fasten the front engine support bracket to the underslung crossmember.

    18.5 Using the crane, lift the engine and pull it forward.

    18.6 Once the engine and transmission are clear of the vehicle, place the engine on engine stands.

Installation

WARNING

WARNING: The crane and lifting chains used to install 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 supported on the engine mounts. An unsecured engine may fall, causing personal injury or death, and component damage.

1. Install the engine and transmission in the vehicle.

    1.1 Attach the chain to the existing lifting eyes at the front and the rear of the engine.

    1.2 With the two engine lifting eyes connected by chain to the crane, lift the engine, and position it in the engine compartment.

    1.3 Connect the engine to the rear engine mounts, and tighten each bolt that runs down through the engine leg, rubber isolators, and engine mount 241 lbf·ft (327 N·m).

    1.4 Assemble the lower isolator under the underslung crossmember and the front engine support bracket, and secure the front engine mount with nuts and washers. Tighten the nuts 136 lbf·ft (184 N·m).

    1.5 Once the engine is securely installed in the vehicle, remove the lifting chains.

2. Under the engine and transmission, connect all engine and transmission components.

    2.1 Connect the wiring to the speedometer sensor at the transmission output.

    2.2 Connect the wiring harness connectors to the back-up alarm switch and the neutral start switch on the transmission top cover.

    2.3 Connect the fuel return line to the back of the engine block.

    2.4 If applicable, connect the wire-braid air compressor outlet line to the chassis air supply line.

    2.5 Route and clamp the battery cable.

3. Connect the driveline. For instructions, refer to **Group 41**.

4. Install the exhaust ducting.

    4.1 Under the engine, connect the exhaust pipe to the saddle clamp mounted on the flywheel.

    4.2 Tighten the V-band clamp that holds the forward end of the exhaust ducting to the rear of the turbocharger.

5. If applicable, connect the air lines to the air governor on top of the air compressor.

6. At the fuel/water separator, connect the fuel delivery line that runs to the engine.

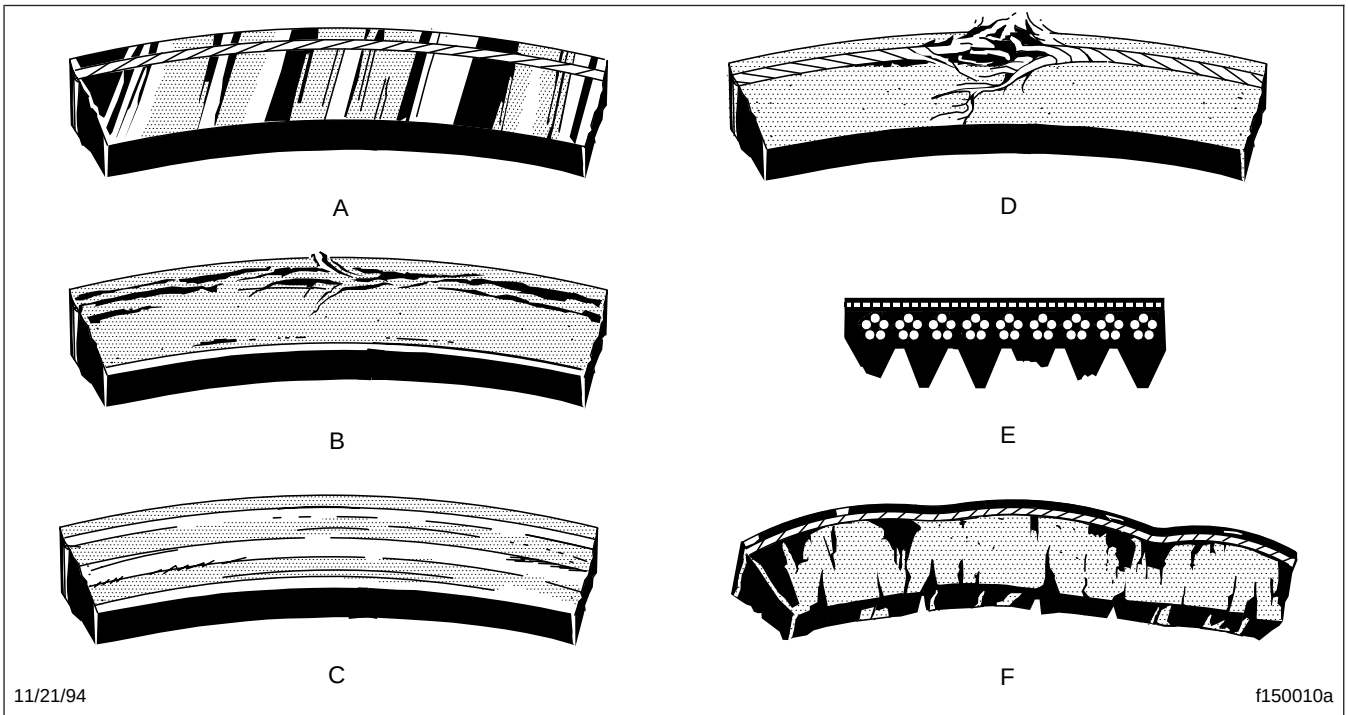
Engine Removal and Installation, Caterpillar CFE

7. Connect the clutch cable. For instructions, refer to **Group 25**.
8. If equipped, connect the ether start tube and sensor wire.
9. Connect the power steering components. For instructions, refer to **Group 46**.
10. Connect the engine wiring.
    - 10.1 Connect the wiring to the starter.
    - 10.2 Connect the ground strap to the alternator.
    - 10.3 Connect the wiring to the alternator.
    - 10.4 Connect the wiring to the coolant temperature sensors.
    - 10.5 Plug the lower wiring harness connector into the electronic control module.
11. Connect the heater hoses.
12. Install the radiator. For instructions, refer to **Group 20**.
13. Install the air cleaner housing. For instructions, refer to **Group 09**.
14. Connect the parking brake and shift cables.
15. Fill the radiator.
16. Install the hood and bumper. For instructions, refer to **Group 88**.
17. Install the right fender splash shield.
18. Connect the batteries.
19. Remove the chocks from the tires.
20. Start the engine, and check for leaks. Repair any leaks found.
21. Test drive the vehicle.

Pulley and Drive Belt Inspection, Cummins Engines

Inspection

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



A. Glazing
B. Separating Layers
C. Streaked Sidewalls
D. Tensile Break
E. Uneven Ribs
F. Cracks

Fig. 1, Drive Belt Problems

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.

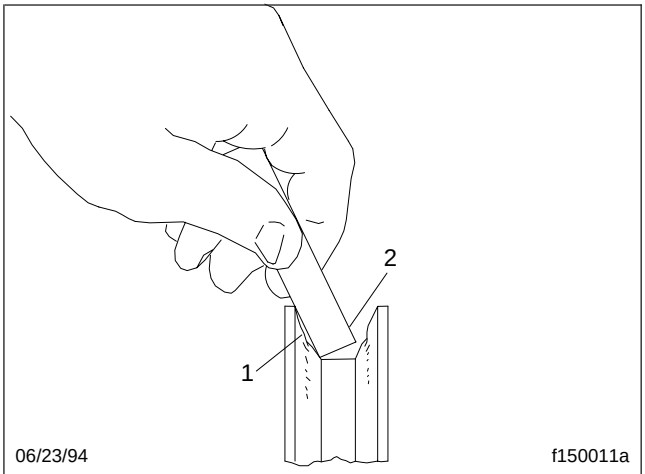
2. Check all pulley bearings for roughness. Replace the bearings if they're rough.

3. Inspect all pulleys for foreign objects, oil, or grease in the grooves. Use a nonflammable

Pulley and Drive Belt Inspection, Cummins Engines

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

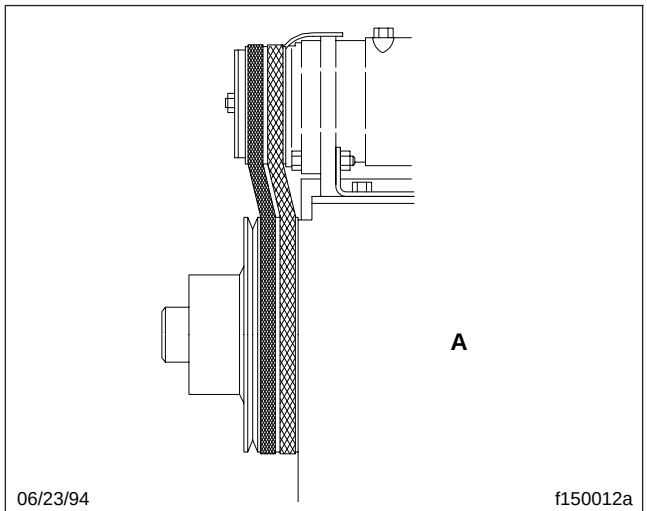
Fig. 2, Check for Pulley Wear

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, Check for Misaligned Pulleys

Accessory Drive Belt Replacement, Cummins B and C Series Engines

Replacement

1. Disconnect the batteries.
2. Insert a 3/8-inch breaker bar in the belt tensioner, and rotate the tensioner up and off the belt. See **Fig. 1**.

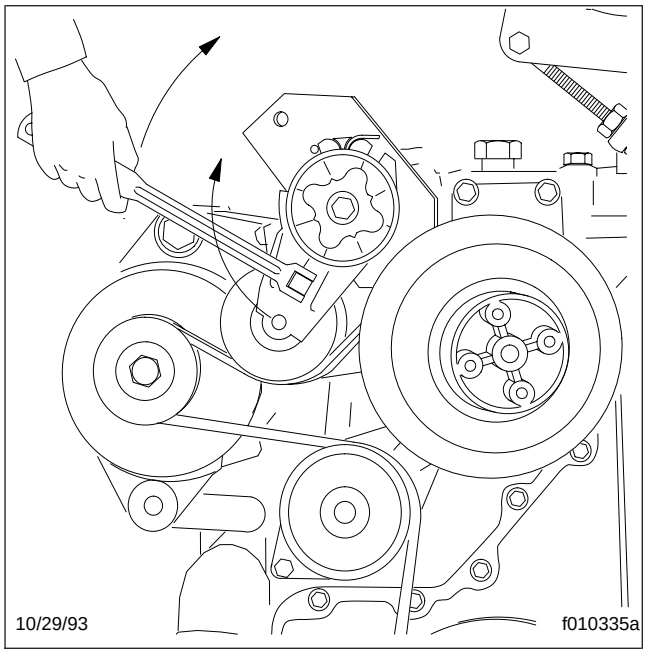


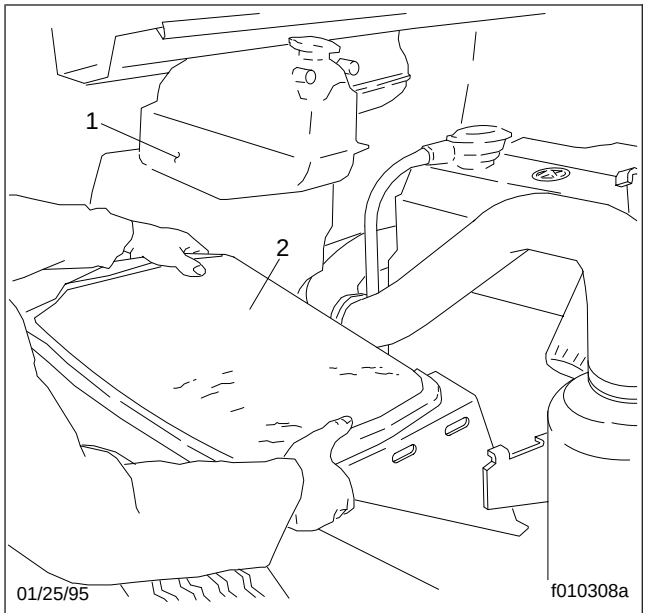
Fig. 1, Belt Tensioner Rotation

3. Holding the belt tensioner up, remove the belt from the alternator pulley.
4. Slowly release the belt tensioner, and remove the breaker bar.
5. Lower the belt, and take it off the vibration damper.
6. Raise the belt, and take it off over the fan.
7. Inspect the pulleys and the belt (even if installing a new belt) as instructed under **Subject 100**.
8. Loop the belt around the fan and align it in the rear channel of the fan pulley.
9. Loop the belt down and around the vibration damper pulley.
10. Insert a 3/8-inch breaker bar in the belt tensioner, and rotate the tensioner up while installing the belt on the alternator pulley. See **Fig. 1**.
11. Slowly release the tensioner assembly onto the belt. The tensioner automatically tightens the belt to the correct tension.
12. Remove the breaker bar from the tensioner.
13. Connect the batteries.
14. The Cummins belt tensioner automatically adjusts the fan and alternator belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the engine manufacturer's service literature.

Removal

NOTE: Because the transmission is supported entirely by the engine, removing them as an assembly (as described below) is easier than disconnecting them and removing the engine only.

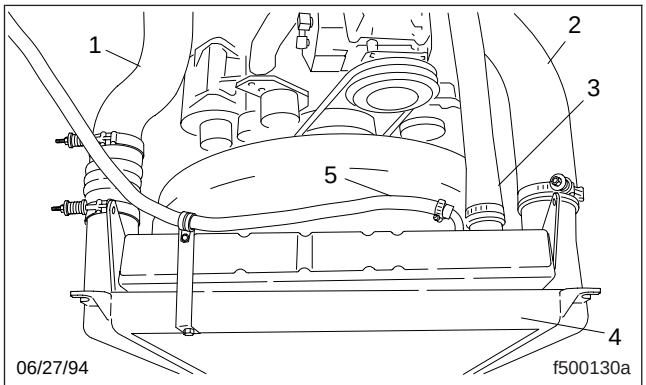
1. Apply the parking brakes, chock the tires, and (if applicable) drain the air system.
2. Disconnect the batteries.
3. Remove the hood and bumper. For instructions, see **Group 88**.
4. Drain the radiator. For instructions, see the vehicle maintenance manual.
5. Remove the right fender splash shield. See **Fig. 1**.



1. Surge Tank
2. Splash Shield

Fig. 1, Remove the Right Fender Splash Shield

6. Remove the air cleaner. For instructions, see **Group 09**.
7. Disconnect or remove the air intake, exhaust pipe, and hoses.
   - 7.1 If the vehicle is equipped with air brakes, disconnect the air compressor outlet line.
   - 7.2 If the vehicle is equipped with air brakes, disconnect the two air signal lines from the air governor at the top of the compressor.
   - 7.3 Disconnect the air inlet and outlet hoses from the charge air cooler. See **Fig. 2**.



1. Charge Air Cooler Inlet Hose
2. Charge Air Cooler Outlet Hose
3. Radiator Inlet Hose
4. Charge Air Cooler
5. Radiator Vent Hose

Fig. 2, Engine Hoses

   - 7.4 Disconnect the air intake pipe from the turbocharger.
   - 7.5 Disconnect the V-clamp connecting the exhaust pipe to the rear of the turbocharger. Remove the pipe from the turbocharger.
8. Disconnect the coolant hoses.
   - 8.1 Disconnect the coolant inlet and outlet hoses from the radiator.
   - 8.2 Disconnect the vent hose from the radiator, and remove the hose bracket from the condenser mounting bolt. See **Fig. 2**.
   - 8.3 Disconnect the fill hose from the bottom of the surge tank.
   - 8.4 Disconnect the heater hoses.
9. Remove the radiator and charge air cooler assembly. For instructions, see **Section 20.01**.
10. Remove the two power steering pump mounting bolts, and move the pump aside while keeping the steering fluid system intact.

Engine Removal and Installation, Cummins B Series

11. Disconnect the engine fuel and oil system components.
    - 11.1 Disconnect the fuel delivery line below the fuel filter.
    - 11.2 Disconnect both ends of the throttle return springs.
    - 11.3 Disconnect the throttle cable from the cable bracket and the engine throttle lever.
    - 11.4 Disconnect the fuel return line from the injection pump.
    - 11.5 Disconnect the oil pressure gauge line under the fuel injection pump.
    - 11.6 Disconnect the turbocharger oil return line at the turbocharger.
12. Disconnect the engine electrical connections.
    - 12.1 Disconnect the ground strap from the engine.
    - 12.2 Disconnect the wires from the starter and label them for reassembly.
    - 12.3 Disconnect the engine wiring harness from the rear of the alternator, then the coolant temperature sensors, the refrigerant compressor clutch, the fuel shutoff solenoid, and other applicable options.
    - 12.4 Remove the heat shield from the wiring harness routed above the exhaust pipe.
    - 12.5 Disconnect the wiring harness brackets secured to the firewall.
    - 12.6 If equipped, disconnect the ether start hose and sensor wire from the engine.
    - 12.7 Remove the engine wiring harness from the engine.
13. Disconnect the top of the left front shock absorber, and remove the top shock absorber mount from the frame rail.
14. Disconnect the transmission-mounted components.
    - 14.1 Disconnect the tachometer sensor at the engine flywheel.
    - 14.2 Disconnect the speedometer sensor at the transmission output.
    - 14.3 If the vehicle is equipped with hydraulic brakes, release the parking brake, and disconnect the parking brake cable from the parking brake.
    - 14.4 Disconnect the shift cable.
    - 14.5 At the transmission bell housing, remove the bracket that supports the exhaust pipe.
    - 14.6 Remove the driveshaft from the transmission output end yoke. For instructions, see **Group 41**.
15. Remove the engine from the vehicle.

⚠ WARNING

WARNING: The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are 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.

- 15.1 Attach a chain to the two engine lifting eyes and position a crane to lift the engine. Attach the chain to the crane, and raise the chain to remove any slack.
- 15.2 Remove the bolt from the front engine mount.
- 15.3 Remove the bolts from the two rear engine mounts.
- 15.4 Carefully lift the engine and pull it forward to remove it from the engine compartment.

Installation

1. Examine all engine support components for damage and extreme wear. Replace components as necessary.
2. Install the engine in the vehicle.

⚠ WARNING

WARNING: The crane and lifting chains used to install 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 mounts. An unsecured engine may fall, causing personal injury or death, and component damage.

2.1 Attach a chain to the lifting eyes of the engine. Attach the chain to a crane, and raise the chain to remove any slack.

2.2 Carefully lower the engine, and push it back onto the engine mounts.

2.3 Install the bolts in the two rear engine mounts, and tighten them 241 lbf·ft (327 N·m).

2.4 Install the bolt in the front engine mount and tighten it 150 lbf·ft (203 N·m).

2.5 Remove the lifting chain from the two engine lifting eyes.

3. Install the heat shield over the wiring harness where it passes over the exhaust pipe.

4. Install the two rear engine mounts. For instructions, see **Section 01.02**.

5. Connect the transmission-mounted components.

5.1 Connect the driveline to the transmission output end yoke. See **Group 41** for instructions.

5.2 Install the exhaust pipe bracket on the transmission bell housing.

5.3 Connect the shift cable.

5.4 Connect the speedometer sensor at the transmission output.

5.5 Connect the tachometer sensor at the engine flywheel.

6. Connect the engine electrical connections.

6.1 Route the engine wiring harness, attaching it at the injection pump, then the fuel shutoff solenoid, the coolant temperature sensors, the rear of the alternator, and at any other applicable options.

6.2 Connect the wiring harness brackets to the firewall.

6.3 Connect the starter wires.

6.4 Connect the engine ground strap to the frame rail.

7. Connect the fuel and oil components.

7.1 Connect the ether start tube and wire.

7.2 Connect the oil pressure gauge line at the fuel injection pump.

7.3 Connect the fuel return line at the injection pump.

7.4 Connect the throttle cable to the engine throttle arm.

7.5 Connect both ends of the throttle return springs.

7.6 Connect the fuel delivery line below the fuel filter.

7.7 Connect the oil return line to the turbocharger.

8. Install the power steering pump on the engine. For instructions, see **Group 46**.

9. Install the radiator. For instructions, see **Section 20.01**.

10. Connect the coolant hoses.

11. Connect or install the air intake, exhaust pipe, and hoses.

11.1 Connect the air inlet and outlet hoses to the charge air cooler.

11.2 Connect the exhaust pipe to the rear of the turbocharger, and install the V-clamp that secures the pipe.

11.3 Install the air intake pipe on the turbocharger.

11.4 If the vehicle is equipped with air brakes, connect the air outlet line to the air compressor.

11.5 If the vehicle is equipped with air brakes, connect the two air signal lines to the air governor on top of the compressor.

12. Install the air cleaner. For instructions, see **Group 09**.

Engine Removal and Installation, Cummins B Series

13. Install the right fender splash shield.
14. Install the bumper and hood. For instructions, see **Group 88**.
15. Connect the batteries.
    - 15.1 Connect the positive battery cable to the batteries.
    - 15.2 Connect the battery ground cable to the vehicle frame.
16. Fill the engine coolant system.
17. Start the engine and check for leaks. Eliminate any leaks.
18. After the engine has run for about 20 minutes, check the coolant level and add coolant if needed.
19. Fill and bleed the power steering system as needed. For instructions, see **Group 46**.
20. Lower the hood, and remove the chocks from the tires.

Engine Removal and Installation, Cummins C Series

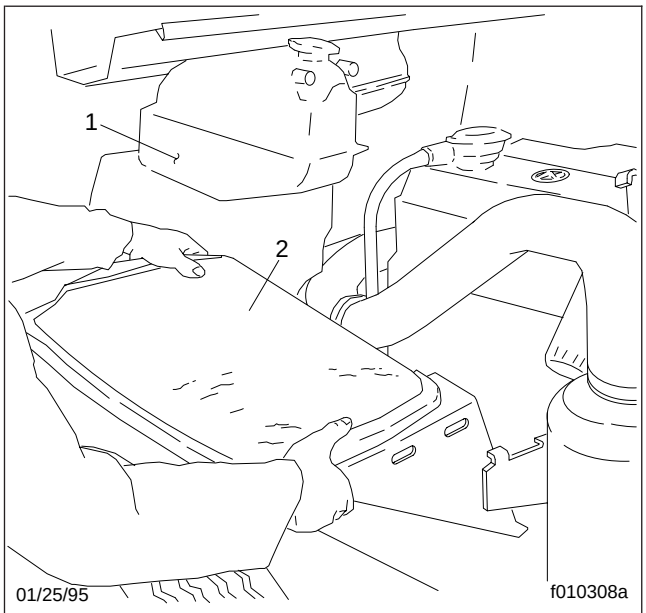
Removal

1. Apply the parking brakes, chock the tires, and (if applicable) drain the air system.
2. Disconnect the batteries.
3. Remove the transmission. For instructions, see **Group 26** in the vehicle workshop manual.
4. Remove the hood and bumper. For instructions, see **Group 88** in the vehicle workshop manual.

⚠ WARNING

Do not drain coolant from a hot engine. Opening the cooling system when the engine and coolant are hot can cause severe personal injury due to scalding by the hot, pressurized coolant.

5. Drain the radiator. For instructions, see the vehicle maintenance manual.
   - 5.1 Open the petcock at the bottom of the radiator to drain the engine coolant.
   - 5.2 Loosen the surge tank cap.
6. Remove the right fender splash shield. See **Fig. 1**.
7. Remove the air cleaner. For instructions, see **Group 09**.
8. Disconnect or remove the air intake and exhaust ducting, and the air hoses.
   - 8.1 Disconnect the air restriction indicator hose, and remove the air intake ducting between the air cleaner and the front of the turbocharger.
   - 8.2 Loosen the V-band clamp that holds the forward end of the exhaust pipe to the rear of the turbocharger.
   - 8.3 Loosen the wide-band clamp that holds the rear end of the exhaust pipe to the flex pipe.
   - 8.4 Remove the exhaust pipe from the vehicle.
   - 8.5 Remove the air ducting between the turbocharger and the charge air cooler.
   - 8.6 Disconnect the air outlet hose from the charge air cooler.



1. Surge Tank
2. Splash Shield

Fig. 1, Splash Shield Removal

   - 8.7 If the vehicle is equipped with air brakes, disconnect the air compressor outlet line and the two air signal lines at the air compressor and the air governor.
9. Disconnect the coolant hoses.
   - 9.1 Disconnect the coolant inlet and outlet hoses from the radiator.
   - 9.2 Disconnect the vent hoses from the radiator and the engine block.
   - 9.3 Disconnect the fill hose from the engine coolant inlet hose.
   - 9.4 Disconnect the heater outlet hose from the engine coolant inlet hose.
   - 9.5 Disconnect the heater inlet hose from the engine block.
10. Remove the radiator and charge air cooler assembly. For instructions, see **Section 20.01**.
11. Remove the two bolts that hold the power steering pump to the rear of the air compressor, and move the pump aside while keeping the steering fluid system intact.

Engine Removal and Installation, Cummins C Series

12. Disconnect the engine fuel and oil system components.
    - 12.1 Disconnect the fuel delivery line at the fuel transfer pump, below the fuel filter.
    - 12.2 Disconnect the throttle cable from the throttle lever, and compress the push-snap fitting to remove the cable from the cable bracket.
    - 12.3 Disconnect the fuel return line from the injection pump.
    - 12.4 Disconnect the oil pressure gauge line from the fitting below the fuel filter.
13. Disconnect the engine electrical connections.
    - 13.1 Disconnect the engine ground strap from the starter.
    - 13.2 Disconnect the wires from the starter, and label them for reassembly.
    - 13.3 Disconnect the harness wiring connector at the coolant temperature sensor behind the oil filter.
    - 13.4 Disconnect the harness wiring connector at the coolant temperature sensor behind the alternator.
    - 13.5 Disconnect the harness from the alternator, and label the alternator connections for reassembly.
    - 13.6 Disconnect the harness wiring connector at the engine shutdown solenoid.
    - 13.7 Disconnect the wiring connector for the tachometer sensor, at the upper, left side of the engine flywheel housing.
    - 13.8 Disconnect the engine wiring harness from any additional options, and label the wiring connectors for reassembly.
    - 13.9 Disconnect the harness from the stand-off bracket on the rear of the engine intake manifold.
    - 13.10 Pull the harness off to the left side of the engine where it will be out of the way.
14. Remove the engine from the vehicle.

WARNING

WARNING: The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are 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.

- 14.1 Securely attach a lifting chain to the engine. Attach the chain to a crane, and raise the chain to remove any slack.
- 14.2 Remove the two bolts from the front engine mount isolators.
- 14.3 Remove the bolt from each of the two rear engine mount isolators.
- 14.4 Carefully lift the engine, and pull it forward to remove it from the engine compartment.

Installation

1. Examine all engine support components for damage and extreme wear. Replace components as necessary.
2. Install the engine in the vehicle.

WARNING

WARNING: The crane and lifting chains used to install 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 mounts. An unsecured engine may fall, causing personal injury or death, and component damage.

- 2.1 Securely attach a lifting chain to the engine. Attach the chain to a crane, and raise the chain to remove any slack.
- 2.2 Lift the engine from the engine stands, and carefully lower the engine onto the engine mounts.
- 2.3 Install the bolts in the two rear engine mounts, and tighten them 241 lbf·ft (327 N·m).

2.4 Install the two bolts in the front engine mount, and tighten them 150 lbf·ft (203 N·m).

2.5 Remove the lifting chain from the engine.

3. Connect the engine electrical connections.

3.1 Route the engine wiring harness across the engine from the left side and connect the harness connector to the coolant temperature sensor behind the oil filter.

3.2 Connect the harness connector to the coolant temperature sensor behind the alternator.

3.3 Connect the harness to the alternator. If the alternator wires are not labeled for reassembly, see **Group 15** for alternator wiring instructions.

3.4 Connect the harness wiring connector to the engine shutdown solenoid.

3.5 Connect the wiring connector to the tachometer sensor, on the left side of the engine flywheel housing.

3.6 Connect the engine wiring harness to any additional options.

3.7 Connect the harness to the wiring standoff bracket on the rear of the engine intake manifold.

3.8 Connect the wires to the starter. If the wires are not labeled for reassembly, see **Group 15** for starter wiring instructions.

3.9 Connect the engine ground strap to the starter.

4. Connect the engine fuel and oil system components.

4.1 Connect the oil pressure gauge line to the fitting below the fuel filter.

4.2 Connect the fuel return line to the injection pump.

4.3 Thread the throttle cable down through the throttle cable bracket, and connect the cable to the throttle lever. Compress the push-snap fitting to install the cable in the cable bracket.

4.4 Connect the fuel delivery line at the fuel transfer pump, below the fuel filter.

5. Install the power steering pump on the rear of the air compressor, and tighten the two mounting bolts 28 lbf·ft (38 N·m).

6. Install the radiator and charge air cooler assembly. For instructions, see **Section 20.01**.

7. Connect the coolant hoses.

7.1 Connect the heater inlet hose to the engine block.

7.2 Connect the heater outlet hose to the engine coolant inlet hose.

7.3 Connect the fill hose to the engine coolant inlet hose.

7.4 Connect the vent hoses to the radiator and the engine block.

7.5 Connect the coolant inlet and outlet hoses to the radiator.

8. Connect or install the air intake and exhaust ducting, air hoses, and air cleaner.

8.1 Connect the air outlet hose to the charge air cooler.

8.2 Install the air ducting between the turbocharger and the charge air cooler.

8.3 If the vehicle is equipped with air brakes, connect the air compressor outlet line and the two air signal lines to the air compressor and the air governor.

8.4 Connect the rear of the exhaust pipe to the flex pipe, and connect the forward end of the exhaust pipe to the rear of the turbocharger.

8.5 Tighten the wide band clamp that holds the exhaust pipe to the flex pipe.

8.6 Tighten the V-band clamp that holds the exhaust pipe to the turbocharger 71 lbf·ft (81 N·m). Tap the V-band clamp all the way around with a rubber hammer, and tighten the clamp again.

8.7 Install the air cleaner. For instructions, see **Group 09**.

8.8 Install the air intake ducting between the front of the turbocharger and the air cleaner.

Engine Removal and Installation, Cummins C Series

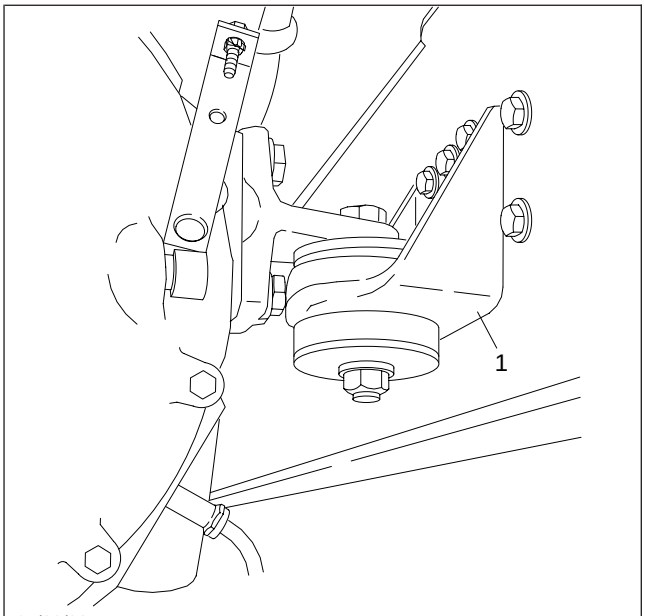
8.9 Connect the air restriction indicator hose to the air intake ducting.

9. Install the right fender splash shield. See **Fig. 1**.
10. Install the bumper and hood. For instructions, see **Group 88**.
11. Connect the batteries.
12. Fill the engine coolant system.
13. Start the engine and check for leaks.
14. After the engine has run for about 20 minutes, check the coolant level and add coolant if needed.
15. Fill and bleed the power steering system as needed. For instructions, see **Group 46**.
16. Lower the hood, and remove the chocks from the tires.

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 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. Caterpillar and Cummins B and C series engines use a rear engine leg which rests flat on the mount.

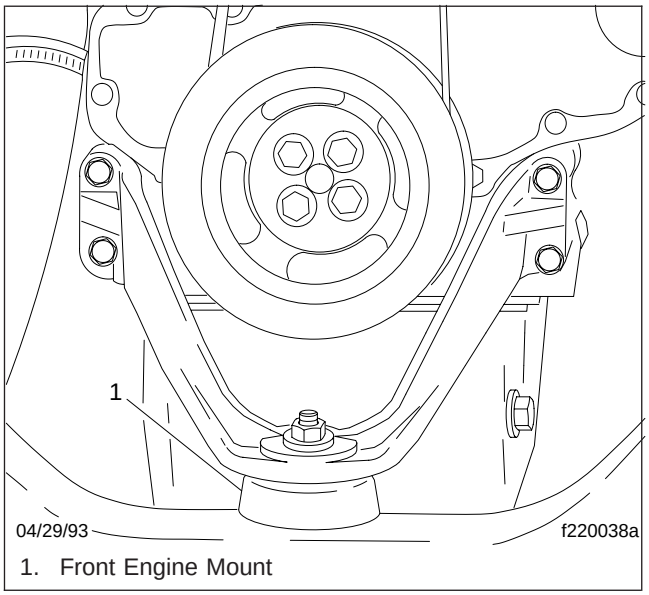


NOTE: Right mount shown.
1. Rear Engine Mount

Fig. 1, Rear Engine Mount

The front engine mount is an underslung crossmember under the front of the engine. It supports a bracket which is bolted to the engine at each side of the vibration damper pulley. See **Fig. 2**.

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



1. Front Engine Mount

Fig. 2, Front Engine Mount, Cummins B Series Engine Shown

snubbers to hold the assembly together and hold the engine on the mount.

Rear Engine Mount Replacement

Replacement

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 2 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.

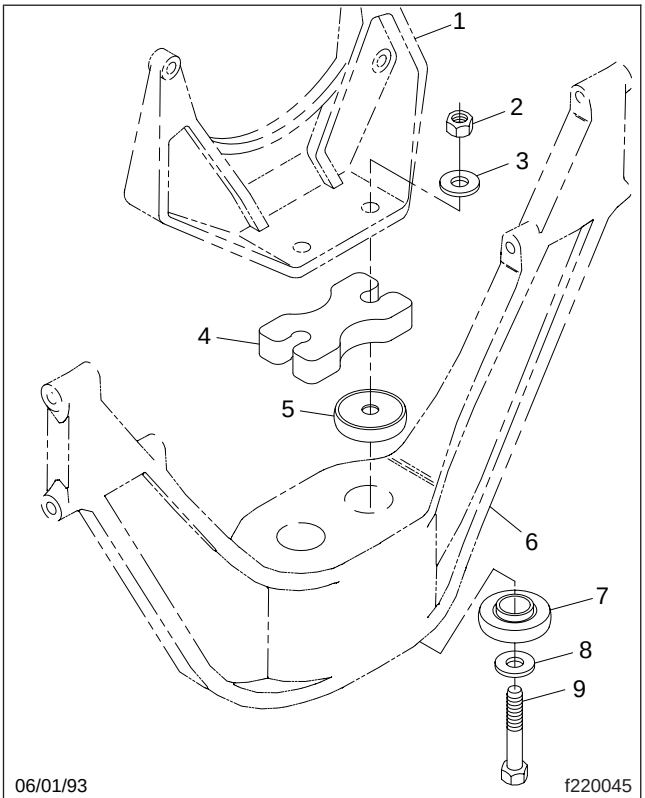
2. Disconnect the engine from the right rear engine mount. **See Fig. 1**.
   - 2.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.
   - 2.2 Remove the bolt from the right rear engine mount. Save the fasteners, rubber isolator cushions, and snubbers.
   - 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 which secure the mount to the frame rail. Remove the mount from the frame rail.

   If necessary, remove the four bolts which 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 as follows:

   For Caterpillar engines: tighten the nuts 45 lbf·ft (61 N·m).

   For Cummins B and C Series engines: tighten the nuts 80 lbf·ft (108 N·m).
5. If removed, install the engine support bracket on the side of the flywheel housing. Apply thread lock compound to the bracket mounting bolts, and tighten them as follows:

   On Caterpillar engines: tighten the bolts 100 lbf·ft (136 N·m).



A. Engine mount inverted for Cummins B Series engine.

1. Bolt	8. Bolt
2. Hardened Washer	9. Hardened Washer
3. Engine Support Bracket	10. Hardened Washer
	11. Nut
4. Hardened Washer	12. Rear Engine Mount
5. Bolt	13. Lower Isolator
6. Snubber	14. Hardened Washer
7. Upper Isolator	15. Nut

Fig. 1, Rear Engine Mount Assembly for Caterpillar and Cummins B and C Series Engines

On Cummins B and C Series engines: tighten the bolts 55 to 65 lbf·ft (75 to 88 N·m). Cummins B Series engines used with Allison automatic transmissions have an iron flywheel housing instead of the standard aluminum housing. On B Series engines with iron flywheel housings, tighten the support bracket bolts 60 to 76 lbf·ft (81 to 103 N·m).

On Mercedes MBE 900 engines: tighten the bolts 82 to 102 lbf·ft (111 to 138 N·m).

Rear Engine Mount Replacement

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 2 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 engine mounts.
   - 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.
   - 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).

⚠ WARNING

The jack used to lift the engine must be capable of safely lifting and supporting 2 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.

9. Disconnect the engine from the left rear engine mount.
   - 9.1 Place a jack under the rear of the engine, and raise the jack until it's braced against the engine.
   - 9.2 Remove the bolt from the left rear engine mount. Save the fasteners, rubber isolator cushions, and snubbers.
   - 9.3 Lift the engine slightly to take its weight off the left rear engine mount. Place engine stands under the engine to keep it off the engine mount.
10. Remove the capscrews which secure the mount to the frame rail. Remove the mount from the frame rail.

    If necessary, remove the four capscrews which secure the left engine support bracket to the flywheel housing, and remove the bracket from the engine.
11. Place a new engine mount against the inside of the frame rail, and secure it with bolts, washers, and nuts. Tighten the nuts as follows:

    For Caterpillar engines: tighten the nuts 45 lbf·ft (61 N·m).

    For Cummins B and C Series engines: tighten the nuts 80 lbf·ft (108 N·m).
12. If removed, install the engine support bracket on the side of the flywheel housing. Apply thread lock compound to the bracket mounting bolts, and tighten them as follows:

    On Caterpillar engines: tighten the bolts 100 lbf·ft (136 N·m).

    On Cummins B and C Series engines: tighten the bolts 55 to 65 lbf·ft (75 to 88 N·m). Cummins B Series engines used with Allison automatic transmissions have an iron flywheel housing instead of the standard aluminum housing. On B Series engines with iron flywheel housings, tighten the support bracket bolts 60 to 76 lbf·ft (81 to 103 N·m).

    On Mercedes MBE 900 engines: tighten the bolts to 82 to 102 lbf·ft (111 to 138 N·m).
13. 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.

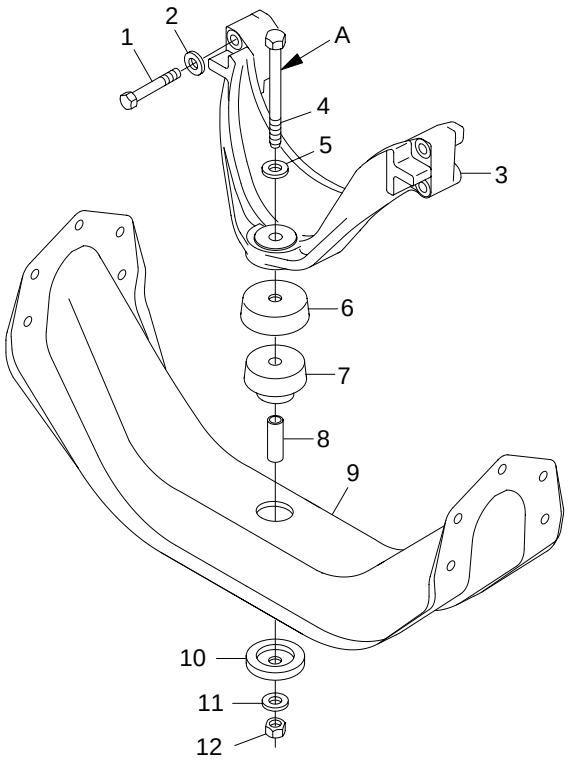
14. Install the upper isolator in the engine mount. If applicable, place the snubber on the isolator.

⚠ WARNING

The jack used to lower the engine must be capable of safely lifting and supporting 2 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.

15. Secure the engine to the engine mounts.
    - 15.1 If not in place, set a jack under the rear of the engine and raise the jack until it is braced against the engine.
    - 15.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.
    - 15.3 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).
16. Remove the jack from under the engine, and remove the chocks from the tires.

Replacement



04/29/93 f220034

A. The bolt runs up through the mounting assembly for Cummins C Series engines.

1. Bolt
2. Hardened Washer
3. Front Engine Support Bracket
4. Bolt
5. Hardened Washer
6. Snubber
7. Upper Isolator
8. Tube
9. Front Underslung Crossmember
10. Lower Isolator
11. Hardened Washer
12. Nut

Fig. 1, Front Mount Assembly, Cummins B Series Engine

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

⚠ WARNING

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 engine from the front engine mount. See **Fig. 1**.
   - 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).

   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 which secure the engine support bracket to the front of the engine. Remove the bracket from the engine.
4. If necessary, install a new engine support bracket on the front of the engine. Secure it with two bolts at each side of the vibration damper pulley, and tighten the bolts as follows:

   On Caterpillar engines: tighten the bolts 75 lbf·ft (102 N·m).

   On Cummins B Series engines: tighten the bolts 55 to 65 lbf·ft (75 to 88 N·m).

   On Cummins C Series engines: tighten the bolts 75 to 90 lbf·ft (102 to 122 N·m).
5. Inspect the engine mount rubber isolators for wear or damage and replace them if necessary.

⚠ CAUTION

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).

Front Engine Mount Replacement

⚠ WARNING

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 engine to the front engine mount.
   - 7.1 Attach a chain to the front engine lifting hook(s). Attach the chain to a lifting device, and raise the chain to 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 nut(s) as follows:

     For Caterpillar engines: tighten the bolts 136 lbf·ft (184 N·m).

     For Cummins B and C Series engines: tighten the bolts 150 lbf·ft (203 N·m).

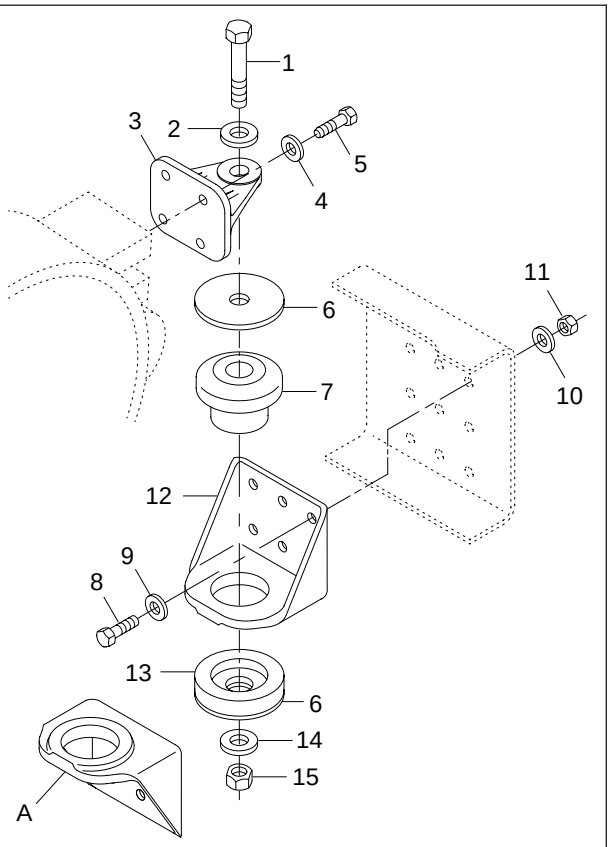
   NOTE: If you loosened the bolts that run through the rear engine mounts, tighten those bolts 241 lbf·ft (327 N·m).

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

Rear Engine Mount Isolator Replacement

Replacement

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



12/13/93 f220035

A. Framerail mount inverted for Cummins B Series engine.

1. Bolt
2. Hardened Washer
3. Engine Support Bracket
4. Hardened Washer
5. Bolt
6. Snubber
7. Upper Isolator
8. Bolt
9. Hardened Washer
10. Hardened Washer
11. Nut
12. Rear Engine Mount
13. Lower Isolator
14. Hardened Washer
15. Nut

Fig. 1, Rear Engine Mount Assembly, Caterpillar and Cummins B and C Series Engines

WARNING

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 engine from the right rear engine mount. See **Fig. 1**.
   - 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.

CAUTION

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

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

WARNING

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.

4. Secure the engine to the engine mount.
   - 4.1 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 Isolator Replacement

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

4.3 Holding the lower isolator 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).

⚠ WARNING

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.

5. Disconnect the engine from the left rear engine mount.

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

   5.2 Remove the bolt from the left rear engine mount. Save the fasteners and snubbers. Discard the rubber isolators.

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

⚠ CAUTION

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

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

⚠ WARNING

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.

7. Secure the engine to the engine mount.

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

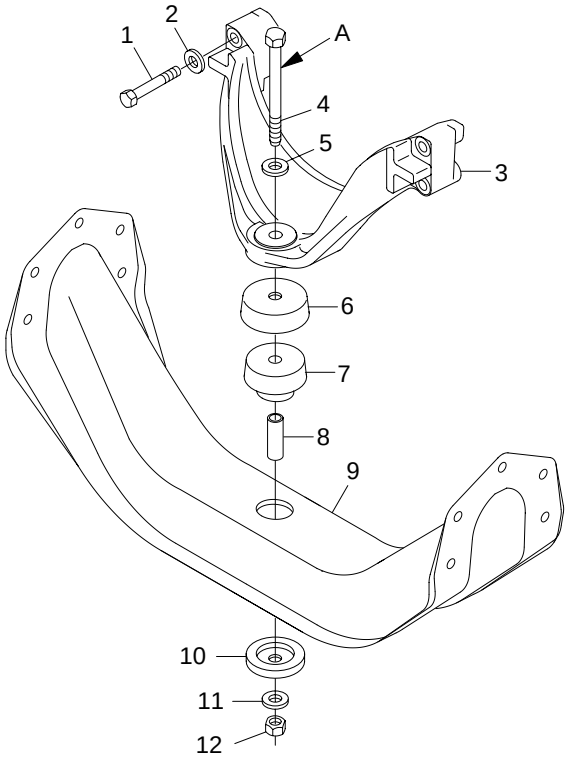
   7.2 Lift the engine slightly to remove the engine stands. Remove the stands, and carefully lower the engine onto the engine mount.

   7.3 Holding the lower isolator 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).

8. Remove the jack from under the engine, and remove the chocks from the tires.

Front Engine Mount Isolator Replacement

Replacement



04/29/93 f220034

A. The bolt runs up through the mounting assembly for Cummins C Series engines.

1. Bolt
2. Hardened Washer
3. Front Engine Support Bracket
4. Bolt
5. Hardened Washer
6. Snubber
7. Upper Isolator
8. Tube
9. Front Underslung Crossmember
10. Lower Isolator
11. Hardened Washer
12. Nut

Fig. 1, Front Mount Assembly, Cummins B Series Engine

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

⚠ WARNING

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 engine from the front engine mount. See **Fig. 1**.

   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, 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.

⚠ CAUTION

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

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

⚠ WARNING

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.

4. Secure the engine to the front engine mount.

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

Front Engine Mount Isolator Replacement

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

4.3 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 nut(s) as follows:

For Caterpillar engines: tighten the bolts 136 lbf·ft (184 N·m).

For Cummins B and C Series engines: tighten the bolts 150 lbf·ft (203 N·m).

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

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

5. Remove the chocks from the tires.

General Information

During cold weather starts, the KBi starting fluid system injects vaporized ether into the engine manifold to help ignite the diesel fuel in the cylinders. The diesel 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 may never reach the temperature it needs to ignite. Ether ignites at 360°F (182°C). Therefore, ether vapor injected with the engine intake air ignites at the lower cylinder temperature, and the burning ether ignites the diesel.

Using the starting fluid system reduces the necessary cranking time in cold weather, and it prevents excessive wear on the battery and starter.

When the engine is cold, the KBi system begins injecting ether when the starter is cranked. The system continues injecting ether vapor into the manifold for a short time to prevent stalling. The system consists of the starting fluid cylinder, the ether injection nozzle in the engine manifold, and the engine temperature sensor. See **Fig. 1** and **Fig. 2**.

The starting fluid cylinder is mounted with the receiver-dryer against the firewall. See **Fig. 3**. It fits into the Dieselmatic® valve and Blockor® fitting which measure, hold, and release a controlled amount of fluid for each start attempt.

Ether travels through plastic tubing to the engine manifold where it sprays through the injection nozzle into the engine intake air. Inside the manifold, vaporized ether fills the cylinders and ignites.

If the weather is warm, or the engine is already warmed, the engine temperature sensor mounted in the engine water jacket prevents the KBi from injecting ether vapor. The system will inject ether only if the engine is cooler than about 40°F (4°C).

General Information

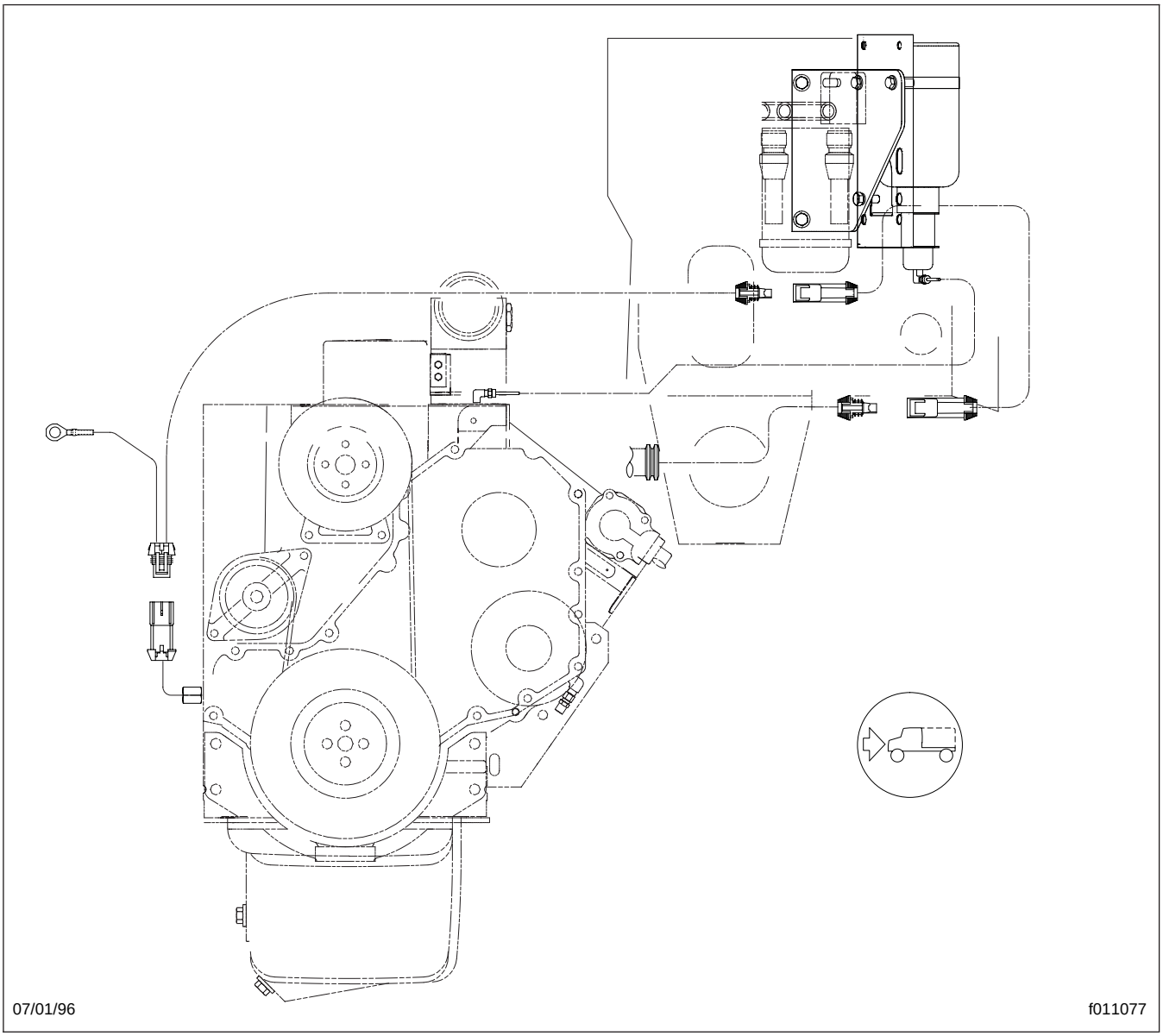


Fig. 1, Starting Fluid System Installation, Front View

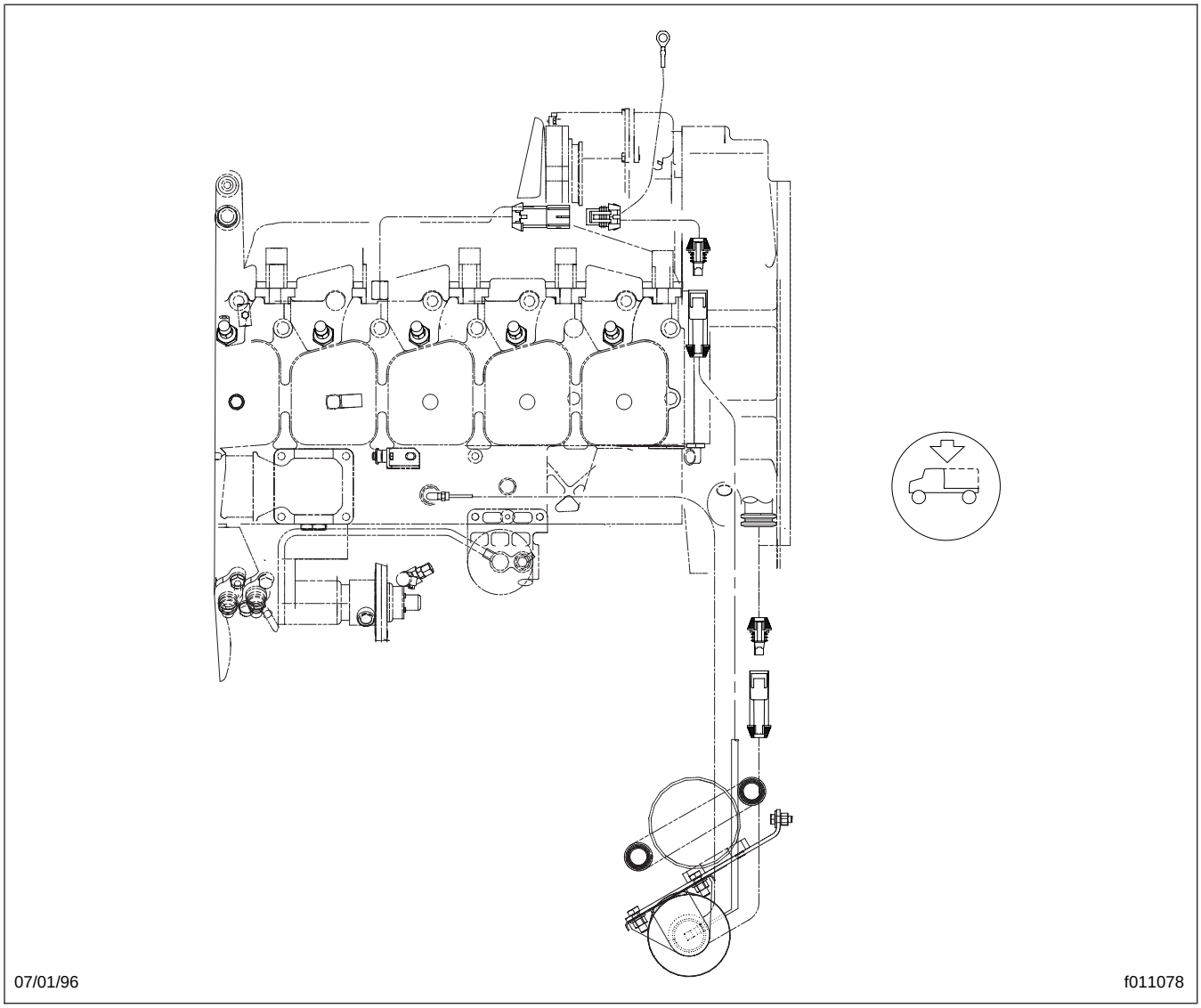
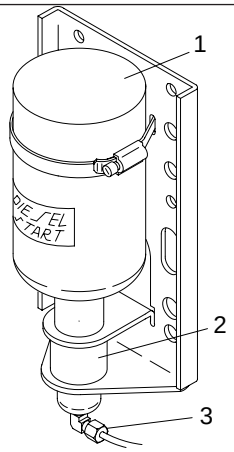


Fig. 2, Starting Fluid System Installation, Overhead View

General Information

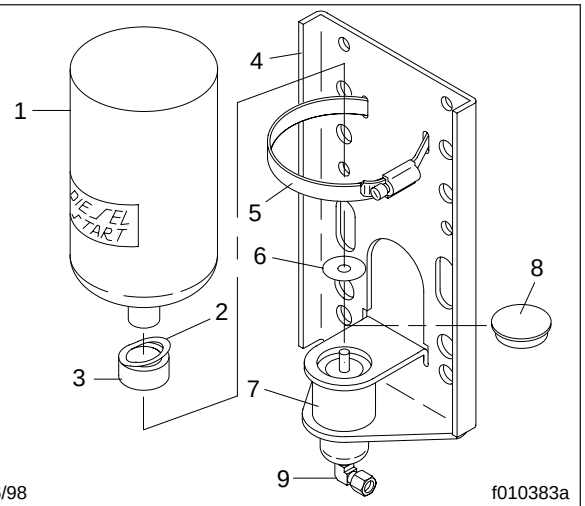


06/17/94 f010385a

1. Starting Fluid Cylinder
2. Dieselmatic Valve
3. Blockor Fitting

Fig. 3, Ether Cylinder Components

Replacement



1. Starting Fluid Cylinder
2. Paper Backing
3. Dirt Eliminator Collar
4. Mounting Plate
5. Cylinder Clamp
6. Valve Gasket
7. Dieselmatic Valve
8. Valve Cap
9. Blockor Fitting

Fig. 1, Cylinder Installation

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

⚠ WARNING

WARNING: Service starting fluid systems only in a well-ventilated area away from sparks and open flames. The ethyl ether in these systems is flammable and toxic. Wear protective gloves and glasses, and avoid breathing ether fumes. Failure to take these precautions could result in personal injury or property damage.

3. Remove the old cylinder. See **Fig. 1**.
   - 3.1 Clean all dirt from the neck of the cylinder and the top of the Dieselmatic® valve before removing the cylinder.
   - 3.2 Loosen the cylinder clamp.
   - 3.3 Pry the dirt eliminator collar off the neck of the cylinder.
   - 3.4 Unscrew the cylinder from the Dieselmatic valve.

NOTE: If not replacing the cylinder immediately, place the valve cap in the valve to prevent dirt or other debris from entering the system.

4. Remove the old dirt eliminator collar from the valve assembly.
5. Apply a light film of clean oil to a new Dieselmatic valve gasket and install the new gasket.
6. Place a new dirt eliminator collar, adhesive-side up, on the valve assembly. Peel off the collar's paper backing to expose the adhesive.
7. Install the new cylinder.
   - 7.1 Place the new cylinder into the Dieselmatic valve and hand tighten it firmly.
   - 7.2 Slide the dirt eliminator collar up so it sticks to the cylinder.
   - 7.3 Tighten the clamp around the cylinder 60 lbf·in (680 N·cm).
8. If the ambient temperature is below 40°F (4°C), test the starting fuel system.
9. Lower the hood, and remove the chocks from the tires.

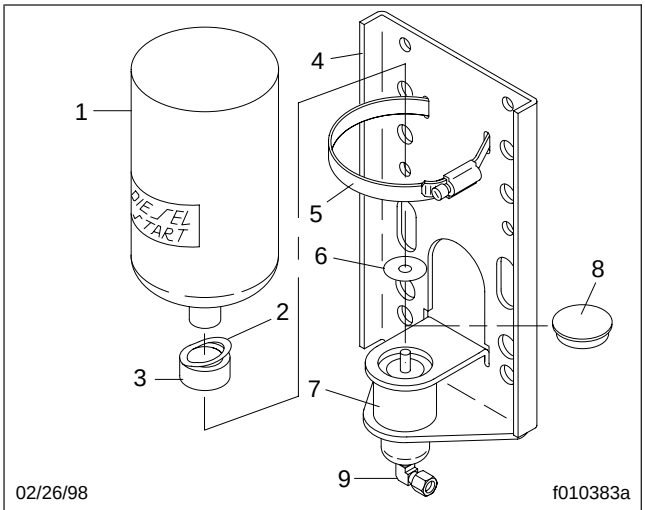
Removal

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

⚠ WARNING

WARNING: Service starting fluid systems only in a well-ventilated area away from sparks and open flames. The ethyl ether in these systems is flammable and toxic. Wear protective gloves and glasses, and avoid breathing ether fumes. Failure to take these precautions could result in personal injury or property damage.

3. Remove the starting fluid cylinder. See **Fig. 1**.



1. Starting Fluid Cylinder
2. Paper Backing
3. Dirt Eliminator Collar
4. Mounting Plate
5. Cylinder Clamp
6. Valve Gasket
7. Dieselmatic Valve
8. Valve Cap
9. Blockor Fitting

Fig. 1, Cylinder Installation

3.1 Clean all dirt from the neck of the cylinder and the top of the Dieselmatic® valve before removing the cylinder.

3.2 Loosen the cylinder clamp.

3.3 Pry the dirt eliminator collar off the neck of the cylinder.

3.4 Unscrew the cylinder from the Dieselmatic valve.

NOTE: If not replacing the cylinder immediately, place the valve cap in the valve to prevent dirt or other debris from entering the valve.

4. Remove the old dirt eliminator collar from the valve assembly.
5. Remove the mounting plate and valve assembly.
   5.1 Disconnect the wires running from the assembly to the "M" terminal of the starter and to the engine temperature sensor.
   5.2 Disconnect the ether tubing from the nozzle in the engine manifold.
   5.3 Remove the four bolts that hold the mounting plate to the mounting bracket, and remove the plate and the valve assembly from the vehicle.
6. Remove the engine temperature sensor.
   6.1 Disconnect the sensor ground wire at the alternator ground terminal.
   6.2 Unscrew the sensor from the engine block, and seal the port with an appropriate water jacket plug.
7. Remove the ether nozzle from the engine manifold, and seal the hole in the manifold with an appropriate plug. See **Fig. 2**.

Installation

⚠ WARNING

WARNING: Service starting fluid systems only in a well-ventilated area away from sparks and open flames. The ethyl ether in these systems is flammable and toxic. Wear protective gloves and glasses, and avoid breathing ether fumes. Failure to take these precautions could result in personal injury or property damage.

Do not install a starting fluid system on a vehicle with an air intake warmer, for example, a glow plug or a flame start system. An air intake warmer could prematurely ignite the starting fluid

Starting System Removal and Installation

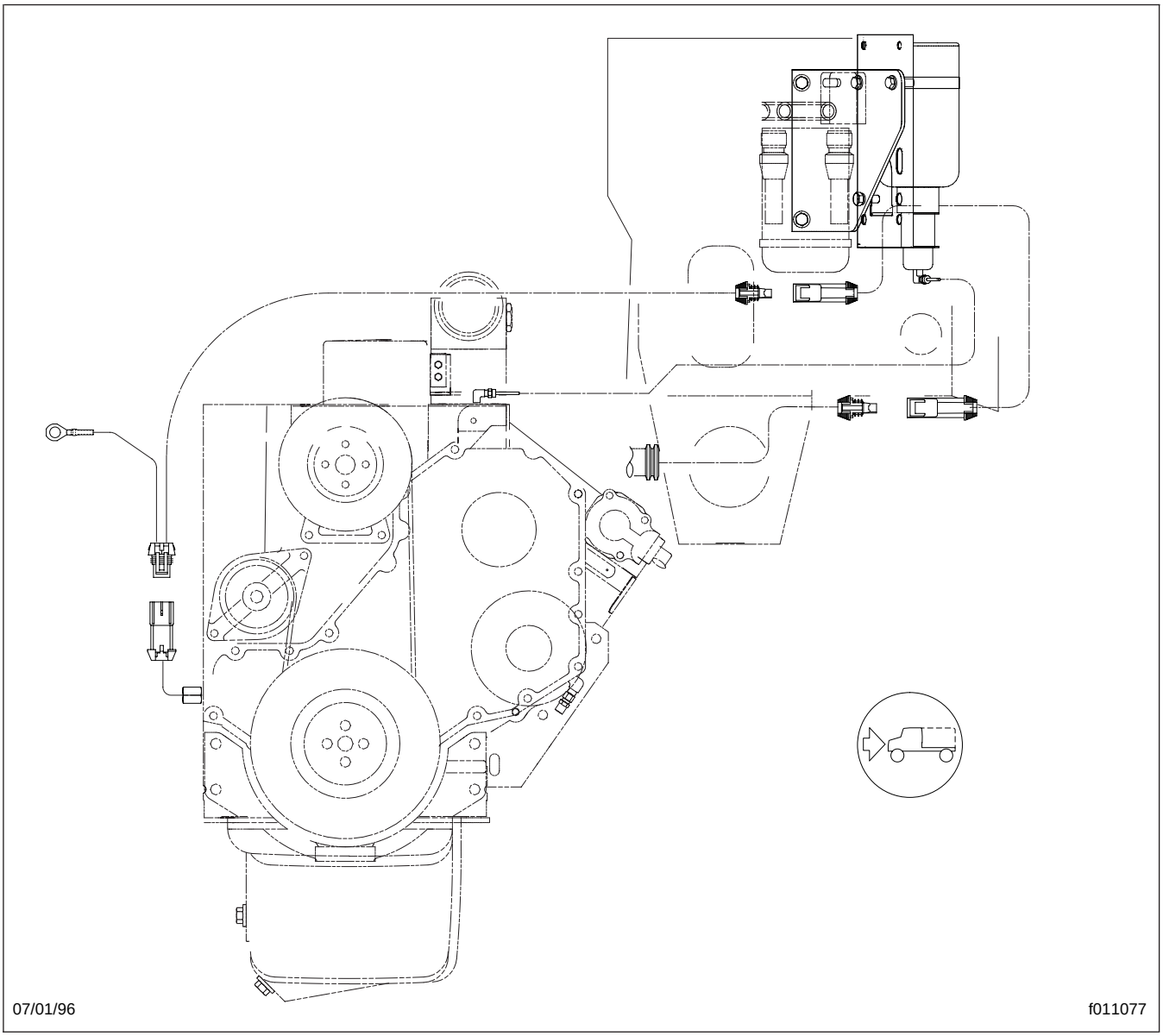


Fig. 2, Starting Fluid System

and cause an explosion in the air intake manifold resulting in personal injury and property damage

1. Remove the plug in the engine intake manifold and screw the ether nozzle in place. See **Fig. 2**.
2. Install the engine temperature sensor.
   - 2.1 Remove the plug from the water jacket, and screw the sensor in place until finger-tight. Using a wrench, tighten the sensor one more turn.
   - 2.2 Connect the ground wire from the sensor to the alternator ground terminal.
3. Install the mounting plate and valve assembly.
   - 3.1 Place the mounting plate against the mounting bracket, and secure it with four bolts. Tighten the bolts 22 lbf·ft (30 N·m).

3.2 Connect the ether tubing to the injection nozzle in the intake manifold. Tighten the nozzle fitting finger-tight, then, using a wrench, tighten the nozzle one more turn.

3.3 Connect the black wire from the valve assembly to the engine temperature sensor.

3.4 Connect the remaining wire from the assembly to the "M" terminal of the starter.

4. Install the starting fluid cylinder. See **Fig. 1**.

4.1 Apply a light film of clean oil to a new Dieselmatic valve gasket and install the new gasket.

4.2 Place a new dirt eliminator collar, adhesive-side up, on the valve assembly. Peel off the collar's paper backing to expose the adhesive.

4.3 Place the new cylinder into the Dieselmatic valve and hand-tighten it firmly.

4.4 Slide the dirt eliminator collar up so it sticks to the cylinder.

4.5 Tighten the clamp around the cylinder 60 lbf·in (680 N·cm).

5. If the ambient temperature is below 40°F (4°C), test the starting fuel system.

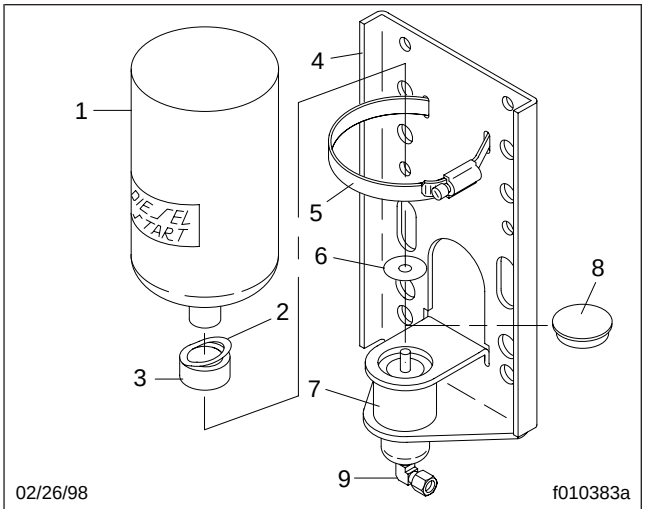
Troubleshooting

Use the following procedures to check for most common problems that may prevent starting fluid delivery.

⚠ WARNING

WARNING: Service starting fluid systems only in a well-ventilated area away from sparks and open flames. The ethyl ether in these systems is flammable and toxic. Wear protective gloves and glasses, and avoid breathing ether fumes. Failure to take these precautions could result in personal injury or property damage.

EMPTY FLUID CYLINDER



1. Starting Fluid Cylinder
2. Paper Backing
3. Dirt Eliminator Collar
4. Mounting Plate
5. Cylinder Clamp
6. Valve Gasket
7. Dieselmatic Valve
8. Valve Cap
9. Blockor Fitting

Fig. 1, Cylinder Installation

1. Remove the old cylinder. See **Fig. 1**.
   - 1.1 Clean all dirt from the neck of the cylinder and the top of the Dieselmatic® valve before removing the cylinder.
   - 1.2 Loosen the cylinder clamp.
   - 1.3 Pry the dirt eliminator collar off the neck of the cylinder.
   - 1.4 Unscrew the cylinder from the Dieselmatic valve.
   - 1.5 Remove the cylinder from the mounting plate. Cover the top of the valve after the cylinder is removed.
   - 1.6 Remove the old dirt eliminator collar from the valve assembly.
2. Weigh the cylinder to see if it is empty. See **Table 1** for the weight of each cylinder size.

Cylinder Size oz (g)	Weight	
	Empty oz (g)	Full oz (g)
21 (595)	16 (455)	37 (1050)
18 (510)	15 (425)	33 (935)
8 (225)	10 (285)	18 (510)

Table 1, Starting Fluid Cylinders

3. Apply a light film of clean oil to a new Dieselmatic valve gasket and install the new gasket.
4. If the cylinder is good, install it; if not, replace it.
   - 4.1 Place a new dirt eliminator collar, adhesive-side up, on the valve assembly. Peel off the collar's paper backing to expose the adhesive.
   - 4.2 Place the new cylinder into the Dieselmatic valve and hand-tighten it firmly.
   - 4.3 Slide the dirt eliminator collar up so it sticks to the cylinder.
   - 4.4 Tighten the clamp around the cylinder 60 lbf·in (680 N·cm).

CLOGGED ETHER NOZZLE

1. Disconnect the ether tubing from the nozzle, and cover the nozzle fitting. See **Fig. 2**.
2. Disconnect the black ground wire from the engine temperature sensor, and ground it.

Troubleshooting

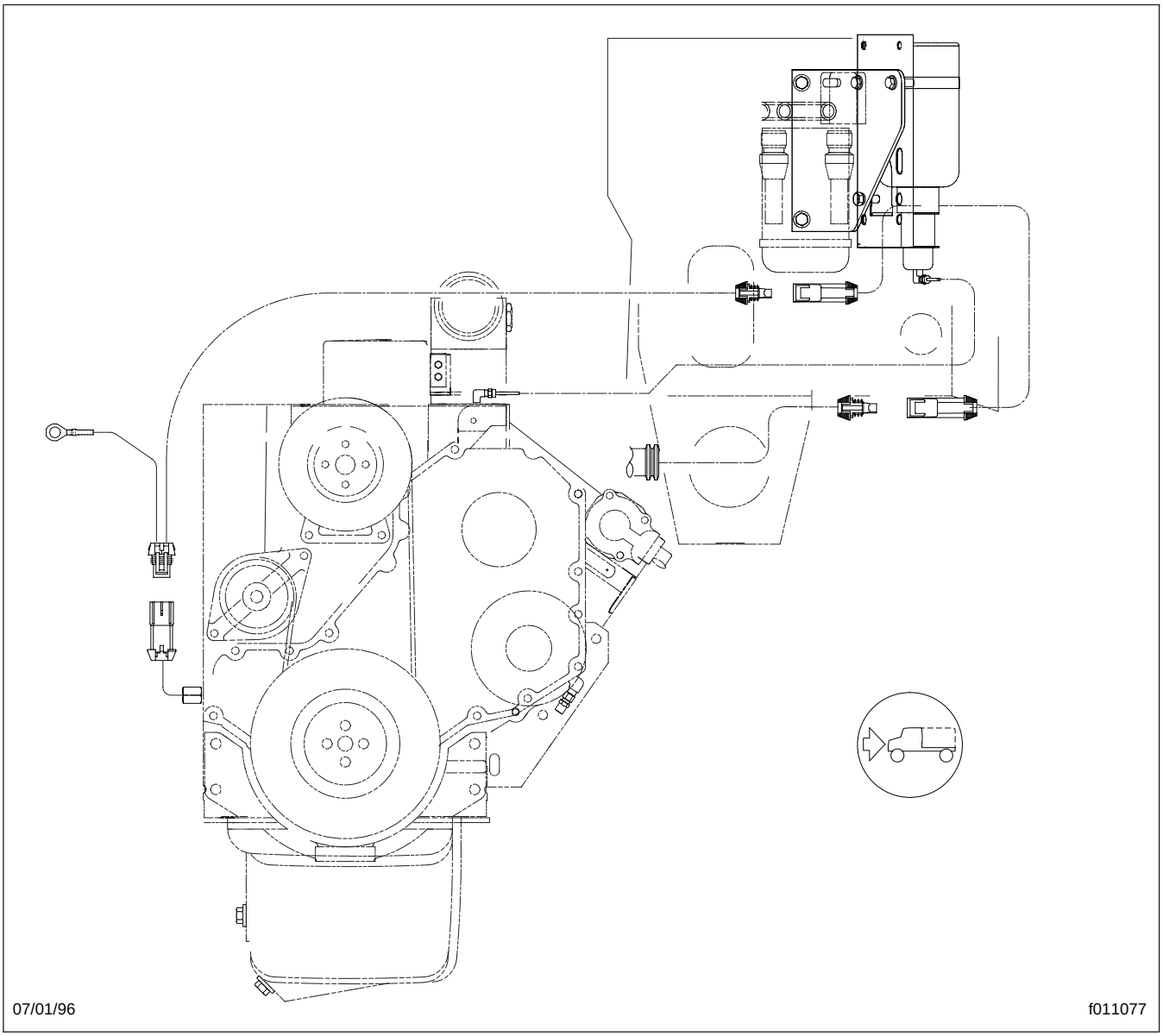


Fig. 2, Starting Fluid System

⚠ WARNING

WARNING: When testing the starting fluid system, wear protective gloves and glasses, and spray the vaporized ether into a container. Failure to do so could result in personal injury.

3. Start the engine, and look for ether to spray from the tubing.

⚠ CAUTION

CAUTION: Do this test only two times. Activating the starting fluid system in this manner more than twice could result in damage to the system.

4. If no ether sprays from the tubing, disconnect the tubing at the Blockor® fitting in the base of the cylinder assembly. See **Fig. 1**.

5. Start the engine, and look for ether to spray from the Blockor fitting in the base of the cylinder assembly.

CAUTION

CAUTION: Do this test only two times. Activating the starting fluid system in this manner more than twice could result in damage to the system.

6. If ether sprays from the fitting, but not from the tubing, check for kinks or blockages in the ether tubing and the nozzle. Repair or replace the tubing and nozzle, as needed.

   If no ether sprays from the fitting or tubing, check the Blockor fitting for blockages. Repair or replace the fitting, as needed.

ELECTRICAL PROBLEMS

1. Check for a blown fuse, and for loose wiring connections, shorts, and broken wires.
2. Check that the black ground wire from the valve assembly is connected to the engine temperature sensor, and that the ground wire from the sensor is connected to the alternator ground terminal.
3. Check that the second wire from the valve assembly is connected to the "M" terminal of the starter.

WARNING

WARNING: When testing the starting fluid system, wear protective gloves and glasses, and spray the vaporized ether into a container. Failure to do so could result in personal injury.

4. Test the valve.
   - 4.1 Remove the starting fluid cylinder.
   - 4.2 If the ambient air temperature is over 40°F (4°C), remove the black ground wire from the engine temperature sensor, and ground it.
   - 4.3 Crank the starter, and look for the valve plunger to move up and stay up while the starter is cranked. See **Fig. 3**.

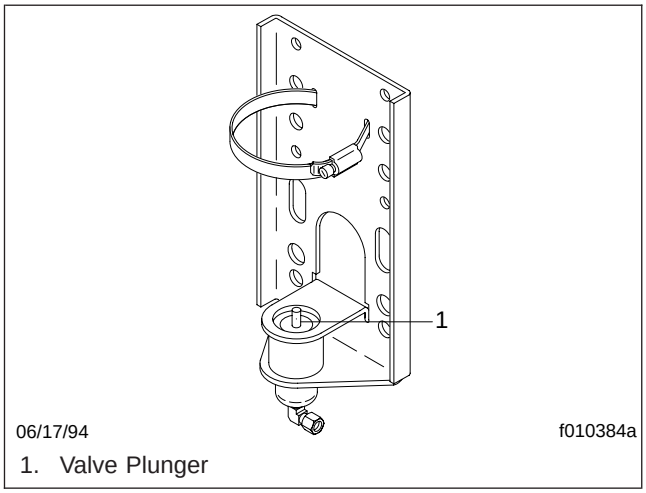


Fig. 3, Valve Testing

CAUTION

CAUTION: Do this test only two times. Activating the starting fluid system in this manner more than twice could result in damage to the system.

5. If the plunger does not move, disconnect both valve assembly wires and momentarily touch the leads across battery terminals. If the valve plunger still does not move up, replace the valve.
6. If the valve operates correctly, check the engine temperature sensor.
   - 6.1 Connect the appropriate wire to the "M" terminal of the starter.
   - 6.2 Remove the sensor from the engine water jacket, and chill it to below freezing for at least ten minutes.
   - 6.3 Install the sensor, grounding it at the alternator ground terminal.
   - 6.4 Connect the black ground wire from the valve assembly to the sensor.
   - 6.5 Crank the engine, and look for the valve plunger to move up and stay up while the starter is cranked.

CAUTION

CAUTION: Do this test only two times. Activating the starting fluid system in this manner more than twice could result in damage to the system.

Troubleshooting

7. If the plunger does not move, replace the sensor.

General Information

The Phillips Temro oil pan heater keeps the crankcase oil about 32°C (90°F) warmer than the ambient air temperature. In cold weather, the heater helps prevent water from condensing in the oil, it creates a better seal in the combustion chambers for start-up, and it keeps the oil free-flowing for instant lubrication.

The heater consists of a 150-or 300-watt element that screws into the side of the engine oil pan. See **Fig. 1** or **Fig. 2**. A cord plugs onto the outside end of the element, and the cord runs to a receptacle mounted in the front bumper. See **Fig. 3**.

NOTE: When a vehicle is also equipped with an engine block heater, the engine block heater is wired in tandem with the oil pan heater. The cord from the oil pan heater element, and the receptacle in the front bumper, provide power to the engine block heater.

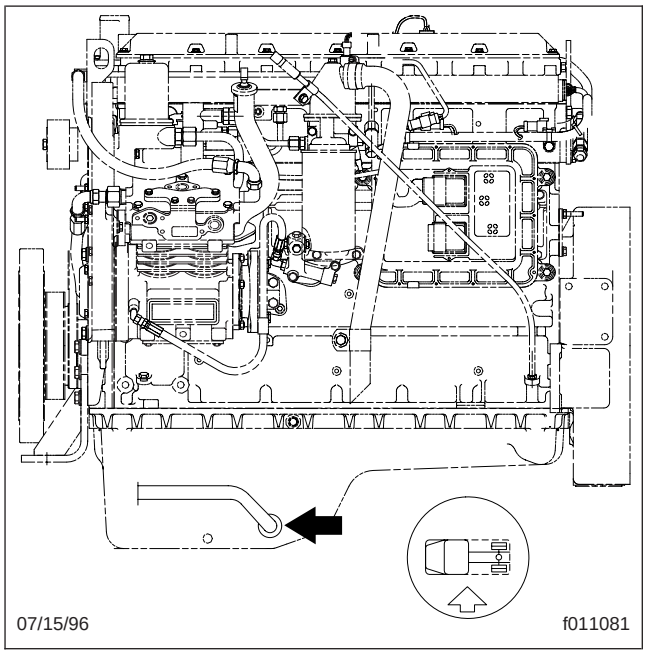


Fig. 1, Oil Pan Heater Location, Caterpillar 3126 Engine

To turn on the heater, open the spring-loaded cover on the receptacle, and connect a power source to the receptacle. The element has no thermostat. Heat dissipating from the crankcase prevents oil overheating.

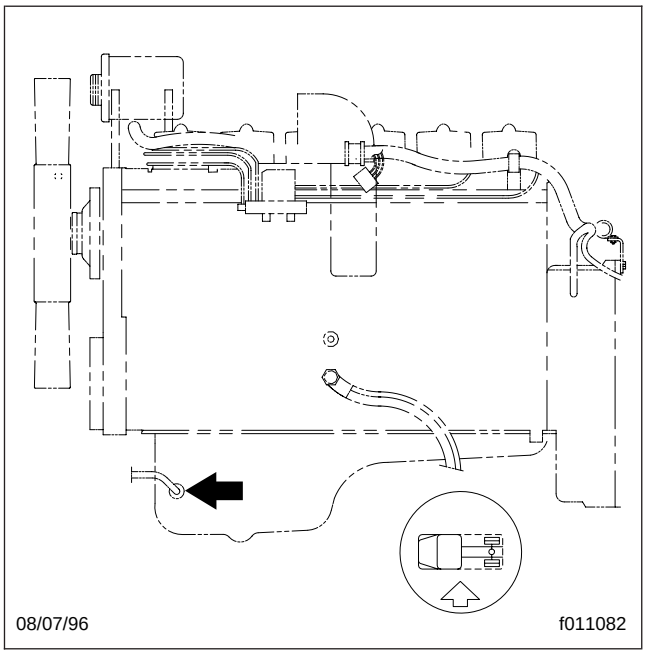
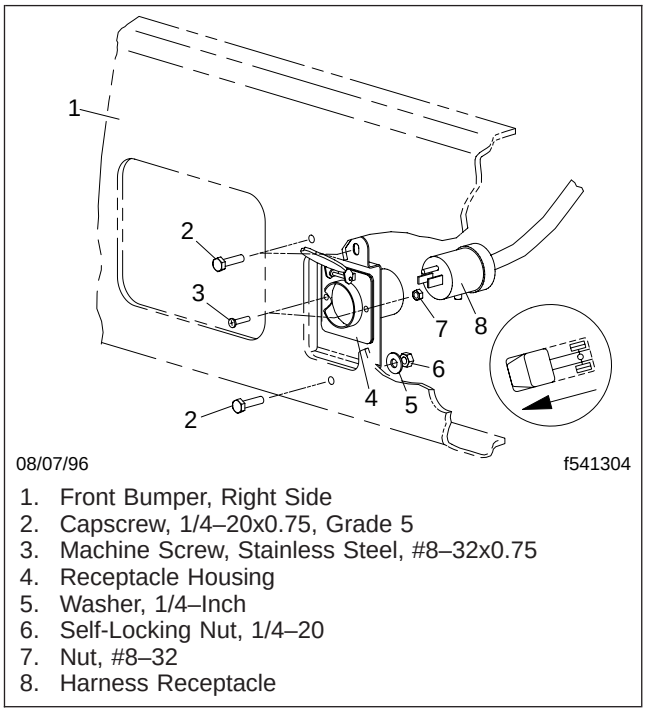


Fig. 2, Oil Pan Heater Location, Cummins B Series Engine



1. Front Bumper, Right Side
2. Capscrew, 1/4–20x0.75, Grade 5
3. Machine Screw, Stainless Steel, #8–32x0.75
4. Receptacle Housing
5. Washer, 1/4–Inch
6. Self-Locking Nut, 1/4–20
7. Nut, #8–32
8. Harness Receptacle

Fig. 3, Heater Receptacle Location

Oil Pan Heater Element Removal and Installation

Removal

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

⚠ WARNING

WARNING: Drain the oil pan only when the oil and engine are cool. Draining it when they are hot could cause severe personal injury due to scalding.

3.1 Place a suitable container under the oil pan drain plug.

3.2 Remove the plug, and allow the oil to drain.

4. Unscrew the threaded cover that secures the cord to the element. See **Fig. 1** or **Fig. 2**.

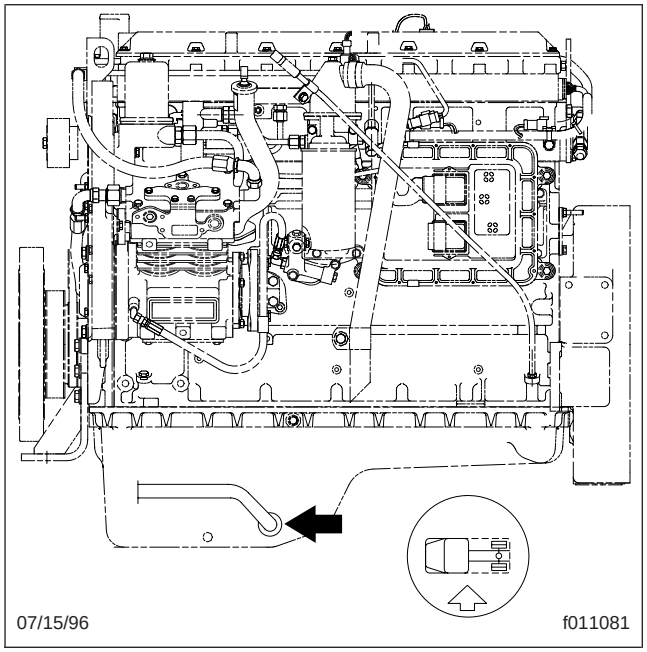


Fig. 1, Oil Pan Heater Location, Caterpillar 3126 Engine

5. Pull the cord off the element.
6. Unscrew the element from the oil pan port.

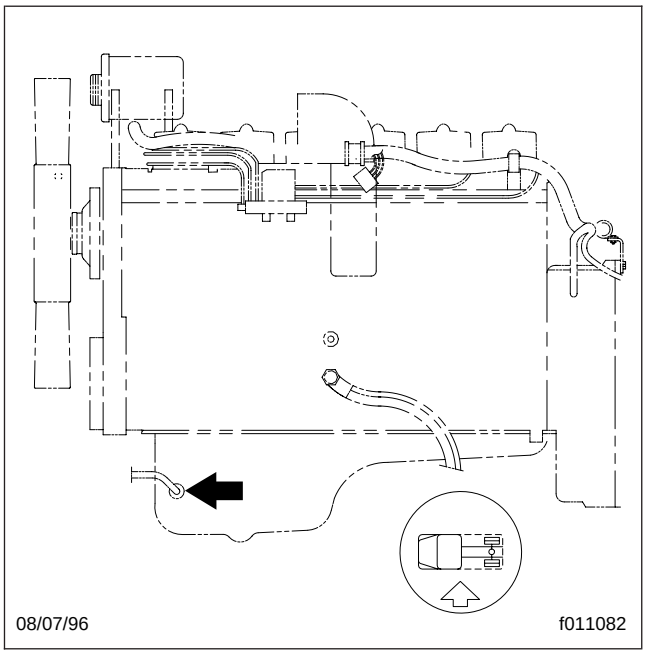


Fig. 2, Oil Pan Heater Location, Cummins B Series Engine

Installation

1. Screw the element into the port until finger-tight. Then, use a wrench to tighten the element one more turn.
2. Plug the cord onto the element and secure it by screwing the threaded cover in place.
3. Install the oil drain plug in the crankcase, and fill the engine with oil. For recommended oil types and engine oil capacities, refer to the engine operating manual.
4. Start the engine and check for leaks. Repair any leaks as necessary.
5. To test the heater, plug a wattmeter into a power source, and connect the heater cord in the receptacle to the meter. A reading on the meter will indicate the heater is working.

Troubleshooting

Use the following procedures to check for the most common oil pan heater problems.

WIRING PROBLEMS

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element. See **Fig. 1** or **Fig. 2**.

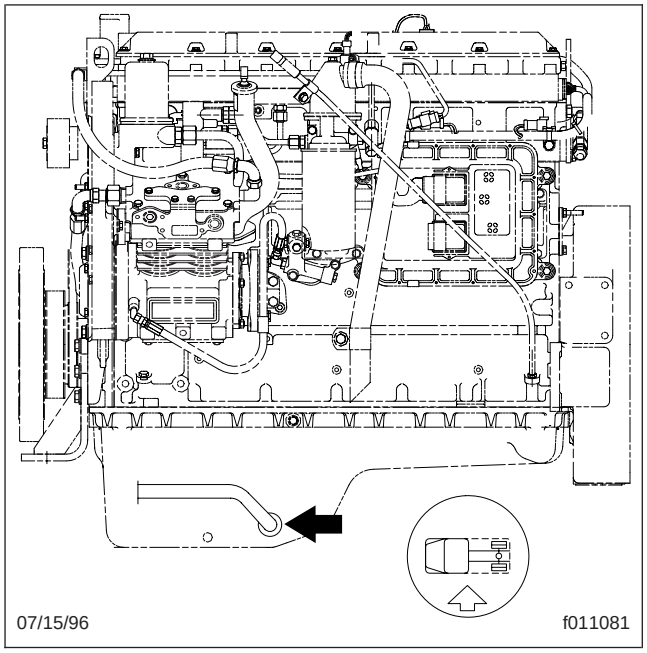


Fig. 1, Oil Pan Heater Location, Caterpillar 3126 Engine

4. Using an ohmmeter, check the continuity between the two poles of the element. On Cummins B Series, the resistance should be about 96 ohms. On Cummins C Series and Caterpillar CFE engines, the resistance should be about 48 ohms. If there is no reading, the element is burnt out.
5. If the element is good, check the cord. Plug the cord onto the element and secure it by screwing the cover in place.

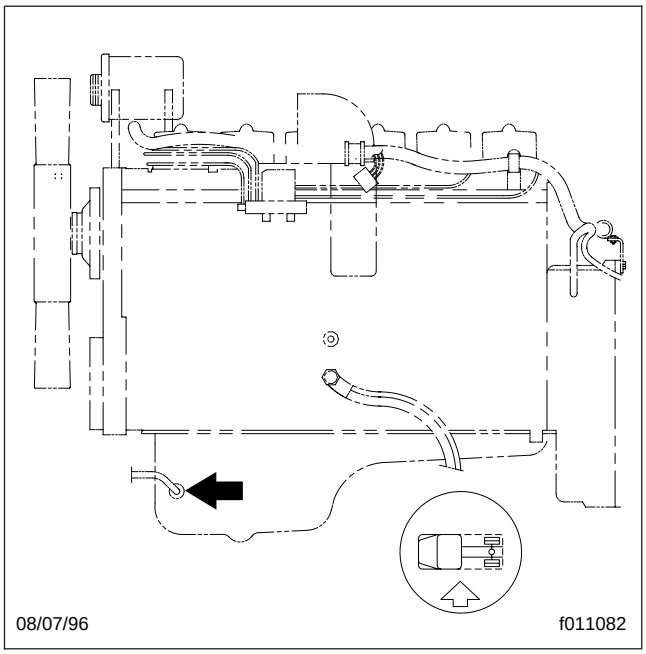


Fig. 2, Oil Pan Heater Location, Cummins B Series Engine

6. Using an ohmmeter at the receptacle, check the continuity between the two power terminals. On Cummins B Series engines, the resistance should be about 96 ohms. On Cummins C Series and Caterpillar CFE engines, the resistance should be about 48 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, apply the parking brakes, and chock the tires.
2. Tilt the hood.

Troubleshooting

WARNING

WARNING: Drain the oil pan only when the oil and engine are cool. Draining it when they are hot could cause severe personal injury due to scalding.

3. Drain the oil.
   - 3.1 Place a suitable container under the oil pan drain plug.
   - 3.2 Remove the plug, and allow the oil to drain.
4. Unscrew the threaded cover that secures the cord to the element. Pull the cord off the element. See **Fig. 1** or **Fig. 2**.
5. Unscrew the element from the oil pan port.
6. Inspect the element for charred oil that may insulate it. If burnt oil is present, replace the element, and change the engine oil and oil filter.

Removal

1. Park the vehicle on a level surface, apply the parking brake, chock the tires, and (if applicable) drain the air system.
2. Disconnect the battery cables at the batteries.
3. Remove the hood. For detailed instructions, see **Section 88.00**, Subject 140.
4. Drain the oil. See **Fig. 1** for the location of the oil drain plug.

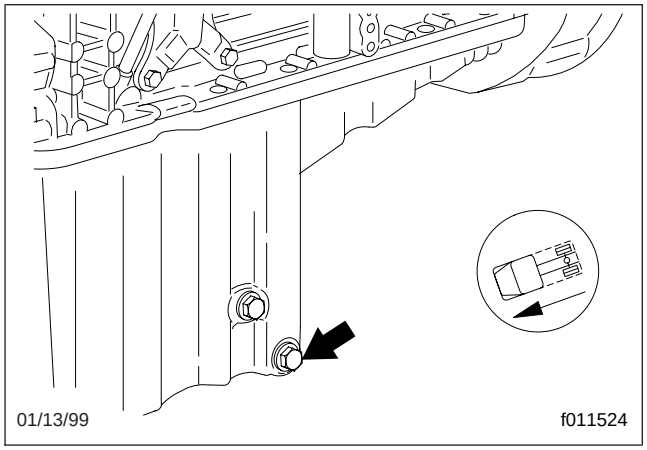


Fig. 1, Oil Drain Plug

⚠ WARNING

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

5. Drain the coolant from the radiator. See **Fig. 2**.
6. Remove the coolant hose standoff bracket.
7. When the coolant has fully drained, remove all of the coolant hoses from the engine. See **Fig. 3** for the coolant delivery hoses from the surge tank, **Fig. 4** for the upper coolant hose, and **Fig. 5** for the lower coolant hose.
   - 7.1 Remove the two small-diameter hoses attached to the surge tank, one going to the engine, the other to the radiator. These are the hoses that were attached to the standoff bracket.

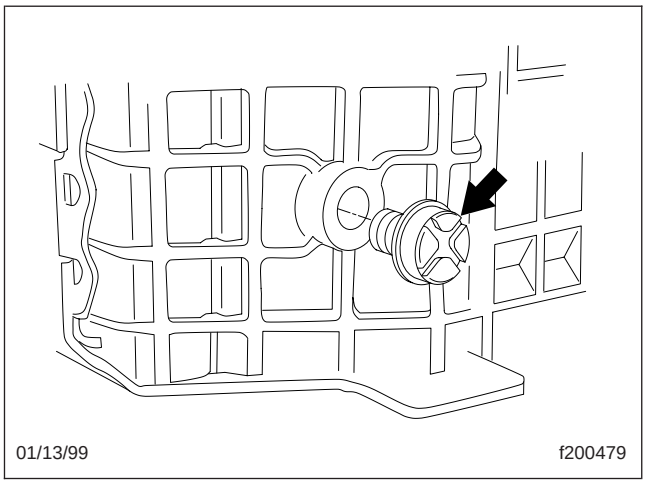
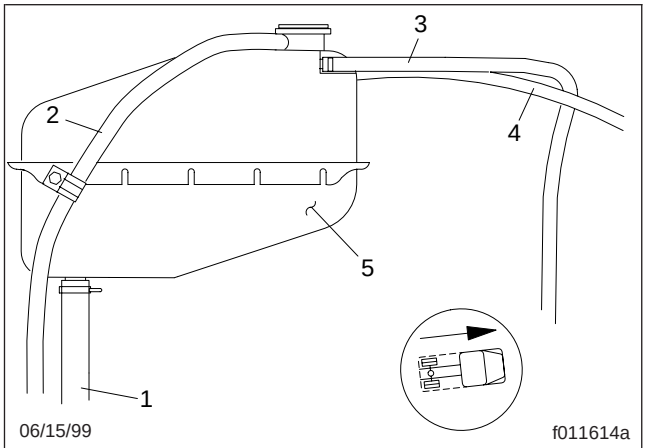


Fig. 2, Coolant Drain Plug

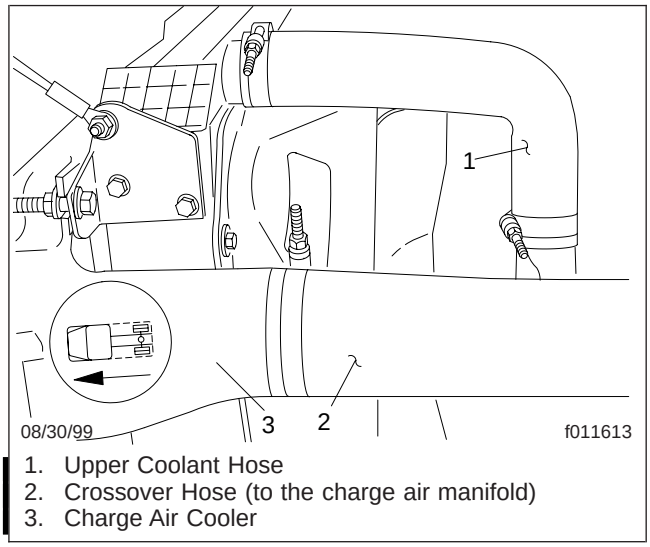


1. Shunt Line
2. Overflow Hose
3. Hose from Engine
4. Hose from Radiator
5. Surge Tank

Fig. 3, Coolant Hoses at the Surge Tank

   - 7.2 Remove the 2-inch (50-mm) inside diameter upper coolant hose attached to the front end of the crankcase, near the cylinder head.
   - 7.3 Remove the lower coolant hose assembly.
   - 7.4 Plug the openings with a clean shop towel.
8. Remove the intake air circulation pipes and hoses. See **Fig. 5**.

Engine Removal and Installation



1. Upper Coolant Hose
2. Crossover Hose (to the charge air manifold)
3. Charge Air Cooler

Fig. 4, Hoses, Left-Hand Side

8.1 Remove the crossover hose from the charge air inlet pipe to the charge air cooler (cold air).

8.2 Remove the convoluted hose from the turbo outlet pipe to the charge air cooler (warm air).

8.3 Remove the pipe from the air cleaner to the turbo inlet (air cleaner pipe).

8.4 Remove the crankcase breather hose from the crankcase inlet tubing.

8.5 Remove the air compressor inlet hose between the air cleaner pipe and the air compressor inlet tubing.

8.6 For ease of installation, mark the outlets on each pipe with a paint pen.

8.7 Plug the openings with a clean shop towel.

IMPORTANT: Leave all air conditioning hoses attached to avoid depressurizing the A/C system.

9. Remove the air conditioning (A/C) condenser. See **Fig. 6**. Wrap the condenser, with hoses attached, in a protective blanket, and secure it out of the way.
10. Remove the charge air cooler. See **Fig. 7**. For detailed procedures, see the instructions in **Section 09.01**, Subject 100.
11. Remove the radiator assembly. See **Fig. 7**. For detailed procedures, see the instructions for frame-rail mounted radiators in **Section 20.01**, Subject 100.
12. Release the tension on the poly-V belt. See **Fig. 8**.
13. Disconnect the fuel lines from the fuel filter housing. See **Fig. 9**.
14. Remove the refrigerant compressor. See **Fig. 10**.
15. Disconnect the electrical connectors from the engine.

    15.1 Disconnect the engine harness connector from the PLD (engine control unit). See **Fig. 11**.

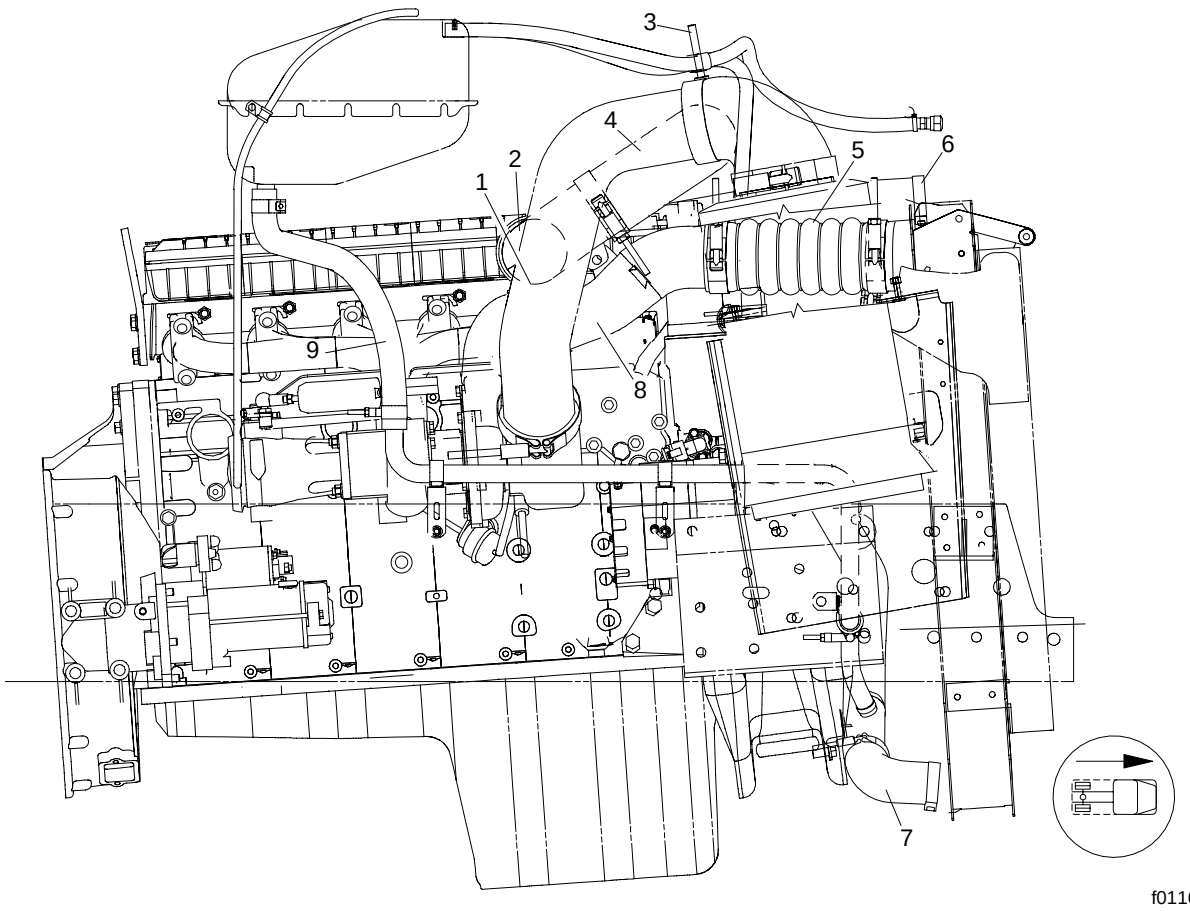
    15.2 Disconnect the fan solenoid connector. This connector is along the left-hand side, between the PLD and the air compressor. See **Fig. 12**.

    15.3 Disconnect the exhaust brake solenoid connector, if installed. This connector is on the left-hand side near the PLD. See **Fig. 12**.
16. Disconnect the power steering pump from the air compressor. Secure it, with the lines attached, up and out of the way. See **Fig. 13**.
17. Remove the air line from the exhaust brake, if installed. See **Fig. 14**.
18. Disconnect the exhaust pipe. See **Fig. 15**.
19. Remove the starter and engine ground strap. Set the starter out of the way.

    19.1 Remove the ground strap from the engine to the chassis.

    19.2 Remove the starter mounting bolts.

    19.3 Move the starter up and out of the way, with the cables attached. Tie the starter in place.
20. Remove the electrical leads from the back of the alternator. See **Fig. 16**.
21. Remove the transmission. For procedures, see **Group 26**.
22. Remove the hydraulic clutch line, if installed. See **Fig. 17**.



1. Air Cleaner Pipe
2. Charge Air Inlet Pipe (cold air)
3. Coolant Hose Standoff Bracket
4. Crossover Hose (cold air)
5. Convoluted Hose (warm air)
6. Upper Coolant Hose
7. Lower Coolant Hose
8. Turbocharger Outlet Pipe (warm air)
9. Surge Tank Shunt Line

Fig. 5, Charge Air and Coolant Pipes and Hoses

23. Remove the rain tray and wiper arms.

CAUTION

To avoid damage to the crankcase breather valve cover, make sure the chains on the front lifting eye provide adequate clearance.

To avoid damage to the wiper conlink, make sure the chains on the rear lifting fixture do not contact the conlink when the engine is lifted.

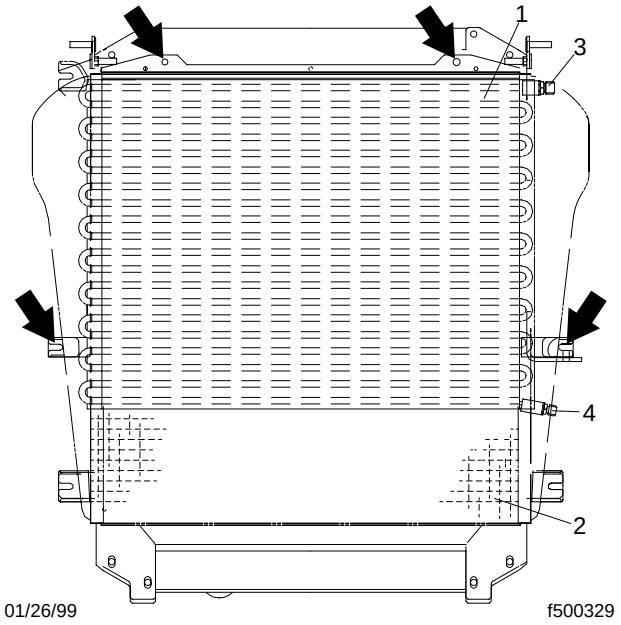
24. Attach a lifting hoist to the engine. Run the chains through the front lifting eye and rear lifting fixture. See **Fig. 18** for attachment to the front lifting eye and **Fig. 19** for attachment to the rear lifting fixture.

25. Loosen the engine mounts. See **Fig. 20** for the front engine mount and **Fig. 21** for the rear engine mounts.

    25.1 Loosen the front engine mounting bolt where it attaches to the front crossmember.

    25.2 Loosen the four rear engine mounting capscrews that attach the mount to the engine.

Engine Removal and Installation



Remove the four mounting bolts.

1. Air Conditioning (A/C) Condenser
2. Charge Air Cooler
3. Condenser Inlet
4. Condenser Outlet

Fig. 6, A/C Condenser

26. Support the rear of the engine with a jack.
27. Remove both rear engine mounts. For proper clearance, remove both ends of the mount.
28. Remove the front crossmember to obtain proper clearance for removal of the engine. See **Fig. 22**.

⚠ WARNING

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are 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.

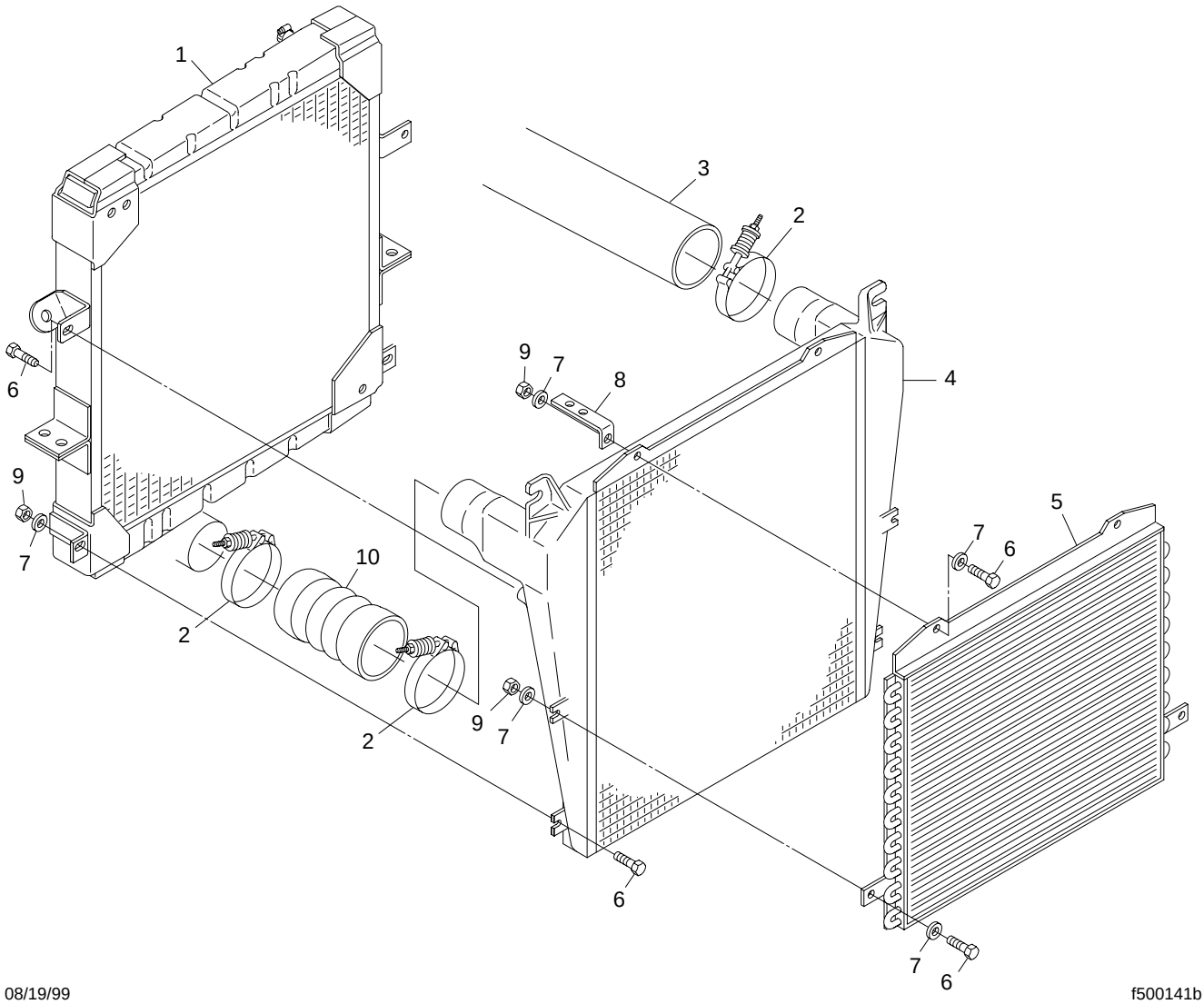
29. Remove the engine from the vehicle. See **Fig. 23**.
    - 29.1 Raise the hoist slightly until it is holding the full weight of the engine.
    - 29.2 Lower the engine just enough to allow it to move forward until it can be lifted without hitting the frontwall or wiper conlink.
    - 29.3 Pull the engine forward and up to clear the vehicle. If a new engine is to be installed, transfer all needed components from the old engine to the new engine.

Installation

⚠ WARNING

The crane and lifting chains used to remove the engine must be capable of safely lifting and supporting two metric tons. Once the engine mounts are 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.

1. Using the hoist as removed, lower the engine into the engine compartment until the rear of the engine is resting on the jack used during removal. Check clearances on all sides, as removed.
2. Install the front crossmember. Tighten the locknuts on the mounting bolts 60 lbf·ft (81 N·m).
3. Install the front engine mounting bolt, isolator, and nut. Tighten the nut 136 lbf·ft (184 N·m).
    - 3.1 Position the isolator on the crossmember.
    - 3.2 Move the engine on the hoist until it rests directly on the isolator.
    - 3.3 Insert the bolt through the crossmember, isolator, and engine. Install and tighten the nut.
4. Install both rear engine mounts. See **Fig. 21** and **Fig. 24**.
    - 4.1 Install the engine mounts on the frame-mounted brackets. Tighten the mounting bolts 241 lbf·ft (347 N·m).
    - 4.2 Lower the jack under the rear of the engine slightly, until the holes in the timing case line up with the holes in the engine mounts.
    - 4.3 Insert the engine mounting capscrews and tighten them 155 lbf·ft (210 N·m).



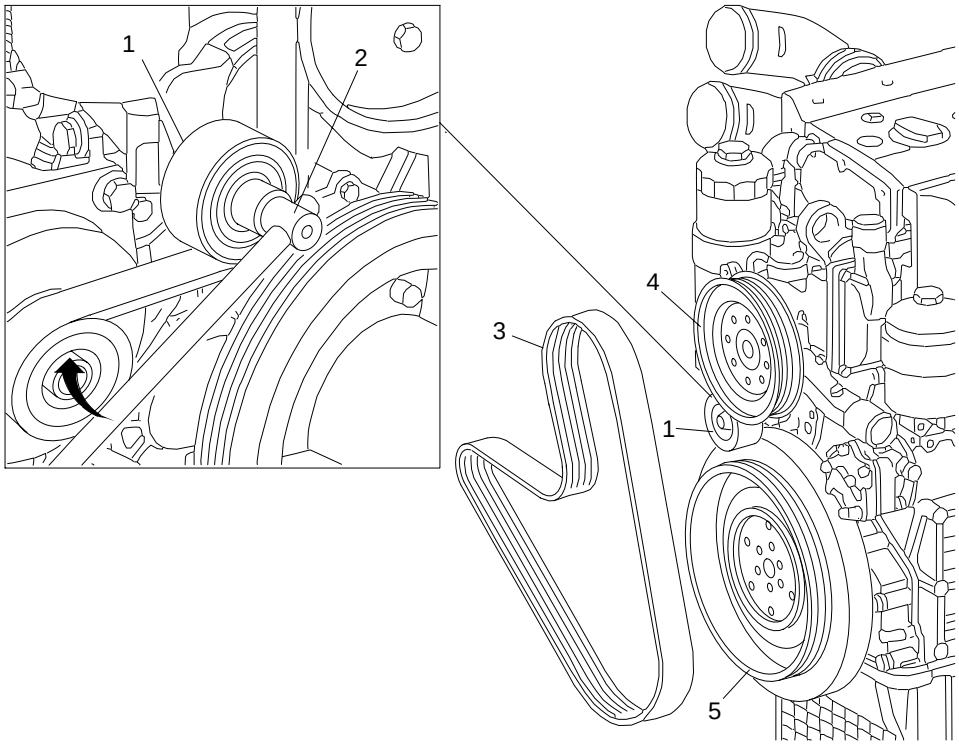
1. Radiator
2. Constant-Torque Hose Clamp
3. Charge Air Hose
4. Charge Air Cooler (CAC)
5. A/C Condenser
6. Mounting Bolt
7. Washer
8. Stand-Off Bracket
9. Nut
10. Convoluted Hose

Fig. 7, Charge Air Cooler and Radiator

4.4 Lower and remove the jack.

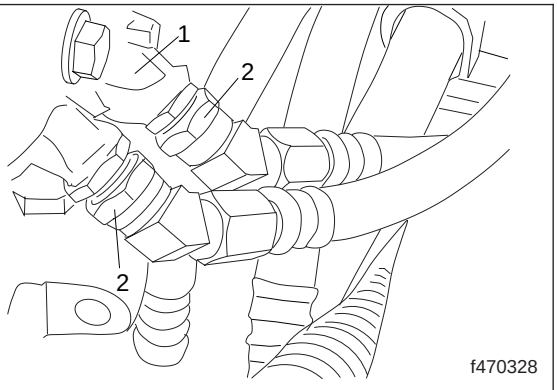
5. Remove the hoist from the front lifting eye and the rear lifting fixture.
6. Install the transmission on the engine timing case. Tighten the timing case to transmission mounting bolts 33 lbf·ft (45 N·m). For detailed procedures, see **Group 26**.
7. If removed, install the air line on the exhaust brake. See **Fig. 14**.
8. Connect the exhaust pipe. See **Fig. 15**.
9. Install the starter and engine ground strap.

Engine Removal and Installation



1. Belt Tensioner
2. Socket
3. Poly-V Belt
4. Fan Pulley
5. Vibration Damper

Fig. 8, Belt Tensioner



1. Fuel Filter
2. Fuel Line Fittings

Fig. 9, Fuel Lines

9.1 Untie the starter. Position the starter so that the starter ring gear lines up with the flywheel.

9.2 Install the starter mounting bolts and tighten them 37 lbf·ft (50 N·m).

9.3 Install the ground strap from the chassis to the engine.

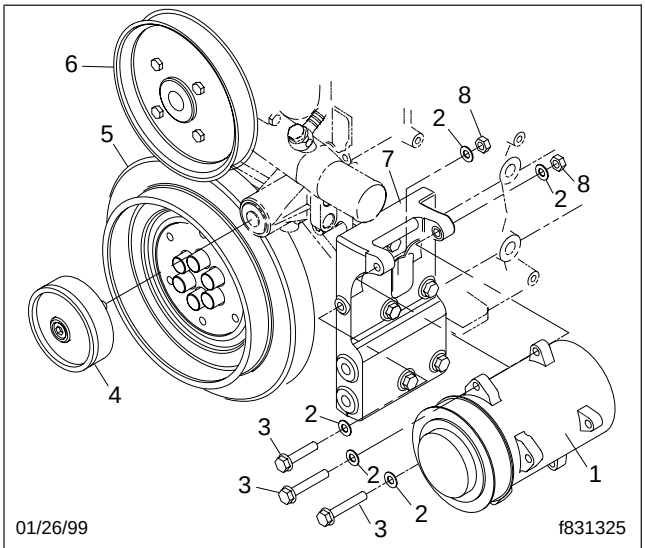
10. Install the alternator wiring on the alternator terminals. See **Fig. 16**. Tighten the output (BAT) terminal nut 100 lbf·in (1140 N·cm). Tighten the ground (G) terminal nut 65 lbf·in (740 N·cm), and the indicator light (I) terminal nut 20 lbf·in (220 N·cm).

11. Install the refrigerant compressor. See **Fig. 10**. Tighten the mounting bolts 34 lbf·ft (46 N·m).

12. Install and put tension on the poly-V belt. See **Fig. 25**.

12.1 Route the belt through and around the fan, alternator, idler, and refrigerant compressor pulleys.

12.2 Relax the tension on the belt tensioner.



1. Refrigerant Compressor
2. Hardened Flatwasher
3. Mounting Bolt, M10
4. Idler Pulley
5. Vibration Damper
6. Fan Pulley
7. Mounting Bracket
8. Locknut, M10

Fig. 10, Refrigerant Compressor

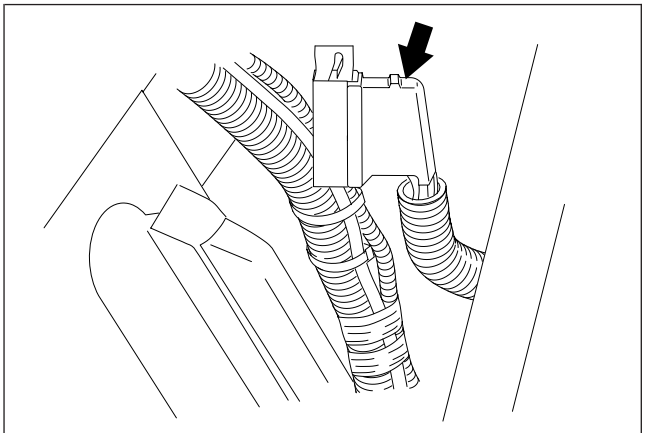
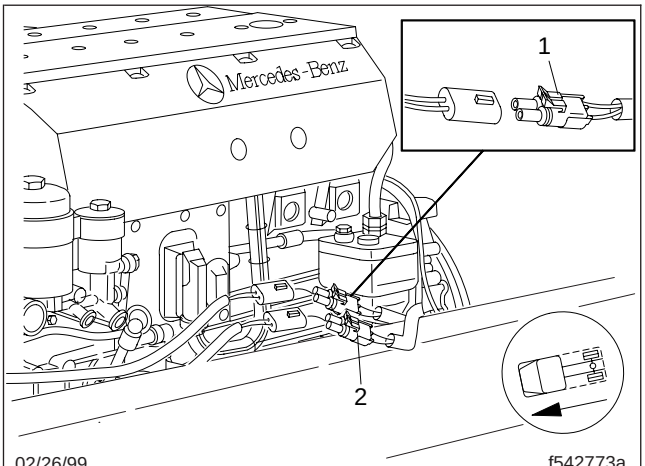


Fig. 11, Engine Harness Connector

12.3 Route the belt through the belt tensioner pulley and allow the belt tensioner to tighten the belt.

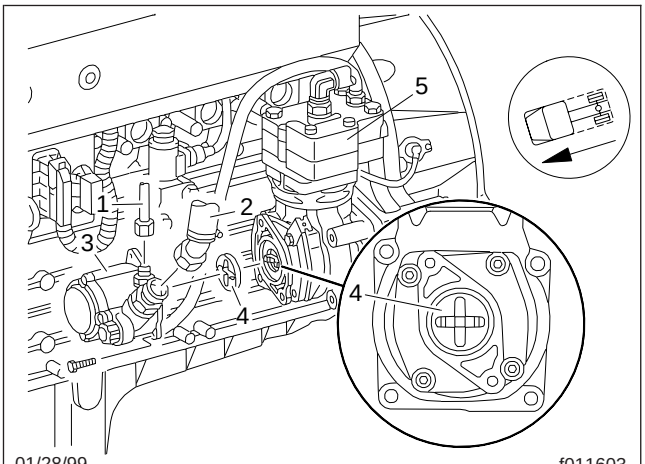
12.4 Check all the pulleys to make sure the belt is correctly installed and aligned.

13. Connect the electrical connectors to the engine.



1. Fan Solenoid Connector
2. Exhaust Brake Solenoid Connector

Fig. 12, Fan Solenoid and Exhaust Brake Solenoid Connector



1. Pressure Line
2. Return Line
3. Power Steering Pump
4. Cross Plate
5. Air Compressor

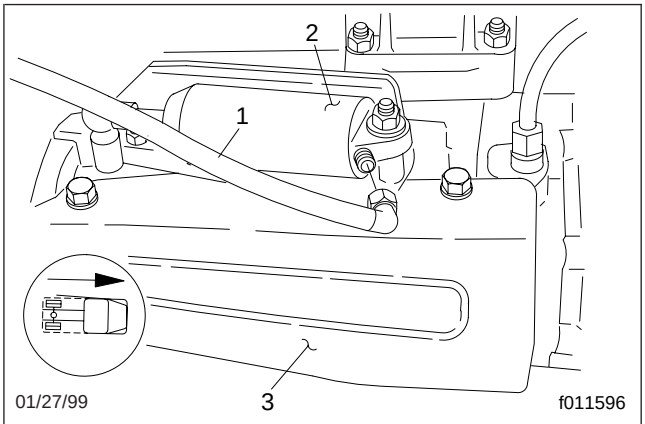
Fig. 13, Power Steering Lines

13.1 Connect the engine harness connector to the PLD (engine) control unit. See **Fig. 11**.

13.2 Connect the fan solenoid connector. See **Fig. 12**.

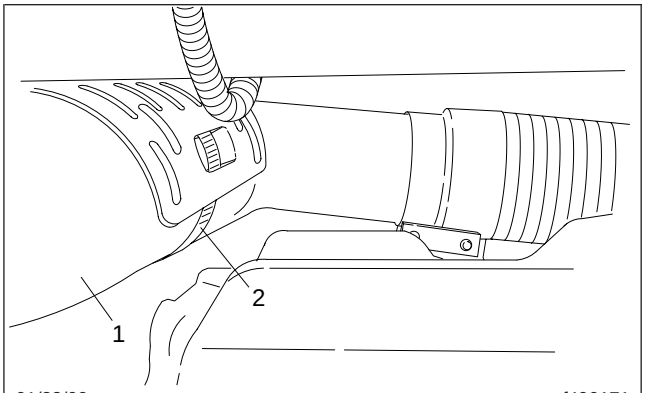
13.3 If removed, connect the exhaust brake solenoid connector. See **Fig. 12**.

Engine Removal and Installation



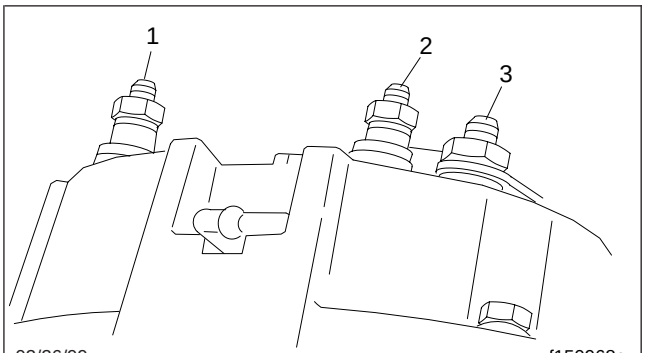
1. Compressed Air Line
2. Exhaust Brake
3. Turbocharger

Fig. 14, Exhaust Brake Air Line



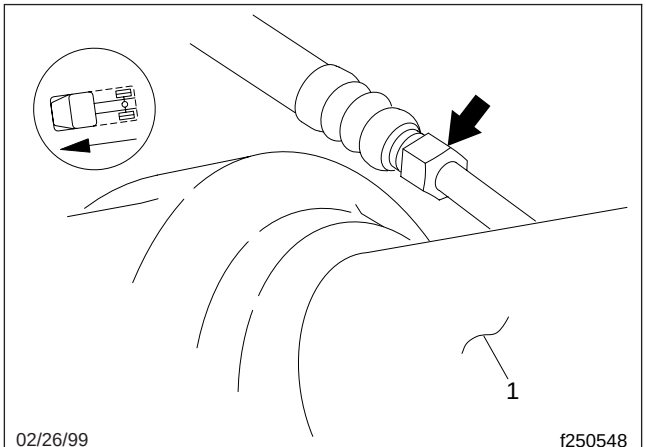
1. Exhaust Pipe
2. Clamp

Fig. 15, Exhaust Pipe



1. Ground (G)
2. Indicator Light (I)
3. Output (BAT)

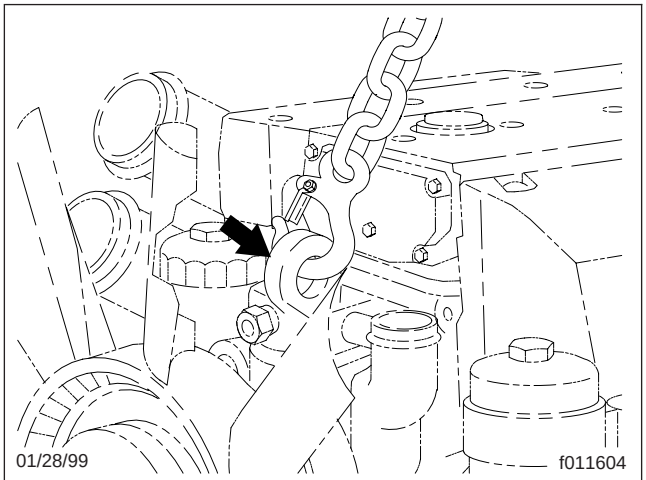
Fig. 16, Alternator Terminals



Loosen the nut on the clutch line at the arrow.

1. Clutch Slave Cylinder

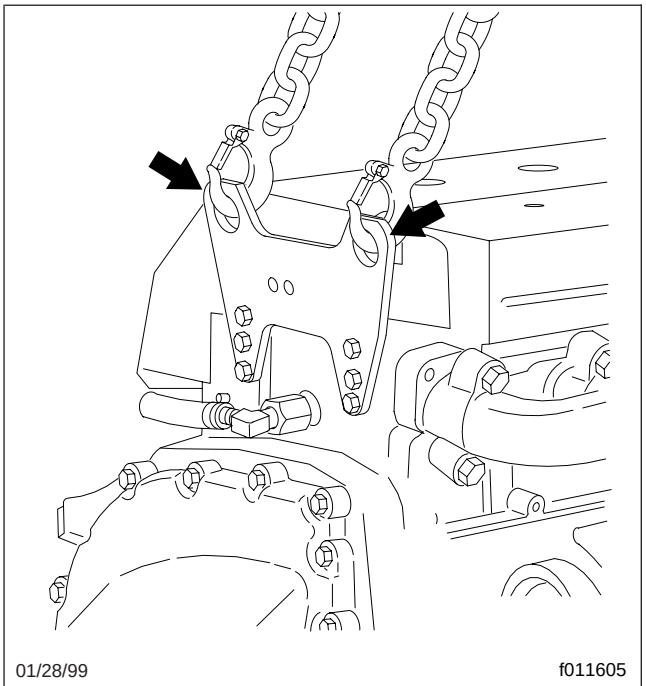
Fig. 17, Hydraulic Clutch Line



When lifting, be sure the front lifting eye is clear of the crankcase breather valve cover.

Fig. 18, Front Lifting Eye

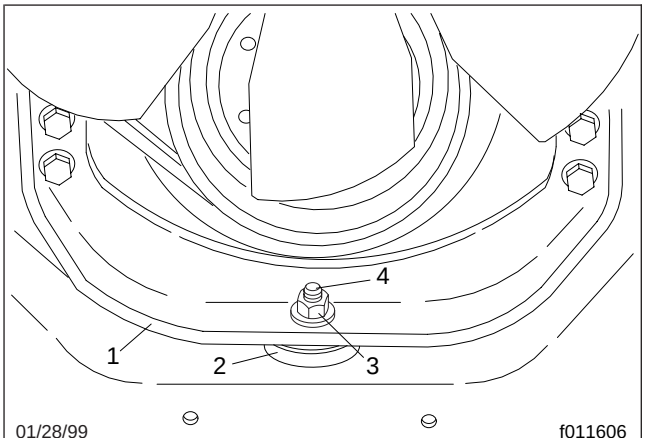
14. Connect the fuel lines to the fuel filter housing. See **Fig. 9**.
15. Connect the power steering pump to the air compressor. See **Fig. 13**.
16. Install the radiator assembly. See **Fig. 7**. For detailed instructions, see the procedures for frame-rail mounted radiators in **Section 20.01**, Subject 100. Tighten the nuts on the radiator brace isolators 25 lbf·ft (34 N·m).



01/28/99 f011605

When lifting, be sure the rear lifting fixture is clear of the frontwall and the wiper conlink.

Fig. 19, Rear Lifting Fixture

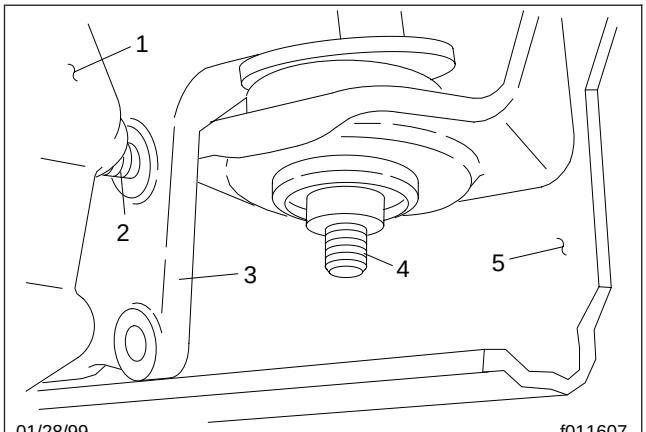


01/28/99 f011606

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

Fig. 20, Front Engine Mount

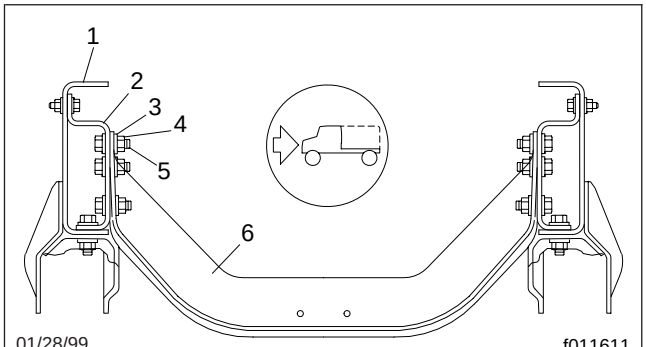
17. Install the charge air cooler. See **Fig. 7**. For detailed instructions, see the procedures in **Section 09.01**, Subject 100. Tighten the mounting bolts 16 lbf·ft (22 N·m).



01/28/99 f011607

1. Timing Case
2. Engine Mounting Capscrew, M16
3. Rear Mount
4. Frame-Mounted Bracket Mounting Bolt, 3/4–10
5. Frame Rail

Fig. 21, Rear Engine Mount Removal



01/28/99 f011611

1. Frame Rail
2. Mounting Bracket
3. Bearing Washer
4. Locknut, 1/2–13
5. Mounting Bolt, 1/2–13
6. Crossmember

Fig. 22, Engine Crossmember

18. Install the A/C condenser and secure all hoses. See **Fig. 6**. Tighten the mounting bolts 16 lbf·ft (22 N·m).
19. Install the coolant hoses. See **Fig. 3**, **Fig. 4** and **Fig. 5**.

Engine Removal and Installation

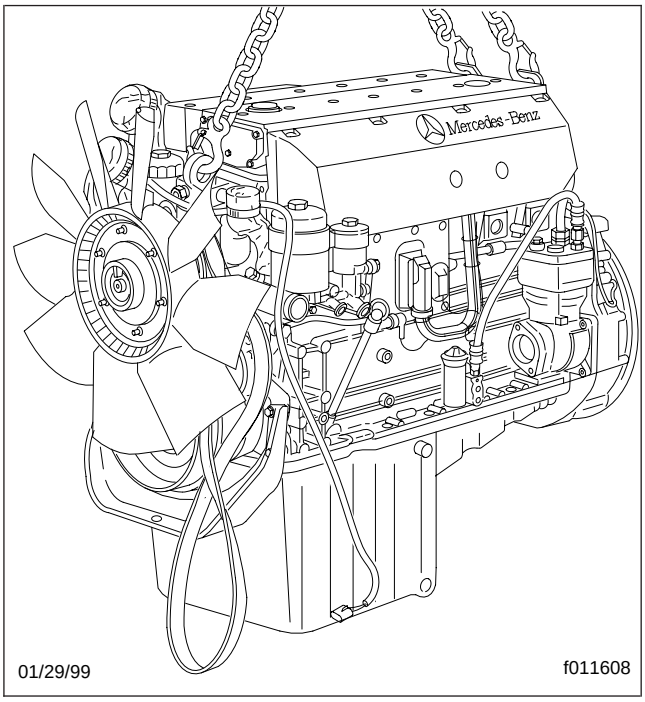
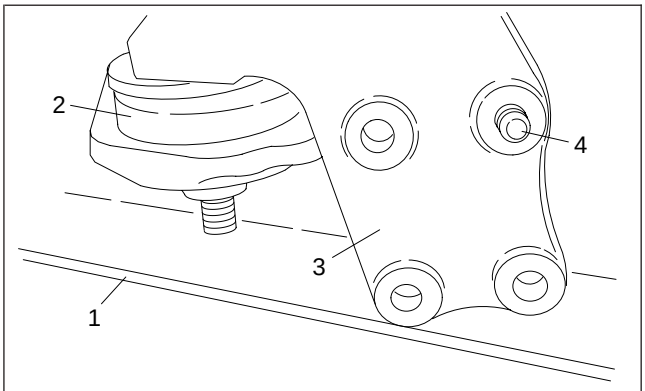


Fig. 23, Engine Removed from the Vehicle

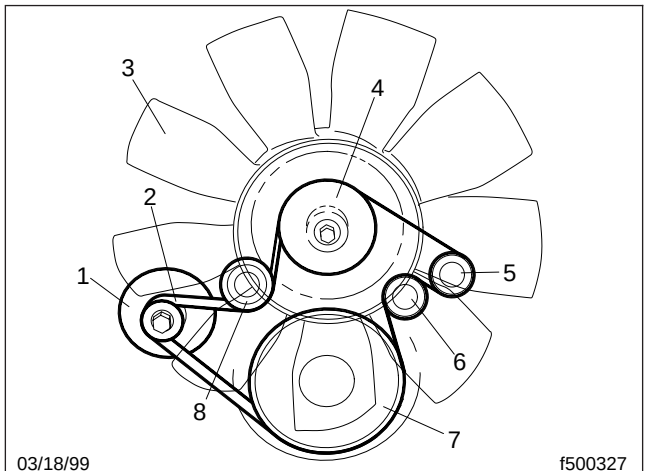


1. Frame Rail
2. Isolator
3. Rear Mount
4. Engine Mounting Capscrew, M16

Fig. 24, Rear Engine Mount Installation

19.1 Install the two small-diameter coolant delivery hoses attached to the surge tank.

19.2 Install the medium-diameter upper coolant hose attached to the front end of the crankcase, near the cylinder head.



1. Alternator
2. Poly-V Belt
3. Fan
4. Fan Pulley
5. Refrigerant Compressor
6. Idler Pulley
7. Vibration Damper
8. Belt Tensioner

Fig. 25, Belt Routing

19.3 Install the lower coolant hose assembly.

20. Install the coolant hose standoff bracket.

21. Install the charge air cooler hoses, as marked on removal. Make sure the pipes fit correctly and the clamps are tight. Make sure the crossover hose is oriented correctly. See **Fig. 26**.

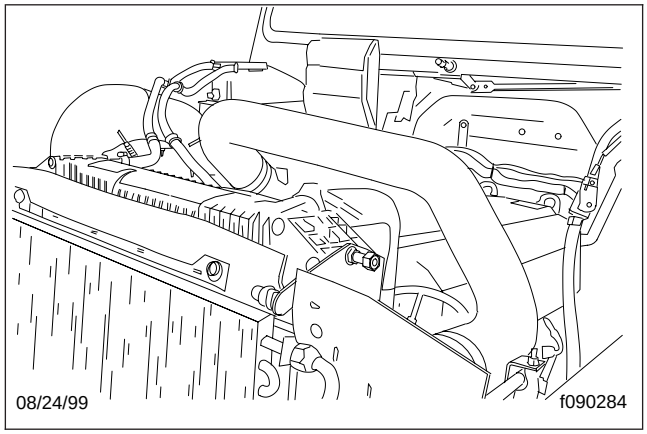
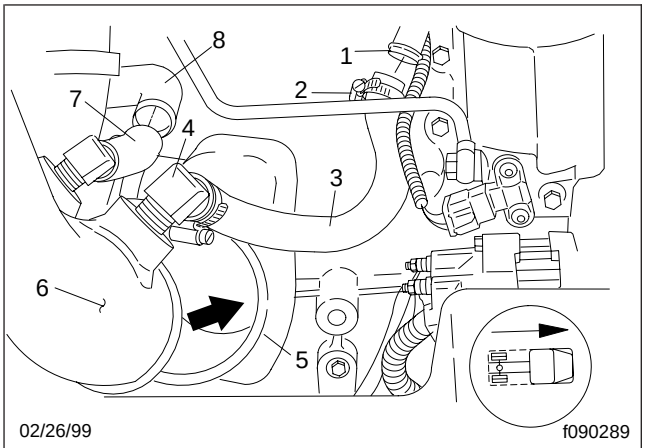


Fig. 26, Crossover Hose

21.1 Install the crossover hose leading between the charge air cooler and the charge air inlet pipe (cold air).

21.2 Install the convoluted hose between the turbo outlet pipe and the charge air cooler (warm air).

22. Install the air cleaner pipe, as marked on removal. Make sure the pipe fits correctly down on the inlet, is firmly connected, and the clamps are tight. See **Fig. 27** for correct fit of the air cleaner pipe to the turbo inlet.



1. Crankcase Inlet
2. Clamp
3. Crankcase Breather Hose
4. 90° Elbow
5. Turbo Inlet
6. Air Cleaner Pipe
7. Air Compressor Inlet Hose
8. Air Compressor Inlet

Fig. 27, Air Cleaner Pipe and Breather Hose

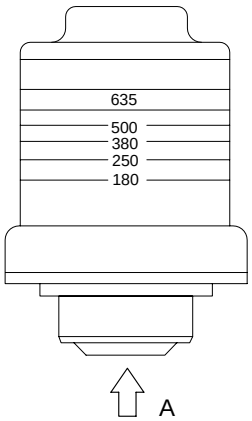
23. Install the air compressor inlet hose, as marked on removal. Make sure the hose fits correctly down on the air compressor inlet tubing, is firmly connected, and the clamp and elbow is tight. See **Fig. 27** for correct fit of the breather hose to the inlet tubing.
24. Install the crankcase breather hose, as marked on removal. Make sure the hose fits correctly down on the crankcase inlet tubing, is firmly connected, and the clamp and elbow is tight. See **Fig. 27** for correct fit of the breather hose to the inlet tubing.
25. Install the rain tray and wiper arms.
26. If removed, install the hydraulic clutch line and bleed the hydraulic clutch system. See **Fig. 17**.
27. Install the hood. For detailed instructions, see **Section 88.00**, Subject 140.
28. Install the coolant drain plug. Fill the radiator with coolant. Make sure the coolant drain plug is tight and is not leaking.
29. Install the oil drain plug and tighten it 48 lbf·ft (65 N·m). Fill the engine with oil. Make sure the oil drain plug is tight and is not leaking.
30. Connect the battery cables to the batteries.
31. Turn on the ignition keyswitch and test the engine for good operation. Pay attention to oil pressure, coolant temperature, warning lights, fluid leaks, and any other signs of a problem.
32. Remove the chocks from the tires.

General Information

An average diesel engine needs over 10,000 gallons (38 000 liters) of clean air for approximately each 1/4-gallon (1 l) of fuel burned. So complete combustion occurs in each engine cylinder, more clean air than is needed is present in each cylinder. The air intake system routes this supply of outside air through an air cleaner, which filters out dirt, dust, abrasive particles, and other foreign material from the intake air, without restricting air flow. From there, the air intake ducting routes this clean air to the engine turbocharger.

The air intake ducting consists of a high-temp plastic housing for the air cleaner, followed by aluminum tubes and neoprene hoses. Stainless steel hose clamps fasten all the components together in one of two configurations depending on which engine is used.

On some engines, a lock-up air restriction indicator is attached to the intake ducting near the air cleaner. See **Fig. 1**. As an option, an air restriction indicator or gauge mounts in the dashboard. Nylon tubing connects the remote-mounted indicator or gauge to the ducting. The air restriction indicator or gauge indicates when the air cleaner element needs to be replaced. The amount of allowable air restriction varies with engine type.



A. Press to reset the indicator

Fig. 1, Air Restriction Indicator

On vehicles equipped with a Bendix AirMaster® air compressor, the compressor air inlet hose mounts to the air intake pipe just past the air restriction indicator.

Air Intake Ducting Removal and Installation, Cummins 6B Series Engine

General Instructions

WARNING

Do not operate the engine with any under-hood 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.

IMPORTANT: Replace damaged components with new, identical parts. Neoprene hoses and nylon ducts that have been enlarged, extended, or otherwise modified, are not acceptable for installation between the air cleaner and the engine.

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

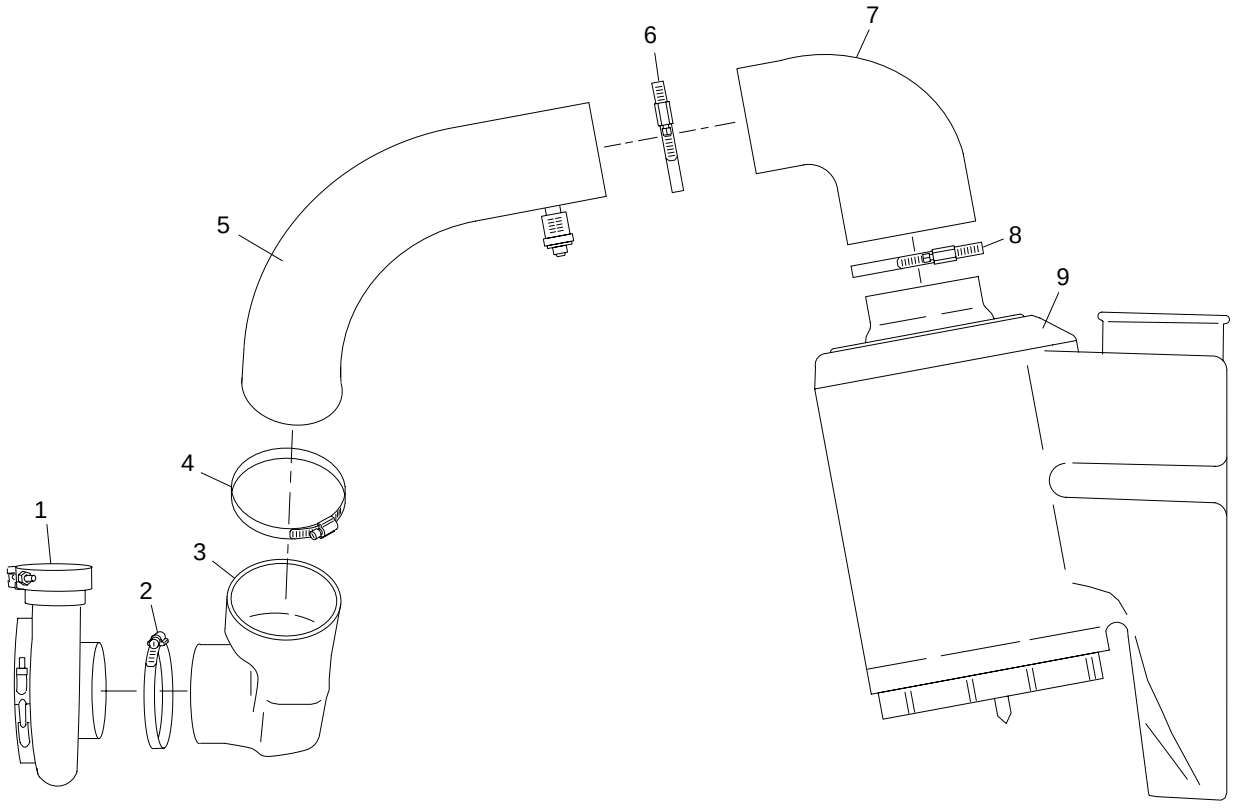
Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Disassemble the air intake ducting. See **Fig. 1**.
   - 3.1 Loosen the clamp (Ref. 8) that holds the elbow (Ref. 7) to the top of the air cleaner, and remove the elbow from the cleaner.
   - 3.2 Loosen the clamp (Ref. 6) that holds the elbow to the forward end of the air intake pipe (Ref. 5), and remove the elbow from the pipe.
   - 3.3 Loosen the clamp (Ref. 4) that holds the pipe to the elbow (Ref. 3) at the forward side of the turbocharger, and remove the pipe from the elbow.
   - 3.4 Loosen the clamp (Ref. 2) that holds the elbow to the forward side of the turbocharger, and remove the elbow from the turbocharger.

Installation

1. Replace any damaged parts with new identical parts.
2. Assemble the air intake ducting. See **Fig. 1**.
   - 2.1 Install the new or undamaged elbow (Ref. 3) on the forward side of the turbocharger, and loosely install the clamp (Ref. 2).
   - 2.2 Install the new or undamaged air intake pipe (Ref. 5) in the elbow at the forward side of the turbocharger, and loosely install the clamp (Ref. 4).
   - 2.3 Install the new or undamaged elbow (Ref. 7) on the forward end of the air intake pipe, and loosely install the clamp (Ref. 6).
   - 2.4 Install the elbow on the top of the air cleaner, and tighten all hose clamps.
3. Lower the hood.
4. Remove the chocks from the tires.

Air Intake Ducting Removal and Installation, Cummins 6B Series Engine



07/06/94 f090059a

1. Turbocharger
2. Hose Clamp
3. Elbow Duct
4. Hose Clamp
5. Air Intake Pipe
6. Hose Clamp
7. Elbow Duct
8. Hose Clamp
9. Air Cleaner

Fig. 1, Cummins 6B Series Engine, Air Intake Ducting

Air Intake Ducting Removal and Installation, Caterpillar CFE Series Engine

General Instructions

WARNING

Do not operate the engine with any under-hood 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.

IMPORTANT: Replace damaged components with new, identical parts. Neoprene hoses and nylon ducts that have been enlarged, extended, or otherwise modified, are not acceptable for installation between the air cleaner and the engine.

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

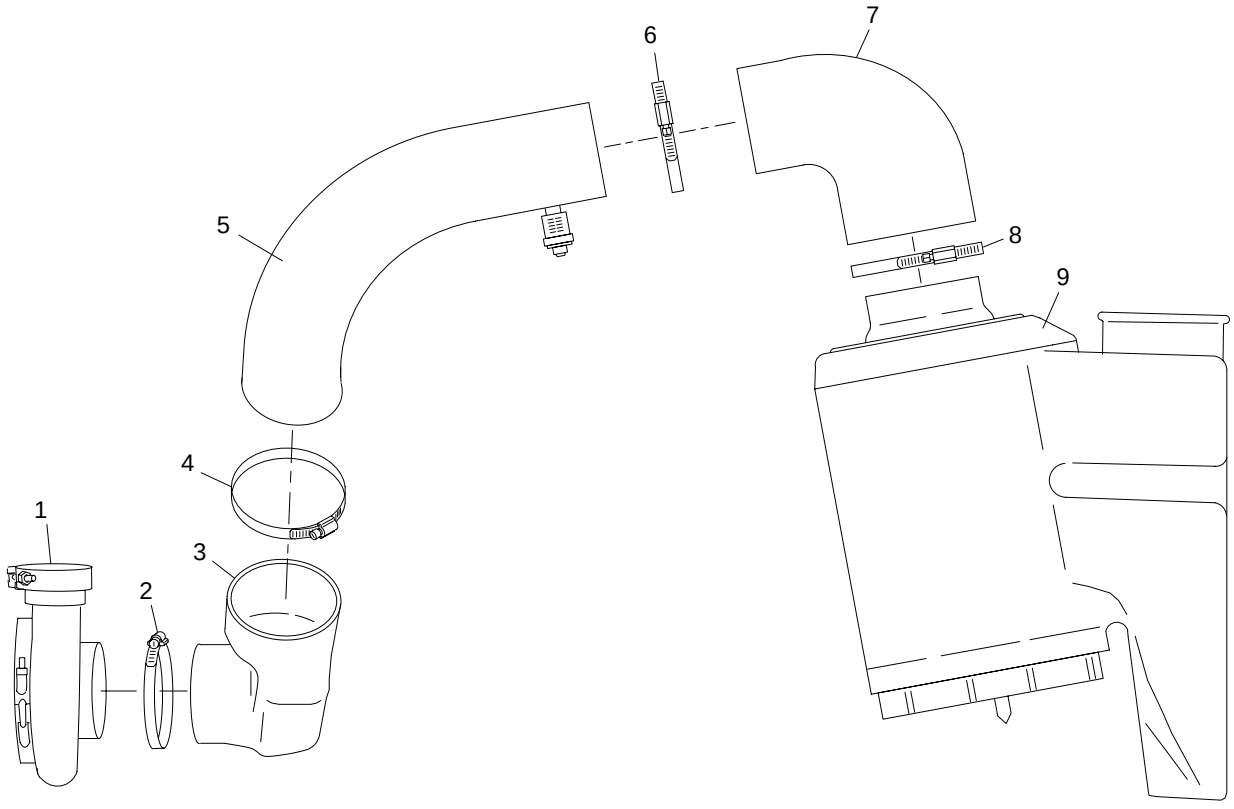
Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Disassemble the air intake ducting. See **Fig. 1**.
   - 3.1 Loosen the clamp that holds the elbow reducer to the top of the air cleaner, and remove the elbow reducer from the cleaner.
   - 3.2 Loosen the clamp that holds the elbow to the forward end of the air intake pipe, and remove the elbow from the pipe.
   - 3.3 Loosen the clamp that holds the air intake pipe to the 90-degree elbow that connects the pipe to the turbocharger assembly. Remove the pipe from the elbow.
   - 3.4 Loosen the clamp and remove the 90-degree elbow from the turbocharger.

Installation

1. Replace any damaged parts with new identical parts.
2. Assemble the air intake ducting. See **Fig. 1**.
   - 2.1 Install the new or undamaged 90-degree elbow onto the turbocharger, and loosely install the hose clamp.
   - 2.2 Install the new or undamaged air intake pipe onto the 90-degree elbow. Loosely install the clamp.
   - 2.3 Attach the new or undamaged air intake pipe onto the elbow reducer, and loosely install the clamp.
   - 2.4 Install the elbow reducer to the air cleaner housing.
   - 2.5 Install the elbow on the top of the air cleaner, and tighten all hose clamps.
3. Lower the hood.
4. Remove the chocks from the tires.

Air Intake Ducting Removal and Installation, Caterpillar CFE Series Engine



07/06/94 f090059a

1. Turbocharger
2. Hose Clamp
3. Elbow Duct
4. Hose Clamp
5. Air Intake Pipe
6. Hose Clamp
7. Elbow Duct
8. Hose Clamp
9. Air Cleaner

Fig. 1, Caterpillar CFE Series Engine, Air Intake Ducting

General Information

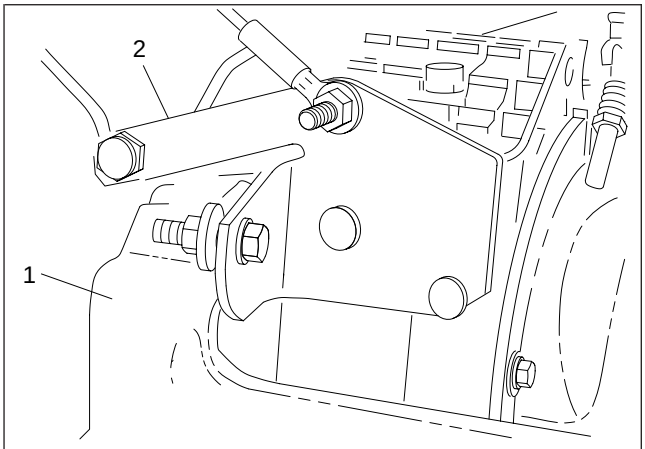
The charge air cooler (CAC) is attached to the front of the radiator. It is similar to a radiator: outside ambient air passing through the CAC core cools the engine's intake air charge.

Air leaving the turbocharger is compressed, which heats it to about 275° to 325°F (135° to 162°C), depending on the ambient temperature and boost. The CAC reduces this temperature to the engine manufacturer's specified air intake temperature before the air reaches the engine intake manifold. Lower temperatures reduce exhaust emissions, improve fuel economy, and increase horsepower.

Charge Air Cooler Removal and Installation

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Remove the hood; for instructions, see **Group 88**.
3. Remove the charge air cooler (CAC).
   - 3.1 Remove the hood cable brackets from the radiator. See **Fig. 1**.
   - 3.2 Disconnect the air inlet and outlet hoses from the CAC. See **Fig. 2**.
   - 3.3 Remove the four CAC mounting bolts. See **Fig. 3**. Then, remove the CAC from the radiator.

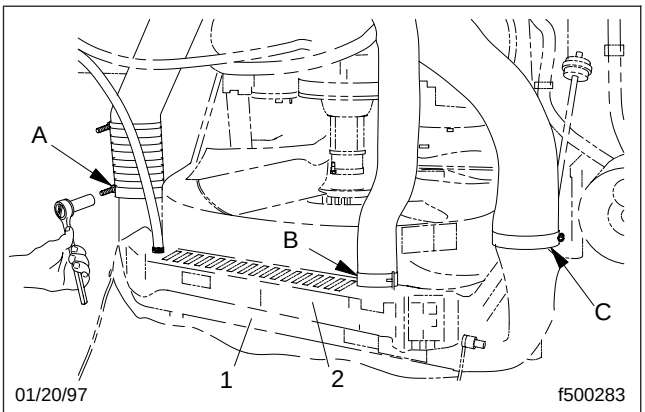


1. Charge Air Cooler 2. Hood Cable Bracket

Fig. 1, Hood Cable Bracket Removal/Installation

Installation

1. Install the charge air cooler (CAC).
   - 1.1 Position the CAC on the radiator, and secure it with the four mounting bolts. See **Fig. 3**. Tighten the bolts 15 lbf·ft (20 N·m).
   - 1.2 Connect the hoses to the CAC. See **Fig. 2**. Tighten the hoses 60 lbf·in (680 N·cm).

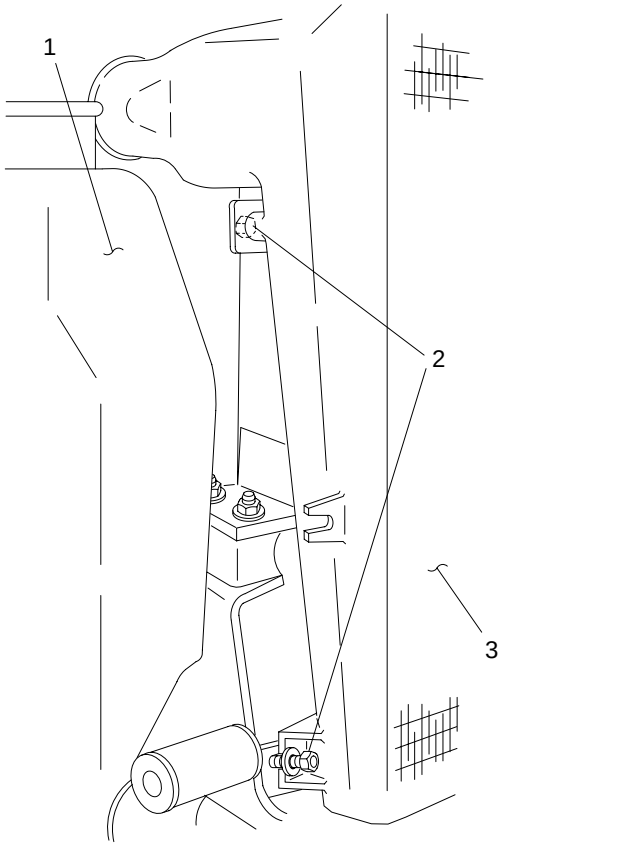


A. Remove the CAC outlet hose.
B. Radiator Hoses (leave attached)
C. Remove the CAC inlet hose.
1. Charge Air Cooler 2. Radiator

Fig. 2, CAC and Radiator Hose Connections (overhead view)

   - 1.3 Install the hood cable brackets on the radiator. See **Fig. 1**. Tighten the bracket bolts 48 lbf·in (540 N·cm).
2. Install the hood; for instructions, see **Group 88**.
3. Remove the chocks from the tires.

Charge Air Cooler Removal and Installation



1. Air Cleaner
2. Right-Side Mounting Bolts
3. Charge Air Cooler

Fig. 3, CAC Mounting

Charge Air Cooler Inspection and Leakage Test

Inspection

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Check the charge air cooler (CAC) convoluted hoses and the inlet and outlet piping for holes or other damage. Also, check for loose or damaged constant-torque hose clamps. Replace damaged parts. If hose clamps are loose, turn them so their tightening screws are under the hoses or facing inboard; then tighten the screws 45 lbf·in (500 N·cm).
3. Check the CAC core fins. If the fins are bent, use a small pair of needle-nose 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 below represents a loss of less than 0.1 percent of charge airflow. See **Table 1**. Based on this rate, there should be no measurable loss of performance.

Engine	Pressure Drop in 15 Seconds	Start Pressure (psig)
Caterpillar	5 psi	30
Cummins	7 psi	30

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 directly from Kent-Moore/SPX at 1.800.328.6657.

CAC CORE LEAKAGE TEST

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Connect the test equipment to the CAC core. See **Fig. 1**.
   - 2.1 Remove the inlet and outlet air piping from the convoluted hoses that attach them to the CAC air inlet and air outlet.
   - 2.2 Slip a safety ring with thumbscrew over each convoluted hose, and onto the CAC air inlet and air outlet, then turn the rings so the thumbscrews are facing outboard and the safety chains are inboard. Tighten the thumbscrews securely.
   - 2.3 Install an additional constant-torque hose clamp on each convoluted hose.
   - 2.4 Install the test plug without an adapter in the CAC air inlet, and turn the plug so the safety chain is inboard. Tighten both of the rearmost constant-torque hose clamps 72 lbf·in (820 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 hose clamps 72 lbf·in (820 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.

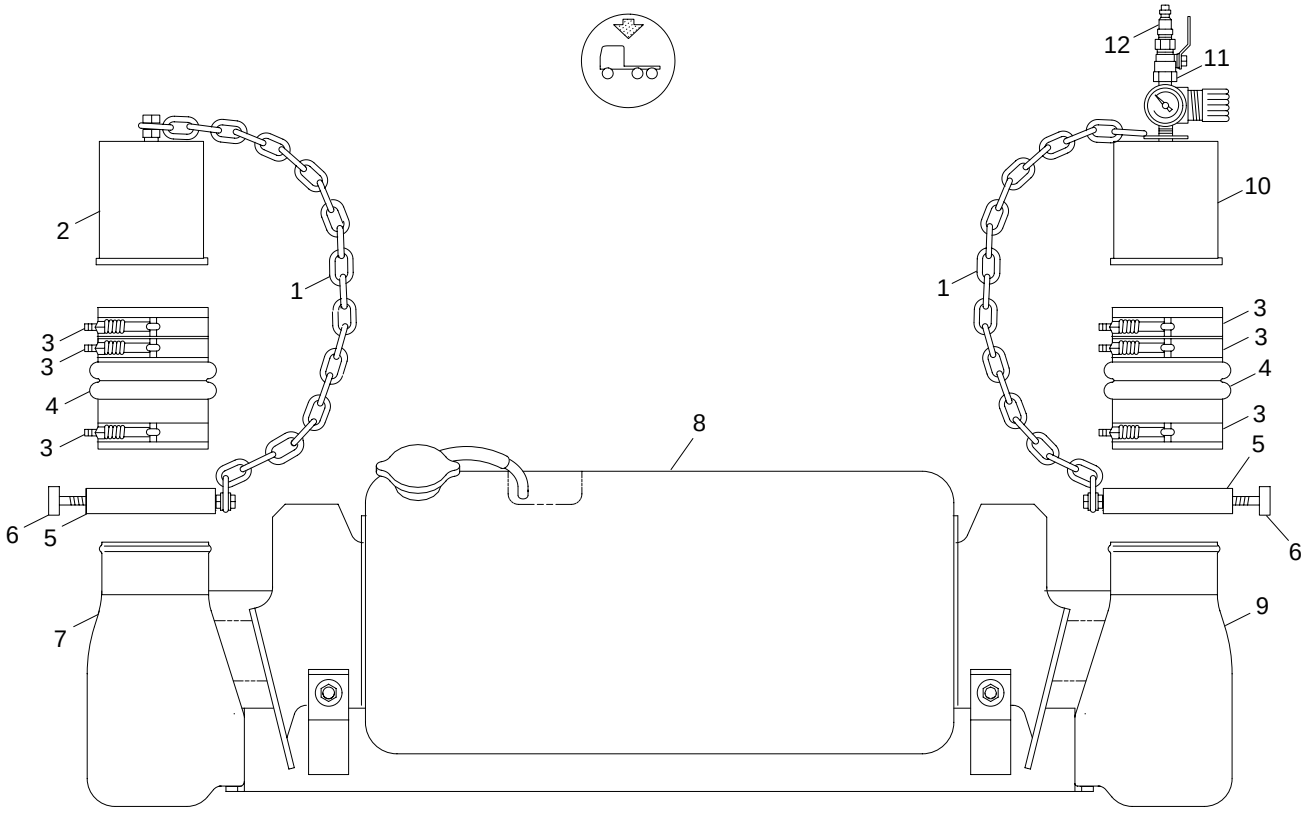
   - 2.6 If not already installed, install a test valve/gauge assembly and air chuck in the test plug with adapter.
   - 2.7 Attach a pressurized air line to the air chuck on the pressure regulator valve.
3. Test the CAC core.

WARNING

Do not stand in front of the test plugs while the core is pressurized. A plug could suddenly release debris flying at high speed, possibly resulting in eye injury or other serious personal injury.

   - 3.1 Open the shutoff 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 Hose Clamp
4. Convoluted Hose
5. Safety Ring
6. Thumbscrew
7. CAC Air Inlet
8. Radiator Surge Tank
9. CAC Air Outlet
10. Test Plug with Adapter
11. Test Valve/Gauge Assembly
12. Air Chuck

Fig. 1, CAC Core Testing (typical installation shown)

3.2 Close the shutoff 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. See **Table 1**.

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 hose clamps) from the convoluted hoses.

5. Pull the convoluted hoses and constant-torque hose clamps rearward until the hoses cover about 1-1/2 inches (38 mm) of the CAC air inlet and air outlet piping.

NOTE: The convoluted hoses must cover the CAC air inlet and air outlet piping about 1-1/2 inches (38 mm) at each connection.

6. Turn the clamps so their tightening screws are under the hoses or facing inboard; then tighten the screws 45 lbf·in (500 N·cm).

7. Lower the hood and 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-hand 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.

Specifications

Description	Grade	Size	Torque	
			lbf·ft (N·m)	lbf·in (N·cm)
Charge Air Cooler to Radiator Mounting Bolt	5	5/16"	15 (20)	—
Hood Cable Bracket Bolts	8.8	10 mm	—	48 (540)
Charge Air Cooler Constant-Torque Hose Clamps	5	6.3 mm	—	60 (680)
Air Recirculation Shield Bolt	5	5/16"	15 (20)	—

Table 1, Fastener Torques

General Information

The air cleaner is vertically mounted on the outside of the right frame rail, directly behind the bumper. Air enters through the grill and is diverted into the air cleaner housing where it passes from the outside to the inside of a replaceable, moisture-resistant, fine-mesh paper filter element. Filtered air exits the air cleaner through an outlet port at the top of the housing.

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.

A lock-up air restriction indicator is mounted on the underside of the air intake pipe. The indicator shows when the air filter element needs to be replaced. As an optional location, the air restriction indicator can be mounted in the dashboard. Nylon tubing connects the remote-mounted indicator or gauge to the air intake piping.

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.

Element Replacement

NOTE: Replace the air cleaner element only when it reaches the maximum restriction level allowed by the engine manufacturer; see **Subject 120**.

NOTICE

Do not operate the engine with the air filter element or any intake component removed—damage to the engine could occur.

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Check the seams around the air cleaner inlet and outlet ports. See **Fig. 1**. Check the outer surface of the cleaner housing for cracks, dents, or damage. If there are signs of leaks or damage, repair or replace the parts.

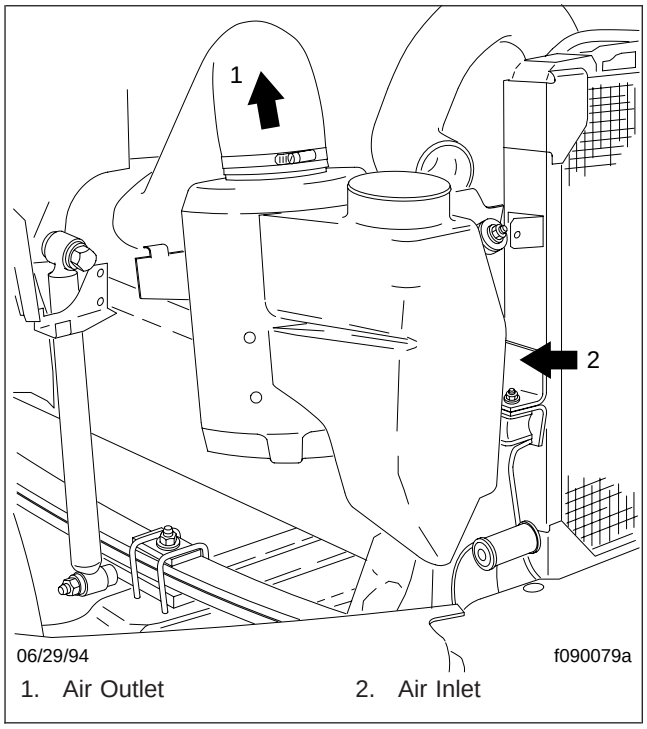


Fig. 1, Air Cleaner Housing Ports

4. Remove the two thumbscrews from the bottom of the housing. See **Fig. 2**. Remove the cover.

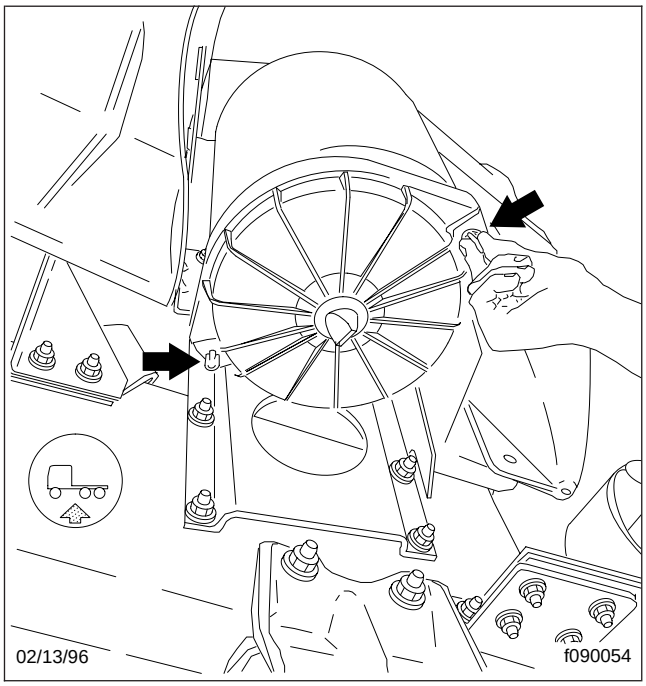


Fig. 2, Air Cleaner Housing Thumbscrews

5. Grip the base of the filter element firmly. See **Fig. 3**. Gently twist and pull the filter element down and out of the housing.
6. Inspect the element and clean the housing.
   - 6.1 Check the filter element for soot or oil. If soot is present, check for leaks in the engine exhaust system, and for exhaust from other equipment. If the element is oily, check for fumes escaping from the engine crankcase breather. Excessive oil mist shortens the life of any dry-type filter; correct the cause.
   - 6.2 Inspect the filter element radial seal surface for dust trails (from gasket leakage). See **Fig. 4**. Check the cleaner housing for damage or dirt build-up that may cause sealing problems. If there is leakage or damage, repair or replace the parts.
   - 6.3 Wipe the inside of the cleaner housing with a clean damp cloth.

Air Cleaner Element Replacement

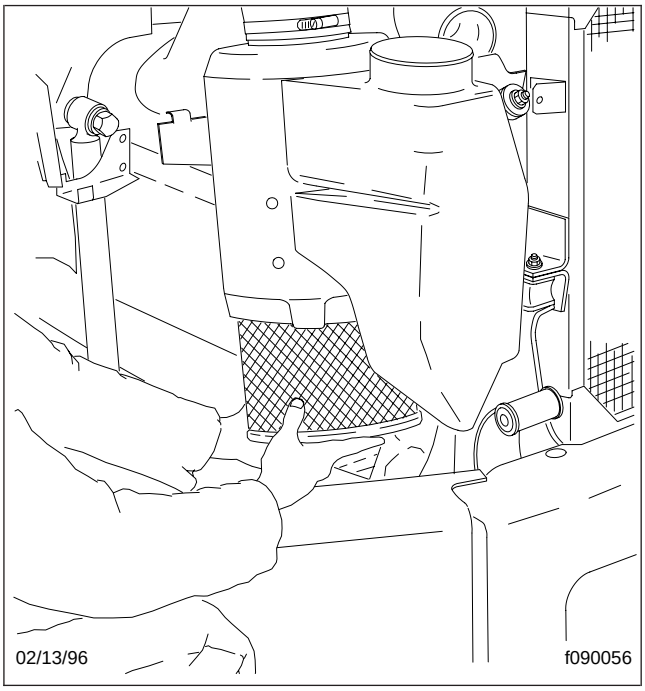


Fig. 3, Filter Element Removal/Installation

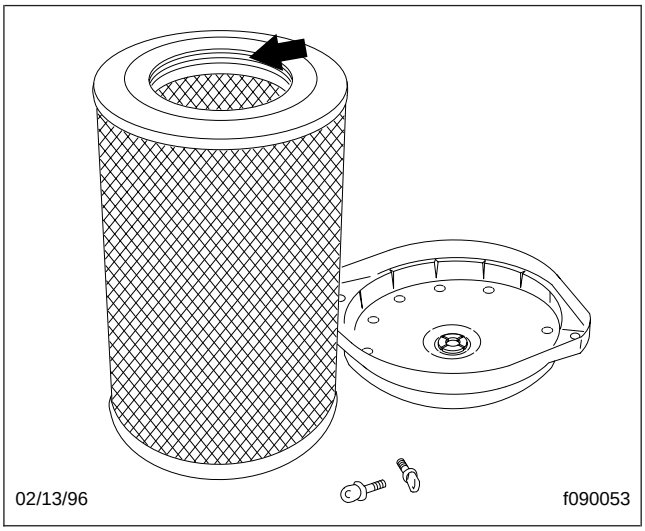


Fig. 4, Radial Seal Surface of Filter Element

NOTICE

Any dirt in the cleaner housing, on the clean side of the element gaskets, could be drawn into the engine, causing damage.

7. Inspect the new filter element before installing it. See **Fig. 4**.
   - 7.1 Inspect the element for radial seal surface damage and dented metal parts. If the radial seal surface is damaged to the extent that dust might bypass it, do not use the element.
   - 7.2 Place a bright light inside the element, and rotate the element while looking through it from the outside. The light will reveal, by a bright spot, any hole or rupture. Any hole in the element will allow dust to enter the engine; do not use the element if it is damaged.
8. Position the filter element in the air cleaner housing. See **Fig. 3**. Push the element up into place until only about 2.5 cm (1 inch) still extends below the bottom of the housing.
9. Place the cover over the bottom of the element, and secure the cover with the two thumbscrews.
10. Check all clamps for tightness, and all ducting and hoses for leaks; repair as necessary.
11. Lower the hood, and remove the chocks from the tires.

Replacement

NOTICE

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 during engine combustion. These particles can grind piston rings, pistons, and cylinder liners. Do not operate the engine with the air filter element or any air intake component removed.

IMPORTANT: Do not modify air cleaners or air intake ducting.

If the air cleaner housing has been dented or damaged, immediately check all ducting and connections to the air cleaner for leakage. Adjust or replace parts as necessary. If needed, replace the air cleaner as follows:

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Remove the air cleaner.
   - 3.1 Remove the two thumbscrews securing the housing cover, and remove the cover. See **Fig. 1.**
   - 3.2 Remove the filter element from the housing; see **Subject 100**.
   - 3.3 Loosen the hose clamp connecting the air intake pipe to the elbow at the top of the air cleaner housing. See **Fig. 2**. Remove the pipe from the elbow, and cover the open end of the pipe.
   - 3.4 Loosen the hose clamp connecting the elbow to the air cleaner housing.
   - 3.5 Remove the elbow from the top of the housing.
   - 3.6 Remove the four nuts that secure the housing to its mounting bracket. See **Fig. 3**.
   - 3.7 Take the air cleaner off its mounting bracket.
4. Install the new air cleaner.

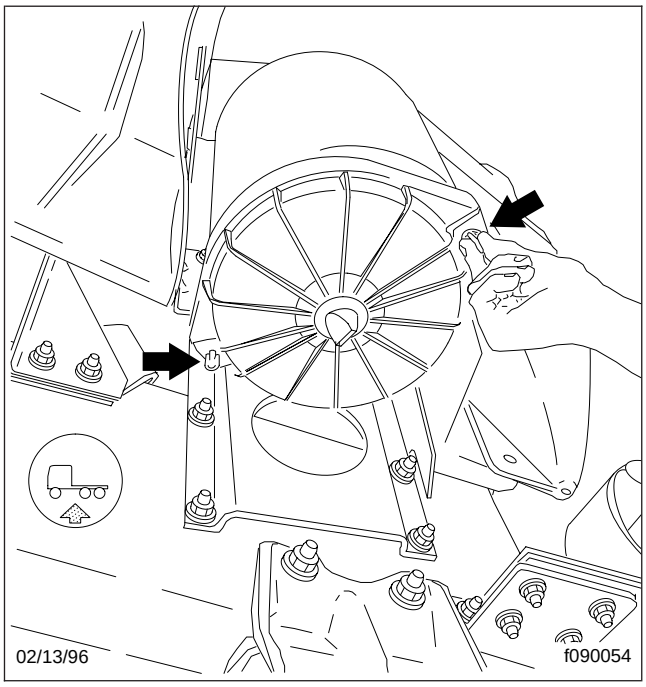
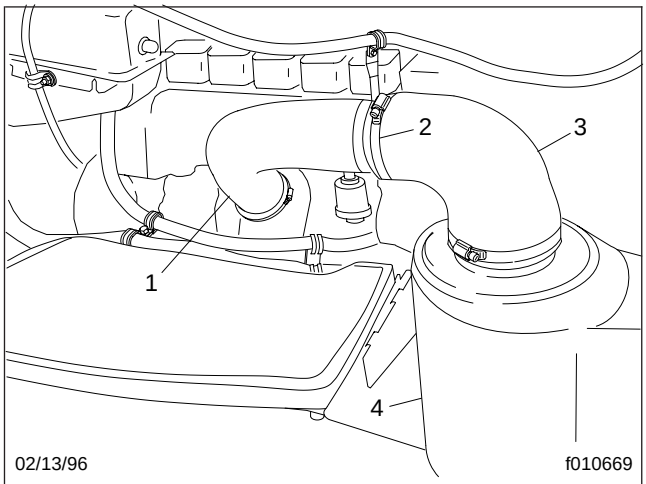


Fig. 1, Air Cleaner Housing Thumbscrews

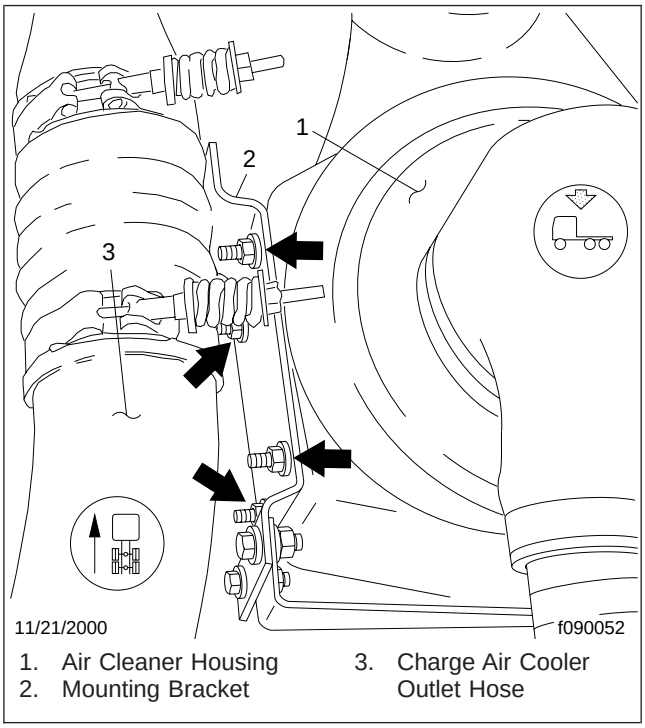


1. Air Intake Pipe
2. Hose Clamp
3. Elbow
4. Air Cleaner Housing

Fig. 2, Elbow to Intake Pipe Connection

- 4.1 Position the air cleaner housing on its mounting bracket. Secure the housing with the four nuts, and tighten them 28 lbf·ft (38 N·m).

Air Cleaner Replacement



1. Air Cleaner Housing
2. Mounting Bracket
3. Charge Air Cooler Outlet Hose

Fig. 3, Air Cleaner Housing Mounting Fasteners

4.2 Connect the elbow to the top of the new housing. Tighten the hose clamp.

4.3 Uncover the air intake pipe, and connect it to the elbow. Tighten the hose clamp.

4.4 Check all clamps for tightness, and all ducting and hoses for leaks; repair as necessary.

NOTICE

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

5. Inspect a new filter element and install it in the new air cleaner; see **Subject 100**.

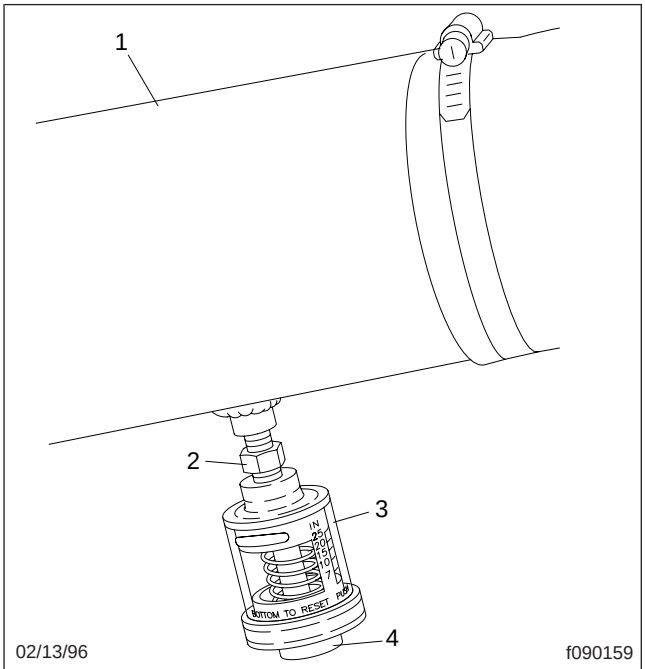
Element Restriction Checking

The restriction of air flow through the air cleaner element is measured at the tap in the air transfer tube joined to the cleaner outlet.

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.

On vehicles with an intake-duct-mounted restriction indicator (manual- or automatic-reset), the indicator is mounted in a safety fitting in the air intake piping. See **Fig. 1**.



1. Air Intake Piping
2. Safety Fitting
3. Air Restriction Indicator
4. Reset Button

Fig. 1, Standard Intake-Duct-Mounted Manual-Reset Air Restriction Indicator

On vehicles with a dash-mounted restriction indicator (manual-reset) or air restriction gauge (automatic-reset), a hose connects the indicator or gauge to the safety fitting in the air intake piping. See **Fig. 2** and **Fig. 3**.

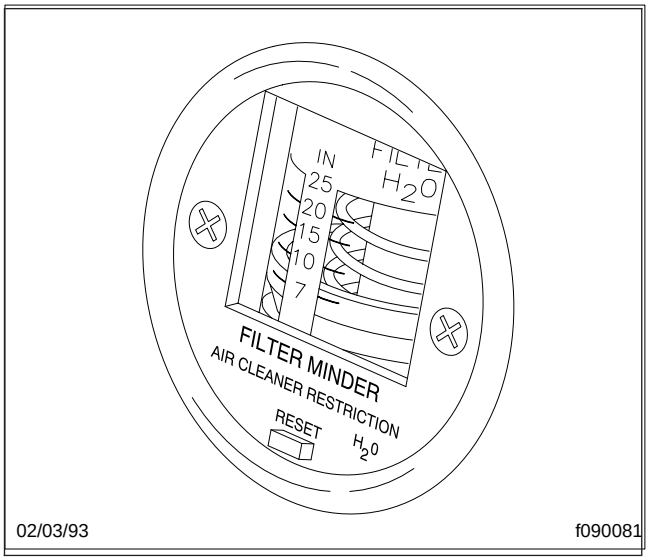


Fig. 2, Optional Dash-Mounted Manual-Reset Air Restriction Indicator

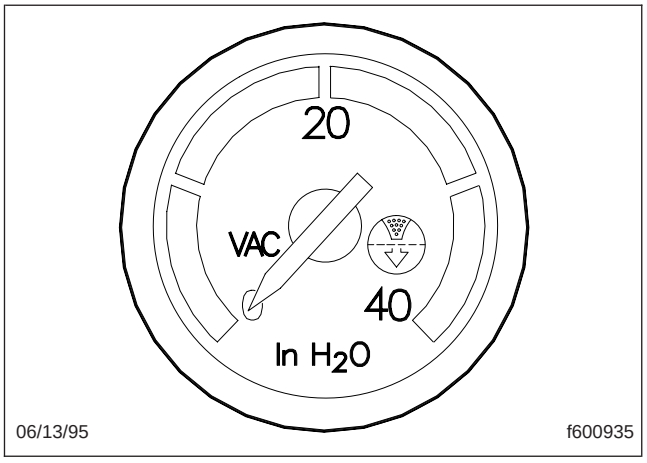


Fig. 3, Optional Dash-Mounted Automatic-Reset Air Restriction Gauge

On vehicles *without* an indicator or gauge, a water manometer or a service gauge must be connected to the air intake ducting to check element restriction.

- For a vehicle with a manual-reset air restriction indicator, check the indicator with the engine off to see if air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction at *full load* and governed rpm. If air

Air Cleaner Element Restriction Checking

restriction is at or above the maximum, push the reset button on the dash-mounted or intake-duct-mounted indicator, then operate the engine at *no-load* and governed rpm, and compare the indicator reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.

- For a vehicle with an air restriction gauge, or a restriction indicator that resets automatically when the engine is shut down, operate the engine at *no-load* and governed rpm, and compare the gauge/indicator reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.
- For a vehicle without a gauge or indicator, test restriction with a water manometer or a service gauge. Refer to the test equipment manufacturer's literature for test procedures. Operate the engine at *no-load* and governed rpm, and compare the reading with the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm.

If air restriction equals or exceeds the value shown in **Table 1** for maximum air restriction at *no-load* and governed rpm, replace the air cleaner element; see **Subject 100**.

Maximum Air Restriction in Inches of Water (inH $_2$O)		
Engine	**At Full Load and Governed RPM**	**At No-Load and Governed RPM**
Cummins	25	12
Caterpillar	25	12

Table 1, Maximum Air Restriction in Inches of Water (inH $_2$O)

Specifications

Fastener Torques			
Description	**Grade**	**Size**	**Torque lbf·ft (N·m)**
Air Cleaner Mounting Nuts	5	3/8–16	28 (38)

Table 1, Fastener Torques

General Description

The Tu-Flo 550 is a two cylinder, single-stage, reciprocating air compressor, which supplies compressed air to the vehicle air system. The Tu-Flo 550 has a rated displacement of 13.2 cfm (374 L/min) of air at 1250 rpm.

The compressor draws air from the air intake pipe, compresses the air, and delivers it to the air system supply reservoir. The compressor runs continuously but has "loaded" and "unloaded" modes, which are regulated by the air governor and the compressor loading assembly. When the governor sends an air signal to the unloader assembly, the unloader assembly holds the compressor air intake valve open so that no more compressed air is forced into the air system. As air in the system is used, its pressure drops, and at a nominal 105 psi (724 kPa), the air governor exhausts the signal to the compressor. Without the signal, the unloader assembly automatically closes the compressor air intake valve to force more air into the system.

On vehicles with air dryers, when the system reaches the nominal cut-out pressure of 125 psi (862 kPa), the air governor also sends an air signal to open the purge valve in the air dryer.

Removal

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Drain the air system.

⚠ WARNING

WARNING: Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

3. Using a cleaning solvent, remove road dirt and grease from the outside of the compressor, then dry the compressor with compressed air.
4. Drain the radiator coolant; refer to **Group 20** in the vehicle workshop manual for instructions.
5. Marking their locations and positions, disconnect all air, coolant, and oil lines attached to the compressor. Remove tie straps as needed to move the lines out of the way.
6. Remove the air governor, and the governor mounting gasket.
7. On Cummins engines, disconnect the wire to the fuel shutoff valve (if so equipped). Remove the fuel pump and gasket; refer to the engine shop manual or rebuild manual for instructions.
8. Remove the power steering pump. For instructions, refer to **Group 46** in this manual.
9. Remove the compressor support bracket, if so equipped.
10. Support the compressor, and remove the bolts that attach it to the auxiliary drive housing, accessory drive, or timing gear plate. Remove the compressor, gasket, and splined coupling, if so equipped.
11. Discard all mounting gaskets.

Installation

IMPORTANT: Be sure the gasket surfaces are cleaned and not damaged.

1. Install the splined coupling (if so equipped) and a new compressor gasket. Hold the compressor in place, and install the bolts that attach it to the auxiliary drive housing, accessory drive, or timing gear plate. Refer to the engine shop manual or rebuild manual for final torque specification.
2. Install the compressor support bracket, if so equipped.
3. Install the power steering pump. For instructions, refer to **Group 46** in this manual.
4. On Cummins engines, install a new gasket, install the fuel pump. Connect the wire to the fuel shutoff valve (if so equipped). Refer to the engine shop manual or rebuild manual for instructions.
5. With a new air governor mounting gasket, install the air governor.
6. Identify and connect all air, coolant, and oil lines to the compressor. Secure the lines as needed with tie straps.
7. Fill the engine cooling system; refer to **Group 20** in the vehicle workshop manual for instructions.
8. Operate the engine and check for leaks.
9. Remove the chocks from the tires and return the hood to the operating position.

Removal

1. Chock the tires; then drain the air from all air reservoirs.

⚠ WARNING

WARNING: Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

2. Using a cleaning solvent, remove road dirt and grease from the outside of the compressor, then dry the compressor with compressed air.
3. Drain the radiator coolant; refer to **Group 20** in the vehicle workshop manual for instructions.
4. Remove the cylinder head from the crankcase. See **Fig. 1**.

   4.1 Scribe an alignment mark across the cylinder head and the crankcase, for assembly alignment.

   IMPORTANT: Do not use a marking method, such as chalk, that can be wiped off during assembling.

   4.2 Note positions of any attached components, then remove the cylinder head capscrews.

   4.3 Tap the cylinder head with a soft mallet to break the gasket seal. Remove the cylinder head.

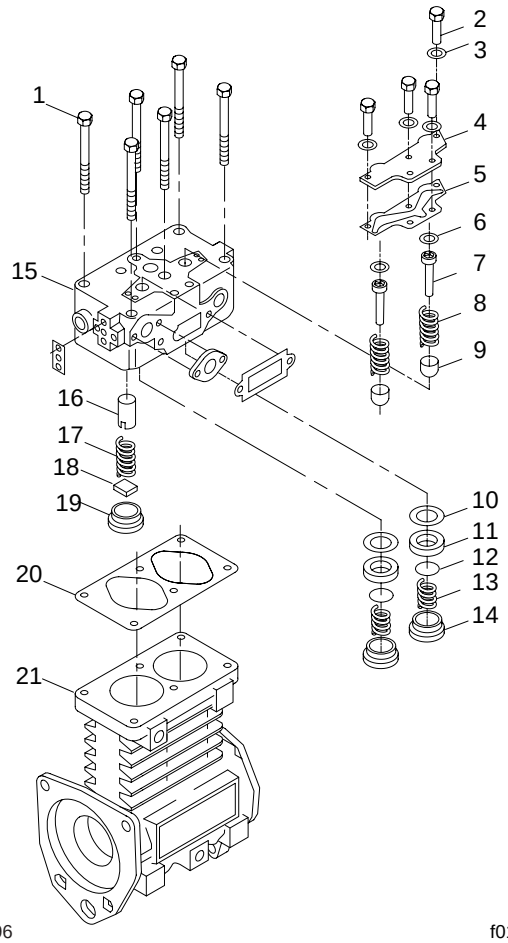
Installation

1. Scrape off any gasket material from the cylinder head and the crankcase.

⚠ WARNING

WARNING: Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

2. Using compressed air, blow dirt particles or gasket material from all cylinder cavities.
3. Install the cylinder head on the compressor crankcase.



01/15/96 f010594

1. Cylinder Head Capscrew
2. Unloader Plate Capscrew
3. Unloader Plate Lockwasher
4. Unloader Plate
5. Unloader Plate Gasket
6. O-Ring
7. Unloader Piston
8. Spring
9. Unloader Bushing
10. Gasket
11. Inlet Valve Seat
12. Inlet Valve
13. Inlet Valve Spring
14. Inlet Valve Stop
15. Cylinder Head
16. Discharge Valve Stop
17. Discharge Valve Spring
18. Discharge Valve
19. Discharge Valve Seat
20. Cylinder Head Gasket
21. Crankcase

Fig. 1, Cylinder Head, Exploded View

3.1 Place a new cylinder head gasket on the crankcase. If the cylinder head gasket has a bead on one side, install the gasket with the bead side up.

Cylinder Head Removal and Installation

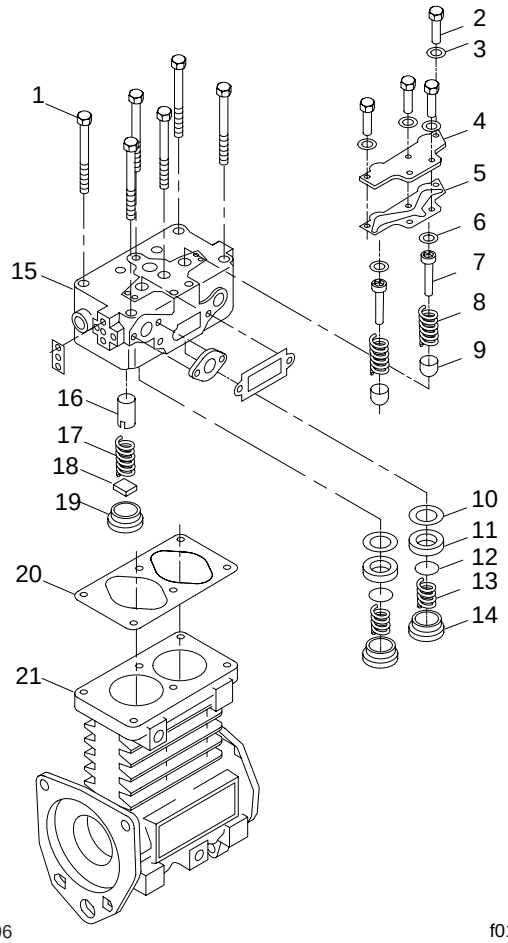
3.2 Using the previously marked alignment, position the cylinder head on the crankcase.

3.3 Position on the cylinder head any brackets, spacers, or clamps that were removed; then install the cylinder head capscrews and tighten them evenly, in a cross pattern 37 to 42 lbf·ft (50 to 57 N·m).

4. Connect the air discharge line and the water lines to the cylinder head.
5. Fill the engine cooling system; refer to **Group 20** in the vehicle workshop manual.
6. Operate the engine and make sure there are no coolant leaks.

Cylinder Head Disassembly, Cleaning and Inspection, and Assembly

Disassembly



01/15/96 f010594

1. Cylinder Head Capscrew
2. Unloader Plate Capscrew
3. Unloader Plate Lockwasher
4. Unloader Plate
5. Unloader Plate Gasket
6. O-Ring
7. Unloader Piston
8. Spring
9. Unloader Bushing
10. Gasket
11. Inlet Valve Seat
12. Inlet Valve
13. Inlet Valve Spring
14. Inlet Valve Stop
15. Cylinder Head
16. Discharge Valve Stop
17. Discharge Valve Spring
18. Discharge Valve
19. Discharge Valve Seat
20. Cylinder Head Gasket
21. Crankcase

Fig. 1, Cylinder Head, Exploded View

1. Remove the compressor from the vehicle. For instructions, refer to **Subject 100**.
2. Place the compressor on a suitable work surface. Remove the cylinder head from the crankcase. See **Fig. 1**. For instructions, refer to **Subject 110**.
3. Remove the unloader mechanism.
   - 3.1 Remove the unloader plate capscrews, lockwashers, and the unloader plate. Scrape off any gasket material from the unloader plate and the cylinder head.
   - 3.2 Remove and discard the unloader pistons, O-rings, and springs.
4. Check the unloader piston bushings. If damaged or worn excessively, replace the compressor.

NOTE: Before disassembling the discharge valve mechanism, measure and record the discharge valve travel from closed to completely open. If the measurement exceeds 0.046 inch (1.17 mm), replace the compressor. If the measurement is within 0.046 inch, proceed to the next step.

5. Using a 9/16-inch Allen wrench, remove and discard the discharge valve seats, discharge valves, and discharge valve springs.
6. Remove and discard the inlet valve stops and springs, along with the inlet valves, inlet valve seats, and gaskets.

Cleaning and Inspection

1. Remove carbon deposits from the discharge cavity, rust and scale from the cooling cavities.
2. Clean carbon and dirt from the inlet and unloader passages.
3. Scrape all foreign material from the body surfaces.

⚠ WARNING

WARNING: Wear goggles when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

4. Using solvent, thoroughly clean all metal parts removed from the cylinder head. Using shop air, blow the dirt particles from the cavities and passages.

Cylinder Head Disassembly, Cleaning and Inspection, and Assembly

5. Check that all cavities and passages are clear, including the inlet and unloader.
6. Check that all mating surfaces are clean of old gasket material. Remove any old material.
7. Inspect the cylinder head for cracks or damage.
8. With the cylinder head and head gasket secured to a flat surface or to the crankcase, apply shop air pressure to one of the coolant ports with all other ports plugged.
9. Check for leaks by applying a soap solution to the exterior of the body. If leakage is detected, replace the compressor.

Assembly

1. Install the unloader mechanism. See **Fig. 1**.
   - 1.1 With the unloader pistons being prelubricated from the manufacturer, install the new unloader springs, and the new unloader pistons. The unloader piston O-rings are pre-installed on the unloader pistons.
   - 1.2 Install the new unloader plate gasket and the unloader plate.
   - 1.3 Install the unloader plate lockwashers and capscrews. Tighten the capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.
2. Install the inlet valve mechanism.
   - 2.1 Install the new inlet valve gaskets, new inlet valve seats, new inlet valves, and the new inlet valve springs into their bores.
   - 2.2 Install the new inlet valve stops and tighten 70 to 90 lbf·ft (95 to 122 N·m).
3. Install the new discharge valve springs, new discharge valves, and the new discharge valve seats into their bores. Tighten the seats 70 to 90 lbf·ft (95 to 122 N·m). The discharge valve travel should be 0.030 inches to 0.046 inch (0.762 mm to 1.17 mm).
4. Test for leakage at the discharge valves by applying 100 psi (690 kPa) through the cylinder head discharge port and apply soap solution to the discharge valve and seat. Leakage in the form of soap bubbles is permissible.

   If there's extreme leakage, leave the air pressure applied and with a hardwood dowel and a hammer, tap the discharge valves off of their seats several times. This will improve the seal between the discharge valve and the valve seat and should reduce leakage.

   If there's still extreme leakage, replace the discharge valve seats.

   With the air pressure still applied at the discharge port of the cylinder head, check for leakage around the discharge valve stop on top of the cylinder head. No leakage is permitted.
5. Install the compressor cylinder head. For instructions, refer to **Subject 110**.
6. Tighten the unloader plate capscrews 15 to 18 lbf·ft (20 to 25 N·m).
7. Install the compressor on the engine. For instructions, refer to **Subject 100**.

Crankcase Disassembly, Cleaning and Inspection, and Assembly

Disassembly

1. Remove the compressor from the vehicle and place it on a suitable work surface. For instructions, see **Subject 100**.
2. Remove the air compressor cylinder head. For instructions, see **Subject 110**.
3. Before disassembling the compressor, use a metal scribe to mark the parts with matching numbers or lines.

IMPORTANT: Do not use a marking method, such as chalk, that can be wiped off during assembling.

4. Remove the pistons and connecting rods. See **Fig. 1**.
   - 4.1 Remove the base plate capscrews.
   - 4.2 Tap the base plate with a soft mallet to break the gasket seal.
   - 4.3 Scrape off any gasket material from the crankcase and base plate.
   - 4.4 Remove the connecting rod bolts and connecting rod caps.
   - 4.5 Push the pistons and connecting rods out through the cylinder bore of the crankcase. Discard the pistons and connecting rod assemblies including the connecting rod caps and the connecting rod bolts.
5. Remove the crankshaft.
   - 5.1 Remove the key or keys from the crankshaft and any burrs from the crankshaft where the key or keys were removed.

   NOTE: Some compressors may have a crankshaft key at each end.

   - 5.2 Remove the end-cover capscrews, the end cover, end-cover seal, and the rear thrustwasher.
   - 5.3 If the compressor has sleeve bearings, remove and discard the sleeve bearings from the crankcase and the end cover.
   - 5.4 If the compressor has a ball-type main bearing, remove the rear snap ring (if so equipped). Press the crankshaft and ball bearing from the crankcase; then press the ball bearing from the crankshaft.
   - 5.5 Remove and discard the front and rear thrustwashers.

Cleaning and Inspection

1. Scrape off any gasket material from the top and bottom of the crankcase.

⚠ WARNING

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

2. Clean all parts with solvent, before inspecting them, and dry the parts with compressed air.
3. Clean all oil passages through the crankshaft, crankcase, end cover, and base plate. Inspect the passages with a wire to be sure they are clear.
4. Check the fit of the new pistons, piston rings, and connecting rods.
   - 4.1 To check the ring gap, place the ring in the top of the cylinder bore and, using a piston, push the ring to mid-point of the cylinder bore and check the ring gap. The gap for compression rings must be 0.002 to 0.013 inch (0.051 to 0.176 mm).

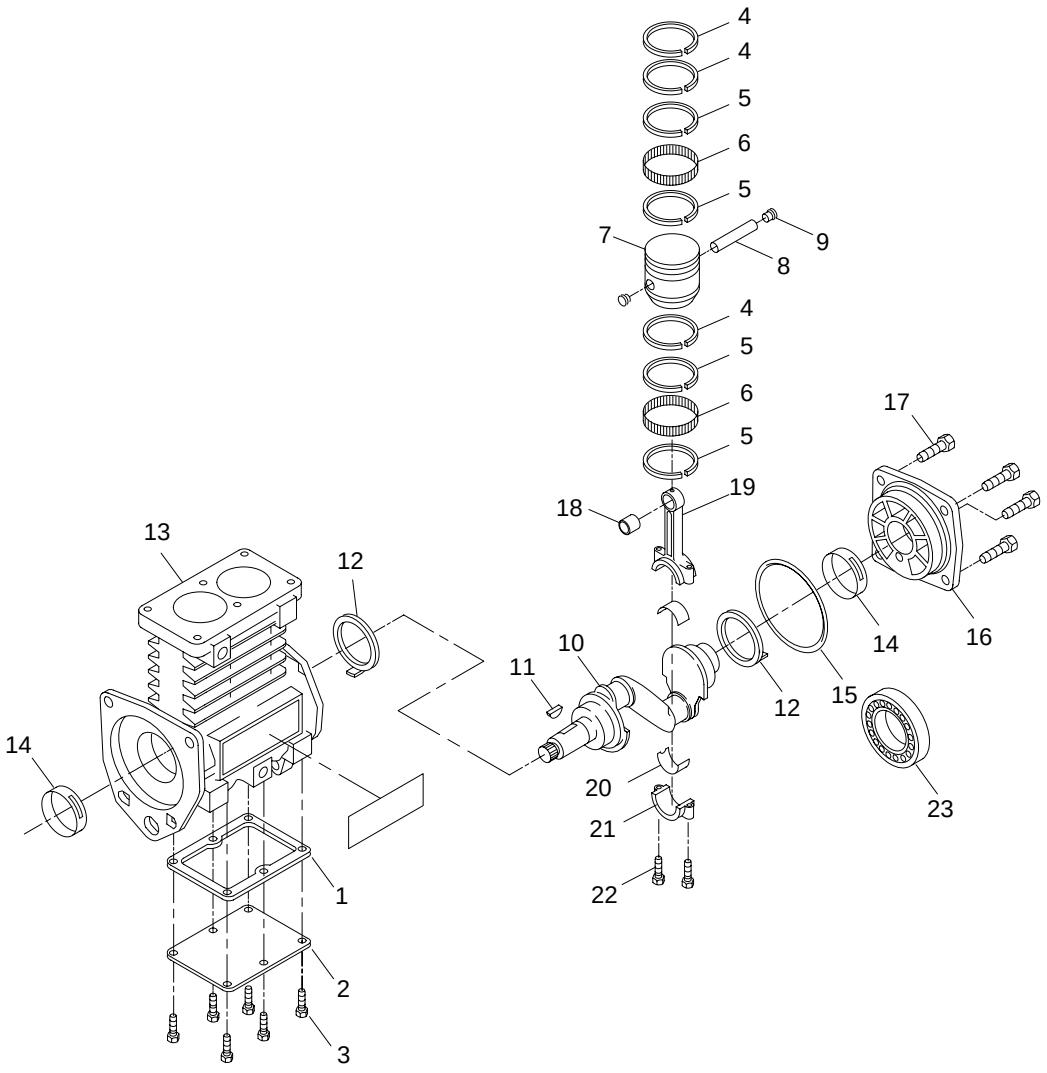
     The gap for oil ring and expander ring must be 0.010 to 0.040 inch (0.255 to 1.016 mm). See **Fig. 2**, and **Table 1**.

Ring	End Gap in inch (mm)
Compression	0.002–0.013 (0.051–0.176)
Oil and Expander	0.010–0.040 (0.255–1.016)

Table 1, Ring End Gap

   - 4.2 Check the fit of the piston rings in the piston ring grooves. Groove clearance for the compression ring is 0.002 to 0.004 inch (0.051 to 0.10 mm). Groove clearance for the expander and oil rings is 0.000 to 0.006 inch (0.000 to 0.152 mm).
5. Inspect the crankcase.

Crankcase Disassembly, Cleaning and Inspection, and Assembly



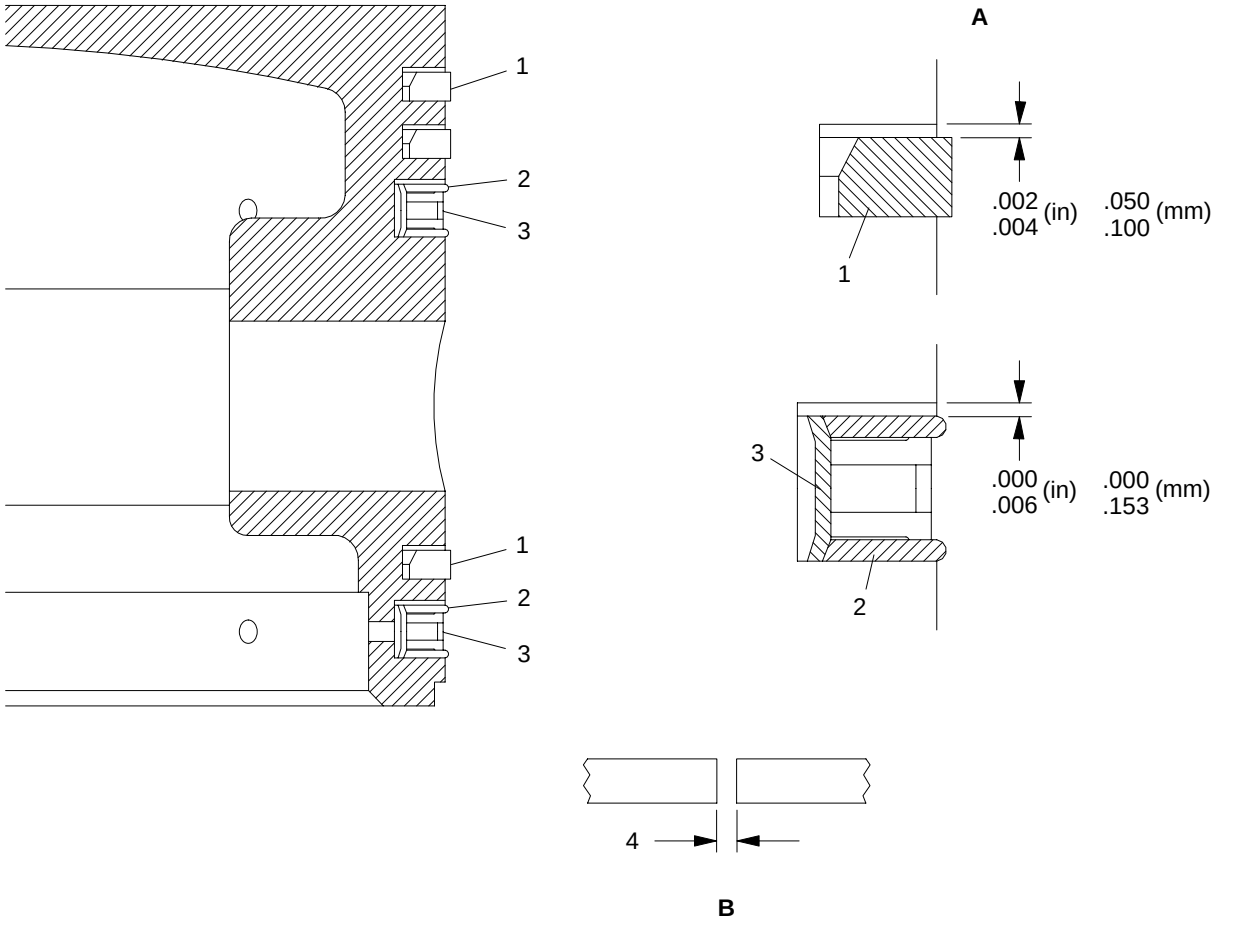
01/15/96 f010595

1. Base Gasket
2. Base Plate
3. Base Plate Capscrew
4. Compression Ring
5. Oil Ring
6. Expander Ring
7. Piston
8. Wrist Pin
9. Wrist Pin Button
10. Crankshaft
11. Crankshaft Key
12. Thrust Washer
13. Crankcase
14. Sleeve Bearing
15. End Cover Seal
16. End Cover
17. End Cover Capscrew
18. Wrist Pin Bushing
19. Connecting Rod
20. Connecting Rod Bearing (Sets)
21. Connecting Rod Cap
22. Connecting Rod Bolt
23. Ball Bearing

Fig. 1, Crankcase, Exploded View

5.1 Check the crankcase surfaces for cracks and damage.

5.2 On compressors where main ball bearings are used, measure the difference between the outside diameter of the ball bearing outer race and the inside diameter of the crankcase bore should be 0.0003 inch (0.008 mm) tight to 0.0023 inch (0.058



A. Side Clearance
1. Compression Ring
2. Oil Ring
B. Ring End Gap With Ring In The Cylinder Bore
3. Expander Ring
4. End Gap

Fig. 2, Piston Specifications

mm) loose. This is to maintain a correct fit. Replace the compressor if the fit is too loose.

5.3 Check the end cover for cracks and damage; replace them as necessary.

5.4 Check the cylinder bore with an inside micrometer or with calipers. Cylinder bores which are scored, out-of-round, or tapered more than 0.0005 inch (0.013 mm) should be rebored and honed oversize. Oversized pistons and piston rings are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm) oversize.

6. Inspect the crankshaft.

6.1 Check the crankshaft splines, gear teeth, tapered ends, and all machined and ground surfaces for wear, scoring, or damage. Repair the damage, or replace the crankshaft if needed.

6.2 Check the crankshaft connecting rod journals for extreme scoring, and measure them for out-of-round wear. Standard

Crankcase Disassembly, Cleaning and Inspection, and Assembly

crankshaft journals are 1.1242 to 1.1250 inches (28.555 to 28.575 mm) in diameter. If the crankshaft is extremely scored or worn out-of-round, and cannot be reground, replace it.

NOTE: If the crankshaft needs to be reground or replaced, do so before proceeding to the next step. For compressors having reground crankshafts, connecting rod bearing inserts are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm) undersize.

Assembly

1. For compressor with sleeve bearings, install the crankshaft and end cover. See **Fig. 1**.
   - 1.1 Press the new sleeve bearings into the end cover and crankcase. Make sure the slot in the bearings line up with the oil passages in the end cover and crankcase.

     If there is no oil passage present in the crankcase, press the sleeve bearing into the crankcase with the slot located 90 degrees from vertical.
   - 1.2 Install the new front thrustwasher with the tang inserted in the slot toward the flange.
   - 1.3 Insert the crankshaft and the rear thrustwasher with the tang toward the end cover of the compressor.
   - 1.4 Place the end-cover seal on the boss of the end cover.
   - 1.5 Install the end cover making sure not to pinch the end cover seal and the tang of the rear thrustwasher is inserted in the slot of the end cover. Install the capscrews and tighten the capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.
2. If one end of the compressor uses a ball-type main bearing, install the crankshaft and endcovers.
   - 2.1 Press the new sleeve bearings into the crankcase. Make sure the slots in the bearings line up with the oil passage in the end cover and crankcase.

     If there is no oil passage present in the crankcase, press the sleeve bearing into the crankcase with the slot located 90 degrees from vertical.
   - 2.2 Install the new front thrustwasher with the tang inserted in the slot toward the flange.
   - 2.3 Press the ball bearing onto the correct end of the crankshaft, so that the drive end of the crankshaft will be positioned in the crankcase as marked before disassembly. Using an arbor press, carefully press the ball bearing and the crankshaft into the crankcase. Install the retainer ring if so equipped.
3. Assemble the new piston rings on the new pistons.

   IMPORTANT: To properly test a compressor under operating conditions, a test rack is necessary for correct mounting, cooling, lubricating, and driving the compressor.

   NOTE: Install the piston rings on the pistons starting at the center of the piston and moving outward. Rotate the piston rings in their respective grooves so that the end gap is at least 90 degrees from the previous ring's end gap.
   - 3.1 Install the expander ring in the piston groove. The ends of the expander ring must butt and must not overlap.
   - 3.2 Install the bottom oil ring by inserting one end below the expander ring in the ring groove, and wind the ring into position. Install the top oil ring in the same manner above the expander ring making sure the gap is staggered from the bottom oil ring and the expander ring.
   - 3.3 Install the compression rings in the correct grooves, with the bevel or "pip" mark (if any) toward the top of the piston.
4. Assemble the new connecting rods on the new pistons.
   - 4.1 Lubricate the wrist pins and the wrist pin bushings in the connecting rods with clean engine oil.

4.2 Position the connecting rods in the pistons and press in the wrist pins. Secure the wrist pins by installing the wrist pin buttons in the ends of the wrist pins.

5. Install the new pistons and new connecting rods.

5.1 Apply clean engine oil to both pistons, the piston rings, the wrist pins, the connecting rod caps and the new connecting rod bearings.

5.2 Turn the crankshaft so its number-one rod journal (the one nearer the drive end) is down and centered.

5.3 Using a piston ring compressor, insert the number-one connecting rod and piston through the top of the number-one cylinder bore.

NOTE: The connecting rods and connecting rod caps are matched sets, therefore the caps must not be switched or rotated end for end.

5.4 Install the connecting rod bearings on the connecting rod and connecting rod cap.

5.5 Tighten the new connecting rod bolts evenly in increments of 11 to 13 lbf·ft (15 to 17 N·m).

5.6 Turn the crankshaft so its number-two connecting rod journal is in the downward, center position.

5.7 Install the number-two connecting rod and piston in the same manner as described above.

6. Before replacing the cylinder head on the crankcase, ensure that the correct pistons have been used by turning the crankshaft one complete revolution such that each piston moves to its maximum upward stroke. At the upward stroke position, each piston should move to the top of the crankcase. If the piston does not approach the top of the crankcase, the piston is incorrect and if not replaced could result in compressor damage.

7. Install the base plate.

7.1 Position the gasket on the crankcase. Install the base plate on the crankcase as marked before disassembly.

7.2 Tighten the six capscrews 15 to 18 lbf·ft (20 to 25 N·m) in a cross pattern.

8. Install the cylinder head on the crankcase. For instructions, see **Subject 110**.

9. Install the compressor on the engine. For instructions, see **Subject 100**.

10. Operate the engine and check for leaks.

Problem—Excessive Oil Passage

Possible Cause	Remedy
Restricted air intake.	Check engine air filter and replace if necessary. Check compressor air inlet for kinks and excessive bends. Repair as needed.
Restricted oil return line to engine.	Check for excessive bends, kinks, and restrictions in oil return line. Return line must descend from compressor to engine crankcase. Repair as needed.
Damaged oil seal ring or loose end cover.	Inspect oil seal ring for wear or damage. Repair as needed. Check the end cover capscrew torques and tighten as necessary.
Insufficient compressor cooling (compressor runs hot).	Remove grease, grime, or dirt from the cooling fins of the compressor. Check for damaged cooling fins. Replace components found damaged. Check for correct coolant line sizes. Check the coolant flow through the compressor. Minimum allowable flow is 2.5 gallons per minute at maximum engine governed speed, and minimum allowable flow is 0.5 gallons per minute at engine idle. If low, inspect the coolant lines for rust scale, kinks, and restrictions. Repair or replace as necessary.
Compressor runs loaded an excessive amount of time.	Check air lines and connections for leakage. Repair or replace lines and connections until leakage is eliminated.
Back pressure from the engine crankcase.	Check for excessive engine crankcase pressure. Repair or replace ventilation components as necessary. NOTE: An indication of crankcase pressure is a loose or partially lifted dipstick.
Excessive engine oil pressure.	Check the engine oil pressure with a test gauge, and compare the reading to the engine specification. Do not restrict the compressor oil supply line.
Malfunctioning compressor.	Replace or repair the compressor after making certain none of the preceding conditions exist.

Problem—Noisy Compressor Operation

Possible Cause	Remedy
Loose drive coupling or gear (as indicated).	Inspect the fit of the drive coupling and gear on the compressor crankshaft. Tighten or replace the components. If the crankshaft keyway is damaged, replace the compressor.
Compressor cylinder head or discharge line restrictions.	Inspect the compressor discharge port and discharge line for carbon build-up. If carbon is detected, remove the carbon and check for proper coolant flow to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Air compressor bearing damaged or worn.	Replace the bearings.
Malfunctioning compressor.	Rebuild or replace the compressor after making certain none of the preceding conditions exist.

Problem—Excessive Build-Up and Recovery Time

Possible Cause	Remedy
Restricted air intake.	Check engine air filter and replace if necessary. Check compressor air inlet for kinks and excessive bends. Repair as needed.

Troubleshooting

Possible Cause	Remedy
Restricted discharge or compressor discharge cavity.	Inspect the compressor discharge port and line for restrictions and carbon build-up. If carbon is detected, remove the carbon. Check for proper cooling to the compressor. Inspect the discharge line for kinks and restrictions. Replace the discharge line as necessary.
Slipping drive components.	Check for faulty drive gears and coupling, and replace as necessary.
Excessive air system leakage (not including the air compressor).	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
Unloader pistons seized.	Check the operation of the unloading mechanism. Check for corrosion and contamination of unloader pistons. Check for correct operation of the compressor air governor. If the governor is operating properly, repair or replace the unloading mechanism.
Malfunctioning compressor.	Rebuild or replace the compressor after making certain none of the preceding conditions exist.

Problem—Compressor Fails to Unload

Possible Cause	Remedy
Faulty or worn unloader pistons or bores.	Inspect for worn, dirty, or corroded unloader pistons and bores. Replace as necessary.
Malfunctioning governor.	Check the setting with an accurate test gauge. Repair or replace the air governor.
Unloader air lines from governor damaged.	Inspect the air lines to and from the governor for kinks or restrictions. Repair or replace the air lines.

Description	Torque lbf·ft (N·m)
Cylinder Head	37–42 (50–57)
Unloader Cover Plate	15–18 (20–25)
Discharge Valve Seat	70–90 (95–122)
Inlet Valve Stop	70–90 (95–122)
End Cover	15–18 (20–25)
Connecting Rod	11–13 (15–17)
Bottom Cover	15–18 (20–25)
Inlet Fitting	15–18 (20–25)
Discharge Fitting	15–18 (20–25)
Governor or Governor Adaptor	15–18 (20–25)

Table 1, Fastener Torque Values

Description	inches (mm)
Discharge Valve Travel (minimum/maximum)	0.030/0.046 (0.76/1.17)
Fit Between Crankcase Bore and Ball-Type Main Bearing (minimum/maximum)	0.0003/0.0023 (0.008/0.058)
Clearance for Crankshaft Main Journals to i.d. of Sleeve-Type Main Bearing (maximum)	0.005 (0.13)
Crankshaft Main Journal Standard Diameter	1.1242–1.1250 (28.555–28.575)
Clearance Between Crankshaft Rod Journals and Connecting Rod Bearing (minimum/maximum)	0.0003/0.0021 (0.008/0.053)
Crankshaft Rod Journal Standard Diameter *	1.1242–1.1250 (28.555–28.575)
Cylinder Bore Out-of-Round (maximum)	0.0005 (0.013)
Cylinder Bore Taper (maximum)	0.0005 (0.013)
Clearance Between Cylinder Bore and Cast Iron Piston (minimum/maximum) †	0.002/0.004 (0.05/0.10)
Clearance Between Wrist Pins and Connecting Rod Bushings (maximum)	0.0007 (0.0178)
Compression Ring Groove Clearance	0.002–0.004 (0.05–0.10)
Oil and Expander Ring Groove Clearance	0.00–0.006 (0.00–0.153)
Compression Ring Gap (installed in cylinder)	0.002–0.013 (0.05–0.176)
Oil and Expander Ring Gap (installed in cylinder)	0.010–0.040 (0.255–1.016)

* For compressors having reground crankshafts, undersize connecting rod bearing inserts are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm).
† Oversized pistons and piston rings are available in 0.010 inch (0.254 mm), 0.020 inch (0.508 mm), and 0.030 inch (0.762 mm).

Table 2, Compressor Specifications

General Description

Cummins B Series engines use the Holset SS191B air-cooled air compressor, an engine-driven, single-piston compressor which supplies compressed air to the vehicle air system. The compressor draws turbo-charged, aftercooled air from the engine manifold. It compresses the air further, and delivers it to the air system supply reservoir.

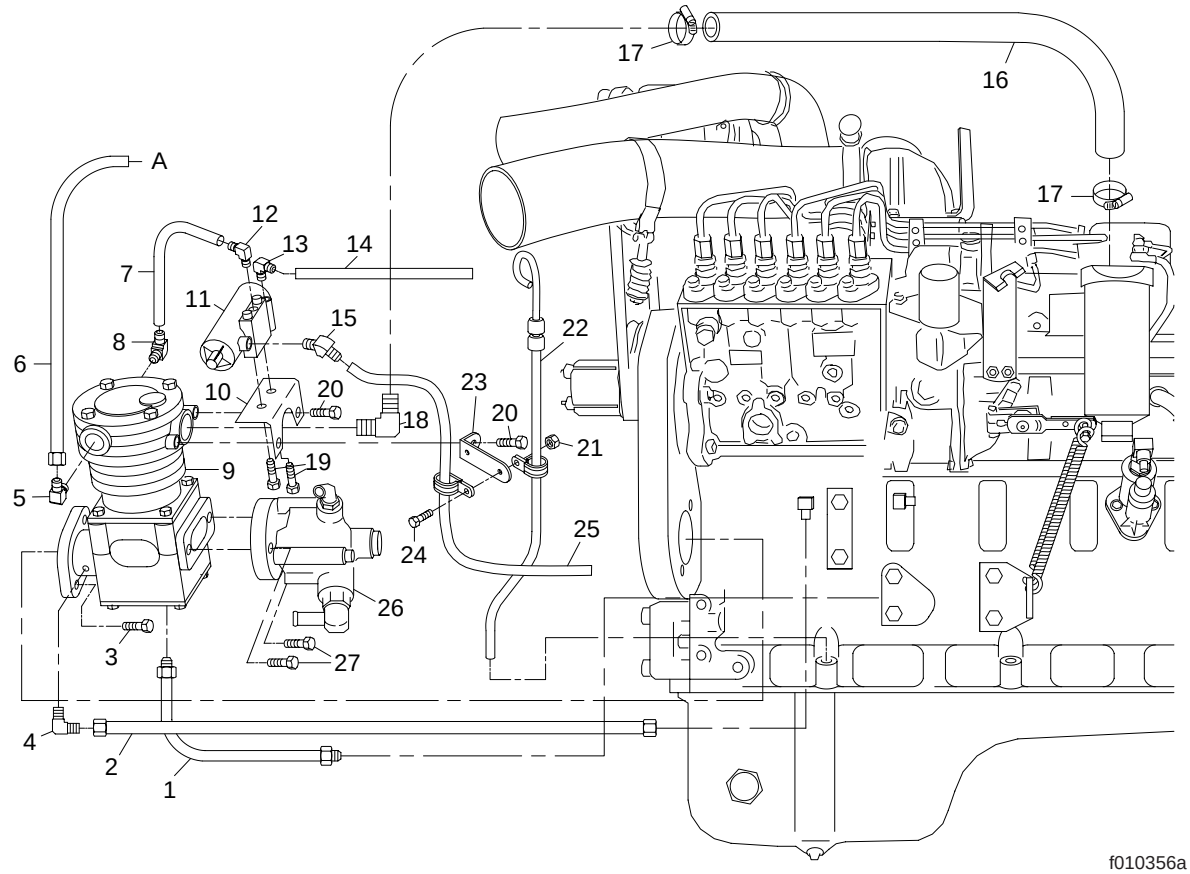
The compressor runs continuously but has "loaded" and "unloaded" modes, which are regulated by the air governor and the compressor loading assembly. When the air system reaches a nominal 125 psi (862 kPa), the governor sends an air signal to the un-loader assembly. The unloader assembly then holds the compressor air intake valve open so that no more compressed air is forced into the air system. As air in the system is used, its pressure drops, and at a nominal 105 psi (724 kPa), the air governor exhausts the signal to the compressor. Without the signal, the unloader assembly automatically closes the compres-sor air intake valve to force more air into the system.

On vehicles with air dryers, when the system reaches the cut-out pressure of a nominal 125 psi (862 kPa), the air governor also sends an air signal to open the purge valve in the air dryer.

For detailed repair procedures and other engine ser-vice not covered in this section, see the *Cummins SS191B Air Compressor Shop Manual* or *Cummins Single Cylinder Air Compressor Shop Manual.*

Removal

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Drain the air reservoirs.
3. Tilt the hood.
4. Carefully disconnect the air lines. See **Fig. 1**.
   - 4.1 Disconnect the air inlet line at the rear of the compressor head.
   - 4.2 Disconnect the air outlet line from the side of the compressor head.



A. To supply tank
1. Oil Return Pipe
2. Oil Supply Line
3. Air Compressor Mounting Bolt
4. Elbow Fitting
5. Elbow Fitting
6. Air Compressor Outlet Line
7. Air Compressor Signal Line
8. Elbow Fitting
9. Air Compressor
10. Air Governor Bracket
11. Air Governor
12. Elbow Fitting
13. Elbow Fitting
14. Air Governor Signal Line
15. Elbow Fitting
16. Air Compressor Input Line
17. Hose Clamp
18. Elbow Fitting
19. Air Governor Mounting Bolt
20. Air Governor Bracket Bolt
21. Nut
22. Dipstick
23. Standoff Bracket
24. Bolt
25. Standoff Bracket Bolt
26. Power Steering Pump
27. Power Steering Pump Mounting Bolt

Fig. 1, Holset SS191B Compressor Mounting

Removal and Installation

4.3 Disconnect the air signal line between the compressor and the air governor.

4.4 Disconnect the air signal lines between the air governor and the chassis air system.

5. Remove the power steering pump. For instructions, refer to **Group 46** in this manual.
6. Remove the dipstick and air signal line clamps from the stand-off bracket at the rear of the air governor.
7. Remove the left air governor bracket bolt to free the stand-off bracket. Remove the bracket.
8. Disconnect the oil lines.

8.1 Disconnect the compressor oil return pipe from the engine.

8.2 Disconnect the compressor oil supply line from the air compressor.

8.3 Remove the two compressor mounting bolts, then lift the compressor from the engine.

Installation

1. Install the air compressor. See **Fig. 1**.

1.1 Position the compressor on the engine, and secure it with the air compressor mounting bolts. Tighten the bolts 54 lbf·ft (73 N·m).

1.2 If removed, install the air governor on the compressor. Install the standoff with the left bracket bolt, and tighten both bolts 15 lbf·ft (20 N·m).

2. Connect the air compressor oil lines.

2.1 Connect the oil supply line to the compressor.

2.2 Connect the oil return pipe to the engine.

3. Install the power steering pump. For instructions, refer to **Group 46** in this manual.
4. Connect the air compressor and air governor air lines.

4.1 Connect the air signal lines between the air governor and the chassis air system.

4.2 Connect the air signal line between the compressor and the air governor.

4.3 Connect the air outlet line to the side of the compressor head.

4.4 Connect the air inlet line at the rear of the compressor head.

5. Clamp the air signal line and the dipstick to the stand-off bracket.
6. Start the engine, and check for leaks in the compressor mounting. Repair any leaks as necessary.
7. Lower the hood, and remove the chocks from the tires.

Specifications

Description	Grade	Size	Torque lbf·ft (N·m)
Air Governor Bracket Bolts	5	5/16–18	15 (20)
Air Compressor Mounting Bolts	8.8	M12 x 1.75	54 (73)
Power Steering Pump Mounting Bolts	5	3/8–16	28 (38)

Table 1, Fastener Torques

General Description

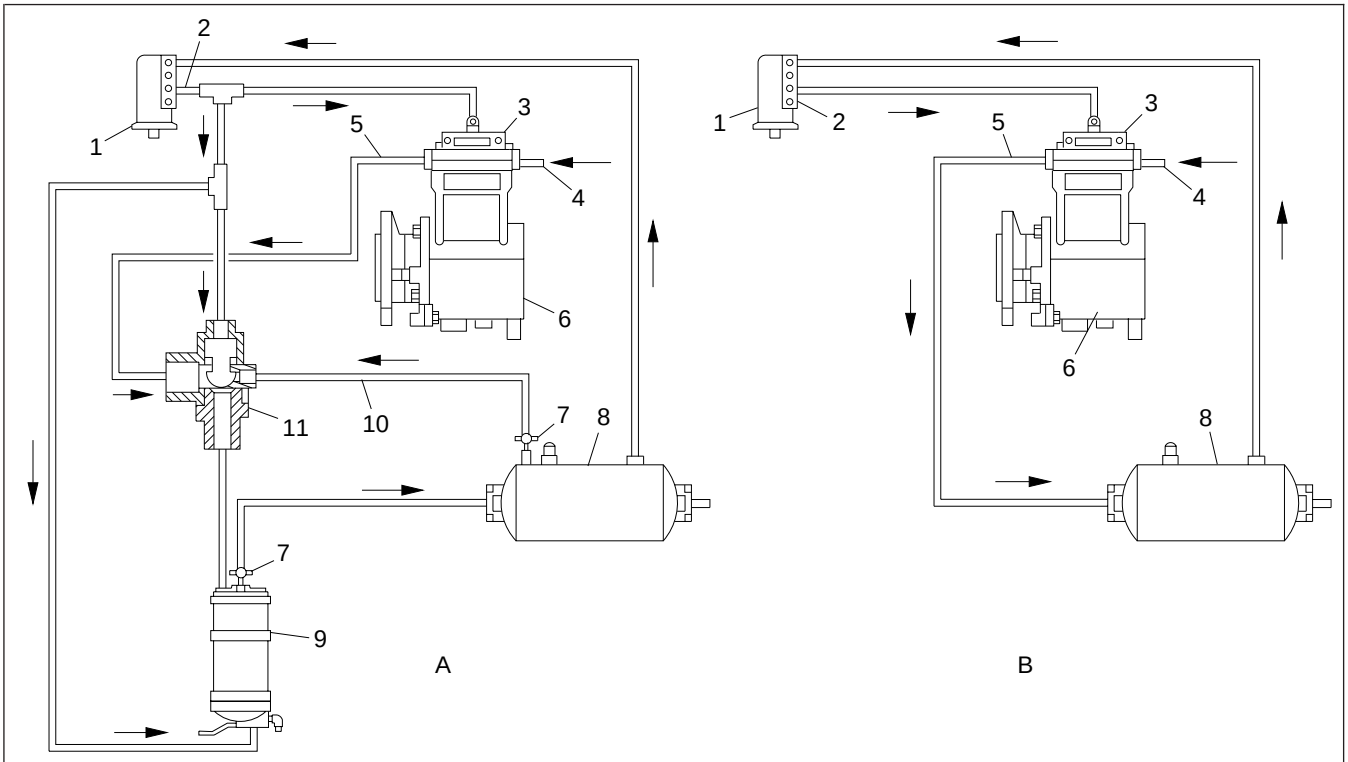
Cummins C Series engines use the Holset SS296 water-cooled air compressor, an engine-driven, piston-type compressor which supplies compressed air to the vehicle air system. See **Fig. 1**. The compressor draws turbocharged, aftercooled air from the engine intake manifold. It compresses the air further and delivers it to the air system supply reservoir.

The compressor runs continuously but has loaded and unloaded modes, which are regulated by the air governor and the compressor loading assembly. The compressor also uses an Economy (E-type) unloader system to reduce pumping and engine boost pressure losses through the compressor intake valve while operating in the unloaded mode. If equipped with an air dryer, an Econ valve must be installed to prevent excessive oil consumption. When the air system reaches a nominal 125 psi (862 kPa), the governor sends an air signal to the unloader assembly. The unloader assembly then seals off incoming air at the intake valve so that no more compressed air enters the air system. As air in the system is used, its pressure drops and at a nominal 105 psi (724 kPa), the air governor exhausts the signal to the compressor. Without the signal, the compressor again pumps more compressed air into the system.

When the system reaches the cut-out pressure of a nominal 125 psi (862 kPa) on vehicles with air dryers, the air governor also sends an air signal to open the purge valve in the air dryer.

For detailed repair procedures and other engine service not covered in this section, see the *Cummins SS296 Air Compressor Shop Manual* or the *Cummins Troubleshooting and Repair Manual C Series Engines*.

General Description



A. With Air Dryer
1. Air Governor
2. Unloader Port
3. E-Type Unloader Valve
4. Air Inlet Line
5. Air Outlet Line
6. Compressor
7. Check Valve
8. Air Reservoir (wet tank)

B. Without Air Dryer
9. Air Dryer
10. Secondary Pressure Line
11. Econ Valve

Fig. 1, Air System Diagram

Removal

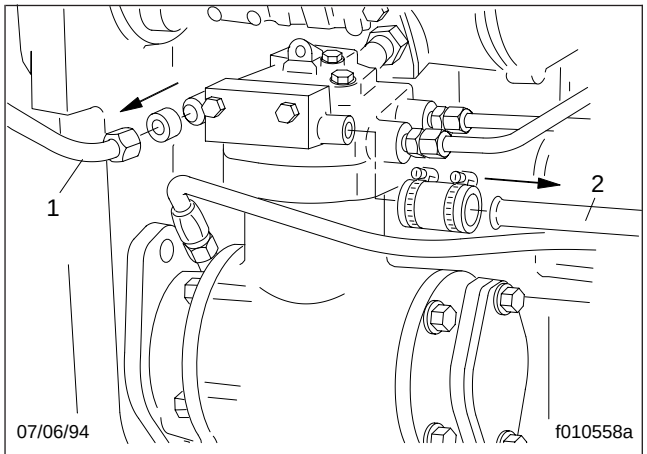
1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.

⚠ WARNING

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

3. Drain the coolant and the air reservoirs.
4. Carefully disconnect the air lines, coolant lines, and the oil supply line.

   4.1 Disconnect the air inlet line at the rear of the compressor head and at the engine. See **Fig. 1**.



1. Air Outlet Line 2. Air Inlet Line

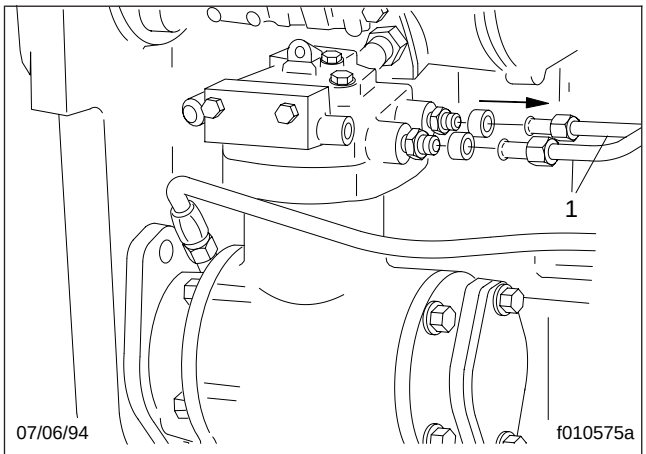
Fig. 1, Disconnect the Air Inlet and Outline Lines

   4.2 Disconnect the air outlet line from the front of the compressor head. See **Fig. 1**.

   4.3 Disconnect the coolant lines at the rear of the compressor head and at the cylinder head and engine block. See **Fig. 2**.

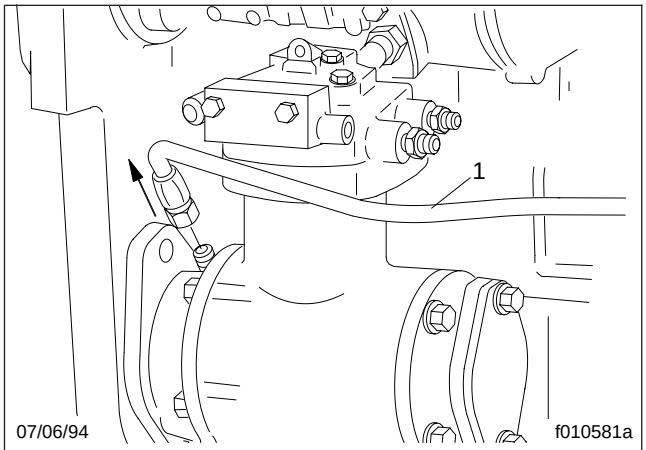
   4.4 Disconnect the two air signal lines between the air governor and the chassis air system.

   4.5 Disconnect the compressor oil supply line from the air compressor. See **Fig. 3**.



1. Coolant Lines

Fig. 2, Disconnect the Coolant Lines



1. Oil Supply Line

Fig. 3, Disconnect the Compressor Oil Supply Line

5. Remove the power steering pump.

   5.1 Remove the power steering pump mounting bolts.

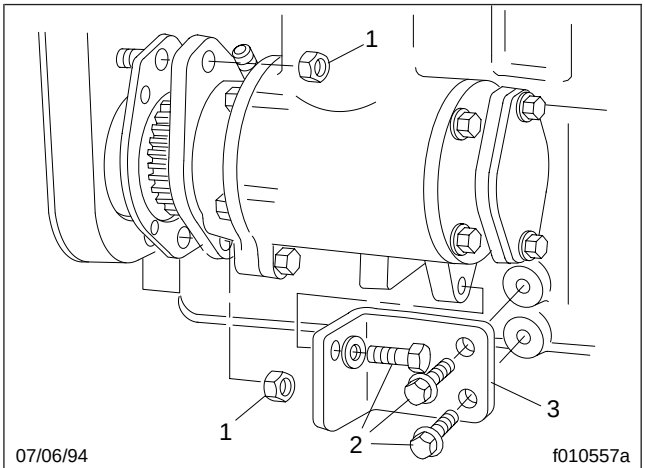
   5.2 Remove the pump from the compressor.

6. Remove the air compressor. See **Fig. 4.**

   6.1 Remove the compressor support-bracket capscrews, then remove the bracket.

   6.2 Remove the compressor mounting nuts, then lift or lower the compressor out of the engine compartment.

Removal and Installation



1. Compressor Mounting Nuts
2. Support-Bracket Capscrews
3. Support Bracket

Fig. 4, Remove the Air Compressor

Installation

1. Install the compressor.
   - 1.1 Position the compressor and a new gasket on the engine.
   - 1.2 Install the mounting nuts and tighten them 57 lbf·ft (77 N·m).
   - 1.3 Install the compressor support bracket and tighten the capscrews 35 lbf·ft (47 N·m).
2. Install the power steering pump.

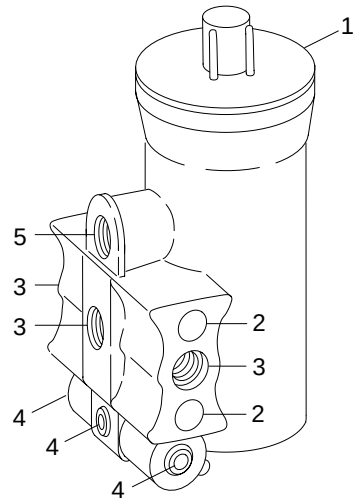
   Position the pump on the air compressor, and secure it with the power steering pump mounting bolts. Tighten the bolts 35 lbf·ft (47 N·m).
3. Connect the air lines, coolant lines, and the oil supply line.
   - 3.1 Connect the air inlet line to the rear of the compressor head and to the engine. See **Fig. 1**.
   - 3.2 Connect the air outlet line to the front of the compressor head. See **Fig. 1**.
   - 3.3 Connect the coolant lines to the rear of the compressor head and to the cylinder head and engine block. See **Fig. 2**.
   - 3.4 Connect the two air signal lines between the air governor and the chassis air system.
   - 3.5 Connect the compressor oil supply line to the air compressor. See **Fig. 3**.
4. Fill the cooling system with approved coolant. For instructions, see Group 20 of the *School Bus Chassis Maintenance Manual*.
5. Start the engine, and check for leaks in the air lines, coolant lines, and the oil supply line. Repair any leaks as necessary.
6. Lower the hood, and remove the chocks from the tires.

General Description

The governor, operating in conjunction with the compressor unloading mechanism, automatically controls the air pressure in the air brake or air supply system between the desired, predetermined maximum and minimum pressures. See **Fig. 1**. Normal air pressure is a nominal 105 to 125 psi (724 to 862 kPa). The compressor runs continuously while the engine runs, but the actual compression of air is controlled by the governor actuating the compressor unloading mechanism, which either stops or starts compression when the maximum or minimum reservoir pressures are reached. The D–2 governor has a piston upon which air pressure acts to overcome the pressure setting spring, and control the inlet and exhaust valve to either admit or exhaust air to or from the compressor unloading mechanism.

D–2 governors have mounting holes, which allow for direct mounting to the compressor.

Porting consists of 3 reservoir ports (1/8-inch NPT), 3 unloader ports (1/8-inch NPT), and 1 exhaust port (1/8-inch NPT).



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

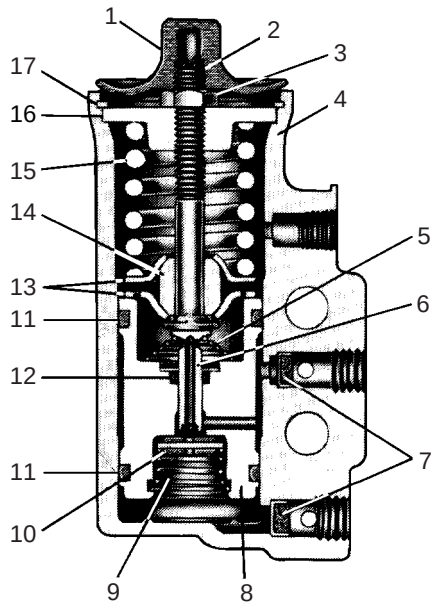
Fig. 1, Governor

Principles of Operation

Pressurized air enters the D–2 governor at one of its reservoir ports, and acts on the area of the piston and beneath the inlet and exhaust valve. See **Fig. 2**. As air pressure builds up, the piston moves against the resistance of the pressure-setting spring. The piston and inlet and exhaust valve move up when the reservoir air pressure reaches the cut-out setting of the governor. The exhaust stem seats on the inlet and exhaust valve, and then the inlet passage opens. Reservoir air then flows by the open inlet valve, through the passage in the piston, and out the unloader port to the compressor unloading mechanism. Air also flows around the piston, and acts upon the additional area of the piston. This added force, which results from a larger area on the piston, ensures 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.

General Description and Principles of Operation



09/28/94 f420301a

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

Fig. 2, Governor, Cross Section View

Tests

The following test should be performed whenever the vehicle air pressure is incorrect and the causes are unknown.

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

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

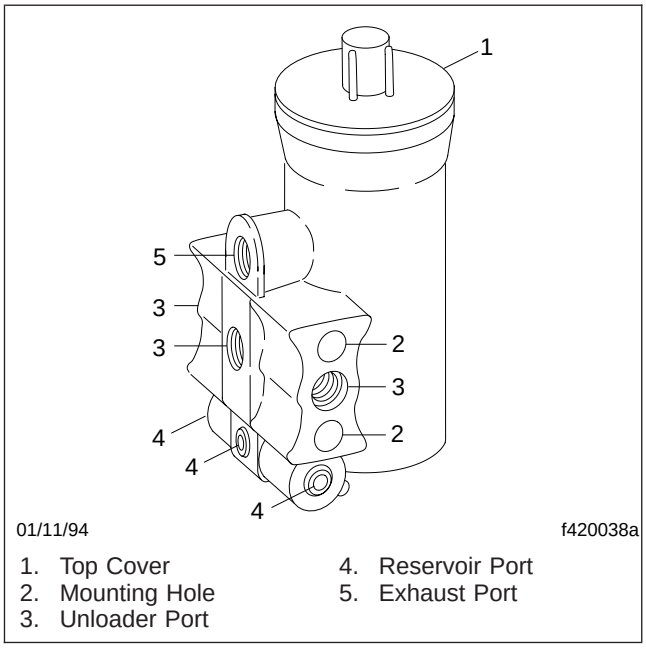
IMPORTANT: Make sure the test gauge is registering accurately before using it to check or adjust the air governor.

3. Using a test gauge attached to the supply reservoir, check the pressure at the time the air governor cuts out. The cut-out pressure should be 120 to 130 psi (827 to 896 kPa).
4. With the engine still running, make a series of brake applications to reduce the air pressure and observe at what pressure the air governor cuts in the compressor. The minimum cut-in pressure should be 100 psi (689 kPa).
5. If either the cut-out or cut-in pressures are incorrect, proceed to **Subject 130**.
6. Test the leakage on the air governor in both the cut-in and cut-out positions.

   6.1 With the compressor in the cut-in position, apply a soap solution to the air governor 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.

   6.2 With the compressor in the cut-out position, apply a soap solution to the air governor exhaust port. See **Fig. 1**. A slight bubble leakage is permitted. Excessive leakage indicates that the exhaust valve seat, stem, O-ring, or upper piston O-ring is worn out.

7. Return the hood to the operating position and remove the chocks from the tires.

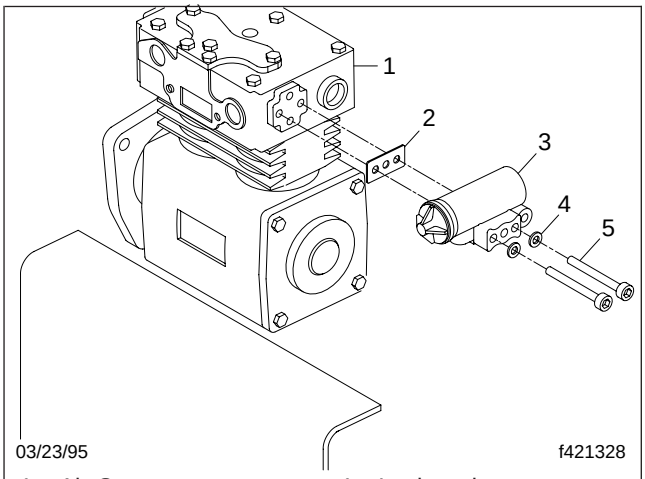


1. Top Cover
2. Mounting Hole
3. Unloader Port
4. Reservoir Port
5. Exhaust Port

Fig. 1, Air Governor

Removal

1. Chock the tires, and drain the air brake system. Open the hood. Refer to the vehicle operator's manual for instructions.



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

Fig. 1, Governor Mounting (Mounting location may change to improve air line routing)

2. Disconnect the reservoir and unloader port air lines. Mark the lines for later reference. Cap the air lines tightly to keep out contaminants.
3. Remove the governor mounting capscrews and lockwashers, and remove the governor. See **Fig. 1**.

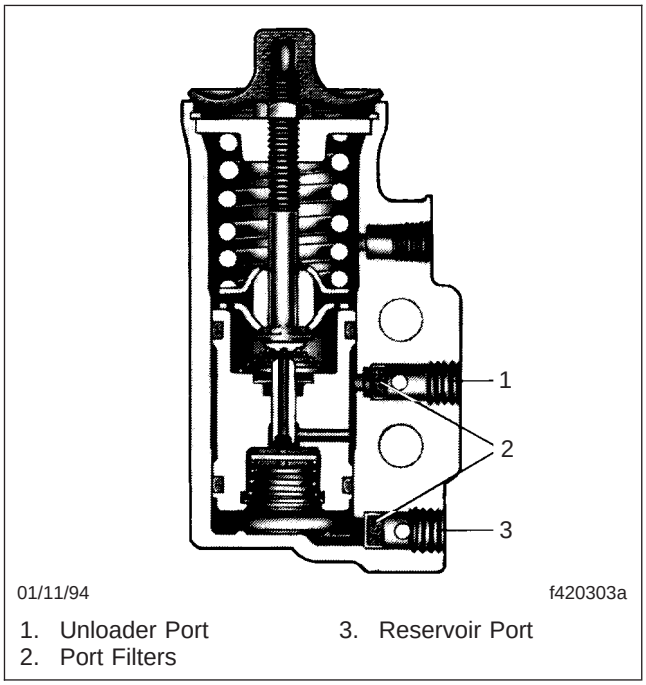
Installation

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 a new governor mounting gasket, install the governor and its mounting capscrews and lockwashers. Tighten the bolts 11 to 15 lbf·ft (15 to 20 N·m).
3. Clean the connecting lines after removing the caps, and apply Loctite® 242, or equivalent sealant in small quantities, to the reservoir and unloader fittings.

⚠ CAUTION

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 and unloader port air lines as referenced earlier. Tighten 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, screw the top cover on tightly until it seals the body, preventing the entry of any foreign matter.
7. If necessary, install new filters in the reservoir and unloader ports. See **Fig. 2**. These cup-shaped filters can be installed with the head of a pencil.



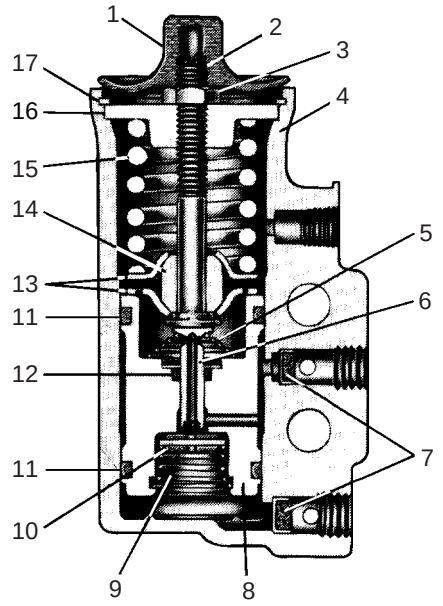
1. Unloader Port
2. Port Filters
3. Reservoir Port

Fig. 2, Filter Installation

8. Return the hood to the operating position, and remove the chocks from the tires. Refer to the vehicle operator's manual for instructions.

Air Governor Disassembly, Cleaning and Inspection, and Assembly

Disassembly



09/28/94 f420301a

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

Fig. 1, Governor, Cross Section View

1. Remove the governor from the vehicle, using the instructions in **Subject 110**.
2. Clean the governor exterior of road dirt and grease.
3. Unscrew the top cover. See **Fig. 1**.
4. With a pair of retaining ring pliers, remove the spring assembly retaining ring.
5. Remove the adjusting screw and spring assembly.
6. Remove the locknut, then the hex-shaped upper spring seat from the adjusting screw.
7. Remove the pressure-setting spring, lower spring seat, spring guide, and the other lower spring seat from the adjusting screw.
8. Remove the exhaust stem and its spring from the top of the piston. With the body in the inverted position, tap lightly and remove the piston.
9. Remove the inlet and exhaust valve spring and the valve from the piston.
10. Remove the two piston O-rings , and with a hooked wire, remove the exhaust stem O-ring.
11. Clean or remove the unloader and reservoir port filters.

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, filters, exhaust stem, and piston are not obstructed.
4. Check the springs for cracks, distortion, or corrosion.
5. Replace all worn or damaged parts.

Assembly

Prior to assembly, lubricate the lower body bore, the top of the piston, the piston grooves, piston O-rings, and the spring guide and adjusting screw with Dow Corning 55-M pneumatic grease, or equivalent.

1. Install the exhaust stem O-ring in its groove in the stem bore of the piston. See **Fig. 1**.
2. Install the upper and lower piston O-rings).
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. Position the exhaust stem spring over the exhaust stem. Carefully press the stem into the stem bore of the piston.
6. Install the piston in the body.

Air Governor Disassembly, Cleaning and Inspection, and Assembly

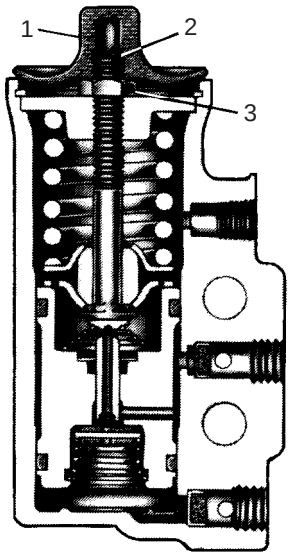
7. Install one lower spring seat, spring guide, the other lower spring seat, pressure-setting spring, and the hex-shaped upper spring seat on the adjusting screw, in that order. Screw the upper spring seat down until the distance from the top of the seat to the bottom of the stem head is about 1-7/8 inches (48 mm).
8. Install the locknut.
9. 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.
10. Install the adjusting screw and spring assembly, and the retaining ring.
11. Install the governor on the vehicle, using the instructions in **Subject 110**.

Adjustment

NOTE: An air governor used with a dryer reservoir module (DRM) is not adjustable.

If the pressure settings of the governor are inaccurate or if they need to be changed, proceed as follows:

1. Apply the parking brakes and chock the tires. Open the hood.
2. Remove the top cover from the governor and loosen the adjusting screw locknut. See **Fig. 1**.



01/11/94 f420305a

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

Fig. 1, Air Governor, Cross Section View

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

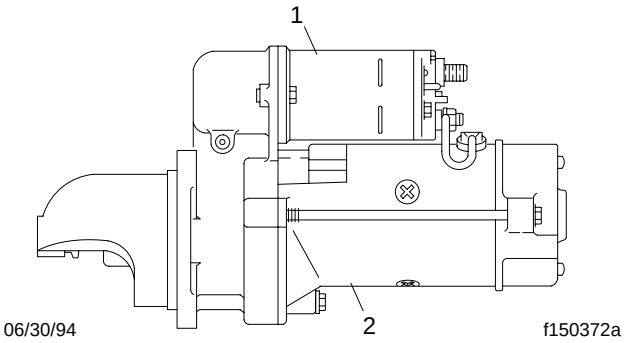
NOTE: The pressure range between cut in and cut out is not adjustable.

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

4. Tighten the adjusting screw locknut and install the top cover.
5. Return the hood to the operating position and remove the chocks from the tires.

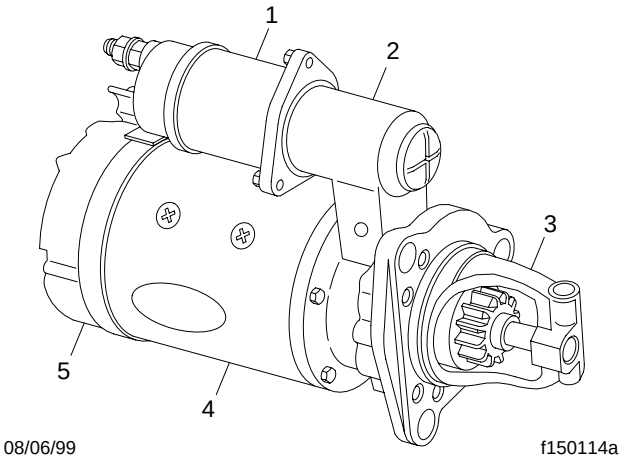
General Information

The Delco Remy 28–MT starter mounts on the right side of the engine at the forward face of the flywheel bell housing on Cummins B Series engines. See **Fig. 1**. The Delco Remy 37–MT starter mounts on the left side of the engine at the forward face of the flywheel bell housing on Caterpillar CFE engines. See **Fig. 2**.



1. Solenoid
2. Cranking Motor

Fig. 1, Delco Remy 28-MT Starter



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

Fig. 2, 37-MT Starter

The starter assembly (see **Fig. 3**) consists of two basic parts: the solenoid and the cranking motor. 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.

The solenoid engages the pinion with the ring gear and the pinion remains engaged until the solenoid circuit is interrupted. In case of a butt engagement, the pinion mechanism will rotate the pinion gear, clearing the butt engagement, engaging the ring gear, and causing the engine to crank.

Under normal operating conditions, no maintenance will be required between engine overhaul periods. At the time of engine overhaul, replace the starter with a remanufactured starter.

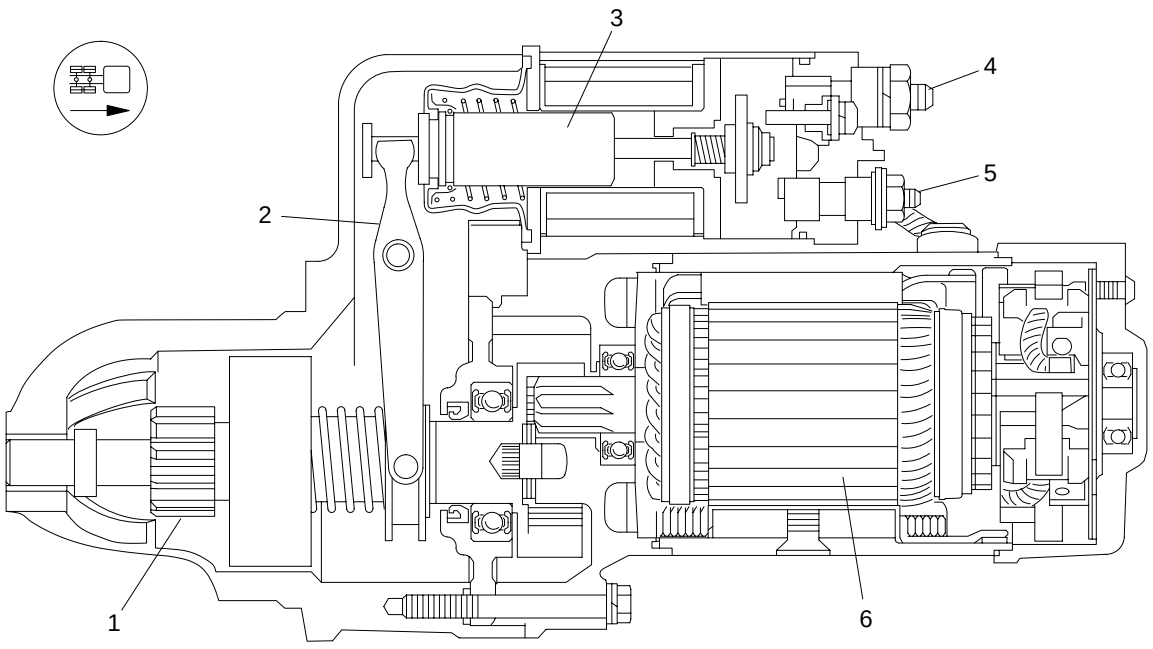
For the basic cranking and charging circuit wiring, see **Fig. 4**.

Turning on the ignition keyswitch and pressing the engine start button closes the magnetic switch contacts, connecting the battery to the solenoid. As a result, the plunger and the shift lever move, causing the pinion to engage the engine flywheel ring gear, closing the solenoid main contacts, and cranking the engine. When the engine starts, the pinion overruns, protecting the armature from excessive speed. When the engine start button is released, the pinion disengages.

IMPORTANT: On vehicles with automatic transmissions, be sure the transmission is in NEUTRAL before attempting to start the engine.

To prevent overrun and damage to the drive and armature windings, release the engine start button as soon as the engine starts. Never crank the motor longer than 30 seconds. Stop and allow the motor to cool for at least two minutes before cranking again.

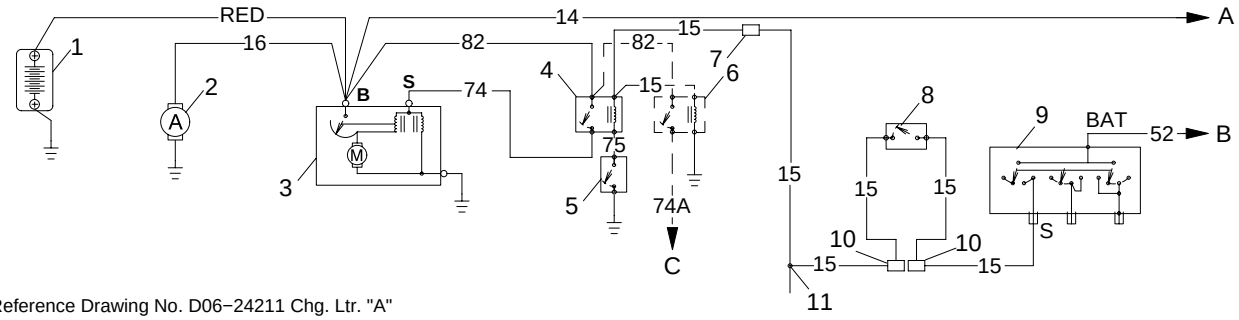
General Information



06/30/94 f150376a

1. Starter Drive Gear
2. Shift Lever
3. Solenoid Plunger
4. Battery (B) Terminal
5. Motor (M) Terminal
6. Cranking Motor

Fig. 3, Starter Components



Reference Drawing No. D06−24211 Chg. Ltr. "A"

08/13/96 f150589

A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 4, Cranking and Charging Circuit Wiring

Removal

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Disconnect the batteries.
   - 2.1 Disconnect the battery ground cable at the vehicle frame.
   - 2.2 Disconnect the positive battery cable from the batteries.
3. Disconnect the wires from the starter solenoid terminals, and label them for reassembly.
4. Remove the starter from the engine by removing the three capscrews that secure the starter to the engine. See **Fig. 1**.

Installation

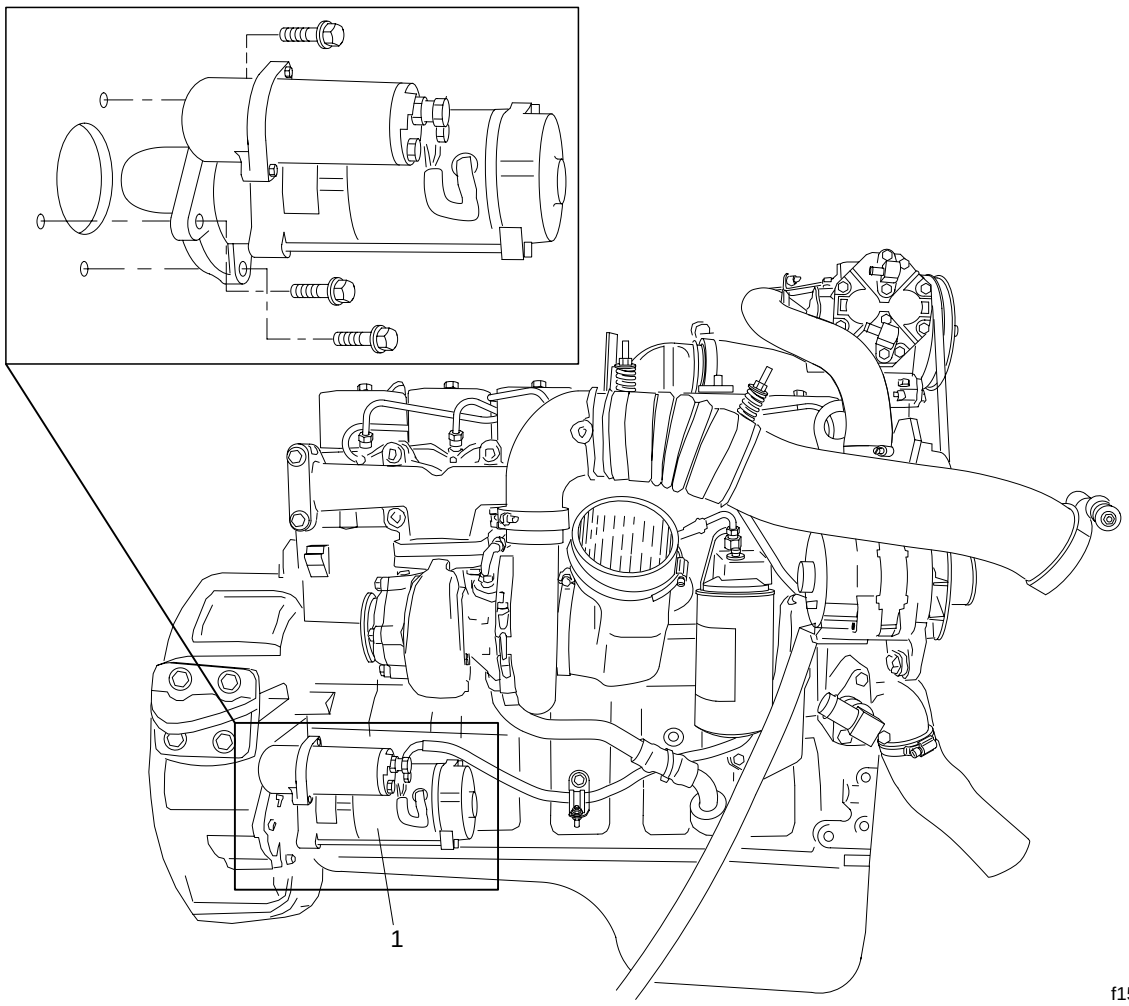
1. Install the starter on the engine. See **Fig. 1**.
   - 1.1 Position the starter and secure it with the three capscrews.
   - 1.2 Tighten the capscrews 38 lbf·ft (52 N·m).
2. Connect the wires to the starter terminals. If the wires were not labeled for reassembly, see the wiring diagram in **Fig. 2**. Tighten the M10 terminal nut on the battery (B) terminal 13 lbf·ft (18 N·m). Tighten the M5 terminal nut on the solenoid (S) terminal 26 lbf·in (300 N·cm).
3. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

Table 1, Approved Dielectric Red Enamel

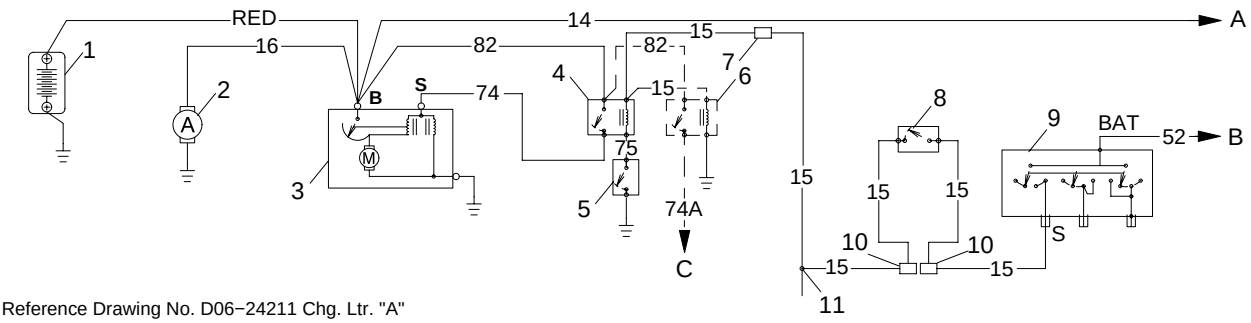
4. Connect the batteries.
   - 4.1 Connect the positive battery cable to the batteries.
   - 4.2 Connect the battery ground cable to the vehicle frame.
5. Lower the hood, and remove the chocks from the tires.
6. Start the engine to test the starter.

Starter Removal and Installation



1. See insert for detail of mounting bolt installation.

Fig. 1, Starter Installation



Reference Drawing No. D06−24211 Chg. Ltr. "A"
08/13/96

f150589

A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

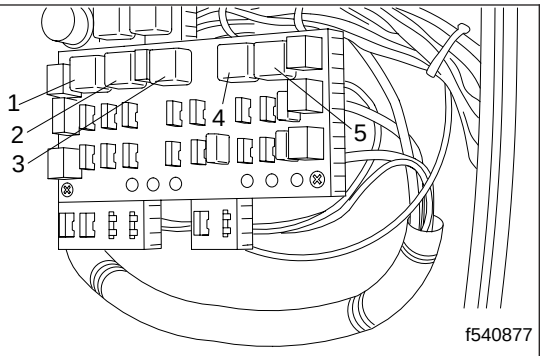
Fig. 2, Cranking and Charging Circuit Wiring

Replacement

The optional starter interrupt relay is located inside the Electrical Power Center (EPC). The EPC is underneath the dash panel on the passenger side.

1. Disconnect the batteries.
2. Remove the starter relay from the EPC.

   2.1 Remove the fasteners holding the EPC cover. Look for the starter relay on the top row of the EPC. For a typical installation, see **Fig. 1**.



1. Fuel Pump Relay
2. Engine Shutdown Relay
3. Starter Relay
4. Stop Lamp Relay
5. Air Conditioning Ground Signal Relay

Fig. 1, Electrical Power Center (EPC)

   2.2 Unplug the old starter relay unit from the EPC.

3. Plug in the new starter relay. Make sure the relay is firmly seated on its mounting plate and that the electrical connections behind the panel are tight.
4. Replace the EPC cover and install the fasteners.
5. Connect the batteries.
6. Start the engine to test the starter relay.

Troubleshooting Table

Problem—Starter Cranks Slowly Or Not At All

Problem—Starter Cranks Slowly Or Not At All	
Possible Cause	**Remedy**
The alternator drive belt is loose.	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.
The alternator 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. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The batteries are undercharged.	Do a load test on the batteries. See Section 54.02, **Subject 130** 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. If the batteries were fully charged and passed the load test, check the starter solenoid circuit. Go to "Starter Solenoid Circuit Test" for instructions.
The battery cables do not deliver sufficient voltage to the starter.	Check the available cranking voltage. Go to "Available Cranking Voltage Test" for instructions.
The starter solenoid circuit is broken.	Check the starter solenoid circuit. Go to "Starter Solenoid Circuit Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
The control circuit is broken.	Check the starter wiring. Go to "Starter Wiring Test" for instructions. Make repairs as needed. Start the engine to verify the repair.
The magnetic switch is broken.	Replace the magnetic switch. Go to **Section 54.04** for replacement instructions.
The starter ring gear or pinion gear is damaged.	Visually check the ring and pinion gears. Go to "Ring and Pinion Gear Test" for instructions.
The starter does not stay engaged.	Go to "Cold Weather Voltage Test" for instructions.
The starter is damaged.	Replace the starter.
There is a mechanical problem in the engine.	See the engine manufacturer's manuals.

Troubleshooting Chart

Problem—Starter Spins, But Does Not Crank

For troubleshooting instructions, see **Fig. 1**.

Problem—Starter Makes Clicking Noise, But Does Not Crank (Or Cranks Intermittently)

For troubleshooting instructions, see **Fig. 1**.

Troubleshooting

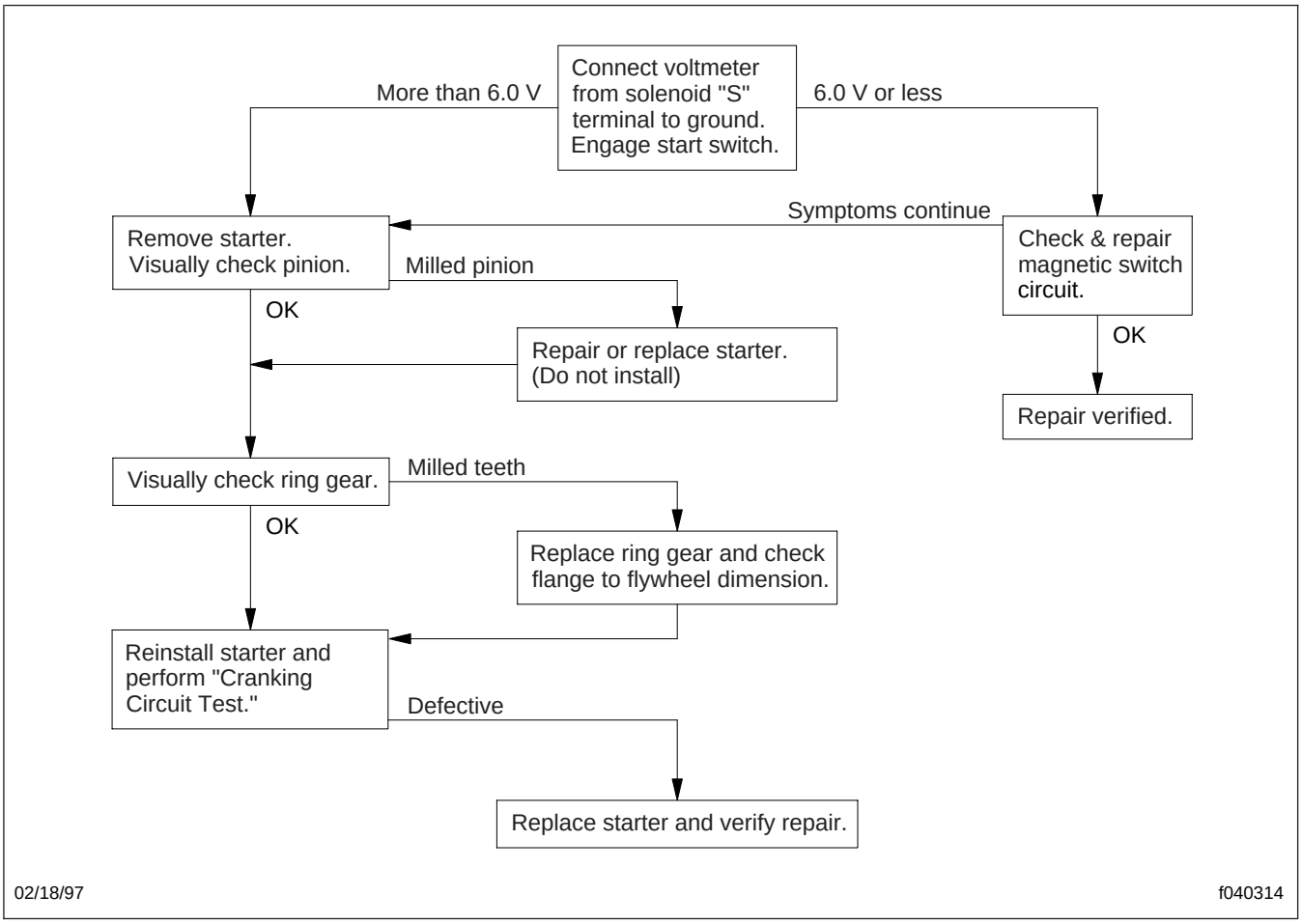


Fig. 1, Milled Pinion Symptoms

Available Cranking Voltage Test

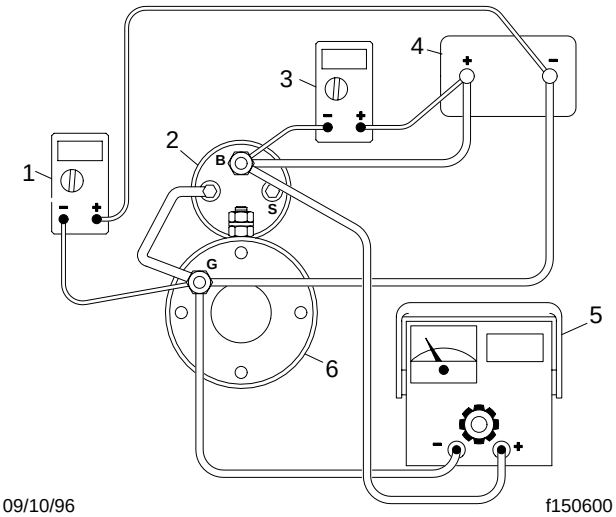
BATTERY CABLE TEST

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. 2**.

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

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



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

Fig. 2, Battery Cable Test

5. Turn on the carbon pile again and adjust it to a 500-amp load, as before. Read and record the voltage (as 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 solenoid "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.
   - 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 keyswitch. See **Fig. 3**. It is part of the cranking circuit.

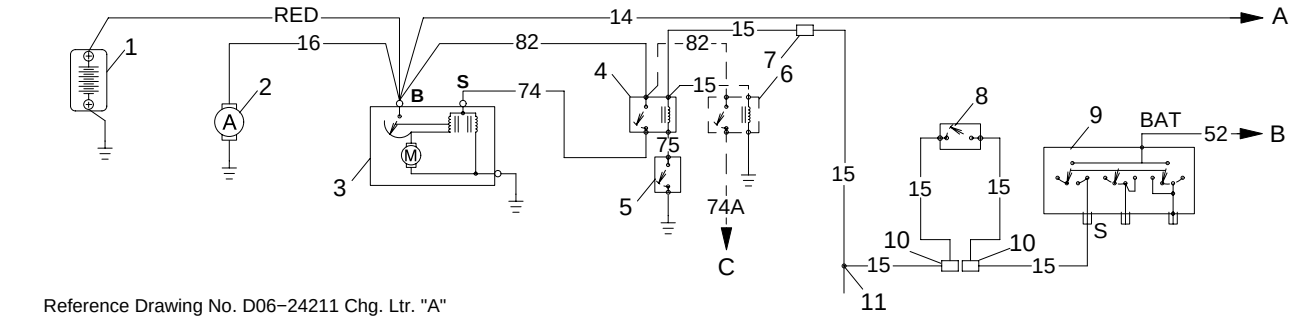
If there is excessive voltage loss in the starter solenoid circuit, the starter may not engage the flywheel at all, or it may drop out too soon when battery voltage goes down. Do the following test to check for excessive voltage loss in the starter solenoid circuit.

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. 4**.
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

Troubleshooting

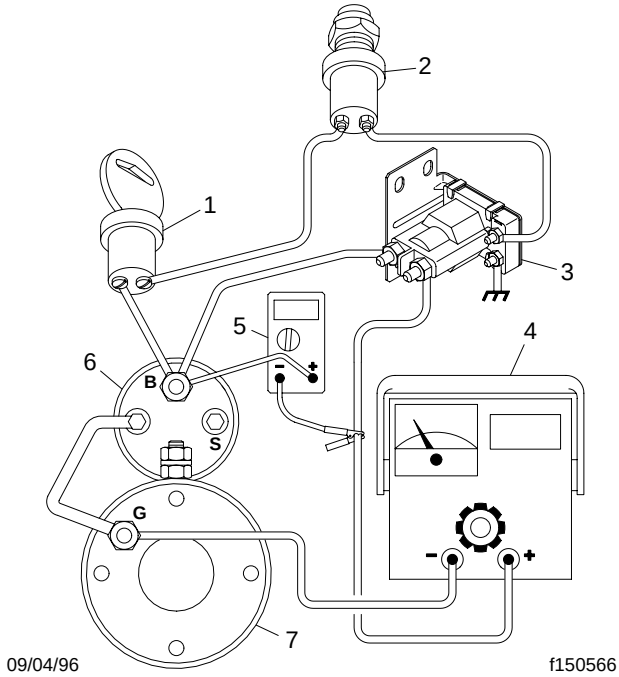


Reference Drawing No. D06−24211 Chg. Ltr. "A"
08/13/96 f150589

A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 3, Cranking and Charging Circuit Wiring



09/04/96 f150566

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

Fig. 4, Starter Solenoid Circuit Test

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.

IMPORTANT: If the magnetic switch does not close, do the Magnetic Switch Circuit Test. For instructions, see **Section 54.04**.

6. Check the starter solenoid circuit voltage loss.

   6.1 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. Do the Magnetic Switch Circuit Test. For instructions, see **Section 54.04**.

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

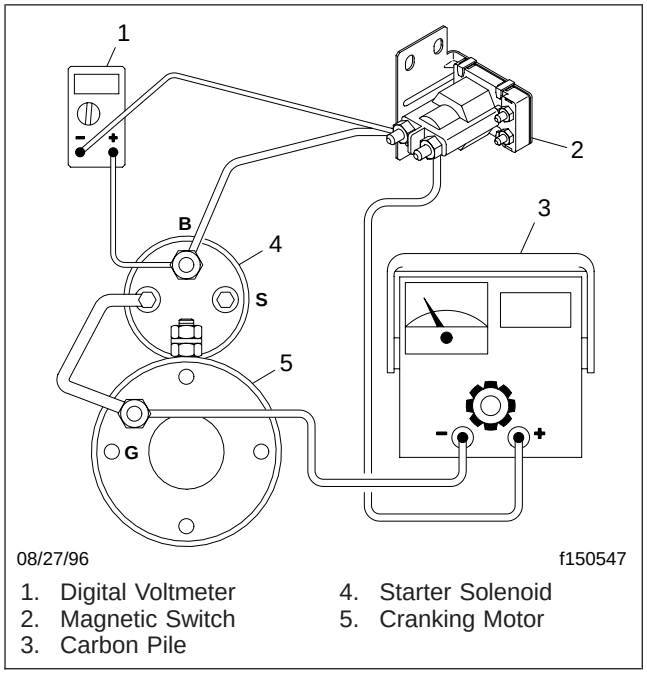
Starter Wiring Test

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 on the magnetic switch that is connected to the starter "B" terminal (circuit 82). See **Fig. 5**. If any voltage shows, the circuit is grounded. Repair as necessary.



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

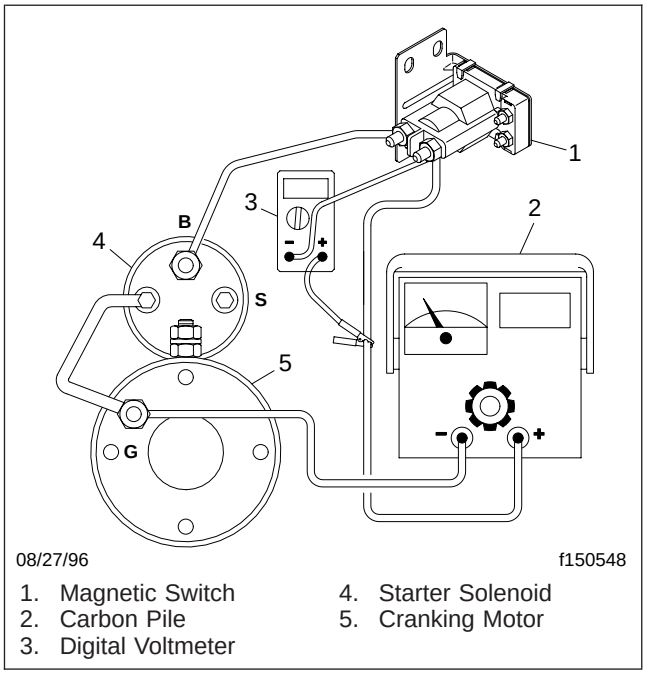
Fig. 5, Starter Wiring Test: First Wire Voltage Loss (V5)

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. For instructions, see **Section 54.04**.

5. Check the first wire voltage loss (V5).
   - 5.1 Turn the ignition keyswitch 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 (as 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 74). See **Fig. 6**.



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

Fig. 6, 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).
   - 8.1 Turn the ignition keyswitch to the START position; then turn on the carbon pile and again adjust it to a 100-amp load.

   NOTE: Ignore the minus (–) sign.
   - 8.2 Now read and record this voltage (as 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. Do the Magnetic Switch Contactor Test. For instructions, see **Section 54.04**.

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 solenoid "S" terminal.
10. Check all wiring and connections and repair or replace as needed.

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 ring gear and pinion gear visually (check all the teeth in both gears).
2. If the pinion teeth are damaged, replace the starter. If the flywheel 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 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.

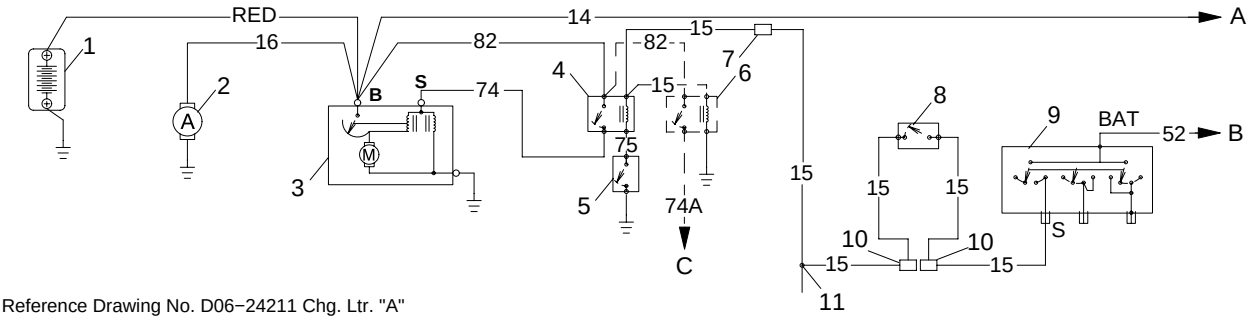
1. With the ignition keyswitch on, clamp a heavy battery jumper cable between the two large studs on the magnetic switch. Remove the jumper immediately to stop the engine from cranking.
2. If the engine starts with the jumper in place, do the "Starter Wiring Test." Repair/replace the wire connections, terminals, and/or magnetic switch as necessary.
3. If the engine now starts properly, check the starter mounting bolts for tightness and test the alternator. On Delco Remy alternators, do the "Alternator Wiring Test" in **Section 15.01**.
4. If the engine still does not start properly, go to "Available Cranking Voltage Test."

For fastener torque values, see **Table 1**.

For a diagram of the cranking and charging circuits, see **Fig. 1**.

Fastener Torque Values				
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
Starter Mounting Capscrews	10.9	M10 x 1.5	38 (52)	—
Battery (B) Terminal Nut	Brass	M10	13 (18)	—
Solenoid (S) Terminal Nut	Brass	M5	—	13 (18)

Table 1, Fastener Torque Values



Reference Drawing No. D06−24211 Chg. Ltr. "A"
08/13/96

f150589

A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

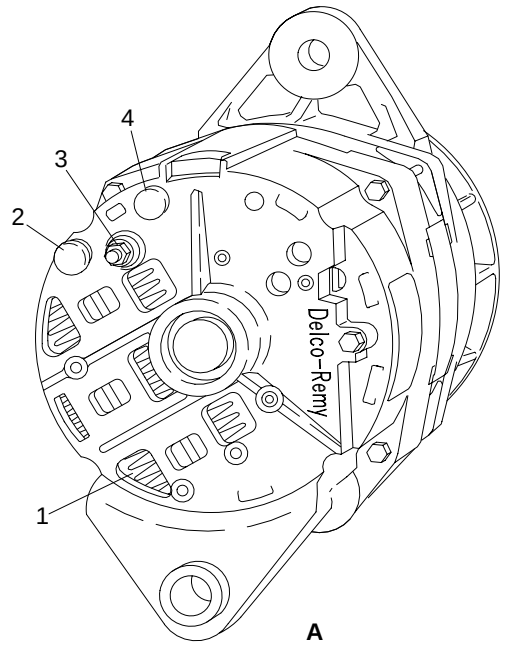
1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 1, Cranking and Charging Circuit Wiring

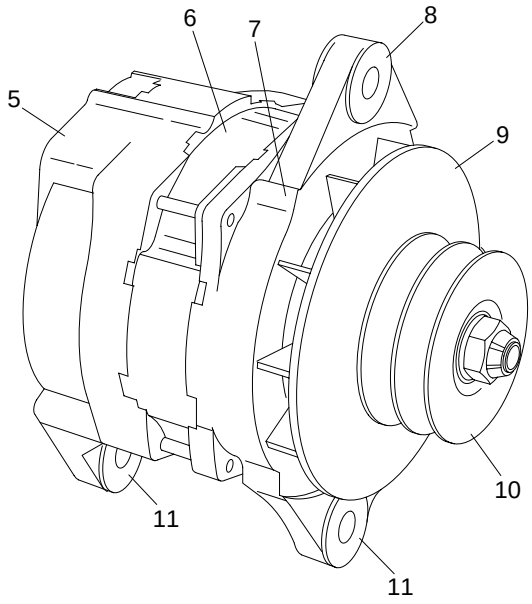
General Information

The Delco Remy 21–SI series alternator features a solid-state regulator that is mounted inside the end frame. See **Fig. 1**. The only moving part in the assembly is the rotor, which is mounted on a ball bearing at the drive end, and a roller bearing at the rectifier end. See **Fig. 2**.

Since the vehicle's system is negative ground, the output terminal connects to the starter's B (positive) terminal.



A



B

01/30/96 f150349a

A. Rectifier End
1. Rectifier Bridge
2. Relay ("R") Terminal
3. Output ("BAT") Terminal
4. Indicator Light ("I") Terminal

B. Drive End
5. Frame, Rectifier End
6. Stator
7. Frame, Drive End
8. Adjustment Lug

9. Fan
10. Pulley
11. Mounting Lug

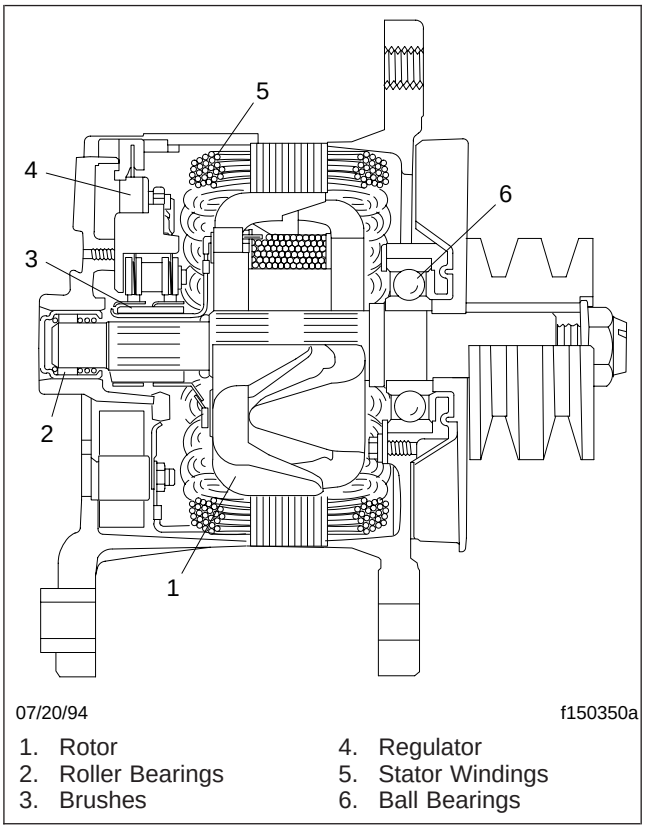
Fig. 1, 21-SI Alternator (exterior view)

All bearings are sealed so that no periodic maintenance is required. The regulator and diodes are enclosed in a sealed compartment. A fan located on the drive end provides air flow for cooling.

As the rotor begins to turn, the permanent magnetism within it induces voltages in the stator windings. The voltages across the diodes cause current to flow, charging the battery.

Normally only one wire connects the alternator to the battery at the starter, along with a ground return.

General Information



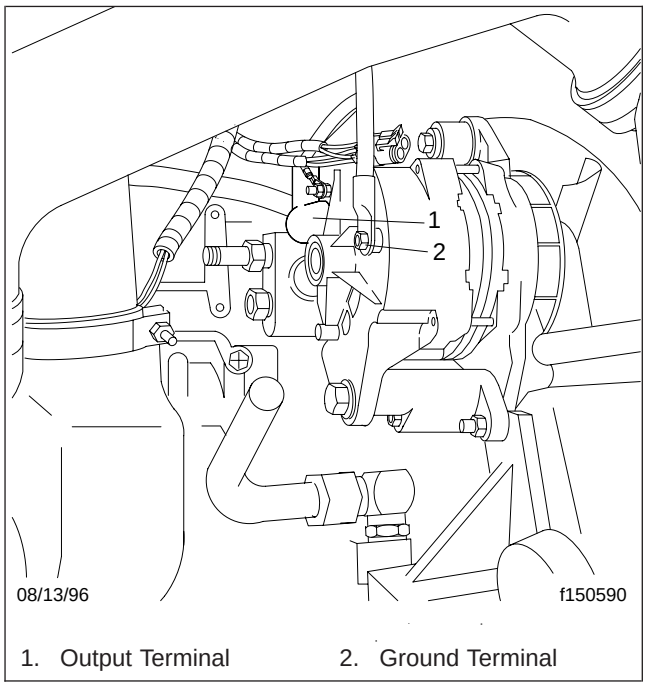
1. Rotor
2. Roller Bearings
3. Brushes
4. Regulator
5. Stator Windings
6. Ball Bearings

Fig. 2, Delco Remy 21-SI Alternator (cutaway view)

Delco Remy Alternator Removal and Installation, Caterpillar CFE

Removal

1. Disconnect the batteries.
2. Mark all electrical leads and disconnect them from the alternator. See **Fig. 1**.



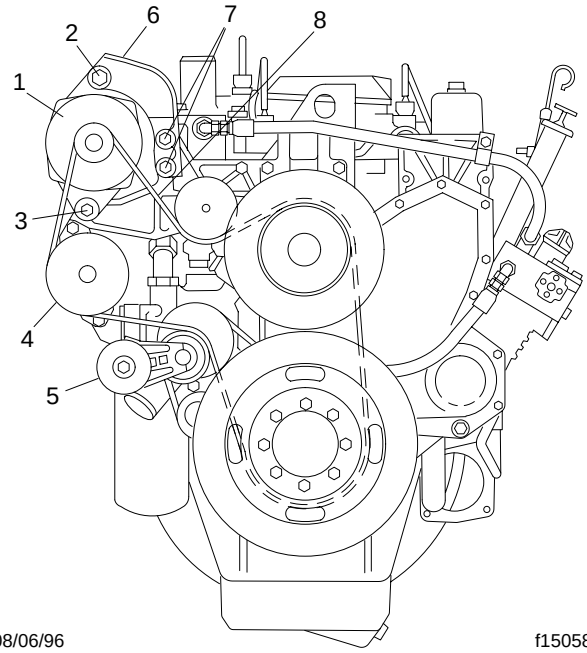
1. Output Terminal 2. Ground Terminal

Fig. 1, Electrical Connectors

3. Insert a breaker bar in the belt tensioner and rotate the tensioner down and off the accessory drive belt. See **Fig. 2**.
4. Holding the belt tensioner down, remove the accessory drive belt from the vehicle.
5. Remove the two alternator mounting capscrews. Remove the alternator from the vehicle.
6. Inspect the drive belt. For instructions, see **Section 01.00, Subject 100**.

Installation

1. Install the alternator on the engine. Install the top and bottom alternator mounting capscrews, but do not tighten them yet.



Rotate the belt tensioner down and off the belt.

1. Delco Remy Alternator
2. Alternator Mounting Capscrew, Upper
3. Alternator Mounting Capscrew, Lower
4. Idler
5. Belt Tensioner
6. Mounting Bracket
7. Alternator Bracket Fasteners
8. Accessory Drive Belt

Fig. 2, Alternator Installation, Caterpillar CFE Engine

CAUTION

CAUTION: Be sure to route the accessory drive belt correctly. If the belt is not routed as in Fig. 2, the water pump pulley may rotate in the wrong direction, allowing the engine to overheat.

2. Install the drive belt on the pulleys, as removed. If installing a new pulley or a new alternator, tighten the pulley nut 75 lbf·ft (102 N·m).

NOTE: The Caterpillar belt tensioner automatically adjusts the accessory drive belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the engine manufacturer's service literature.

3. Tighten both alternator mounting capscrews 65 lbf·ft (88 N·m).

Delco Remy Alternator Removal and Installation, Caterpillar CFE

4. Connect all leads to the back of the alternator as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm). Tighten the ground terminal nut 65 lbf·in (740 N·cm).
5. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

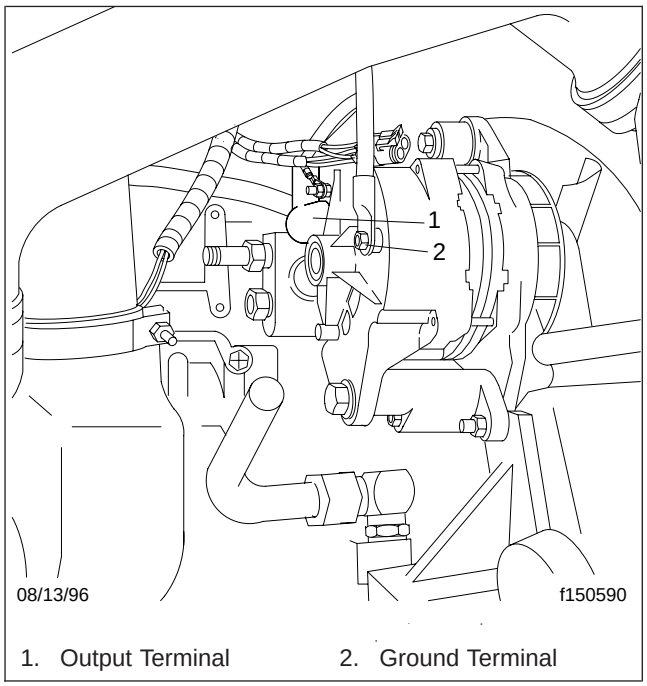
Table 1, Approved Dielectric Red Enamel

6. Connect the batteries.
7. Before returning the vehicle to operation, test the alternator DC output voltage. For instructions, see "Alternator Voltage Output Test" in **Troubleshooting, 300**.

Delco Remy Alternator Removal and Installation, Cummins B

Removal

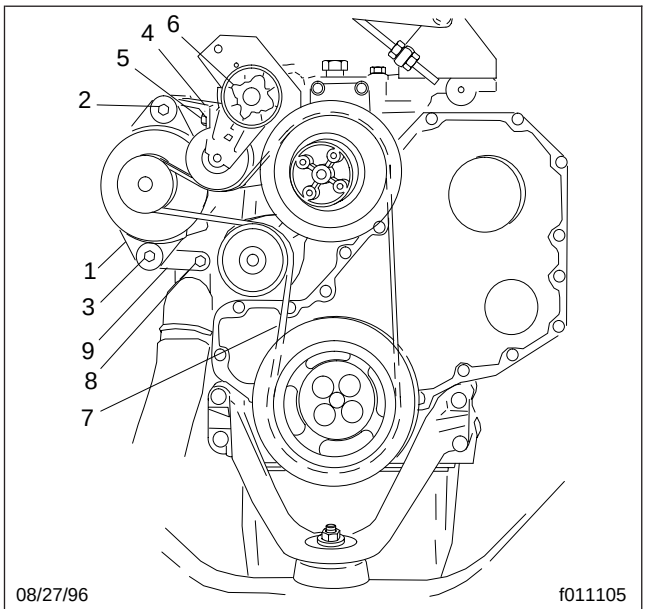
1. Disconnect the batteries.
2. Mark all electrical leads and disconnect them from the alternator. See **Fig. 1**.



1. Output Terminal
2. Ground Terminal

Fig. 1, Electrical Connectors

3. Remove the alternator belt from the alternator pulley. See **Fig. 2**.
   - 3.1 Insert a breaker bar in the belt tensioner and rotate the tensioner up and off the belt.
   - 3.2 Holding the tensioner up, take the belt off the alternator pulley.
   - 3.3 Slowly release the belt tensioner, and remove the breaker bar. It is not necessary to remove the belt from the vehicle.
4. Remove the alternator. See **Fig. 3**.
   - 4.1 Remove the alternator mounting capscrew (Ref. 8) from the link (Ref. 7).
   - 4.2 Remove the nut and washer (Refs. 5 and 4) from the pivot capscrew (Ref. 1).



Rotate the belt tensioner down and off the belt.

1. Delco Remy Alternator
2. Pivot Capscrew
3. Alternator Mounting Capscrew
4. Pivot Bracket
5. Alternator Bracket Fastener
6. Belt Tensioner
7. Alternator Drive Belt
8. Alternator Link Fastener
9. Alternator Link

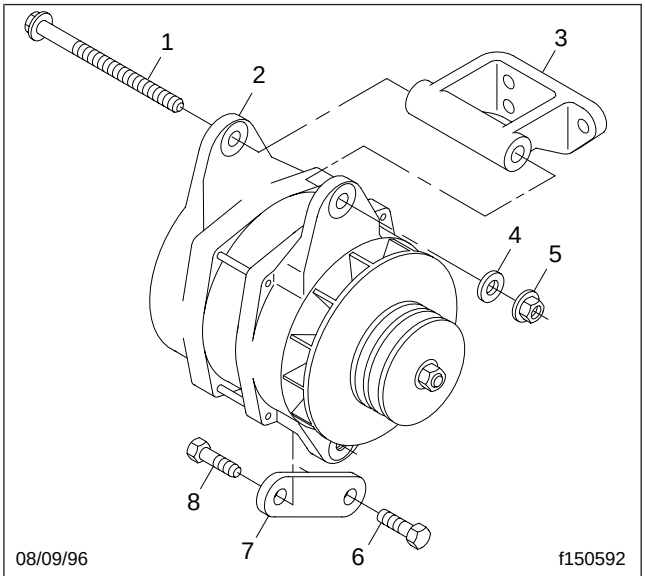
Fig. 2, Alternator Installation, Cummins B Series Engine

   - 4.3 Securely hold the alternator to prevent it from falling, and remove the pivot capscrew.
   - 4.4 Remove the alternator from the vehicle.
5. Inspect the drive belt. For instructions, see **Section 01.01, Subject 100**.

Installation

1. Install the alternator on the pivot bracket. See **Fig. 3**.
   - 1.1 Position the alternator on the bracket.
   - 1.2 Insert the pivot capscrew (Ref. 1) through the alternator and the bracket.

Delco Remy Alternator Removal and Installation, Cummins B



1. Pivot Capscrew
2. Mounting Lug
3. Pivot Bracket
4. Washer
5. Pivot Nut
6. Alternator Link Fastener
7. Alternator Link
8. Alternator Mounting Capscrew

Fig. 3, Mounting Hardware

1.3 Install the washer and nut (Refs. 4 and 5) on the end of the pivot capscrew.

2. Install the alternator mounting capscrew, and tighten it 16 lbf·ft (21 N·m). Tighten the pivot nut 40 lbf·ft (54 N·m).

3. Install the drive belt on the pulley as removed. If installing a new pulley or a new alternator, tighten the pulley nut 75 lbf·ft (102 N·m).

NOTE: The Cummins belt tensioner automatically adjusts the drive belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the engine manufacturer's service literature.

4. Connect all leads to the back of the alternator as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm). Tighten the ground terminal nut 65 lbf·in (740 N·cm).

5. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

Table 1, Approved Dielectric Red Enamel

6. Connect the batteries.

7. Before returning the vehicle to operation, test the alternator DC output voltage. For instructions, see "Alternator Voltage Output Test" in **Troubleshooting, 300**.

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 Delco 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 Delco Intelli-Check Tester, and is similar to the procedures provided by Delco with the Intelli-Check Tester.

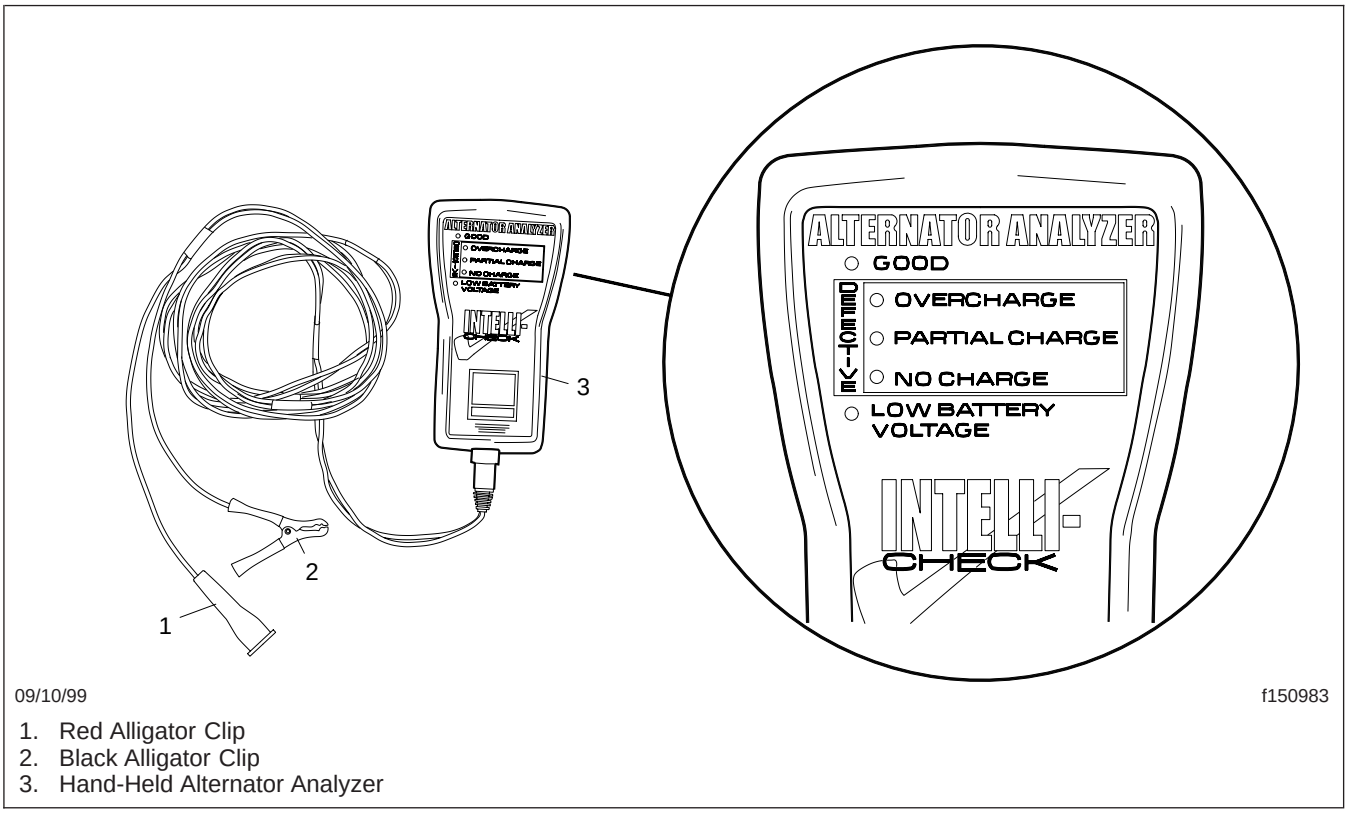
Pre-Test Procedure (Engine Off)

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 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 for 2 hours. Start the test again after charging the batteries.
2. Verify 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

Troubleshooting



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

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

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

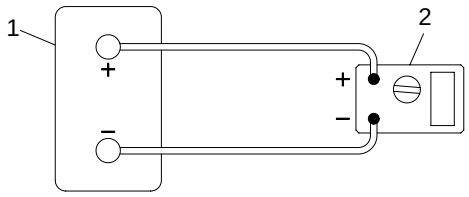
1. Use a digital volt-ohmmeter (VOM) set on the 2-20VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in **Fig. 2**, check for voltage of 12.4 volts or more.

   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.

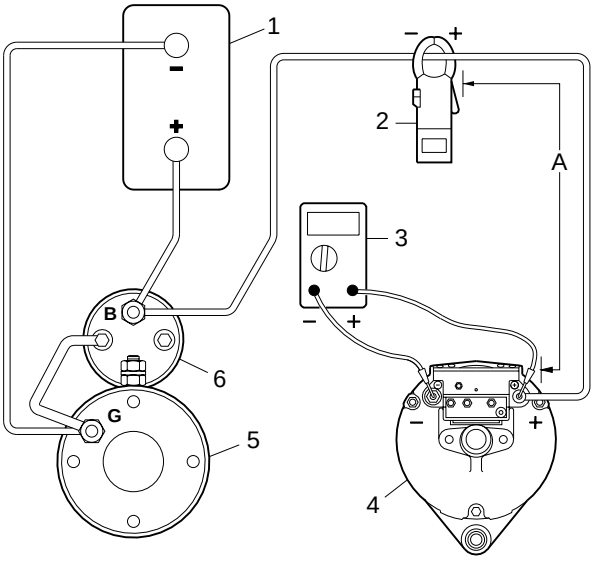
2. Check the alternator output without a load. See **Fig. 3**.



02/26/97 f150607

1. Battery
2. Digital Voltmeter

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



02/11/98 f150938

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 2-20VDC 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 the alternator reads less than 13.8 volts and is adjustable, try to adjust the voltage regulator to 13.8 to 14.2 volts. If unable to obtain acceptable output, replace the alternator.

3. Check the alternator output under load. 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.

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

Troubleshooting

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 rpms 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. 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 volts 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 volts lower than the reading at the alternator, do the next step.

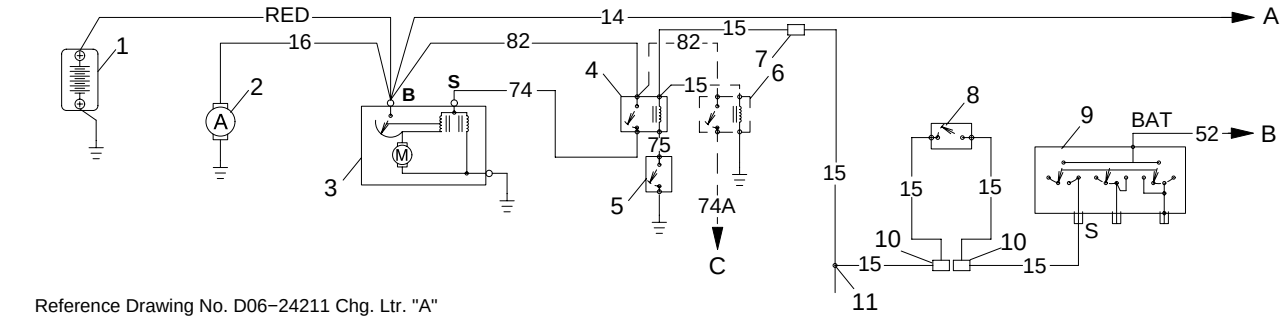
6. Check charging system connections, cables and terminals.

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.

See **Fig. 1** for a charging circuit wiring diagram.



A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 1, Charging Circuit Wiring Diagram

Mounting Fastener Torques, Caterpillar Engines			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Caterpillar CFE Engine			
Alternator Mounting Capscrews	8PO	1/2–13	65 (88)
Alternator Bracket Capscrews	10.9PO	M12	65 (88)

Table 1, Mounting Fastener Torques, Caterpillar Engines

Mounting Fastener Torques, Cummins Engines			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Cummins B Series Engine			
Alternator Mounting Capscrew	10.9PO	M8 x 1.25	16 (21)
Pivot Nut	10.9PO	M10 x 1.5	40 (54)

Table 2, Mounting Fastener Torques, Cummins Engines

Description	Grade	Size	Torque: lbf·in (N·cm)
Alternator Output ("BAT") Terminal Nut	5	5/16–18	100 (1140)
Alternator Ground ("G") Terminal Nut	5	1/4–20	65 (740)

Table 3, Terminal Fastener Torques, All Engines

Specifications

Description	Grade	Size	Torque: lbf·ft (N·m)
Pulley Nut	8PO	1/2–20	75 (102)

Table 4, Pulley Nut Torque, All Engines

General Description

The Leece-Neville JB series alternator is a 14-volt self-load-limiting alternator equipped with a three-step adjustable voltage regulator. See **Fig. 1**. For voltage regulator adjustment procedures, see **Subject 130**.

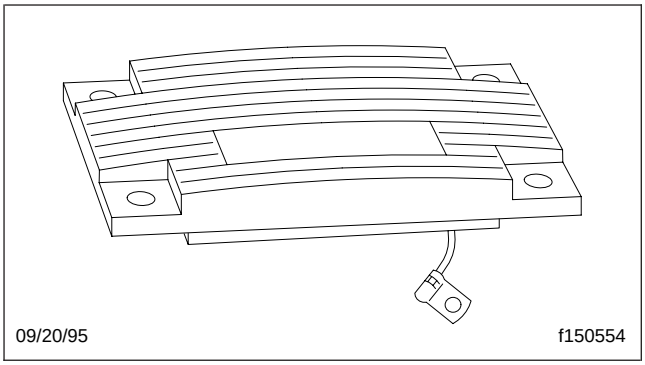


Fig. 1, Three-Step Adjustable Voltage Regulator

Six silicon diodes mounted in heat sinks convert alternating current from the delta-wound stator into direct current. A capacitor connected between the heat sinks helps suppress transient voltage spikes, which could possibly damage the diodes.

The brushes and voltage regulator are located in a waterproof housing that may be removed for replacement or inspection. An external relay terminal is also provided.

The voltage regulator is also equipped with transient voltage protection and will withstand instantaneous opening of the charging circuit under full load conditions.

The LC models are identical to the JB models but are improved in the following ways:

- The rear rotor bearings are stronger and more durable;
- The diode post installation has been improved;
- The rectifier heat sink has a larger capacity.

The LCF models have all the same improvements as the LC models. In addition, the front bearing is secured with five bolts instead of four.

Principles of Operation

Current is produced by rotating a magnet inside a stationary winding. The rotating magnet is called a rotor and the stationary winding is called a stator. See **Fig. 2**.

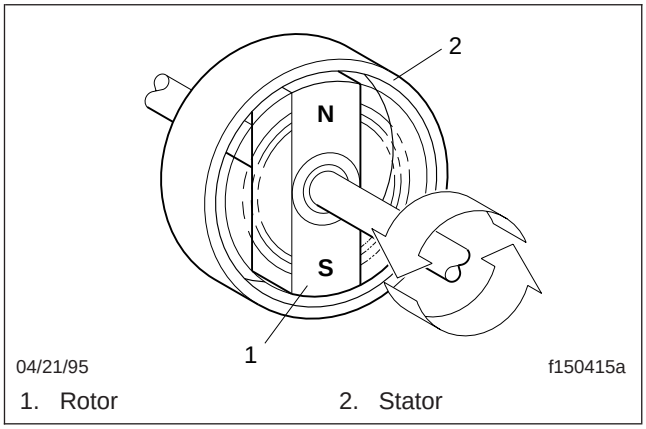


Fig. 2, Producing the Current

The rotor is electrically magnetized by a small current flowing through the brushes, riding on smooth slip rings. See **Fig. 3**. Alternating current is then produced as the magnetic poles of the rotor pass the coil windings of the stator.

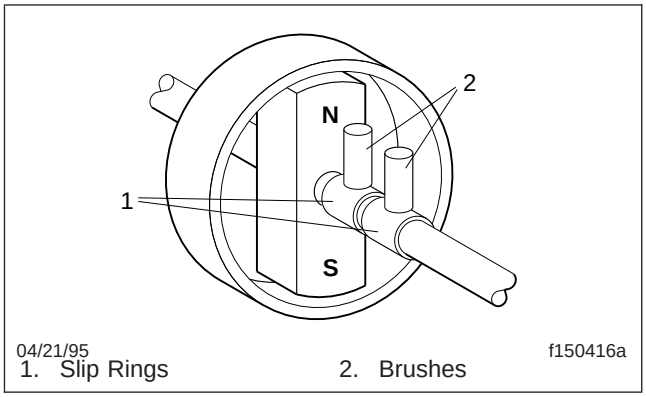


Fig. 3, Magnetizing the Rotor

These alternators have 12 magnetic poles in the rotor and three separate windings in the stator. See **Fig. 4**. Since the rotor produces alternating current as it passes the coil windings of the stator, increased engine speed produces more current. See **Fig. 5**.

Rectifier assemblies convert alternating current to direct current for storage in the batteries. Rectifiers

General Information

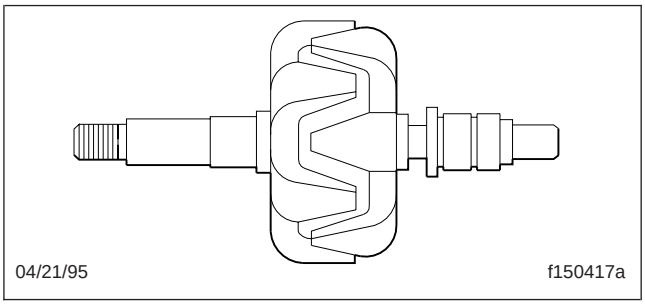


Fig. 4, Rotor

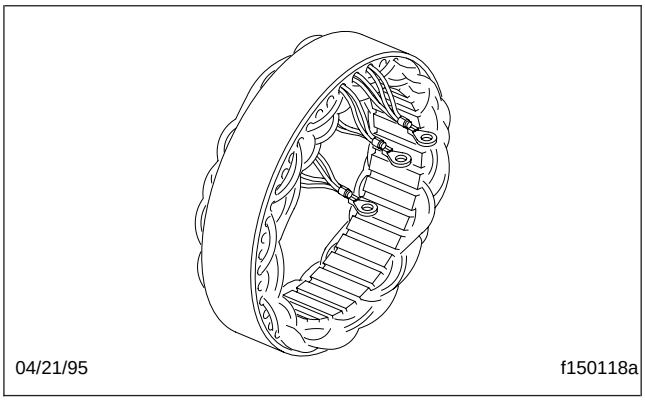


Fig. 5, Stator

consist of silicon diodes that work as electrical switches and permit current flow in only one direction. They are mounted in an aluminum casting, which is finned to dissipate heat. This is called a heat sink. See **Fig. 6**.

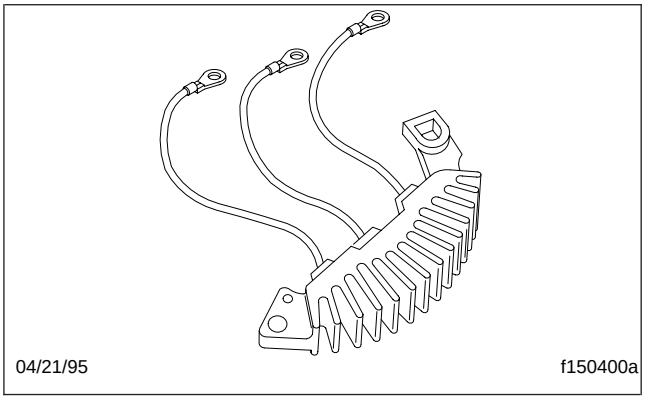


Fig. 6, Heat Sink

The voltage regulator controls the alternator output and the state of charge of the batteries. See **Fig. 1**.

It is used in the charging system to regulate the battery voltage to the vehicle.

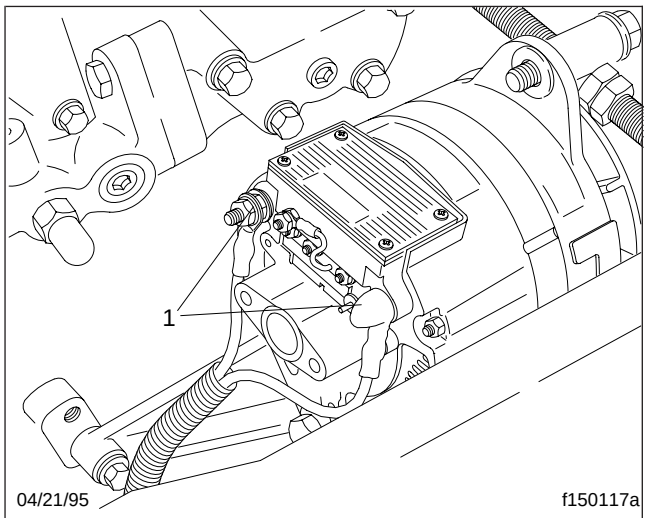
The diode trio converts a small amount of alternating current from the stator into direct current which is used as a signal to turn on the regulator.

When the battery is charged, the regulator reduces the field current flow to the rotor. Reducing the field current flow, in turn, reduces the alternator output. When the headlights or accessories place a load on the battery, the regulator increases the current flow to the rotor, and alternator output increases, to maintain voltage.

Leece-Neville Alternator Removal and Installation, Caterpillar CFE

Removal

1. Disconnect the batteries.
2. Mark all electrical leads and disconnect them from the alternator. See **Fig. 1**.



1. Lead Connections

Fig. 1, Electrical Connectors

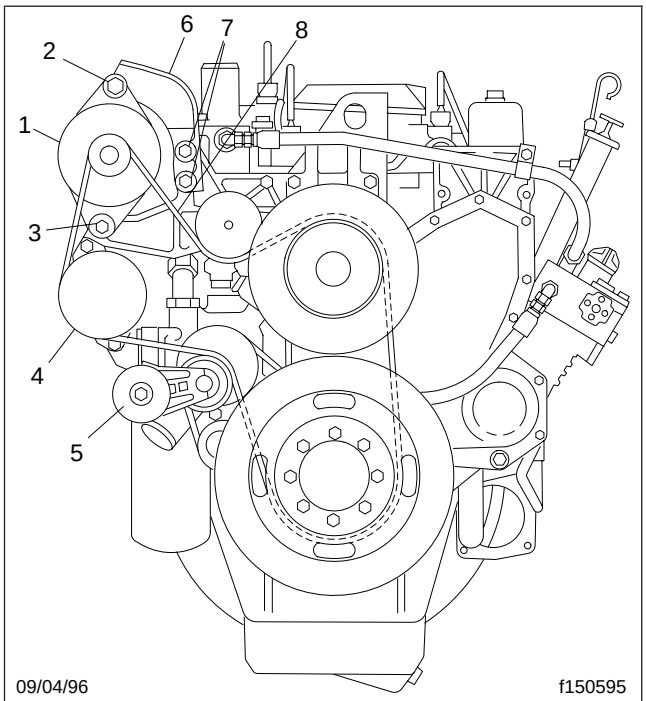
3. Insert a breaker bar in the belt tensioner and rotate the tensioner down and off the accessory drive belt. See **Fig. 2**.
4. Holding the belt tensioner down, remove the accessory drive belt from the vehicle.
5. Remove the two alternator mounting capscrews. Remove the alternator from the vehicle.
6. Inspect the drive belt. For instructions, see **Section 01.00, Subject 100**.

Installation

1. Install the alternator on the engine. Install the top and bottom alternator mounting capscrews, but do not tighten them yet.

CAUTION

CAUTION: Be sure to route the accessory drive belt correctly. If the belt is not routed as in Fig. 2, the water pump pulley may rotate in the wrong direction, allowing the engine to overheat.



Rotate the belt tensioner down and off the belt.

1. Leece-Neville Alternator
2. Alternator Mounting Capscrew, Upper
3. Alternator Mounting Capscrew, Lower
4. Idler
5. Belt Tensioner
6. Mounting Bracket
7. Alternator Bracket Fasteners
8. Accessory Drive Belt

Fig. 2, Alternator Installation, Caterpillar CFE Engine

2. Install the drive belt on the pulleys, as removed. If installing a new pulley or a new alternator, tighten the pulley nut 75 lbf·ft (102 N·m).

NOTE: The Caterpillar belt tensioner automatically adjusts the accessory drive belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the engine manufacturer's service literature.

3. Tighten both alternator mounting capscrews 65 lbf·ft (88 N·m).
4. Connect all leads to the back of the alternator as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm). Tighten the ground terminal nut 65 lbf·in (740 N·cm).

Leece-Neville Alternator Removal and Installation, Caterpillar CFE

5. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

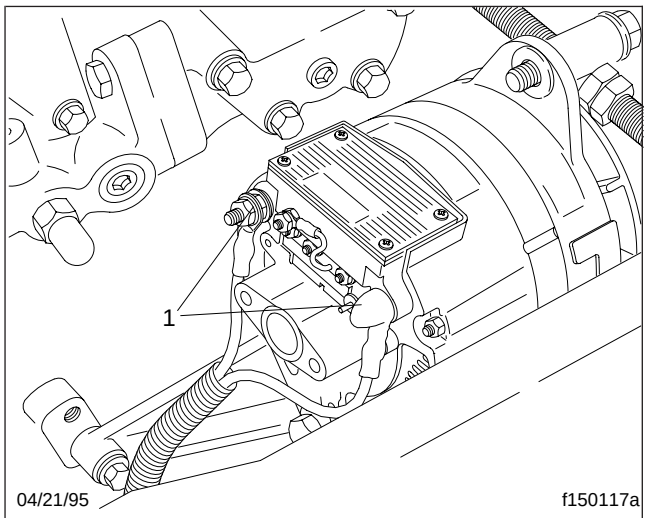
Table 1, Approved Dielectric Red Enamel

6. Connect the batteries.
7. Before returning the vehicle to operation, test the alternator DC output voltage. For instructions, see "Alternator Voltage Output Test" in **Troubleshooting, 300**.

Leece-Neville Alternator Removal and Installation, Cummins B

Removal

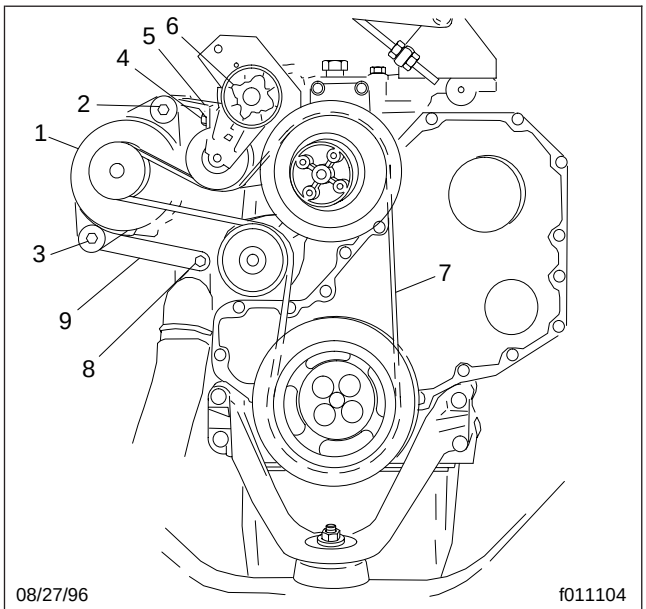
1. Disconnect the batteries.
2. Mark all electrical leads and disconnect them from the alternator. See **Fig. 1**.



1. Lead Connections

Fig. 1, Electrical Connectors

3. Remove the alternator belt from the alternator pulley. See **Fig. 2**.
   - 3.1 Insert a breaker bar in the belt tensioner and rotate the tensioner up and off the belt.
   - 3.2 Holding the tensioner up, take the belt off the alternator pulley.
   - 3.3 Slowly release the belt tensioner, and remove the breaker bar. It is not necessary to remove the belt from the vehicle.
4. Remove the alternator. See **Fig. 3**.
   - 4.1 Remove the alternator mounting capscrew from the link.
   - 4.2 Remove the nut and washer from the pivot capscrew.
   - 4.3 Securely hold the alternator to prevent it from falling, and remove the pivot capscrew.
   - 4.4 Remove the alternator from the vehicle.



Rotate the belt tensioner up and off the belt.

1. Leece-Neville Alternator
2. Pivot Capscrew
3. Alternator Mounting Capscrew
4. Pivot Bracket
5. Pivot Bracket Fastener
6. Belt Tensioner
7. Alternator Drive Belt
8. Alternator Link Fastener
9. Alternator Link

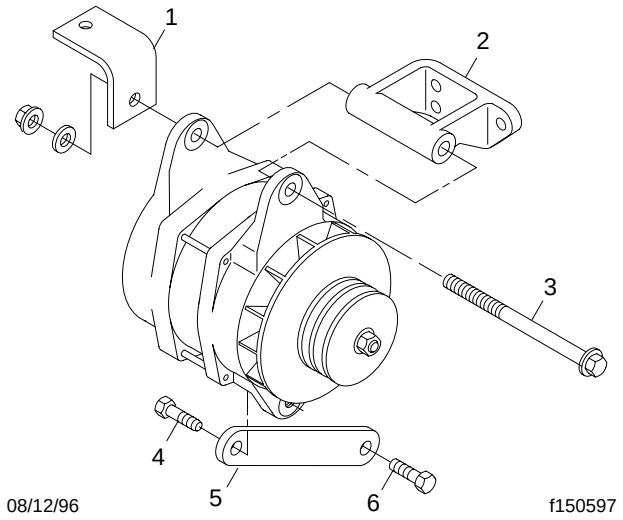
Fig. 2, Alternator Installation, Cummins B Series Engine

5. Inspect the drive belt. For instructions, see **Section 01.01, Subject 100**.

Installation

1. Install the alternator on the pivot bracket. See **Fig. 3**.
   - 1.1 Position the alternator on the bracket.
   - 1.2 Insert the pivot capscrew through the alternator, the bracket, and the brace.
   - 1.3 Install the washer and nut on the end of the pivot capscrew.
2. Install the alternator mounting capscrew, and tighten it 16 lbf·ft (21 N·m). Tighten the pivot capscrew 40 lbf·ft (54 N·m).

Leece-Neville Alternator Removal and Installation, Cummins B



1. Brace
2. Pivot Bracket
3. Pivot Capscrew
4. Alternator Mounting Capscrew
5. Alternator Link
6. Alternator Link Fastener

Fig. 3, Mounting Hardware

3. Install the drive belt on the pulley as removed. If installing a new pulley or a new alternator, tighten the pulley nut 75 lbf·ft (102 N·m).

NOTE: The Cummins belt tensioner automatically adjusts the drive belt to the correct tension. If the belt slips, repair or replace the tensioner. For instructions, see the engine manufacturer's service literature.

4. Connect all leads to the back of the alternator as removed. Tighten the output terminal nut 100 lbf·in (1140 N·cm). Tighten the ground terminal nut 65 lbf·in (740 N·cm).
5. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

Table 1, Approved Dielectric Red Enamel

6. Connect the batteries.
7. Before returning the vehicle to operation, test the alternator DC output voltage. For instructions, see "Alternator Voltage Output Test" in **Troubleshooting, 300**.

Adjustment

NOTE: Before checking or adjusting the alternator voltage, check the wiring, connections, and belt tension.

1. Turn off all accessories. Run the engine at fast idle (approximately 1200 RPM) and charge the batteries.
2. Connect an accurate voltmeter across the batteries to determine the charging voltage. If the voltage is below 13.8V, or above 14.1V, adjust the voltage regulator.
3. Shut down the engine.
4. If needed, adjust the charging voltage.
   - 4.1 Remove the small black cap on the regulator cover to expose the adjustment screw.
   - 4.2 Using a small screwdriver, turn the adjusting screw until the voltage is between 13.8V and 14.1V.
     - To increase the voltage, turn the adjusting screw clockwise.
     - To decrease the voltage, turn the adjusting screw counterclockwise.
5. Run the engine at fast idle (approximately 1200 RPM) and check the voltage again to make sure it has been properly adjusted. Readjust as necessary.

NOTE: If adjustment does not bring the voltage into the proper range, replace the voltage regulator.

6. Shut down the engine.
7. Replace the plastic cap on the access hole over the adjusting screw.

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.

To troubleshoot the SmartChek™ diagnostic alternator perform the following steps:

1. With the engine off, clean the top of the regulator using a shop cloth until you can see the SmartChek indicator.
2. Start the engine. If the SmartChek indicator glows red, replace the alternator.

   If the indicator glows green, go to the next step.
3. Turn on several vehicle accessories, such as lights and heater fans. If the green indicator changes to red, replace the alternator.

   If the indicator continues to glow green, the alternator is OK. Check the other components of the electrical system.

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 Delco 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."

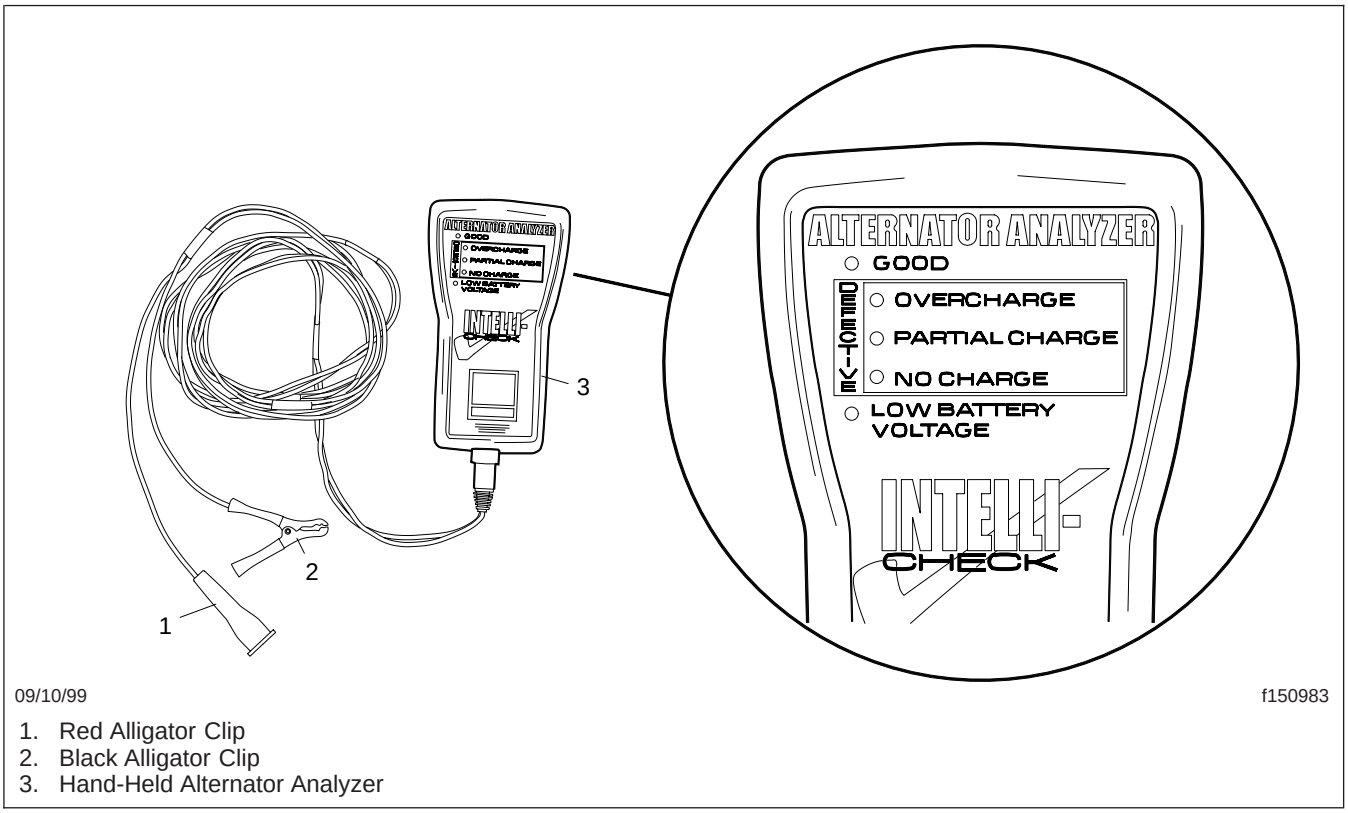
Intelli-Check Alternator Analyzer

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

Troubleshooting



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

Fig. 1, Delco Remy Intelli-Check Alternator Analyzer

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 for 2 hours. Start the test again after charging the batteries.
2. Verify 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

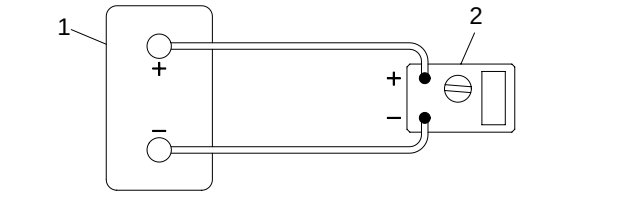
1. Use a digital volt-ohmmeter (VOM) set on the 2-20VDC (or similar) scale to test the battery open circuit voltage (OCV). With the engine shut down and the voltmeter set up as shown in **Fig. 2**, check for voltage of 12.4 volts or more.

   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. See **Fig. 3**.



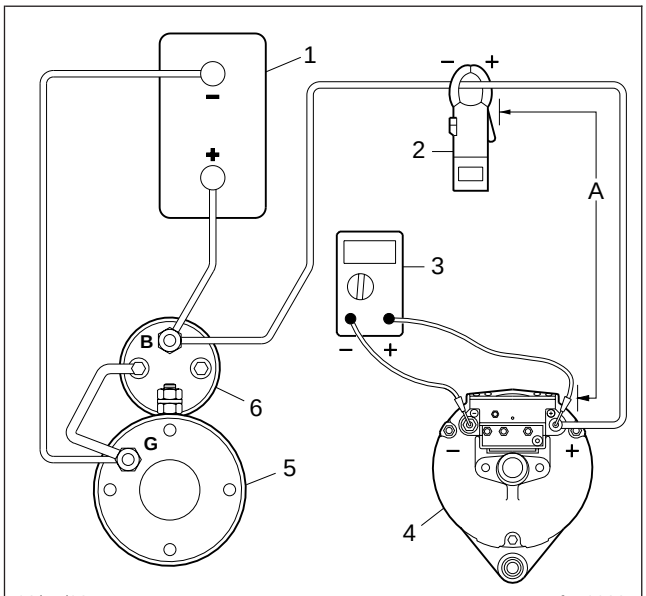
02/26/97 f150607

1. Battery
2. Digital Voltmeter

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

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 2-20VDC or similar scale) to the alternator (battery) terminal. Connect the negative (–) lead of the voltmeter to the alternator negative (–) ground terminal. See **Fig. 3**.



02/11/98 f150938

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 Voltage

2.3 If the voltmeter reads from 13.8 to 14.2 volts, record this reading (V1) and go to the next step. If the alternator reads less than 13.8 volts and is adjustable, try to adjust the voltage regulator to 13.8 to 14.2 volts. If unable to obtain acceptable output, replace the alternator.

3. Check the alternator output under load. 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)

Troubleshooting

- 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.

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 rpms 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. 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 volts 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 volts lower than the reading at the alternator, do the next step.

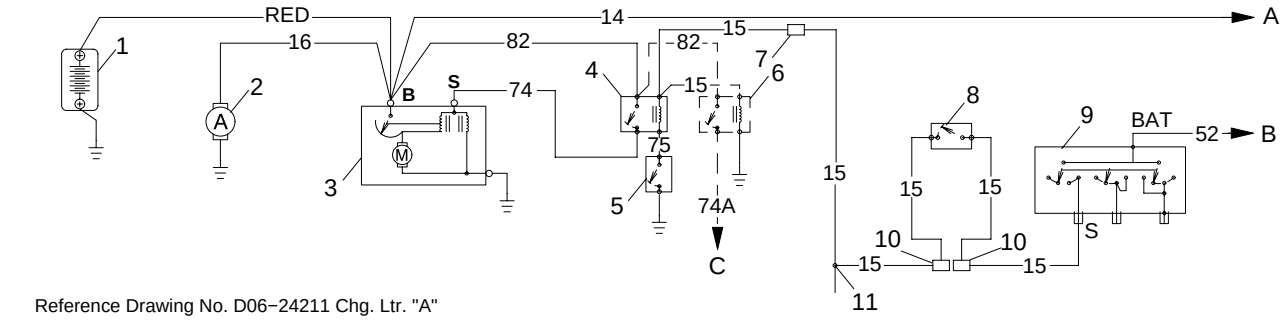
6. Check charging system connections, cables and terminals.

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.

See **Fig. 1** for a charging circuit wiring diagram.



A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 1, Charging Circuit Wiring Diagram

Mounting Fastener Torques, Caterpillar Engines			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Caterpillar CFE Engine			
Alternator Mounting Capscrews	8PO	1/2–13	65 (88)
Alternator Bracket Capscrews	10.9PO	M12	65 (88)

Table 1, Mounting Fastener Torques, Caterpillar Engines

Mounting Fastener Torques, Cummins Engines			
Description	**Grade**	**Size**	**Torque: lbf·ft (N·m)**
Cummins B Series Engine			
Alternator Mounting Capscrew	10.9PO	M8 x 1.25	16 (21)
Pivot Capscrew	10.9PO	M10 x 1.5	40 (54)

Table 2, Mounting Fastener Torques, Cummins Engines

Description	Grade	Size	Torque: lbf·in (N·cm)
Alternator Output ("BAT") Terminal Nut	5	5/16–18	100 (1140)
Alternator Ground ("G") Terminal Nut	5	1/4–20	65 (740)

Table 3, Terminal Fastener Torques, All Engines

Specifications

Description	Grade	Size	Torque: lbf·ft (N·m)
Pulley Nut	8PO	1/2–20	75 (102)

Table 4, Pulley Nut Torque, All Engines

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 coolant plumbing for your vehicle, refer to the applicable figure from the list below:

- For a Cummins B or C Series engine, see **Fig. 1**.
- For a Caterpillar CFE Series engine, see **Fig. 2**.

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.

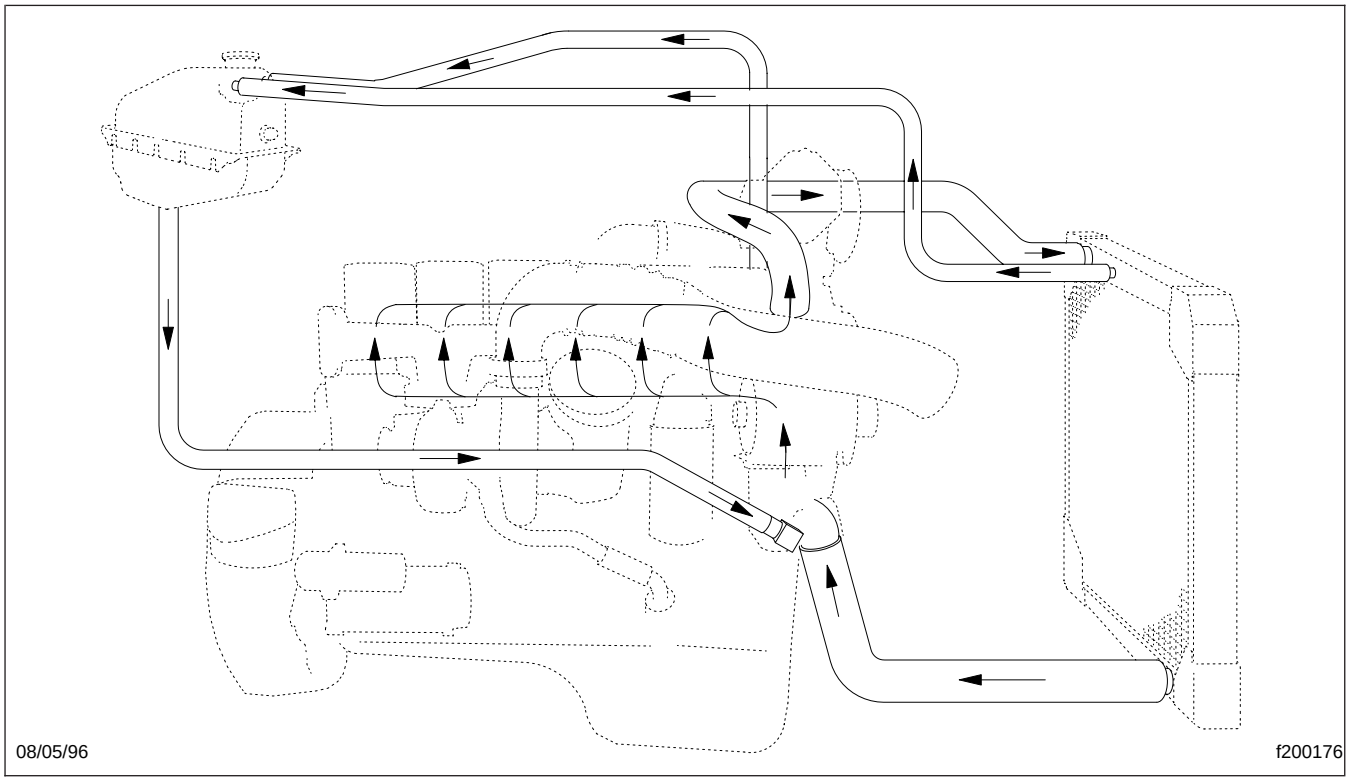
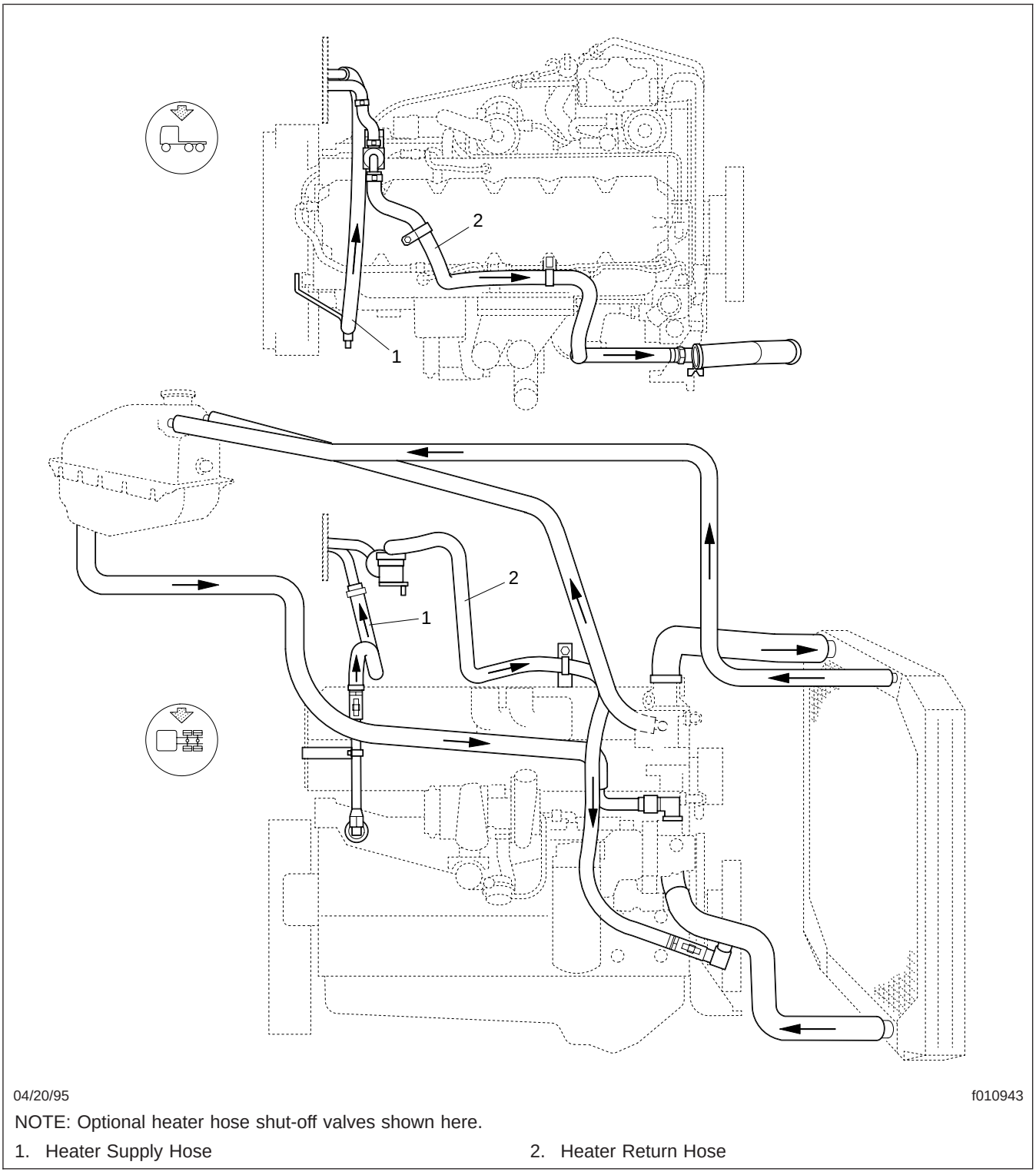


Fig. 1, Coolant Plumbing for a Cummins B or C Series Engine

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, 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



04/20/95 f010943

NOTE: Optional heater hose shut-off valves shown here.

1. Heater Supply Hose
2. Heater Return Hose

Fig. 2, Coolant Plumbing for a Caterpillar CFE Series Engine

Possible causes of abnormally high or low coolant temperatures are listed below. For repairs, refer to other sections of this manual or to the engine and component manufacturer's service publications.

This subject contains the following troubleshooting tables:

- Coolant Temperature Above Normal
- Coolant Temperature Below Normal

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 core 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.	Do the repairs necessary to stop the leaks. Fill to the surge tank sight glass with the correct mixture of antifreeze and water. Refer to the vehicle maintenance manual for coolant specifications.
The temperature gauge is not working.	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.
The radiator or charge air cooler is clogged.	Clean the outside of the core with compressed air directed from the fan side, or with water and a mild laundry soap. Straighten bent fins.
A radiator hose is collapsed or plugged.	Replace the hose(s).
A fan belt or water pump belt is loose.	Adjust belt tension.
The cooling fan shroud is damaged.	Repair or replace the shroud.
The radiator cap is incorrect or malfunctioning.	Make sure the correct radiator cap is installed. If the cap does not hold the correct pressure, replace it.
The viscous fan drive is not operating to specifications.	Check for unobstructed airflow through the radiator core and charge air cooler 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.
The engine oil level is incorrect.	Fill to the high (H) mark on the dipstick.
There is too much antifreeze in the system.	Clean and flush the cooling system. Refill the system with the correct mixture of antifreeze and water.
The thermostat is incorrect or inoperative.	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.
The water pump is not working correctly.	Repair or replace the water pump.

Troubleshooting

Problem—Coolant Temperature Above Normal	
Possible Cause	**Remedy**
The radiator core is internally plugged or damaged.	To check for blockages, warm the engine to normal operating temperature. Turn off the engine, and run your hand over the finned surface of the radiator. If there is a blockage in the radiator, it should cause an obvious temperature difference from one area of the core to another. An obvious difference between inlet and outlet temperatures is normal. If blockage is suspected, clean and flush the cooling system. Repair or replace a damaged core.
Air or combustion gases are entering the cooling system.	Check the cylinder heads, head gaskets, cylinder liners, and charge air cooler for leaks. Repair or replace parts, as necessary.
The charge air cooler is internally plugged or damaged.	Repair or replace the charge air cooler.
The oil cooler is internally plugged or damaged.	Repair or replace the oil cooler.
The engine is receiving too much fuel.	Refer to the engine manufacturer's fuel delivery system adjustment procedures.
The wrong replacement fan was installed.	Install the correct fan.
There is exhaust blockage.	Remove the blockage.
Coolant is frozen in the 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**
The temperature gauge is not working.	Check the gauge circuit wires, circuit breaker, and sending unit. If the gauge circuit is okay, replace the temperature gauge. If the gauge circuit is broken, repair it and then check the temperature gauge operation.
The viscous fan drive operates continuously.	Refer to the viscous fan clutch section in this group for fan clutch inspection procedures and operation tests. Replace the fan drive if necessary.
The thermostat is incorrect or inoperative.	Make sure the correct thermostat is installed. Test the thermostat according to the engine manufacturer's instructions. Replace it if it does not operate correctly.

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 cap. See **Fig. 1**.

The surge tank provides extra 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 extra space in 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.

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

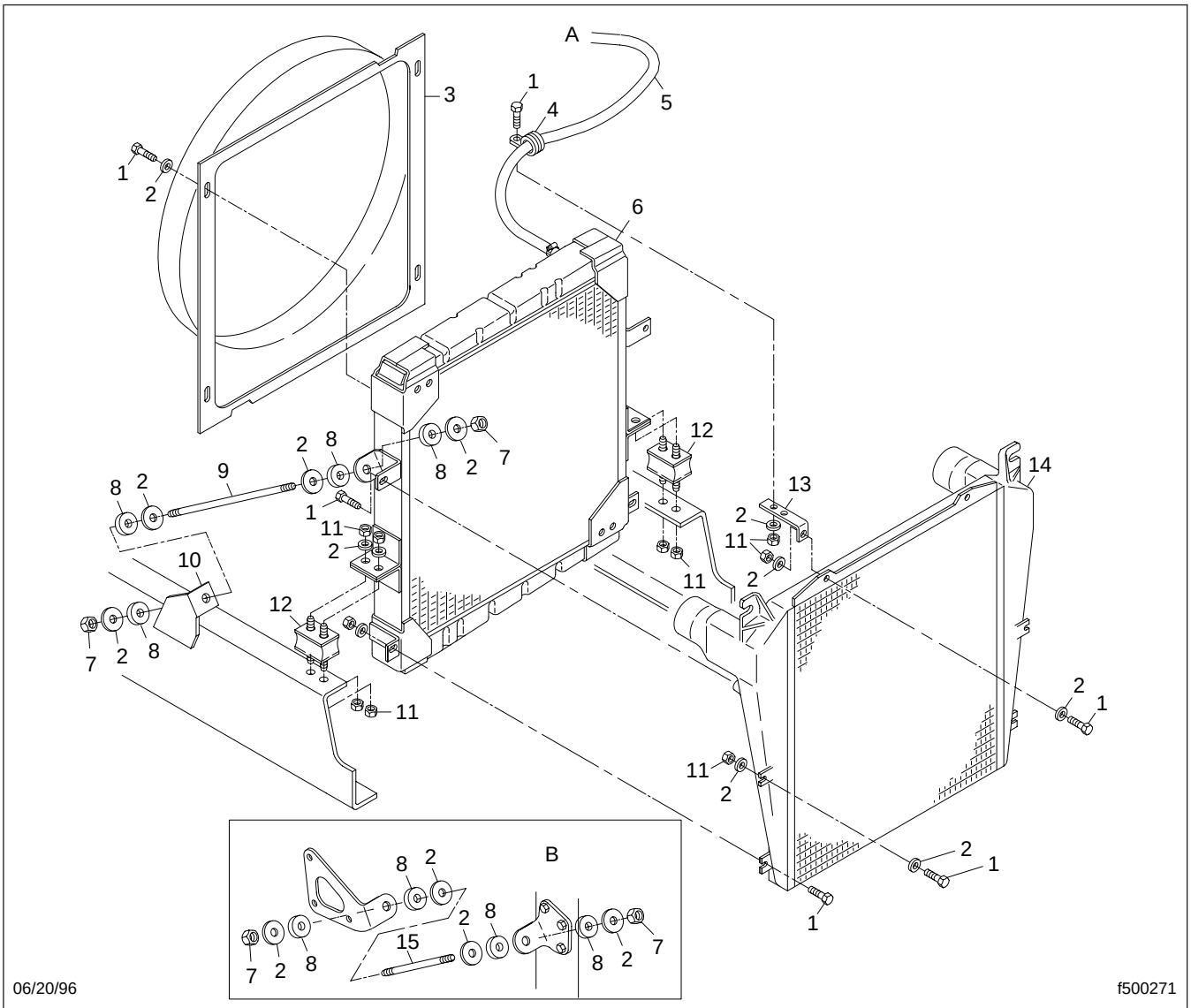
The radiator is composed of a core and two side tanks, and the tanks and radiator core are held in steel side channels that mount on the frame rails. See **Fig. 2**.

The side tanks are made of glass-filled nylon, and the edges of the radiator core header are compressed in a "dimple wave lock" crimp that holds the tanks on the radiator core. See **Fig. 3**. The fins of the radiator core are reinforced along their forward edge to resist damage from road debris and pressure washing.

Because crimping holds the nylon top and bottom tanks in place, the radiator can be disassembled and assembled.

The surge tank cap limits system pressure to about 62 psi (9 kPa), which raises the boiling point of the coolant. If the cooling system overheats, excess coolant is released through the overflow tube.

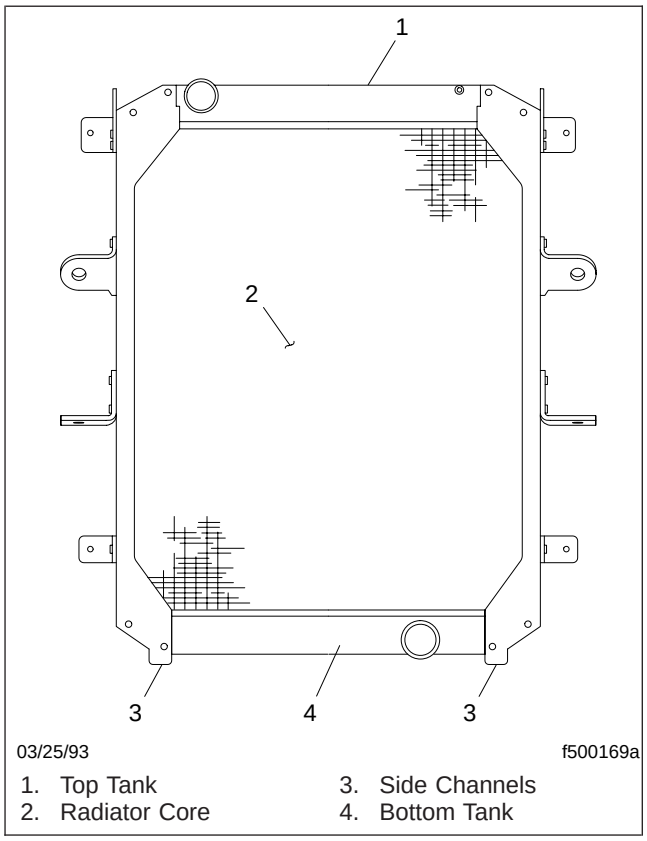
General Information



A. to surge tank
B. Right-Side Strut Installation, Caterpillar CFE Engines

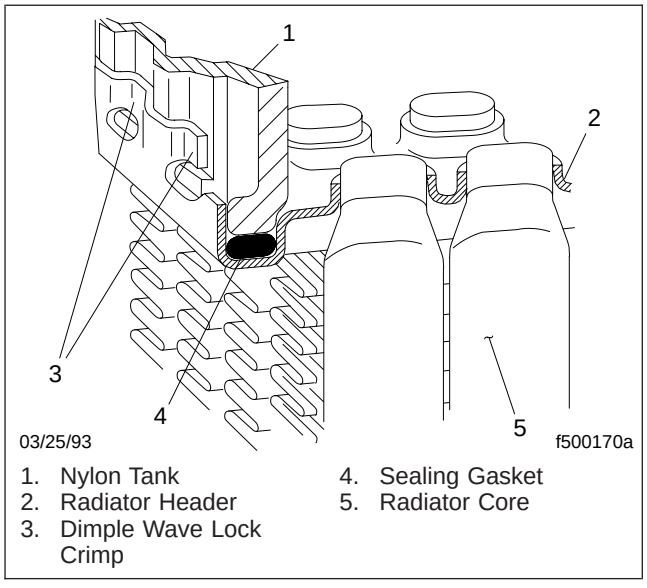
1. Bolt
2. Washer
3. Fan Shroud
4. Hose Clamp
5. Radiator Vent Hose
6. Radiator
7. Nut
8. Rubber Isolator
9. Radiator Strut
10. Radiator Strut Bracket
11. Nut
12. Radiator Mounting Stud
13. Stand-off Bracket
14. Charge Air Cooler
15. Shortened Right-Side Strut, Used with Caterpillar CFE Engines

Fig. 1, Radiator Installation for Caterpillar and Cummins B and C series Engines



1. Top Tank
2. Radiator Core
3. Side Channels
4. Bottom Tank

Fig. 2, Radiator Components



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

Fig. 3, Radiator Crimping

Radiator Removal and Installation

Removal

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

   Tilt the hood.

⚠ WARNING

Do not drain coolant from a hot engine. Opening the cooling system when the engine and coolant are hot can cause severe personal injury due to scalding by the hot, pressurized coolant.

2. Drain the radiator.
3. Remove the hood. For instructions, see **Group 88**.
4. Remove the radiator and charge air cooler assembly.
   - 4.1 Remove the air hoses from the charge air cooler. See **Fig. 1.** Seal the hose ends.
   - 4.2 Remove the radiator vent hose and coolant inlet hose from the radiator. Seal the hose ends.
   - 4.3 Remove the coolant outlet hose from the bottom of the radiator. Seal the hose ends.
   - 4.4 Using lifting chains, secure the radiator and charge air cooler assembly to a crane.
   - 4.5 Remove the radiator mount nuts and washers. See **Fig. 2.**
   - 4.6 Remove the radiator strut nuts, washers, and rubber isolators.
   - 4.7 Using the crane, lift the radiator and charge air cooler assembly from the vehicle. See **Fig. 3**. Place the assembly charge air cooler-down on a work bench.
5. Disassemble the radiator and charge air cooler assembly.
   - 5.1 Remove the four sheet metal bolts that secure the fan shroud to the radiator. See **Fig. 4**. Remove the fan shroud.
   - 5.2 Remove the four bolts holding the radiator to the charge air cooler. See **Fig. 5**.
   - 5.3 Remove the radiator from the charge air cooler.

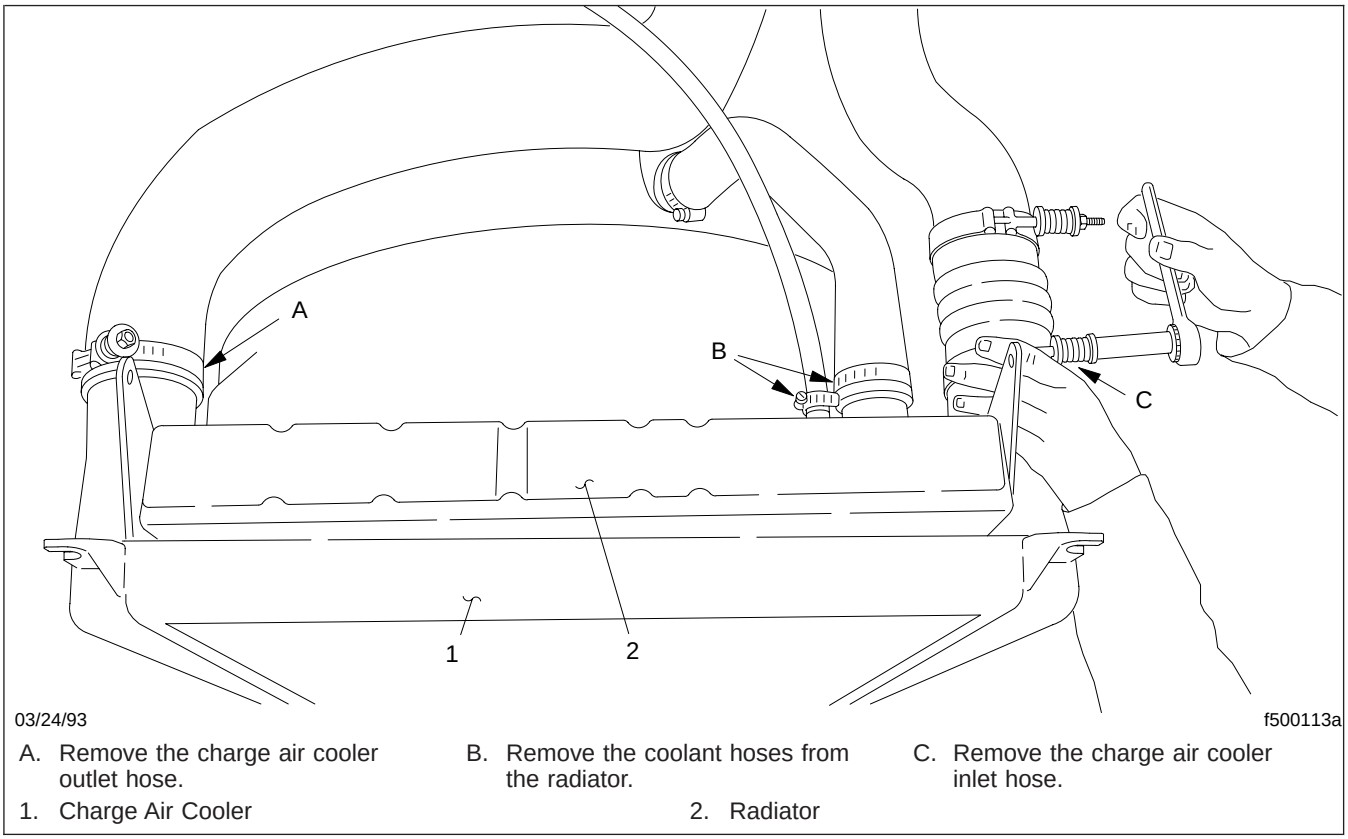
Installation

1. Assemble the radiator and charge air cooler assembly.
   - 1.1 On a work bench, place the radiator on the charge air cooler and secure it with four bolts and washers. Tighten the bolts 15 lbf·ft (20 N·m).
   - 1.2 Install the fan shroud with the four sheet metal bolts and washers. Do not tighten the bolts.
2. Install the radiator and charge air cooler assembly.
   - 2.1 Secure a lifting chain to the charge air cooler, and lift the assembly with a crane.
   - 2.2 Position the radiator and charge air cooler assembly on the radiator mounting studs. Secure the assembly to the mounts with nuts and washers, and tighten the nuts 30 lbf·ft (40 N·m).
   - 2.3 Secure the radiator support struts with rubber isolators, washers, and nuts, and tighten the nuts 35 lbf·ft (47 N·m).
   - 2.4 Remove the lifting chain from the radiator assembly.
   - 2.5 Connect the coolant outlet hose at the bottom of the radiator. See **Table 1** for proper torque values.
   - 2.6 Connect the radiator vent hose and coolant inlet hose to the radiator. See **Table 1** for proper torque values.
   - 2.7 Remove the seals from the coolant hose ends, connect the hoses and tighten the hose clamps. See **Table 1** for proper torque values.

   NOTE: Your hose clamps can be either T-bolt clamps, Breeze Constant-Torque clamps, or ABA clamps. See **Fig. 6**, **Fig. 7**, and **Fig. 8**.

   All hose clamps will lose torque after installation due to "compression set." However, when correctly installed, Breeze Constant-

Radiator Removal and Installation



A. Remove the charge air cooler outlet hose.
B. Remove the coolant hoses from the radiator.
C. Remove the charge air cooler inlet hose.
1. Charge Air Cooler
2. Radiator

Fig. 1, Radiator and Charge Air Cooler Hoses

Torque clamps will hold enough torque to automatically adjust and keep consistent sealing pressure. During vehicle operation and shutdown, the screw tip may adjust according to temperature and pressure changes. The torque may need to be adjusted for individual applications.

When installing ABA clamps, it is typical for the torque to decrease by 30 percent within a short time of tightening them to the recommended torque value. This characteristic is normal and is how the clamps are designed to function.

2.8 Connect the air hoses to the charge air cooler. See **Table 1** for proper torque values.

3. Secure the fan shroud.

3.1 Adjust the vertical clearance between the top of the fan blade and the fan shroud opening. It should be equal within 1/8 inch (3 mm) to the clearance between the bottom of the blade and the shroud opening.

3.2 Tighten the screws 108 lbf·in (1220 N·cm).

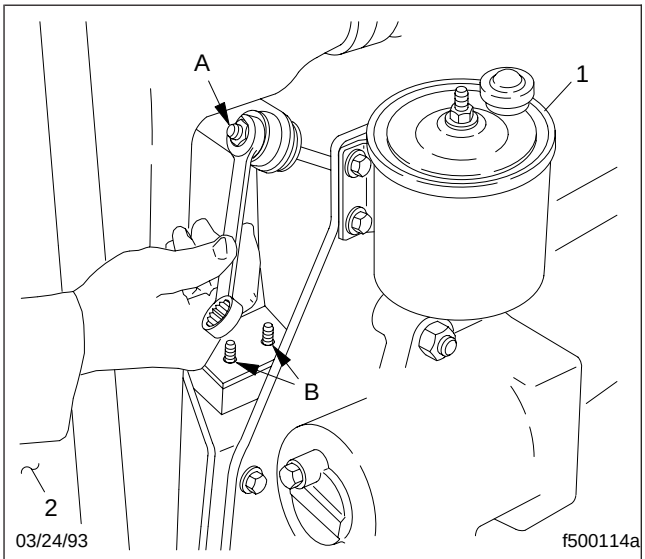
4. Install the hood. For instructions, see **Group 88**.

5. Fill the coolant system, and install the surge tank cap.

6. Start the engine and check for coolant leaks. Repair any leaks. After idling the engine for 15 to 20 minutes, add more coolant if necessary.

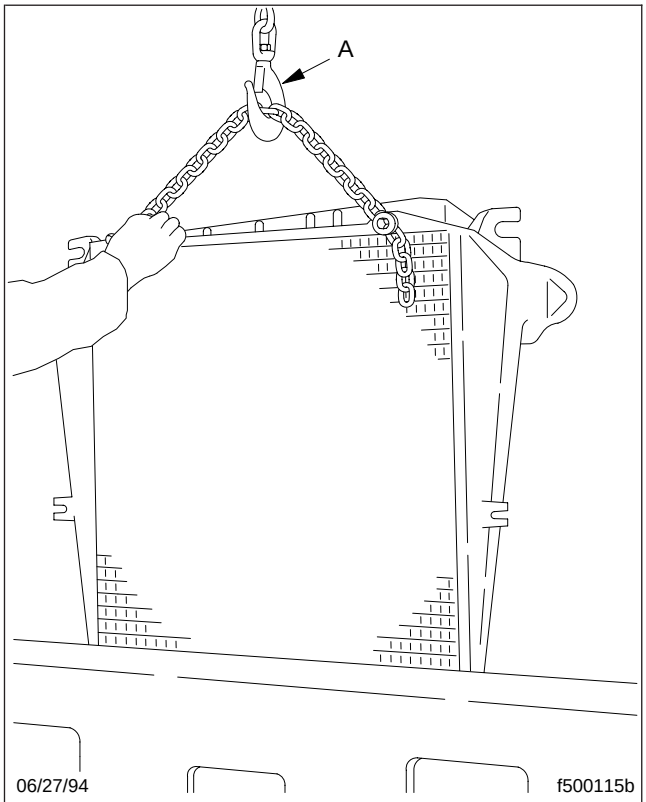
7. Lower the hood, and remove the chocks from the tires.

Radiator Removal and Installation



A. Remove radiator strut nuts.
B. Remove radiator mount nuts.
1. Power Steering Fluid Reservoir
2. Charge Air Cooler

Fig. 2, Radiator Mounts (left side)



A. Use a crane to lift the radiator and charge air cooler.

Fig. 3, Lifting the Radiator

Radiator Removal and Installation

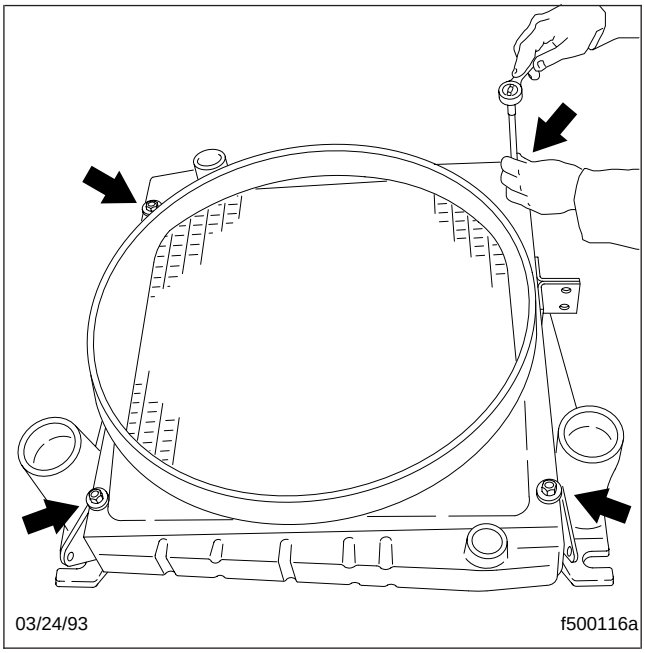
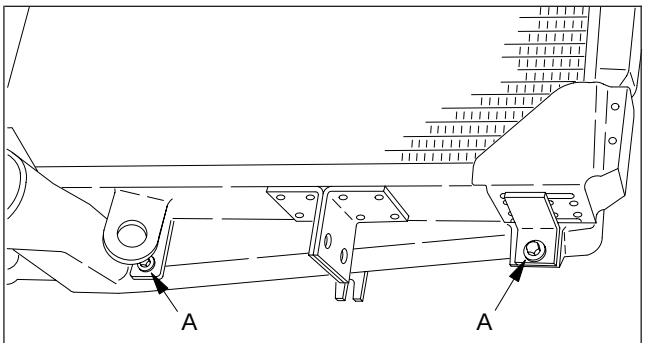


Fig. 4, Removing the Fan Shroud



A. Remove the bolts securing the charge air cooler to the radiator.

Fig. 5, Removing the Charge Air Cooler

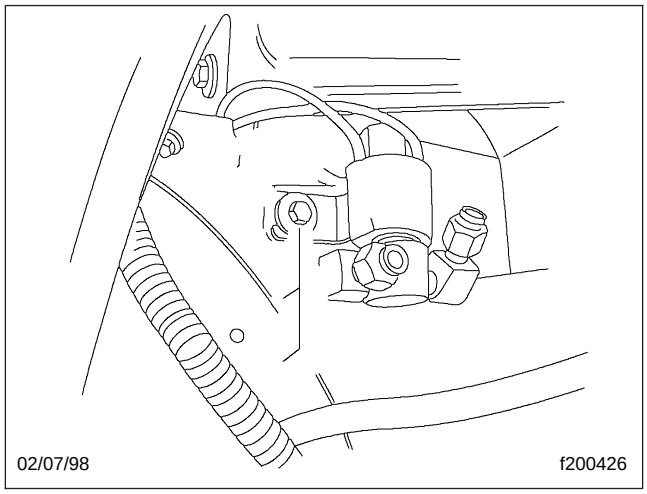
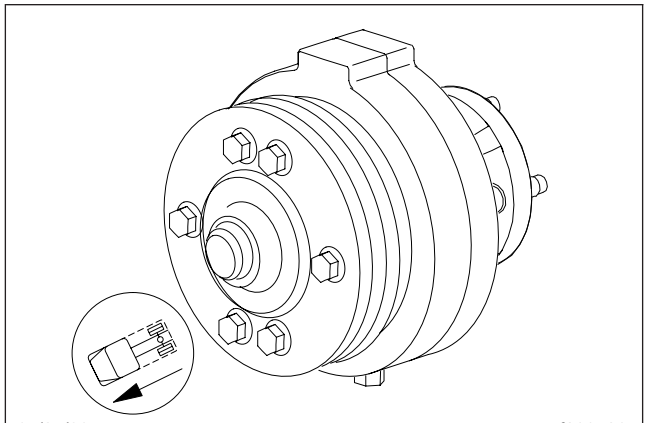


Fig. 6, T-Bolt Type Hose Clamp



A. The screw tip must extend about 1/4 inch (6mm).
B. The belleville washer stacks must be collapsed almost flat.
1. Tightening Screw Hex

Fig. 7, Breeze Constant-Torque Hose Clamp Installation

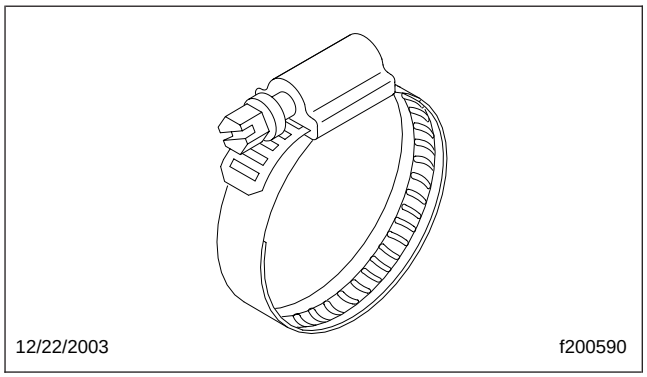


Fig. 8, ABA Radial-Worm-Drive Hose Clamp (typical)

Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque: lbf·in (N·cm)**
T-bolt	All	55 (620)
Breeze Constant-Torque	5/16-in. tightening screw hex	90 (1020)
	3/8-in. tightening screw hex	90 (1020)
ABA	1.26-in. Dia.	31 (360)
	1.50-in. Dia.	35 (400)
	1.73-in. Dia.	35 (400)
	1.97-in. Dia.	35 (400)
	2.28-in. Dia.	35 (400)
	2.68-in. Dia.	40 (460)
	3.03-in. Dia.	40 (460)

Table 1, Hose Clamp Torque Values

Radiator Disassembly and Assembly

IMPORTANT: Disassembling and assembling nylon top- and bottom-tank radiators requires the special tools listed in **Table 1**.

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 Disassembly and Assembly Tools

Order these tools from:

RAD PAL
2381 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 the radiator group of the vehicle maintenance manual. Clean and check the exterior of the radiator, following the instructions in the vehicle operator's manual.

1. Remove the radiator from the vehicle; for instructions, see **Subject 100**.

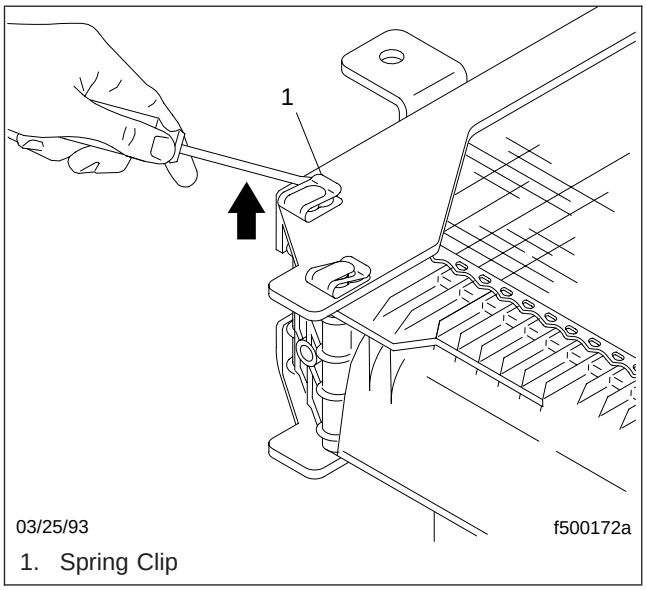
⚠ CAUTION

CAUTION: Use care when handling or supporting the nylon top and bottom tanks. Failure to do so could damage the tanks.

2. Remove the side channels from the radiator assembly.

   2.1 Remove the eight spring clips that hold the side channel mounting pins in position. See **Fig. 1**. 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 eight mounting pins. See **Fig. 2**.



1. Spring Clip

Fig. 1, Removing the Spring Clips

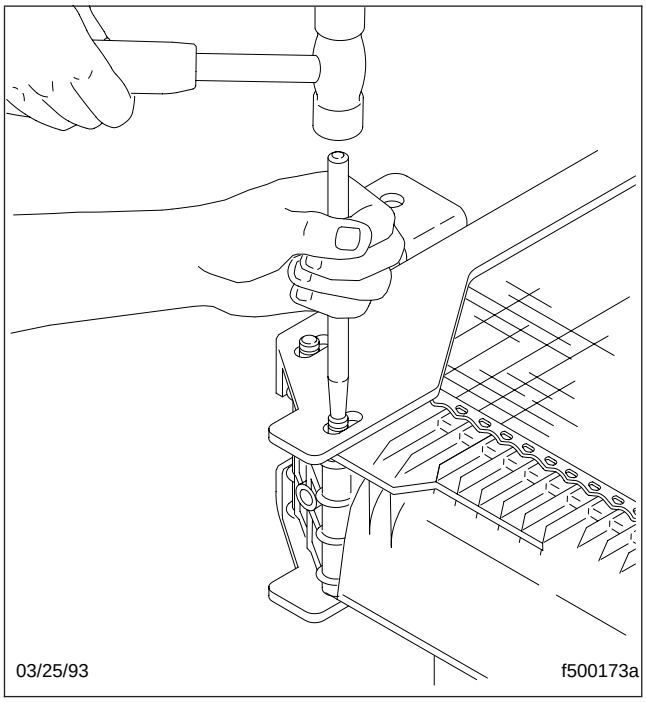
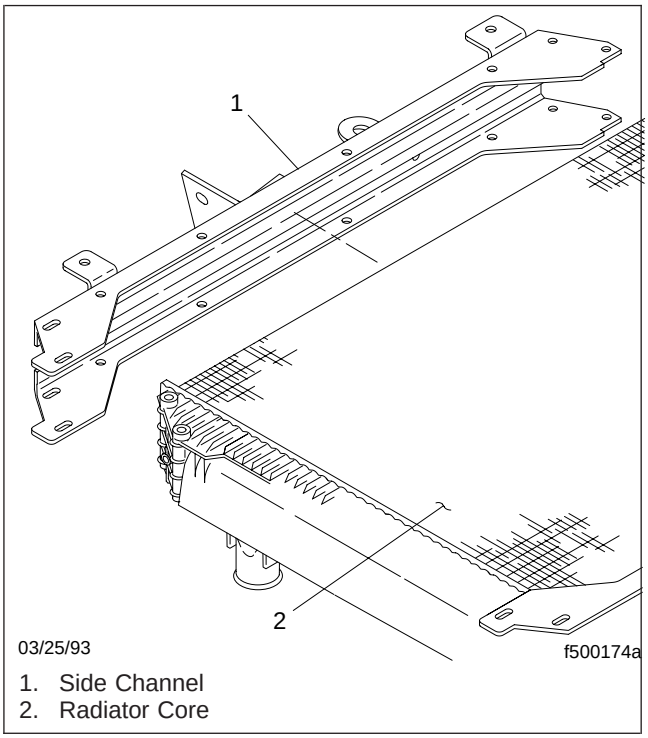


Fig. 2, Removing the Mounting Pins

   2.3 Slip the side channels off the radiator core and tank assembly. See **Fig. 3**.

3. Leak test the radiator core and tank assembly.

Radiator Disassembly and Assembly



1. Side Channel
2. Radiator Core

Fig. 3, Removing the Side Channels

3.1 Securely plug all tank ports.

CAUTION

CAUTION: Don't 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 top and bottom tanks.

4.1 Place the radiator core and tank assembly in the disassembly/assembly fixture, and clamp the assembly securely in place. See **Fig. 4**.

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

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.

CAUTION

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.

4.4 Place the T-bar into the T-bar groove in the disassembly/assembly fixture. See **Fig. 5**.

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. 5**.

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 step until all the wave crimps are unlocked.

5. Once the wave crimps are unlocked, remove the tank.

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

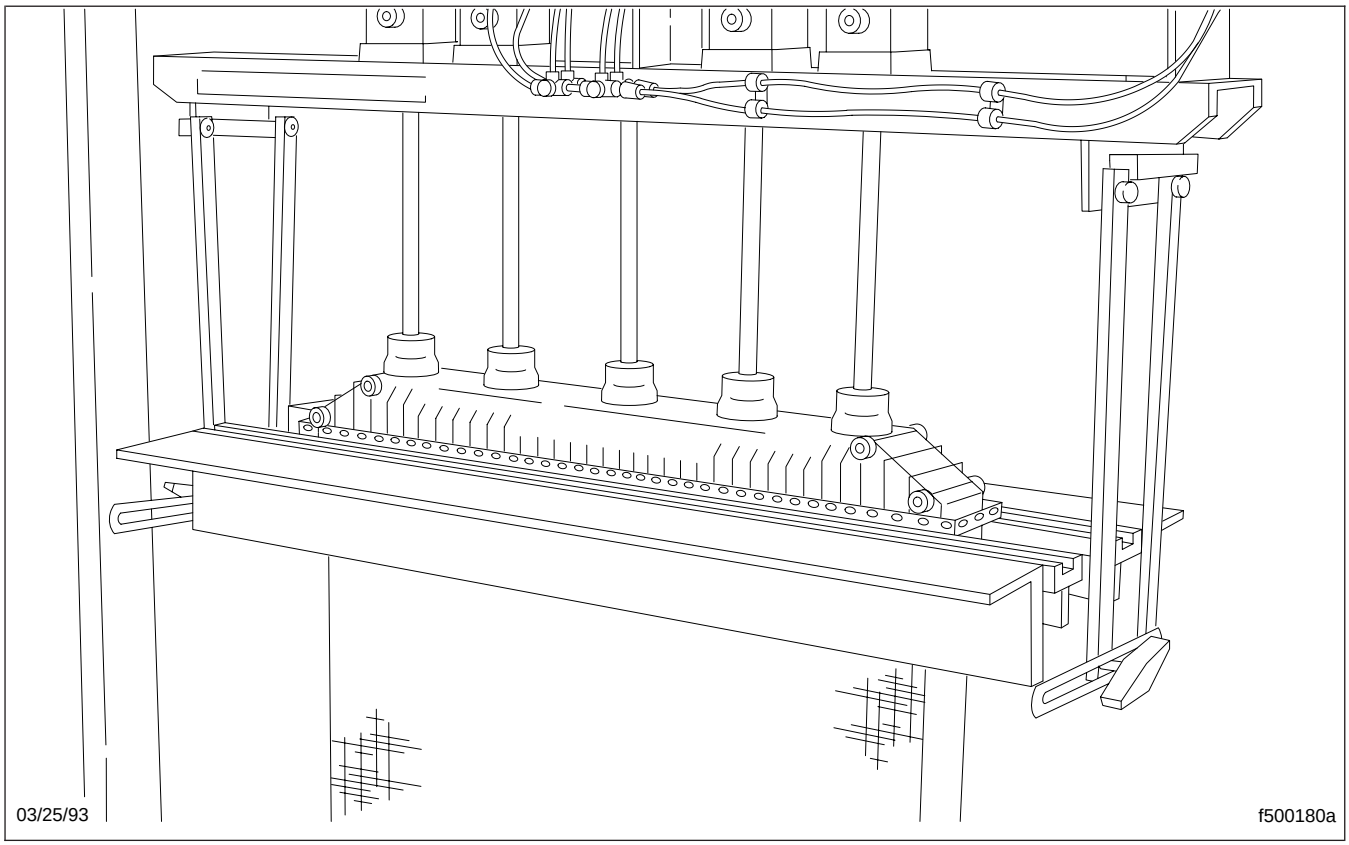


Fig. 4, Disassembly/Assembly Fixture

CAUTION

CAUTION: If needed, use a rubber mallet or the heel of your hand and tap the side of the tank to loosen it. Do not use a screwdriver against the tank sealing flange. A screwdriver blade may damage the flange and prevent a good seal after the tank is installed.

5.2 Lift the tank from the forward side, the side opposite the tank ports. Remove the nylon tank from the radiator core. See **Fig. 6**.

5.3 Remove the sealing gasket from the sealing surface of the radiator core header. See **Fig. 7**.

5.4 Clean the sealing surface of the radiator core header.

5.5 Repair any leaks marked during leak testing.

5.6 Repeat this procedure to remove the opposite tank.

Assembly

1. Install the nylon top and bottom tanks on the radiator core.

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 gasket on the header sealing surface. See **Fig. 7**. To make sure the gasket is not twisted, run a finger along the gasket as it lies on the sealing surface. The mold lines

Radiator Disassembly and Assembly

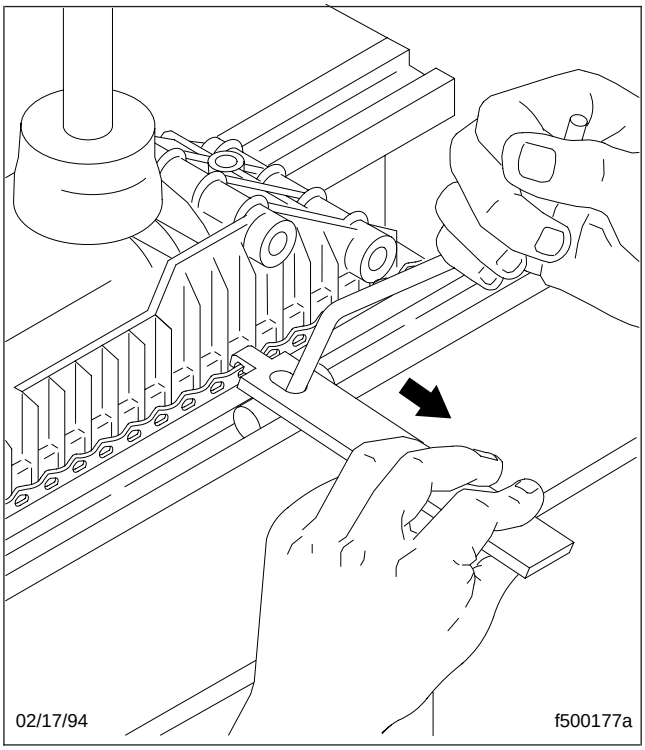


Fig. 5, Using the T-Bar

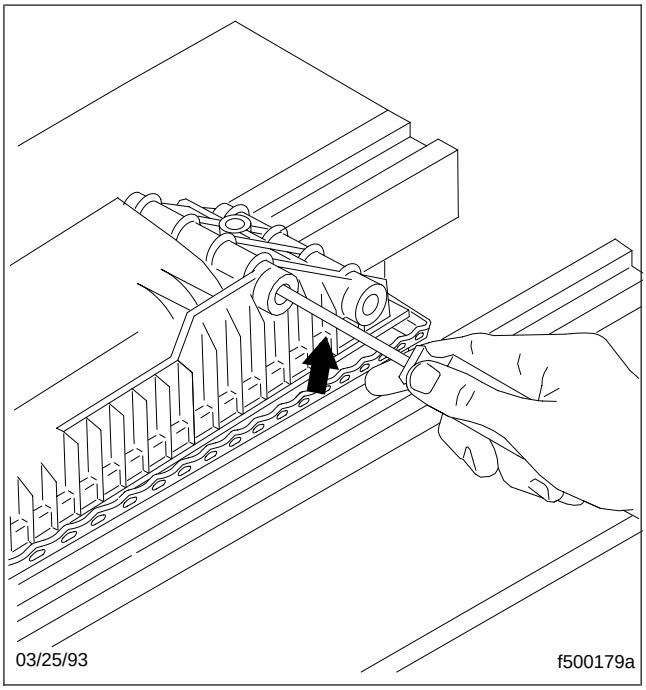
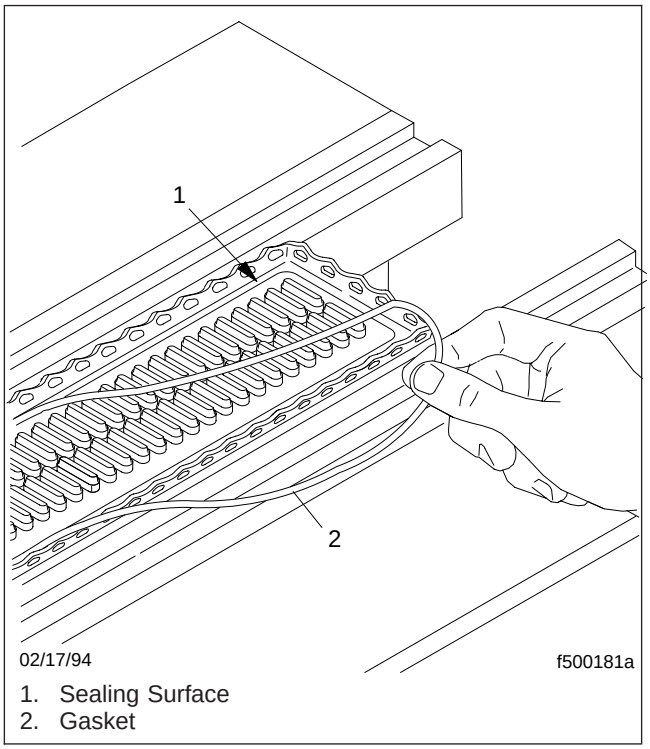


Fig. 6, Removing the Tank



1. Sealing Surface
2. Gasket

Fig. 7, Removing the Gasket

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. 4**.

⚠ CAUTION

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

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. 8**.

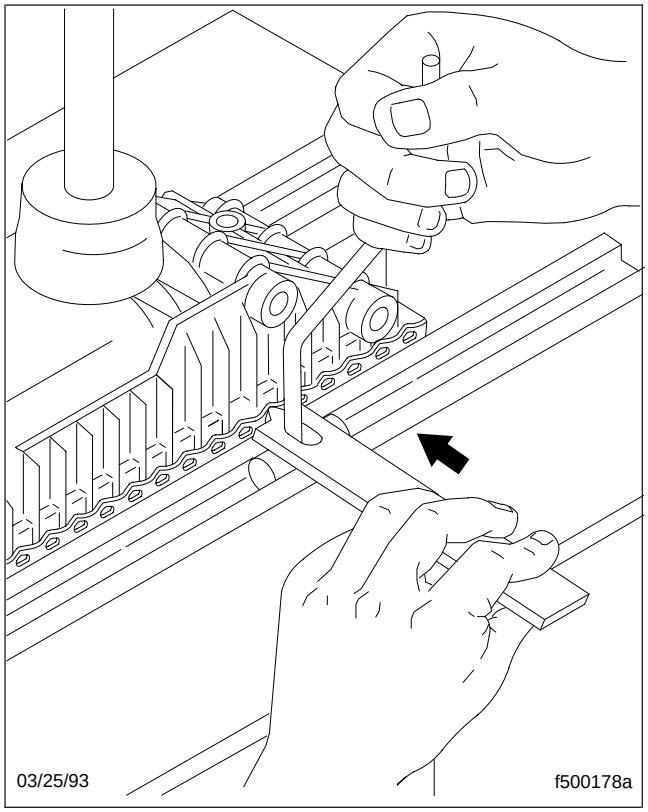


Fig. 8, Crimping the Header Edge

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

CAUTION

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 this procedure 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.

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

3.2 Using a rubber mallet and a punch, install the eight mounting pins through the side channel holes and tank bosses. See **Fig. 9**.

3.3 Install the eight spring clips to secure the mounting pins in position. See **Fig. 10**. 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 clips 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, see **Subject 100**.

Radiator Disassembly and Assembly

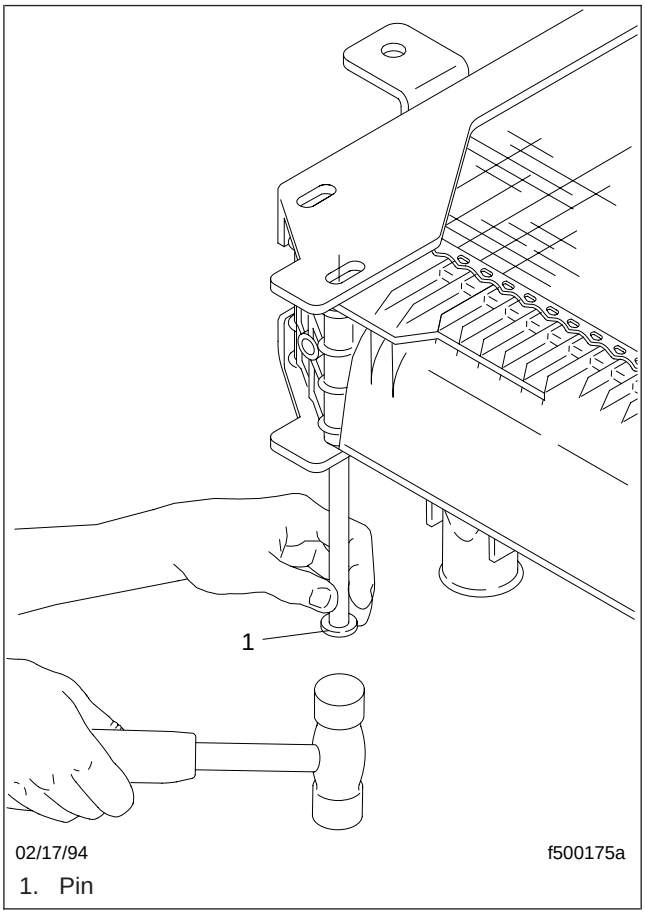


Fig. 9, Installing the Mounting Pins

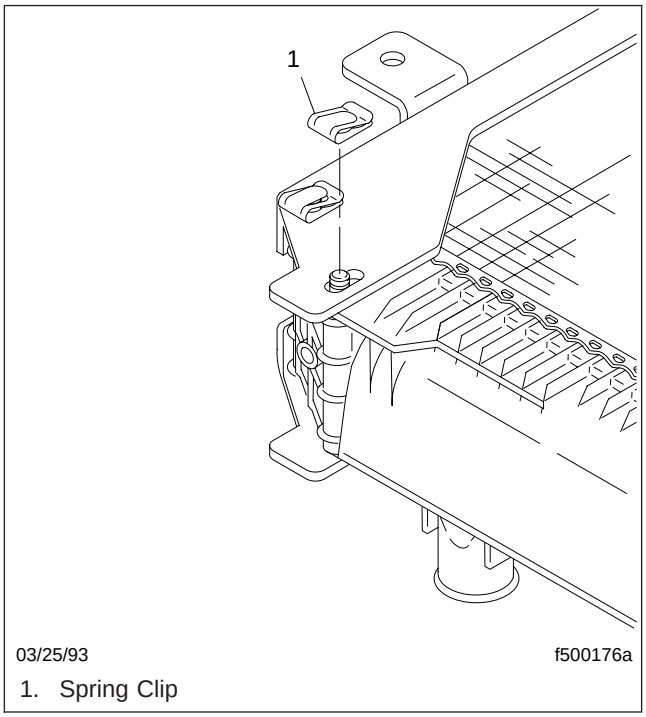


Fig. 10, Installing the Spring Clips

Pressure Testing

1. Remove the radiator. For instructions, see **Subject 100**.
2. Pressure test the radiator as follows:
   - 2.1 Leaving the coolant inlet port open, plug the outlet, and all other ports on the radiator.
   - 2.2 Using the necessary adaptor, connect a pressure regulator and a gauge on the coolant inlet port. Use a hand pump to apply 20 psi (138 kPa) air pressure through the inlet port.

⚠ CAUTION

CAUTION: Don't apply a higher amount of air pressure; too much pressure will damage the radiator core.

   - 2.3 Submerge the radiator in a tank of water and check it for leaks. Remove the radiator from the water.
   - 2.4 Remove the plugs and testing gauge. Repair the radiator, if necessary.
3. Install the radiator. For instructions, see **Subject 100**.

NOTE: For additional troubleshooting information, see **Section 20.00**.

Visual Check

It's a sound service practice to give the cooling system a quick visual check whenever you tilt the hood. Look for signs of visible leaks (or the stains they leave), especially on the engine block. A final check is to look at the inside of the oil breather cap for signs of a milky substance —which means that coolant is leaking into the oil.

Air-to-Air Aftercooler

Since the aftercooler is right in front of the radiator, air must pass through it to get to the radiator. For the heat transfer process to take place, the fins of the radiator and the aftercooler must be free of blockages and deposits such as dirt or bugs. Clean the surfaces with compressed air or water and a mild laundry soap.

Also remember that because these heat-transfer parts are so close to each other, heat will pass between them. A blocked aftercooler will transfer its heat to the radiator.

Radiator Cap

The radiator cap is the most often ignored part in the cooling system. If it's suspect, replace it. An inspection means checking the cap with a pressure tester. A radiator cap in good condition will not open below 9 psi (62 kPa). A visual check is also in order: look for signs of deterioration on the inner gasket. Also look for cracks or breaks in the spring retainer in the cap and for corrosion or deposits on the spring itself. If the spring is not in perfect condition, it has probably lost tension; replace it.

Engine Coolant

Check the level of the coolant at the surge tank. It should be up to the sight glass.

If the engine coolant is dirty or its color is beginning to fade, change it. It should also be replaced if it has a dead fish smell.

Be sure that the mixture is correct. See the maintenance manual for specifications.

Radiator

Radiator problems are limited to external leaks, which can be spotted visually, and internal blockages, assuming that there is good airflow and that the radiator is large enough to do the job.

To check for blockages, warm the engine to normal operating temperature. Shut down the engine, and pass your hand in front of 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, however, is to be expected.

Fan

See **Section 20.02** for fan and fan clutch checks.

Specifications

Hose Clamp Torque Values		
Clamp Type	**Size**	**Torque**
T-bolt	All	55 lbf·in (620 N·cm)
Breeze Constant-Torque	5/16-inch tightening screw hex	90 lbf·in (1020 N·cm)
	3/8-inch tightening screw hex	90 lbf·in (1020 N·cm)
ABA	1.26-inch Diameter	31 lbf·in (360 N·cm)
	1.50-inch Diameter	35 lbf·in (400 N·cm)
	1.73-inch Diameter	35 lbf·in (400 N·cm)
	1.97-inch Diameter	35 lbf·in (400 N·cm)
	2.28-inch Diameter	35 lbf·in (400 N·cm)
	2.68-inch Diameter	40 lbf·in (460 N·cm)
	3.03-inch Diameter	40 lbf·in (460 N·cm)

Table 1, Hose Clamp Torque Values

General Information

The fan drive senses the air temperature behind the radiator core, and engages or disengages the fan depending on that temperature. An increase or decrease in the amount of heat from the radiator coolant causes a change in the air temperature behind the radiator core. A coiled metal heat sensor on the fan drive detects the temperature change; it engages the fan clutch when more cooling (airflow) is needed, and disengages it when the engine is sufficiently cooled.

The fan clutch 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 it and the input plate are constantly turning as the engine runs. The output plate carries the fan blades but engages with the input plate only when extra engine cooling is needed.

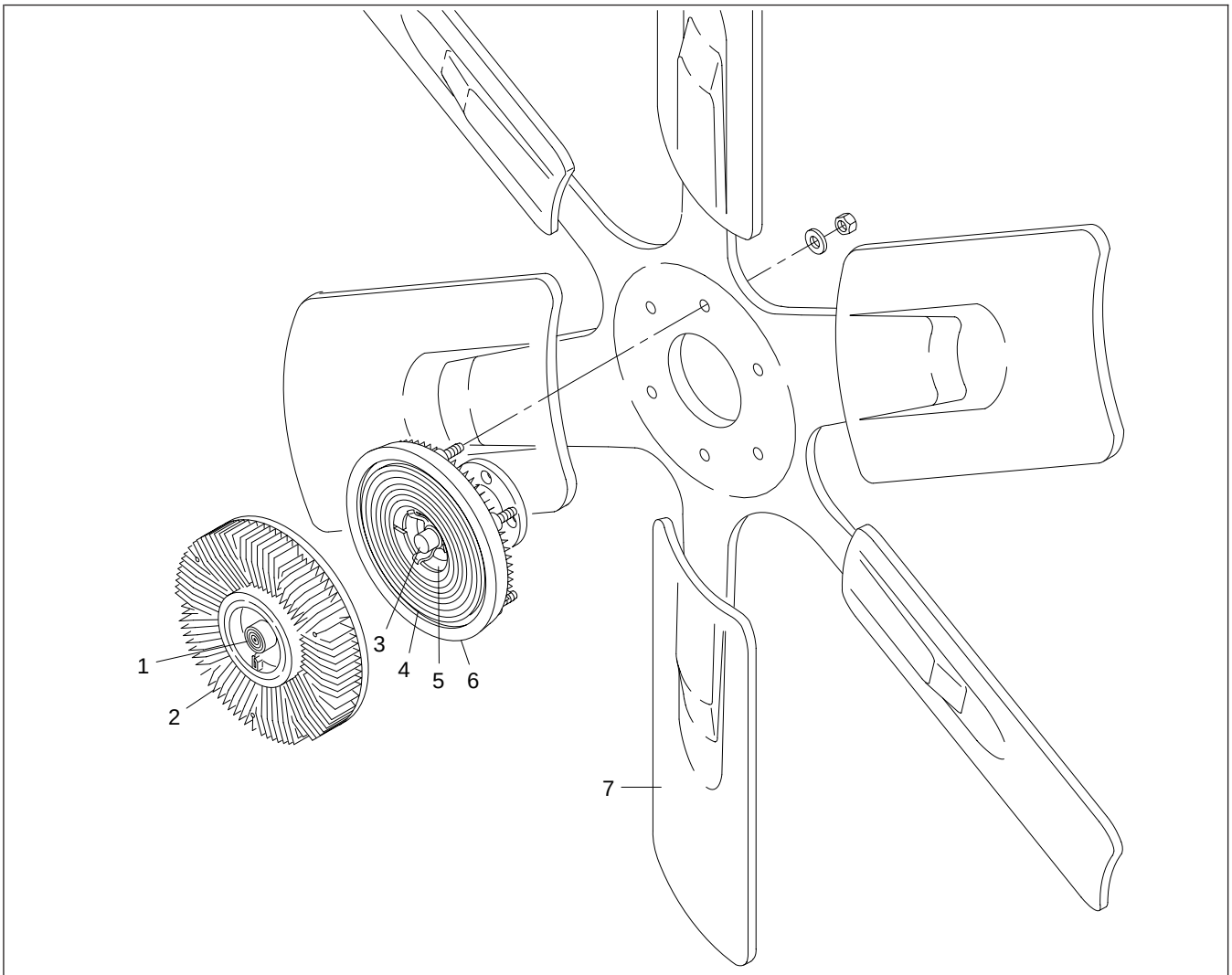
When the fan is disengaged, a single bearing allows the output plate and fan to free-wheel in relation to the input shaft and plate. Both the output and input plates are lined with concentric grooves which intermesh with very close tolerance.

To engage the fan, the heat sensor on the front of the clutch opens a valve in the clutch's drive chamber. The centrifugal force of the turning input plate forces the viscous (thick) silicone fluid stored in the drive chamber to flow out. The fluid flows between the concentric grooves of the input and output plates, creating friction between the two plates. As that friction increases, the output plate and fan begin 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, which 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's beyond the grooves. There, at the outer edge of the clutch, it returns through a passage in the input plate to the drive chamber.

Again, without the fluid to create friction between the two plates, the output plate and fan free-wheel in relation to the input plate and input shaft.

General Information



NOTE: The Eaton 660 fan clutch is shown here. The 610 fan clutch has four studs for mounting the fan.

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

Fig. 1, Viscous Fan Clutch, Exploded

Fan Clutch Inspection and Operation Checking

Inspection

CAUTION

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

The fan drive is only one part of the cooling system and will function well only if all other parts of the system are working right. All parts of the system should be checked if there is a cooling problem. Do all 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. With the engine off, rotate the fan at least one full turn by hand. It should have a smooth, steady drag. If it doesn't, replace the fan clutch.
2. Check for physical damage to the fan or fan shroud.
3. Inspect the fan clutch mounting.
   - 3.1 Check the torque of the nuts holding the fan input shaft to the fan hub. They should be tightened as follows:
     - Fan clutch input shaft to fan hub, Caterpillar CFE engine: 40 lbf·ft (54 N·m);
     - Fan clutch input shaft to fan hub, Cummins B Series engine: 45 lbf·ft (61 N·m);
     - Fan clutch input shaft to fan hub, Cummins C Series engine: 34 lbf·ft (46 N·m);
   - 3.2 Check for wear of the fan clutch bearings. There should be no side-to-side or in-and-out movement of the fan clutch.

Operation Checking

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

1. 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.
2. Disconnect any hydraulic pumps (such as the power steering pump) to prevent oil overheating.
3. Get a piece of cardboard that is 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. Don't put the cardboard in front of the radiator yet.

WARNING

WARNING: Before starting the engine, make sure people's hands and all other objects are away from the fan blades. The fan could start operating without warning, and the spinning fan blades could cause personal injury or property damage.

4. Start the engine, and let it idle until the oil pressure is normal.
5. 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 eight 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 five minutes or less, when the fan clutch disengages.
6. After the fan clutch disengages, put the cardboard in front of the radiator.
7. 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.
8. 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 fan should be fully engaged when the air at the

Fan Clutch Inspection and Operation Checking

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.

9. Remove the cardboard from in front of the radiator. Keep watching the coolant temperature while the clutch is engaged; you should notice a decrease after the cardboard is removed.
10. 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 okay; 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, then 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 okay, 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

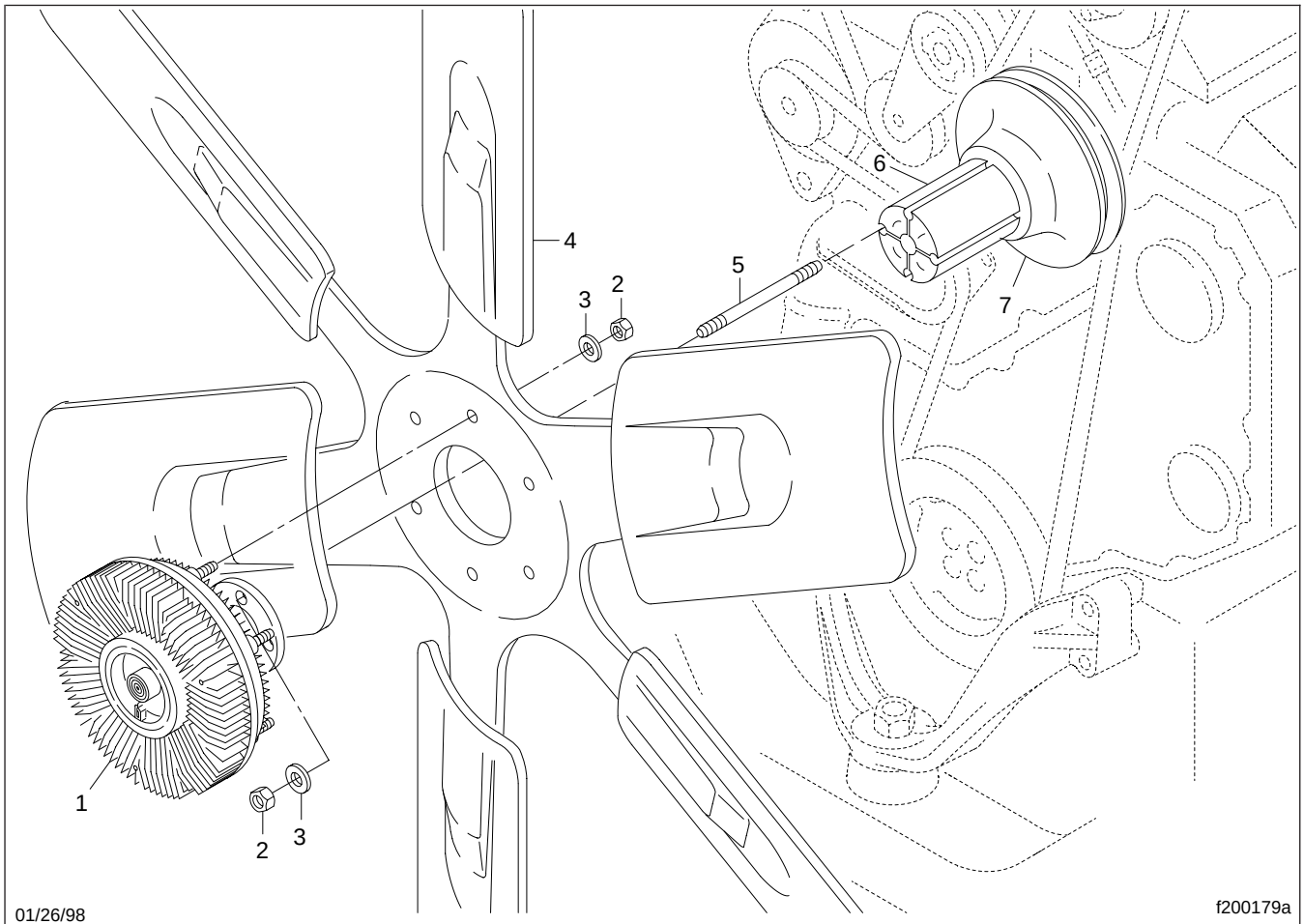
Fan speed must be at least 2009 rpm when the fan clutch is fully engaged.

Fan Clutch Removal and Installation

Removal

1. Shut down the vehicle, apply the parking brakes, chock the tires, and (if applicable) drain the air system.
2. Disconnect the batteries.

   Disconnect the battery ground cable at the vehicle frame.
3. Tilt the hood.
4. Remove the locknuts and lockwashers that hold the clutch to the fan hub. Remove the clutch from the engine. See **Fig. 1**.
5. Remove the nuts and lockwashers that hold the fan blade to the clutch. Remove the blade.



NOTE: The Eaton 660 viscous fan clutch is shown here.

1. Fan Clutch Assembly
2. Locknut
3. Lockwasher
4. Fan Blade
5. Stud
6. Spacer
7. Fan Hub

Fig. 1, Fan Clutch Mounting for Cummins B Series Engine

Fan Clutch Removal and Installation

Installation

1. Install the fan blade on the fan clutch. See **Fig. 1**. Tighten the fan mounting locknuts as follows:
    - Model 610: 40 lbf·ft (54 N·m);
    - Model 660: 22 lbf·ft (30 N·m);
    - Model 575: 15 to 20 lbf·ft (20 to 27 N·m).

NOTE: Use only approved fans, as specified in the *Freightliner Parts Technical Information Manual*. 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 clutch assembly. Tighten the fasteners as follows:
    - Caterpillar CFE engines: 40 lbf·ft (54 N·m);
    - Cummins B Series engines: 45 lbf·ft (61 N·m);
    - Cummins C Series engines: 34 lbf·ft (46 N·m);
3. Lower the hood, connect the batteries, and remove the chocks from the tires.

General Information

The 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 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 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. 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 heater consists of an element that bolts 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 receptacle mounted in the front bumper. See **Fig. 2**.

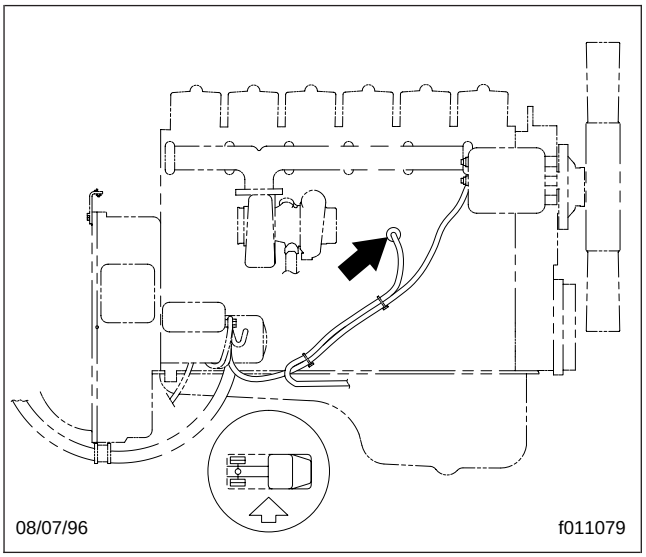
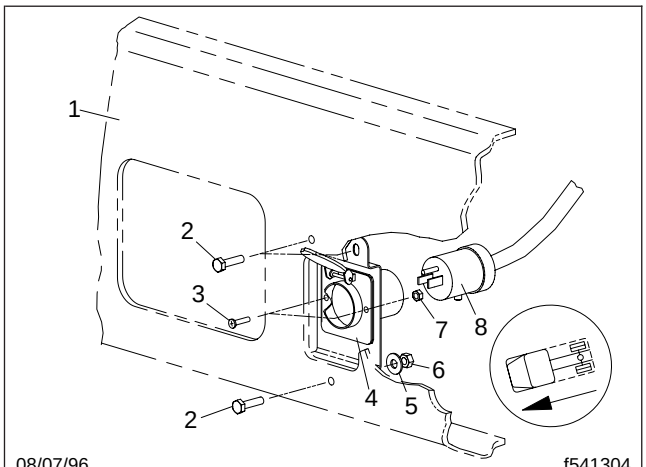


Fig. 1, Engine Block Heater Location, Cummins Series B Engine

NOTE: When a vehicle is also equipped with an oil pan heater, the oil pan heater is wired in tandem with the engine block heater. The receptacle in the front bumper, provides power to both heaters.



1. Front Bumper, Right Side
2. Capscrew, 1/4–20x0.75, Grade 5
3. Machine Screw, Stainless Steel, #8–32x0.75
4. Receptacle Housing
5. Washer, 1/4–Inch
6. Self-Locking Nut, 1/4–20
7. Nut, #8–32
8. Harness Receptacle

Fig. 2, Heater Receptacle Location

To turn on the heater, open the spring-loaded cover on the receptacle, and connect a power source to the receptacle. The element has no thermostat. Heat dissipating from the engine block prevents coolant overheating.

Engine Block Heater Element Removal and Installation

Removal

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

⚠ WARNING

Do not drain coolant from a hot engine. Opening the cooling system when the engine and coolant are hot can cause severe personal injury due to scalding by the hot, pressurized coolant.

3. Drain the radiator.
   - 3.1 Loosen the surge tank cap.
   - 3.2 Open the drain at the bottom of the radiator side tank to drain the engine coolant.
4. Unscrew the threaded cover that secures the cord to the element. See **Fig. 1** or **Fig. 2**.

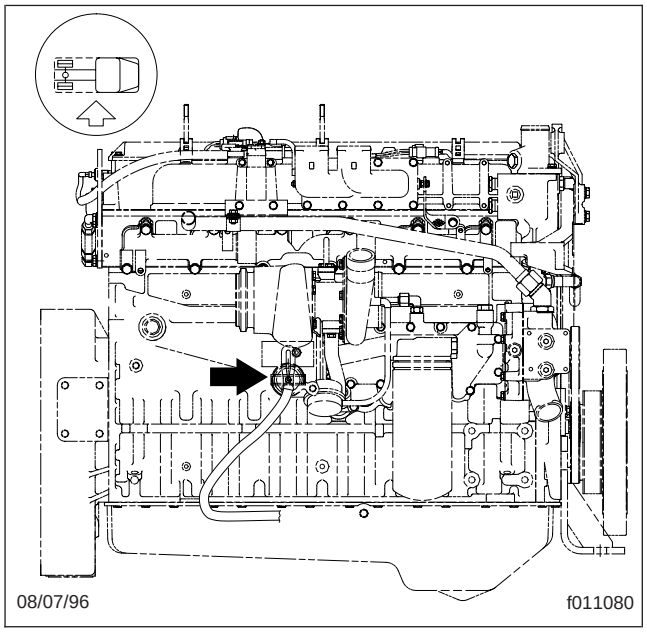


Fig. 1, Engine Block Heater Location, Caterpillar 3126 Engine

5. Pull the cord off the element.
6. Remove the element from the engine block.

   On Caterpillar engines, loosen the capscrew in the center of the element cover, and pull out the element.

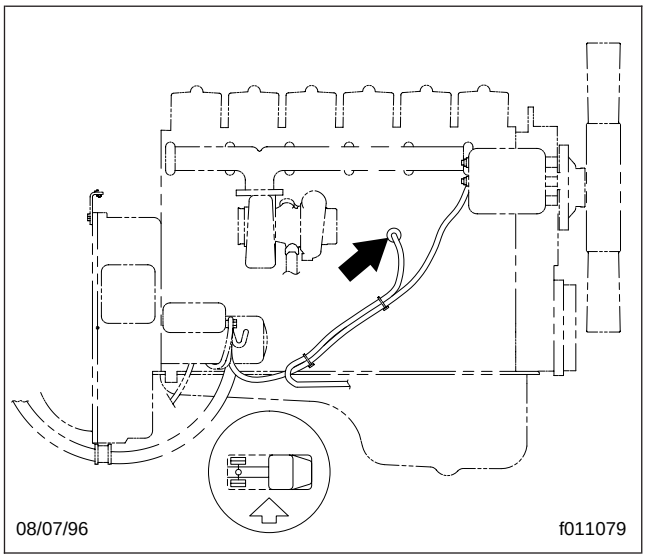


Fig. 2, Engine Block Heater Location, Cummins B Series Engine

   On Cummins engines, unscrew the element from the block.

Installation

1. Install the heater element in the engine block.

   On Cummins engines, screw the element into the engine block, and tighten it firmly.

   On Caterpillar engines, secure the element in the block by tightening the capscrew 35 lbf·ft (48 N·m).
2. Plug the cord into the element and secure it by screwing the threaded cord cover in place.
3. Fill the cooling system. For recommended coolants and cooling system capacities, refer to the vehicle maintenance manual.
4. 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.
5. To test the heater, plug a wattmeter into a power source, and connect the heater cord in the receptacle to the meter. A reading on the meter will indicate the heater is working.

Troubleshooting

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

WIRING PROBLEMS

1. Park the vehicle, apply the parking brakes, and chock the tires.
2. Tilt the hood.
3. Unscrew the threaded cover that secures the cord to the element. See **Fig. 1** or **Fig. 2**. 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, and 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. See **Fig. 1**.

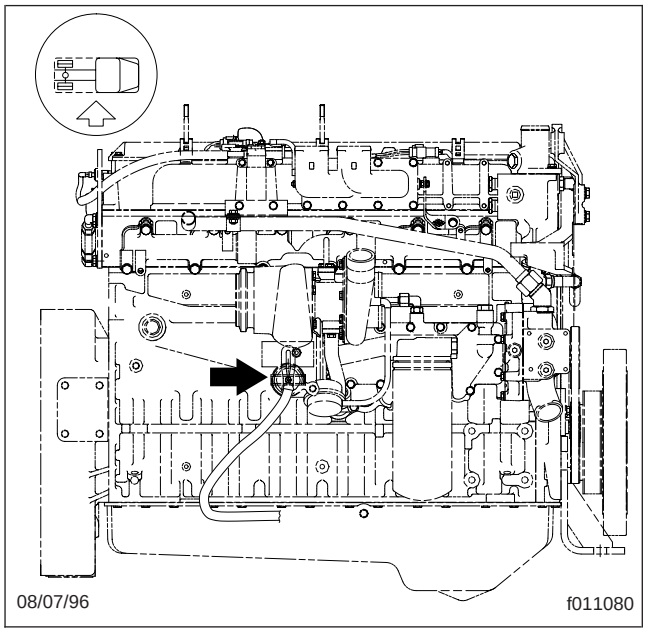


Fig. 1, Engine Block Heater Location, Caterpillar 3126 Engine

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.

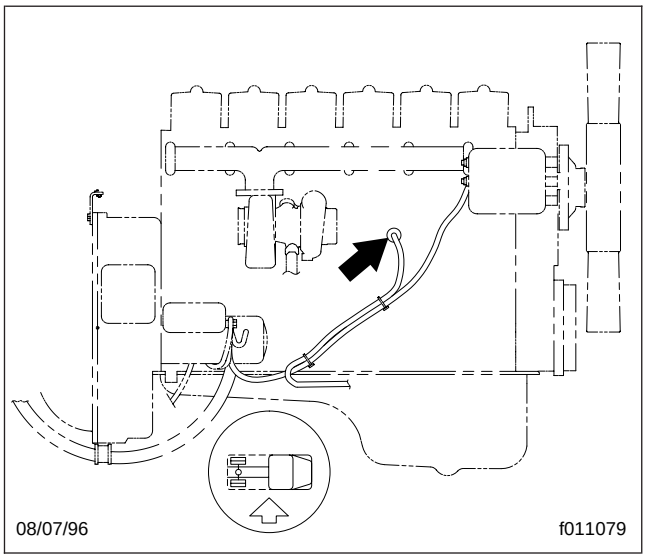


Fig. 2, Engine Block Heater Location, Cummins B Series Engine

FOULED ELEMENT

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

⚠ WARNING

Do not drain coolant from a hot engine. Opening the cooling system when the engine and coolant are hot can cause severe personal injury due to scalding by the hot, pressurized coolant.

3. Drain the radiator.
   - 3.1 Loosen the surge tank cap.
   - 3.2 Open the drain at the bottom of the radiator side tank to drain the engine coolant.

Troubleshooting

4. Unscrew the threaded cover that secures the cord to the element. See **Fig. 1** or **Fig. 2**. Pull the cord off the element. For instructions, see **Subject 100**.
5. Inspect the element for residue deposits, discoloration, or damage.

   Greenish residue indicates the coolant solution contains too much antifreeze. Replace the element, and refer to the vehicle maintenance manual for the recommended antifreeze/water ratio.

   Gray or black residue indicates anti-leak coolant additives have been added to the system. Replace the element, and refer to the vehicle maintenance manual for the recommended coolant additives.

   Blue or black discoloration on the element indicates the cooling system needs more coolant. Replace the element, and fill the cooling system until cooling 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. Replace the element, and refer to the vehicle maintenance manual for the recommended antifreeze to water concentrations.

General Description and Principles of Operation

The Spicer Angle-Ring 14-Inch (350 mm) clutch is a single-plate dry-disc design. There are no internal adjustments.

The clutch-cover assembly is bolted directly to the flywheel with twelve capscrews. The clutch-cover assembly drives the pressure plate through three drive straps. The driven disc uses ceramic friction material and has a spring-loaded center section for dampening.

The Angle-Ring clutch is a push-type release design. Depressing the clutch pedal moves the release (throw-out) bearing toward the engine flywheel. As the clutch is depressed, the pressure plate retracts from contact with the driven disc assembly, and the clutch is disengaged. As the clutch pedal is released, the release bearing and clutch levers move away from the engine flywheel. The belleville spring exerts pressure through the levers onto the pressure plate causing the driven disc to be locked up between the friction surfaces of the pressure plate and the engine flywheel. The clutch is then engaged.

Removal

1. Park the vehicle. Apply the parking brake and chock the tires.
2. Remove the transmission. For instructions, refer to the applicable section in **Group 26** of this manual.

NOTE: The release bearing will drop to the bottom of the bell housing when the transmission is removed.

3. Remove the bell housing.
   - 3.1 Loosen the nuts on the U-bolt holding the exhaust pipe to the bell housing. Remove the capscrews holding the U-bolt bracket to the housing, and rotate the U-bolt bracket out of the way.
   - 3.2 Remove the remaining capscrews around the bell housing. See **Fig. 1**.

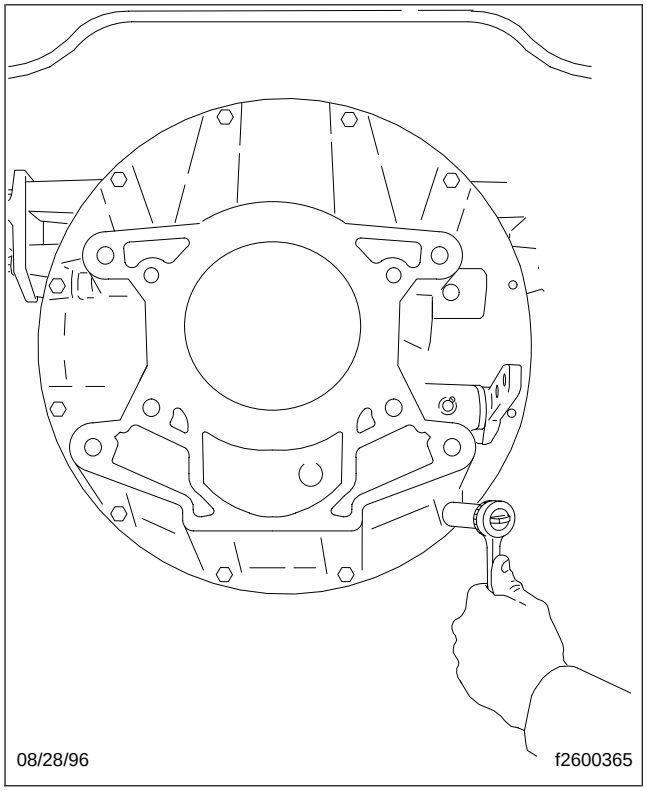


Fig. 1, Remove the Remaining Capscrews

   - 3.3 Lift off the housing. See **Fig. 2**.

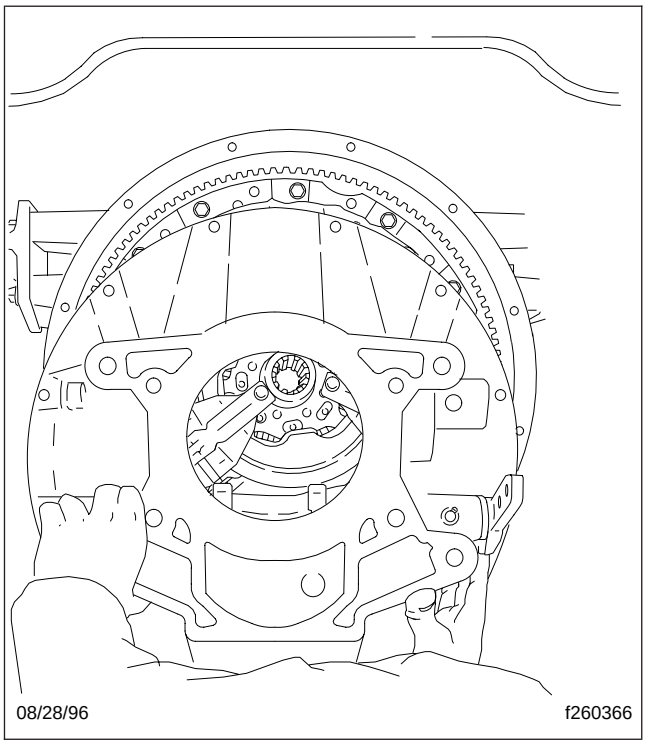


Fig. 2, Lift Off the Housing

4. Remove the clutch assembly.
   - 4.1 Insert the pilot tool. See **Fig. 3**.
   - 4.2 Remove two capscrews from the top of the clutch and install dowels to support the pressure plate and cover assembly. See **Fig. 4**. Remove the remaining capscrews.
   - 4.3 Remove the clutch disc, pressure plate, and cover assembly along with the pilot tool. See **Fig. 5**.
5. Using a puller, remove the pilot bearing. See **Fig. 6**.

Inspection

1. Clean the clutch assembly thoroughly to inspect the parts. If there is excessive wear or damage or if parts are in questionable condition, replace them with a new clutch and driven disc assembly.

IMPORTANT: When taking the following readings, rotate the engine by hand; do not crank

Clutch Removal, Inspection, and Installation

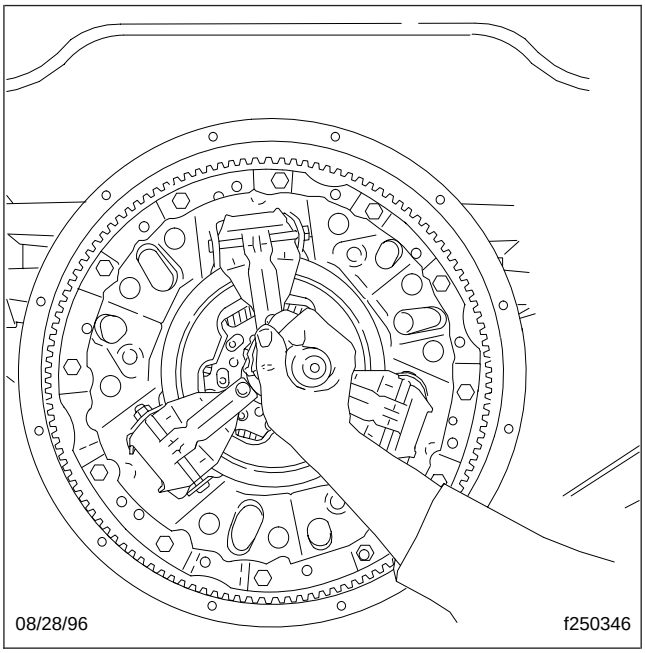


Fig. 3, Insert the Pilot Tool

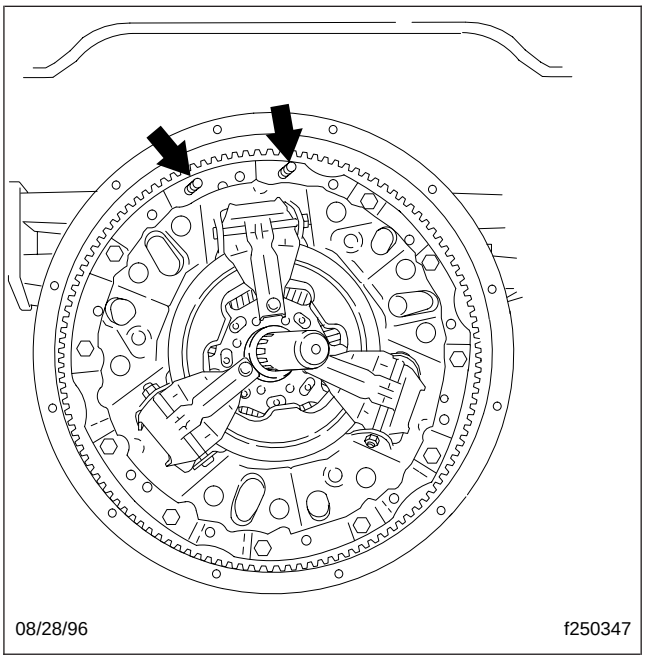


Fig. 4, Install Dowels

the engine with the starter. The engine may be rotated by the flywheel-mounting bolts or the starter ring-gear on the flywheel.

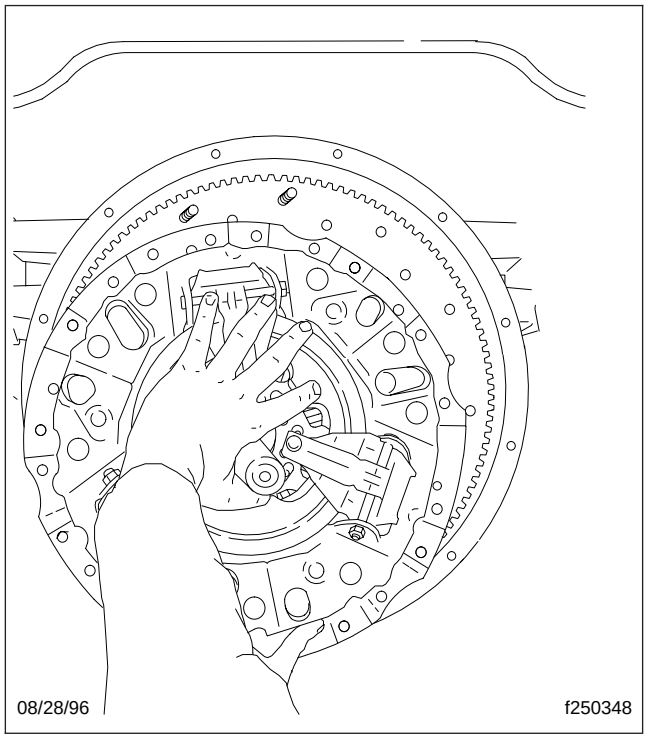


Fig. 5, Remove the Clutch Disc, Pressure Plate, Cover Assembly, and the Pilot Tool

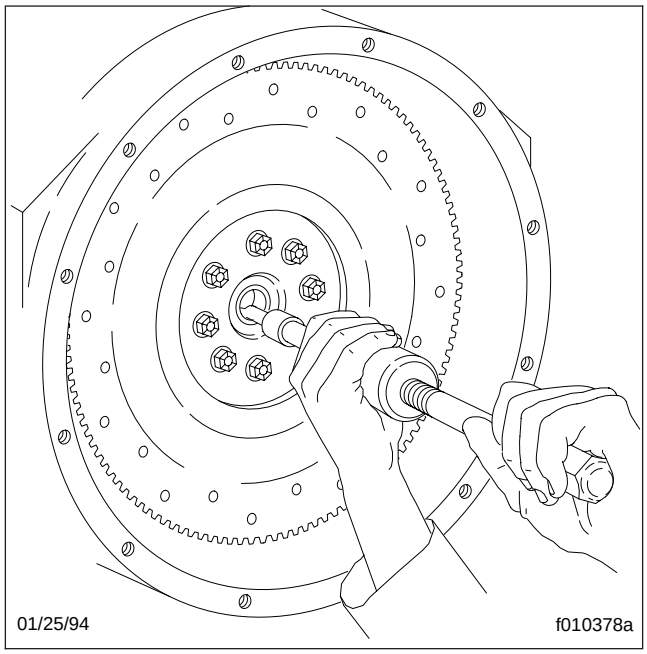


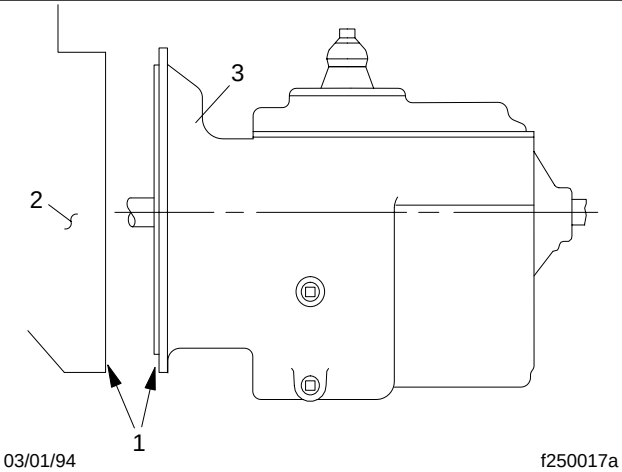
Fig. 6, Remove the Pilot Bearing

NOTE: Due to the design of the clutch assembly, do not rebuild it.

2. Clean the surfaces being measured to ensure accurate measurements.

NOTE: Before measuring the flywheel or flywheel housing, check the end-play of the crankshaft. Mount the dial indicator on the flywheel housing, with the indicator's finger against the flywheel. Force the crankshaft back and forth with a pry bar. If end-play exceeds the maximum, correct it. For specifications and instructions, see the engine manufacturer's service manual.

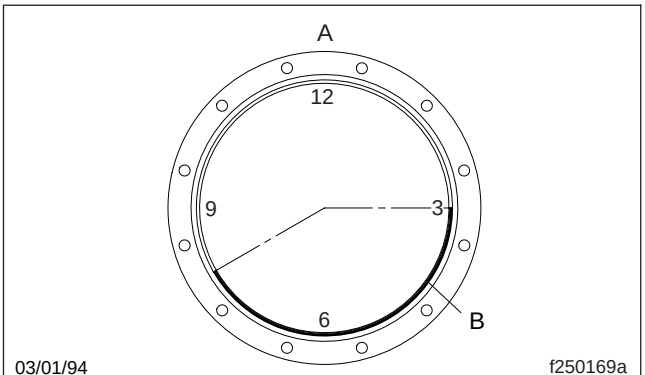
3. Inspect for a worn or corroded pilot on both the bell housing, and the flywheel housing. See **Fig. 7**. The pilot lip of the clutch housing can wear into the flywheel housing. This can be caused by the transmission loosening up, or by road and engine vibration after high mileage. Any measurable wear on either part will cause misalignment; replace the part. Wear may first appear between the 3 o'clock and 8 o'clock positions. See **Fig. 8**.



1. Pilot
2. Engine Flywheel Housing
3. Transmission Clutch Housing

Fig. 7, Inspect the Pilot

3.1 Measure the runout of the pilot (bore) of the flywheel housing. Secure the dial indicator to the flywheel (or crankshaft), with the gauge finger against the housing pilot.



A. Top
B. Most common wear areas are between 3 o'clock and 8 o'clock positions.

Fig. 8, Wear Areas

See **Fig. 9**. With chalk or soapstone, mark the high and low points on the flywheel housing flange, while rotating the flywheel (or crankshaft) by hand. The total runout will be the difference between the highest plus and minus readings. See **Fig. 10**.

The SAE maximum total runout for the flywheel housing pilot is 0.008 inch (0.2 mm). If the readings are higher, replace the housing. For instructions, see the engine manufacturer's service manual.

3.2 Measure the runout of the face of the flywheel housing. With the dial indicator secured to the flywheel (or crankshaft), move the finger to contact the face of the housing. See **Fig 11**. Mark the high and low points.

The SAE maximum total runout for the flywheel housing face is 0.008 inch (0.2 mm). If the readings are higher, replace the housing. For instructions, see the engine manufacturer's service manual.

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

4. Measure the runout of the flywheel face. Secure the dial indicator to the flywheel housing, with the gauge finger against the face of the flywheel near the outer edge. See **Fig. 12**. Turn the flywheel to obtain readings. With readings taken just outside the outer edge of the clutch disc

Clutch Removal, Inspection, and Installation

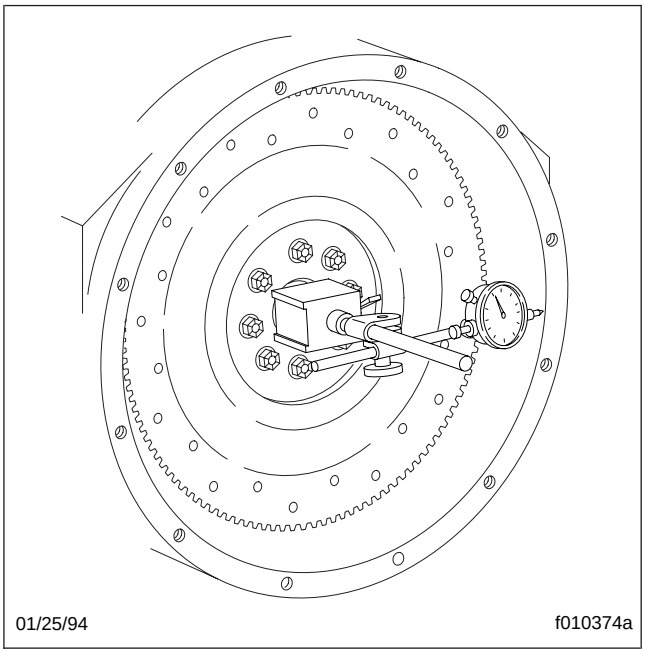
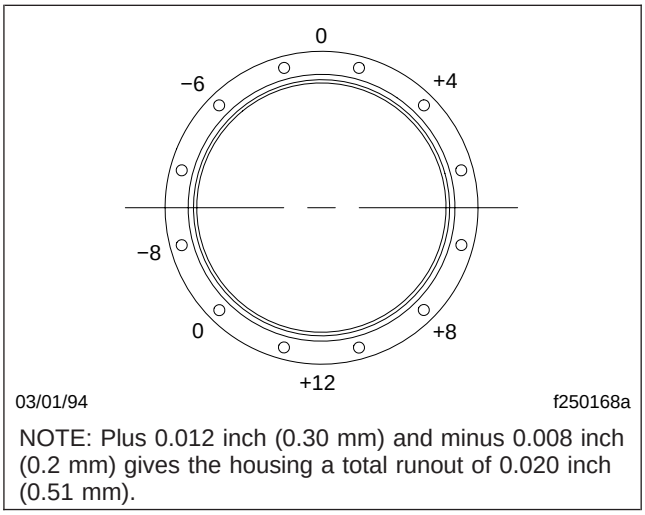


Fig. 9, Secure the Dial Indicator



NOTE: Plus 0.012 inch (0.30 mm) and minus 0.008 inch (0.2 mm) gives the housing a total runout of 0.020 inch (0.51 mm).

Fig. 10, Calculate Total Runout

wear pattern, the maximum tolerance is 0.007 inch (0.18 mm) for the 14-inch (350-mm) clutch. If the readings are higher, repair or replace the flywheel. See the engine manufacturer's service manual for instructions.

5. Measure the runout of the pilot-bearing bore of the flywheel. With the indicator secured to the flywheel housing, move the gauge finger to contact the pilot-bearing bore surface. See **Fig. 13**. Turn the flywheel to obtain the readings.

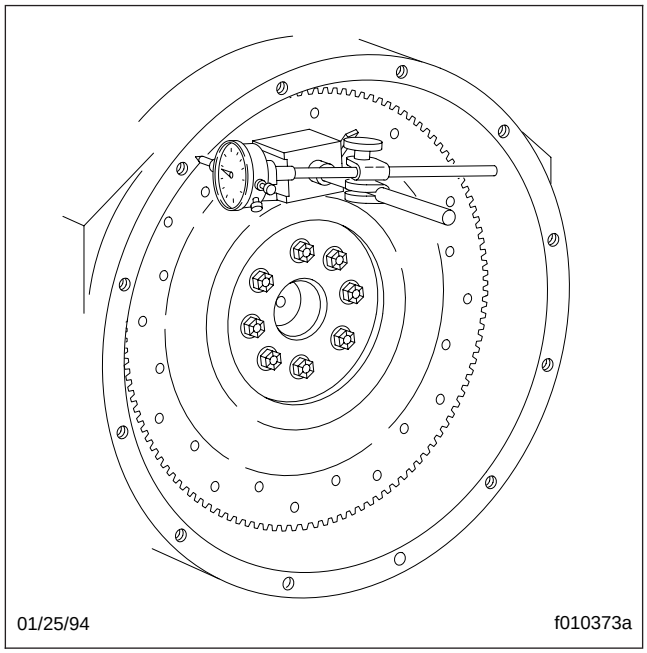


Fig. 11, Measure the Runout

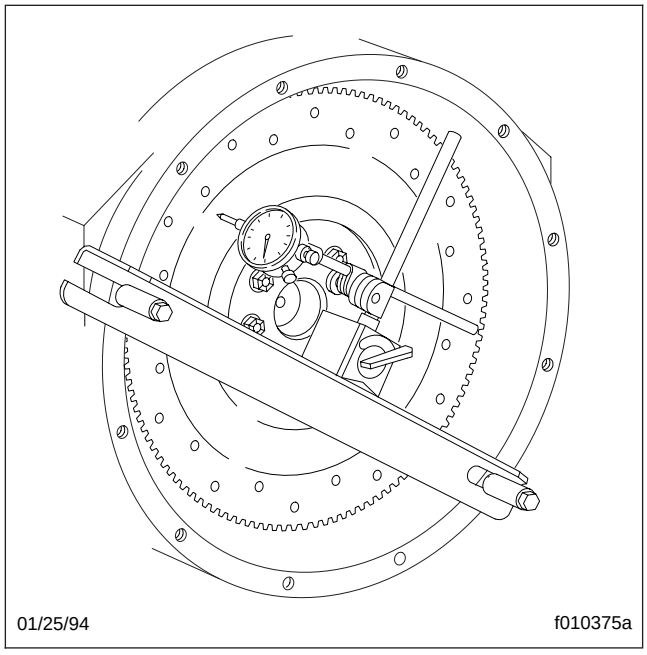


Fig. 12, Secure the Dial Indicator

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

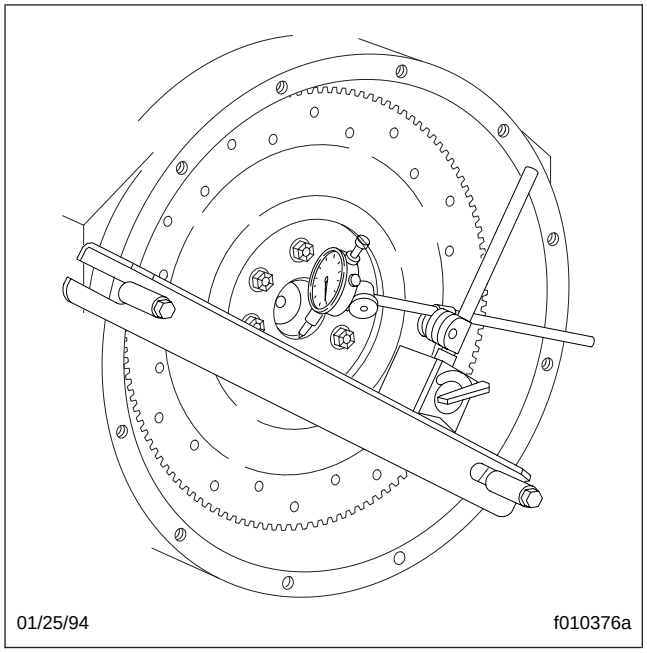


Fig. 13, Move the Gauge Finger

6. Measure the runout of the transmission clutch-housing face and pilot.

   The SAE maximum runout for the clutch-housing face and pilot is 0.008 inch (0.20 mm). If the readings are higher, replace the clutch housing; see the transmission manufacturer's service manual.

CAUTION

CAUTION: The engine and transmission must line up. Misalignment of any parts will cause premature wear of drivetrain components.

NOTE: The clutch-housing face and pilot cannot be checked accurately unless you have a set of case-bore plugs and shaft. This set consists of plugs to be tapped into the front and rear bores of the transmission case. They have a very close fit in the bores. A shaft runs through the center of the plugs, and extends to the front far enough to secure a dial indicator and obtain a reading on the clutch housing.

7. Inspect the friction surface of the flywheel for unevenness, heat checks, scoring, and wear on the contact surface. Inspection for heat checks and scoring must be visual, and based on experience; however, measure the friction surface wear with a straightedge and feelers.

   Replace or repair the flywheel if the wear is extreme. For instructions, see the engine manufacturer's recommendations concerning flywheel replacement or rebuilding.

   If the flywheel has been replaced, measure the runout of the face and pilot diameters to make sure the measurements are within the engine manufacturer's specifications.

8. Check the fit of the splined hub of the clutch disc by sliding it on the transmission input shaft splines. The hub must slide freely so the clutch will release cleanly. If necessary, use a hand stone to dull the sharp edges of the splines. If the input shaft splines are badly worn or notched, replace the input shaft; for instructions, see the transmission manufacturer's service manual.

9. Check for wear on the fingers of the clutch release yoke, release shaft, and the release shaft bushings. Replace any worn parts.

10. Check the pilot bearing and release bearing. Replace parts as needed. Excessive wear can cause poor clutch performance and shortened clutch life.

11. Remove any oil or grease from the flywheel and bell housing area.

Installation

1. Using a driver, install a new pilot bearing. See **Fig. 14**.

2. Install the clutch assembly.

   2.1 Assemble the clutch disc and pressure plate on the pilot tool making sure the correct side of the disc will face the flywheel. See **Fig. 15**.

   2.2 If they were removed, install the dowels in the two upper holes in the flywheel.

Clutch Removal, Inspection, and Installation

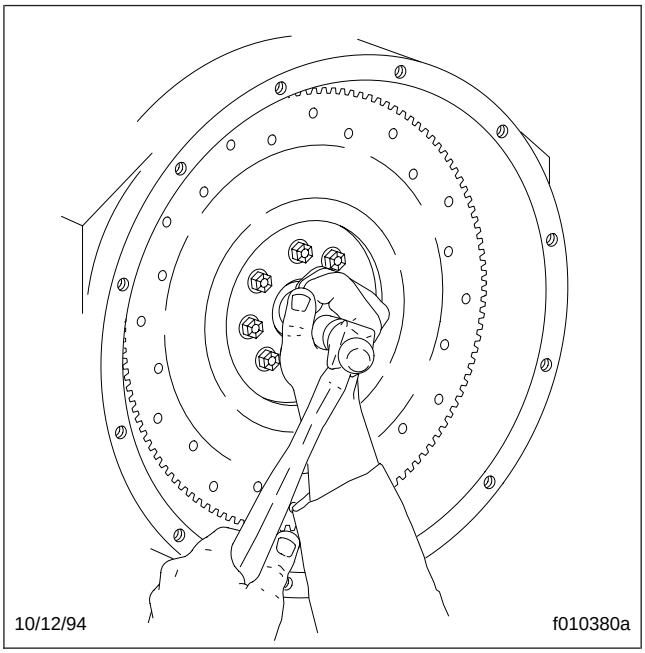


Fig. 14, Install a New Pilot Bearing

2.3 Lift the clutch disc, pressure plate, and pilot tool into position and hang them on the dowels. See **Fig. 5**.

2.4 Install capscrews in the holes without dowels. Remove the dowels and install the remaining capscrews. Tighten them 33 lbf·ft (45 N·m) in the sequence shown in **Fig. 16**.

2.5 Remove the pilot tool.

3. Lift the bell housing into position and install the twelve capscrews around the housing. See **Fig. 2**. Tighten the capscrews 40 lbf·ft (54 N·m).

NOTE: On vehicles with Cummins B Series engines some of the capscrews also hold brackets for the exhaust and various lines and cables.

4. Pull the clutch release fork back; then, slide the release bearing into position. See **Fig. 17**.

5. Install the transmission. For instructions, refer to the applicable section in **Group 26** of this manual.

6. Remove the chocks from the tires.

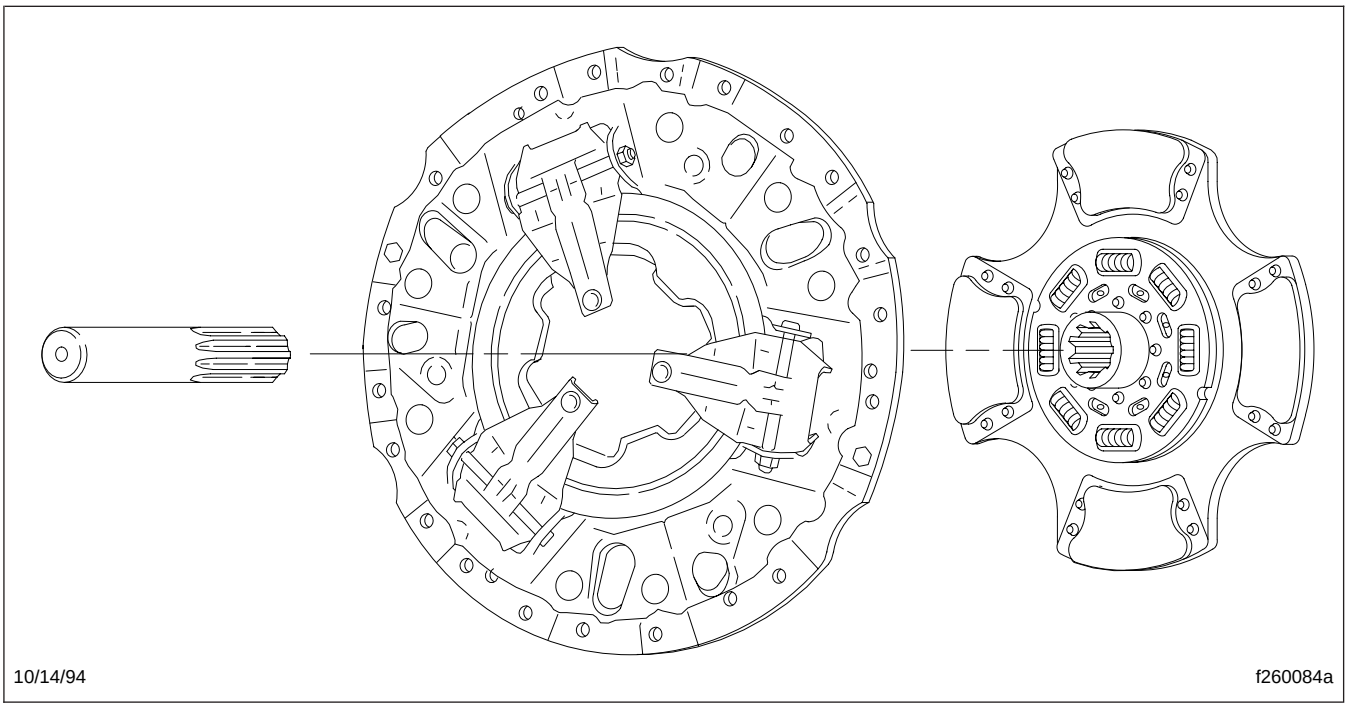


Fig. 15, Assemble the Clutch Disc and Pressure Plate on the Pilot Tool

7. Test drive the vehicle to check for correct clutch operation.

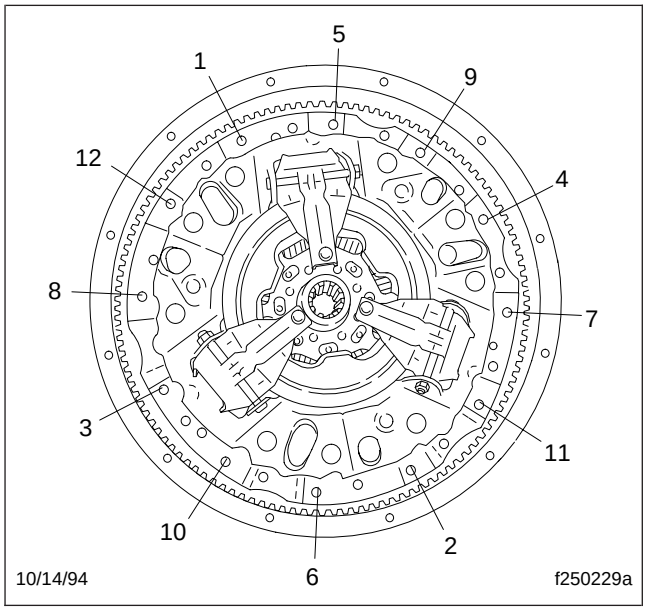


Fig. 16, Tightening Sequence

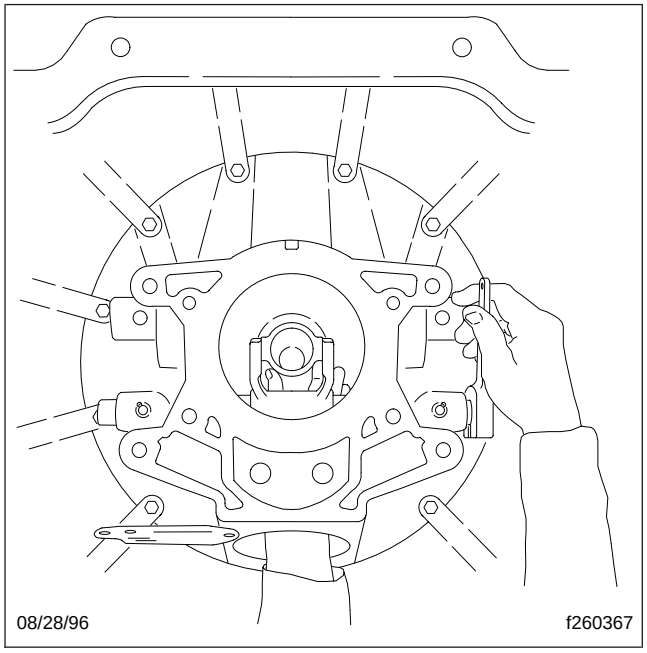


Fig. 17, Pull Back the Clutch Release Fork

Problem—Clutch Drags and Doesn't Release Completely

Possible Cause	Remedy
Slave cylinder is leaking or not working correctly.	Repair or replace the slave cylinder as needed.
Master cylinder is leaking or not working correctly.	Repair or replace the master cylinder as needed.
The clutch driven disc is bent or warped.	Replace the driven disc.

Problem—Clutch Slips

Possible Cause	Remedy
The shipping blocks were not removed.	Remove the shipping blocks and install the clutch correctly.
There is grease or oil on the clutch driven disk, the pressure plate, or the flywheel.	Clean the clutch components with isopropyl alcohol as needed. If the problem is due to a leaking rear crankshaft seal or transmission seal, replace seals as needed.
The driver is riding the clutch pedal.	Instruct the driver in the correct driving techniques. Slipping the clutch will cause clutch and flywheel damage.

Specifications

Description	Size (inches)	lbf·ft (N·m)
Clutch-to-Flywheel Mounting Bolts	3/8	33 (45)
Transmission-to-Bell Housing Bolts	3/8	40 (54)

Table 1, Torque Values

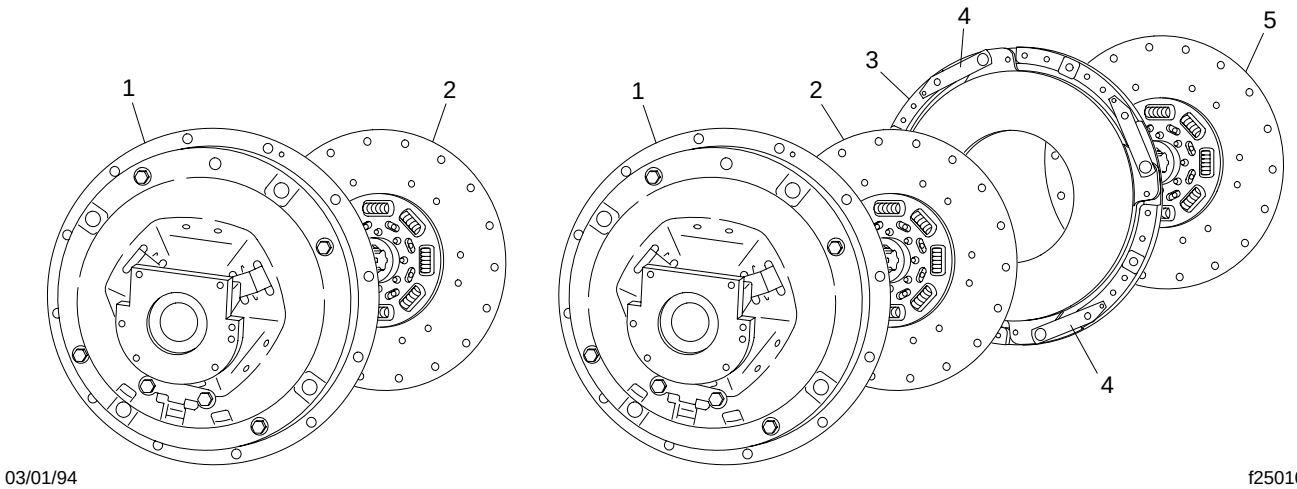
Description	Clutch Size 14 inch (350 mm)
Lever Height from Flywheel Surface	2-7/16 inches (61.93 mm)
Bolt Circle Diameter	15-1/2 inches (393.7 mm)
Rated Plate Load	2400 lbf (10 700 N)
Number of Splines	10
Spline Diameter	1-1/2 inches (38.1 mm)
Driven Disc Facing Material	Ceramic
Facing Thickness (new)	0.400 inch (10.16 mm)
Hub Type	Dampened 8-Spring

Table 2, Spicer Clutch Specifications

General Description

Spicer Angle-Spring clutches are pull-type clutches of a dry-disc design. They are available in 14-inch single-plate (SAS 1401) and two-plate (SAS 1402) versions. See **Fig. 1**. They may be specified with either a manual- or self-adjusting feature. Both versions are mounted to a flat flywheel.

A splined transmission input shaft projects through the cover assembly and driven discs, and rests in a pilot bearing in the center of the flywheel. The splined hubs of the driven discs mesh with the splined input shaft to provide the direct link between the engine and the transmission. This allows the rest of the clutch assembly to spin freely around the input shaft when the clutch pedal is depressed.



1. Cover Assembly
2. Clutch Disc (Driven Disc)
3. Intermediate Plate
4. Drivestrap
5. Front Disc

Fig. 1, Spicer Angle-Spring Clutches

In the two-plate versions, the intermediate plate separating the driven discs is mounted directly to the flywheel. The flywheel ring carries four drivestraps (Ref. 4) to retract the pressure plate when the clutch is disengaged.

Angle-Spring clutches may be specified with ceramic or organic driven discs.

Clutch capacity of all Spicer clutches is indicated by the color code of the pressure springs in the cover assembly. Refer to **Specifications, 400** for color codes.

Principles of Operation

Mounted directly on the flywheel, the domed clutch-cover assembly houses most of the components, including the pressure plate. Six pressure springs inside the cover provide the force necessary to push the pressure plate forward and engage the clutch.

When starting a vehicle moving, and when upshifting the transmission, the engine flywheel is turning faster than the transmission input shaft. The clutch intermediate plate and pressure plate (driving discs) are attached to and turn at the same speed as the flywheel. The clutch driven discs are meshed with and turn at the same speed as the transmission input shaft.

When the clutch pedal is depressed, the release bearing (connected inside the cover assembly) pulls away from the pressure plate. This compresses the pressure springs, and allows the driving discs to slip freely, at a different speed than the driven discs.

As the pedal is being released, the pressure springs force the pressure plate toward the engine flywheel, squeezing the driven discs. Slippage occurs between the driving and driven discs because of the difference in their speeds. As the pedal is further released, the friction between the discs increases, and the slippage and difference in speeds decreases.

General Description and Principles of Operation

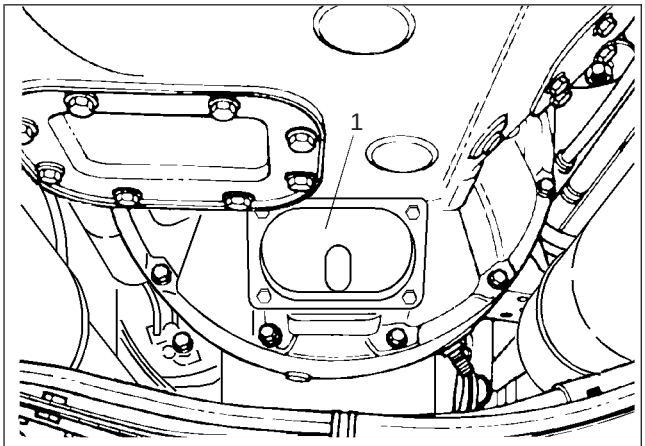
When the pedal is fully released, pressure and friction are sufficient to stop the discs from slipping. With no slippage, the driving and driven members turn at the same speed.

The clutch is a friction-operated unit that allows smooth coupling and uncoupling of the engine (driving member) and the transmission (driven member).

Release-Bearing Clearance Check

IMPORTANT: Do not skip steps in the adjustment operations. Internal adjustments must be correct before making any linkage adjustments for pedal free-travel. Incorrect adjustments can cause transmission gear clash, and slipping and burning of clutch components.

1. Apply the parking brakes, and chock the tires.
2. Remove the clutch inspection cover from the bottom of the transmission clutch housing. See **Fig. 1**.



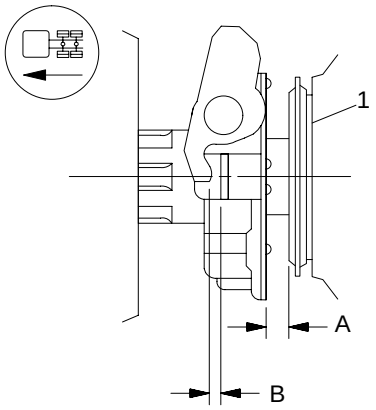
03/01/94 f250002a

1. Clutch Inspection Cover

Fig. 1, Remove the Clutch Inspection Cover

3. Slide the release-bearing as far as possible towards the transmission.
4. Measure the clearance between the aft face of the release bearing and the forward face of the torque-limiting clutch-brake. This clearance must be 1/2 to 9/16 inch (12.7 to 14.3 mm) in order for the release-bearing to release properly. See **Fig. 2**.

IMPORTANT: An inspection tool A02–12254 (available through the PDCs) can be used to check the distance between the release bearing and the release yoke (free travel). See **Fig. 2** and **Fig. 3**. The legs on one end of the tool have green tape on them and are 0.105 inch (2.7 mm) thick; the legs on the other end have blue tape on them and are 0.145 inch (3.7 mm) thick.



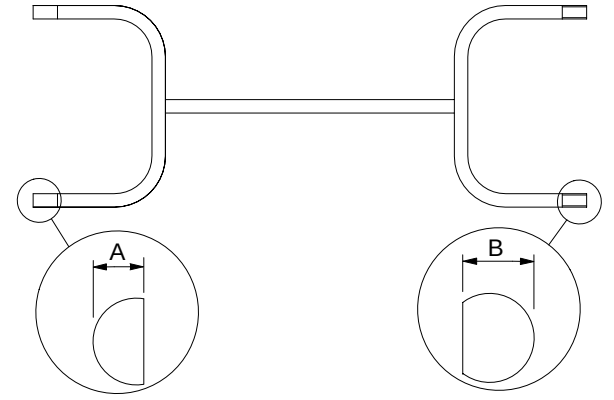
08/16/94 f250172b

A. Release-travel: 1/2 to 9/16 inch (12.7 to 14.3 mm).
B. Free-travel 0.105 to 0.145 inch (2.7 to 3.7 mm) between yoke and wear pads.
1. Clutch Brake

Fig. 2, Clutch Travel Adjustments

5. If using tool A02–12254 to check the distance between the release bearing and the release yoke, position the tool so it straddles the yoke to ensure that there won't be any misalignment. Check the distance with both ends of the tool as follows:
   - 5.1 Insert the blue 0.145 inch (3.7 mm) end. If it fits loosely the gap is too wide and adjustment is needed. Go to the section on clutch linkage adjustment in this group.
   - 5.2 If the blue 0.145 inch (3.7 mm) end can't be inserted in the gap, then try to insert the green 0.105 inch (2.7 mm) end. If the green end of the tool fits, snug or loose, then no adjustment is needed.
   - 5.3 If the green end of the tool can't be inserted in the gap, adjustment is needed. Go to the section on clutch linkage adjustment in this group.

Clutch Adjustments

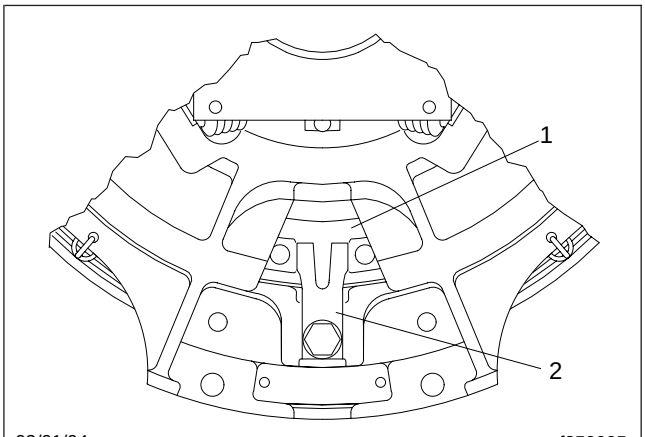


A. 0.105 inch (2.7 mm)
B. 0.145 inch (3.7 mm)

Fig. 3, Inspection Tool A02-12254

Internal Adjustment: Manual Adjusting Clutch

Angle-Spring clutches are adjusted with a lockstrap. See **Fig. 4**.



1. Adjusting Ring 2. Lockstrap

Fig. 4, Clutch Equipped with a Lockstrap

1. Turn the engine flywheel until the lockstrap is aligned with the clutch inspection-cover opening. See **Fig. 1** and **Fig. 4**.
2. Remove the lockstrap. See **Fig. 4**.
3. Release the clutch by depressing the pedal. Block the pedal in the released position, or have someone assist you by holding the pedal down during the adjustment procedure.
4. Using a large screwdriver, turn the adjusting ring to adjust release travel (the clearance between the release-bearing housing and the forward clutch-brake disc).

   If clearance between the release-bearing housing and the clutch brake is *less than* 1/2 inch (12.7 mm), rotate the adjusting ring counterclockwise to move the release-bearing toward the engine.

   If clearance between the release-bearing housing and the clutch brake is *more than* 9/16 inch (14.3 mm), rotate the adjusting ring clockwise to move the release-bearing toward the transmission.

   The lockstrap bolt may be installed and used as a fulcrum in turning the adjusting ring.

NOTE: Each notch in the adjusting ring represents about 0.020 inch (0.5 mm) release-bearing travel. Thus, three notches moved means 0.060 inch (1.5 mm) or about 1/16 inch release-bearing travel.

5. After adjusting, release the pedal, and check the clearance between the release-bearing housing and the forward clutch-brake disc, or torque-limiting clutch brake. When the clearance is 1/2 to 9/16 inch (12.7 to 14.3 mm), the adjustment is complete.
6. Install the lockstrap, and tighten the bolt 35 to 40 lbf·ft (47 to 54 N·m).

IMPORTANT: Use the same length bolt when installing the lockstrap. A longer bolt will lock up the clutch assembly.

NOTE: If the lockstrap will not engage the notches of the adjusting ring, check the clutch assembly for worn parts. For instructions, refer to **Subject 110**.

7. Proceed to the section on clutch linkage adjustment in this manual.

Internal Adjustment: Self-Adjusting Clutch

IMPORTANT: The self-adjusting clutch normally compensates for wear, and should only need adjustment when it is first installed. If the release-bearing clearance check shows the self-adjusting clutch to be out of adjustment, be sure that:

A. the actuator arm is correctly inserted into the release-bearing sleeve retainer. See **Fig. 5**;

B. the adjuster arm is not bent;

C. the release-bearing has at least a 1/2 to 9/16 inch (12.7 to 14.3 mm) travel;

D. other clutch parts (such as the adjusting ring) aren't frozen or damaged.

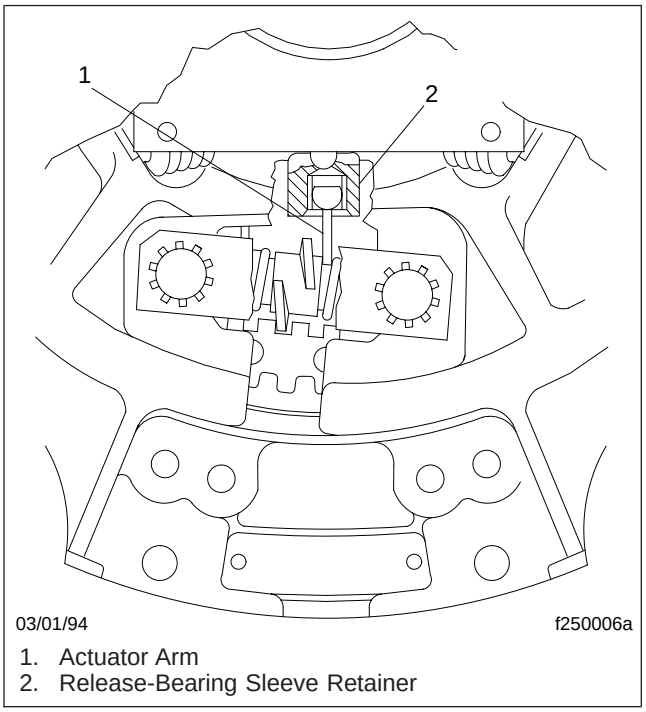


Fig. 5, Actuator Arm Correctly Inserted into the Release-Bearing Sleeve Retainer

If the clutch is damaged, replace it.

If adjustment is needed, do the following:

1. Turn the engine flywheel until the adjuster assembly is in line with the clutch inspection-cover opening. See **Fig. 1** and **Fig. 5**.
2. Remove the right-side bolt from the adjuster assembly, and loosen the left-side bolt one turn. See **Fig. 6**.

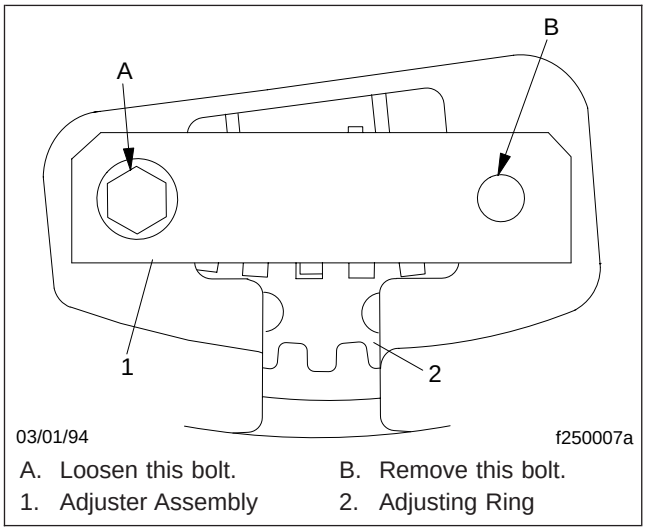


Fig. 6, Remove the Right-Side Bolt from the Adjuster Assembly

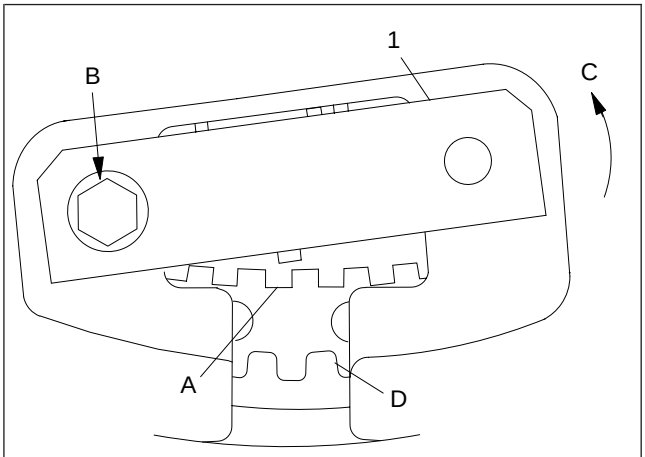
3. To allow manual adjustment, rotate the adjuster assembly upward. See **Fig. 7**. This will disengage the adjuster worm gear from the adjusting ring. Hold the adjuster assembly disengaged, and tighten the left-side bolt.
4. Release the clutch by depressing the pedal; block it in this position.
5. Using a large screwdriver in the lower teeth, turn the adjusting ring clockwise to move the release-bearing toward the transmission, or counterclockwise to move the release-bearing toward the engine. See **Fig. 7**.

CAUTION

CAUTION: Do not pry on the innermost gear teeth of the adjusting ring. See Fig. 7. Doing so could damage the teeth, and prevent the clutch from self-adjusting.

NOTE: Each lower gear tooth of the adjusting ring represents about 0.010 inch (0.25 mm) release-bearing movement. Thus, six notches

Clutch Adjustments



A. Do not pry on the innermost teeth.
B. Tighten the bolt.
C. Rotate up.
D. Use a large screwdriver in the lower teeth.
1. Adjuster Assembly

Fig. 7, Rotate the Adjuster Assembly Upward

moved means 0.060 inch (1.5 mm) or about 1/16 inch release-bearing movement.

6. After adjusting, release the clutch pedal, and check the clearance between the release-bearing housing and the forward clutch-brake disc, or torque-limiting clutch brake. When the clearance is 1/2 to 9/16 inch (12.7 to 14.3 mm), the adjustment is complete.

IMPORTANT: The clutch will not self-adjust if release-bearing travel is less than 1/2 inch (12.7 mm).

7. Loosen the left-side adjuster bolt, and rotate the adjuster assembly down, meshing the adjuster worm gear with the adjusting ring teeth. The ring may have to be moved slightly, to allow the worm to mesh. Install the right-side bolt, and tighten both bolts 30 to 35 lbf·ft (41 to 47 N·m).
8. Visually check that the actuator arm is inserted in the release-bearing sleeve retainer. See **Fig. 5**. If the adjuster assembly is installed correctly, the adjuster assembly spring will move back and forth as the clutch pedal is depressed and released.

IMPORTANT: The clutch will not self-adjust if the actuator arm is not correctly inserted in the release-bearing sleeve retainer.

After making release-bearing adjustments, go to the section on clutch linkage adjustment.

Removal

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

1. Remove the transmission. For instructions, refer to **Group 26** in this manual.

CAUTION

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

2. Remove the clutch brake from the transmission input shaft.
3. Install a spline aligning tool into the release-bearing assembly, and through the driven discs. See **Fig. 1**. An old transmission input shaft may be used for this purpose.

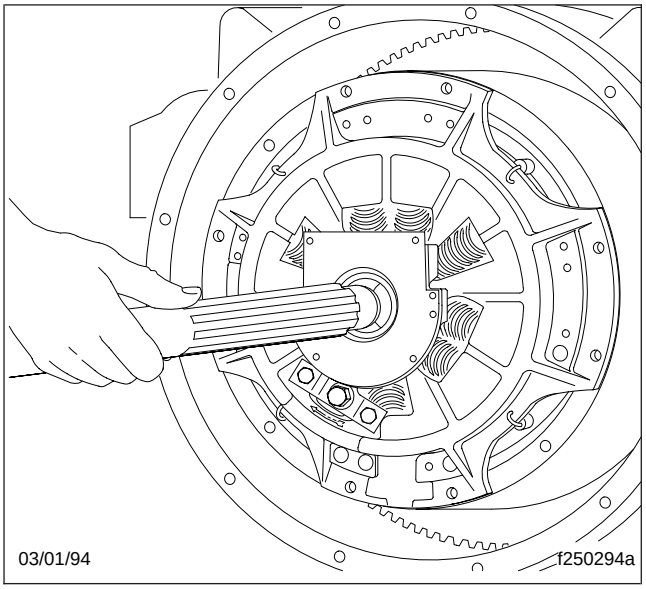
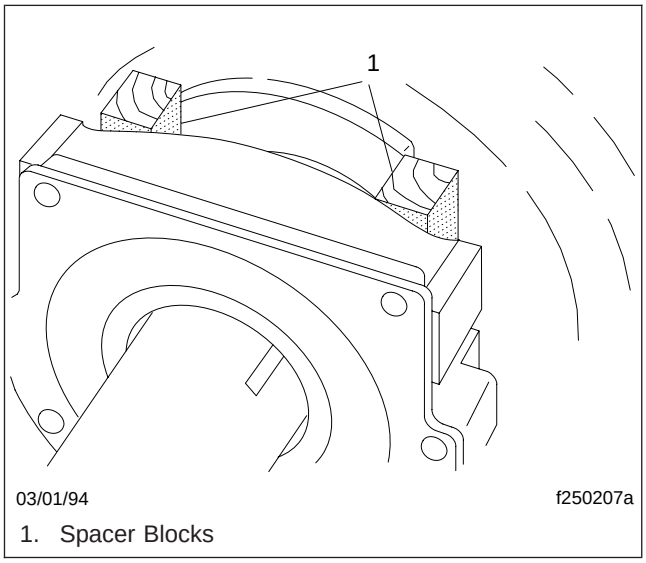


Fig. 1, Installing a Spline Aligning Tool

4. Insert two wooden spacer blocks between the flywheel ring and the release bearing housing. The spacer blocks relieve the internal spring load in the clutch assembly, and facilitate clutch removal. Use two 1-1/2 inch (38 mm) spacer blocks. See **Fig. 2**.



1. Spacer Blocks

Fig. 2, Insert Two Spacer Blocks

5. Remove the two top mounting capscrews from the cover assembly. Install guide studs in the open holes to help support the clutch assembly during removal. For 14-inch clutches, use 3/8-16 by 2-1/2 inch guide studs. See **Fig. 3**.

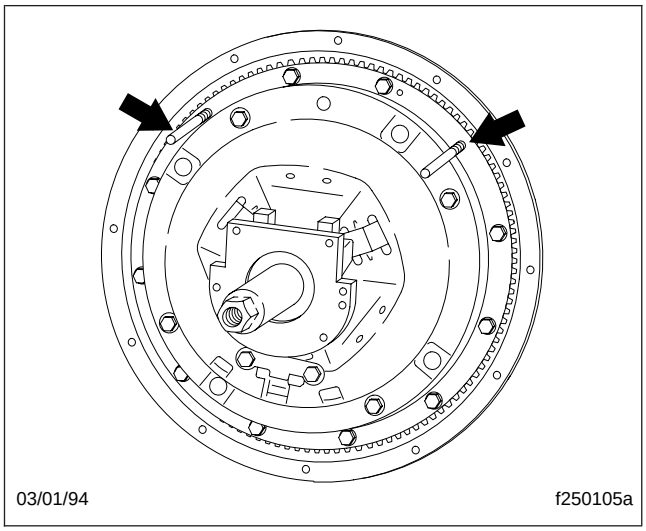


Fig. 3, Guide Stud Installation on 14-Inch Clutches

6. Progressively loosen each of the capscrews in the pattern shown in **Fig. 4** . This will prevent

Clutch Removal, Inspection, and Installation

warping or bending within the clutch, and will ease removal of the clutch-mounting capscrews.

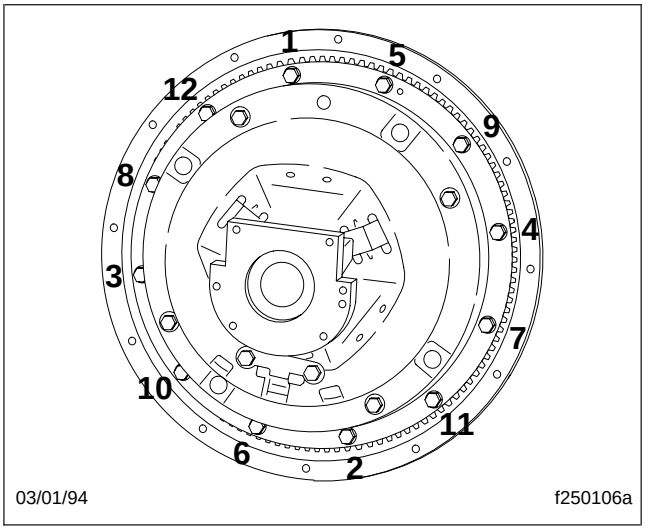


Fig. 4, 12-Bolt Pattern

WARNING

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

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

   With two-plate clutches, be careful to keep the spline aligning tool in place to retain the discs and intermediate plate. Remove the spline aligning tool, the rear driven disc, the intermediate plate, and the front driven disc.

8. Whenever the clutch assembly is serviced or the engine is removed, the pilot bearing in the flywheel should be removed and replaced. Use an appropriate puller to remove the pilot bearing.

   Inspect the old pilot bearing. Correct the cause of any unusual wear or damage. Discard the bearing.

Inspection

The engine and transmission must line up. To check for this, make the following measurements.

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

Clean the surfaces being measured to ensure accurate measurements.

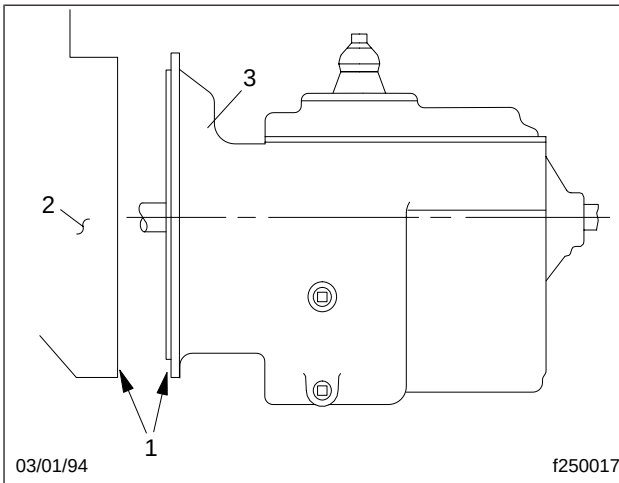
NOTE: Before measuring the engine flywheel or flywheel housing, check the end-play of the crankshaft. Mount the dial indicator on the flywheel housing, with the indicator's finger against the flywheel. Force the crankshaft back and forth with a pry bar. If end-play exceeds the maximum, correct it. For specifications and instructions, refer to the engine manufacturer's service manual.

1. Inspect for a worn or corroded pilot on both the transmission clutch housing, and engine flywheel housing. See **Fig. 5**. The 1/8-inch (3 mm) pilot lip of the clutch housing can wear into the flywheel housing. This can be caused by the transmission loosening up, or by road and engine vibration after high mileage. Any measurable amount of wear on either part will cause misalignment; replace the part. Wear may first appear between the 3 o'clock and 8 o'clock positions. See **Fig. 6**. To check for wear, proceed as follows:

   1.1 Measure the runout of the pilot (bore) of the flywheel housing. Secure the dial indicator to the flywheel (or crankshaft), with the gauge finger against the housing pilot. See **Fig. 7**. With chalk or soapstone, mark the high and low points on the flywheel housing flange, while rotating the flywheel (or crankshaft) by hand. The total runout will be the difference between the highest plus and minus readings. See **Fig. 8**.

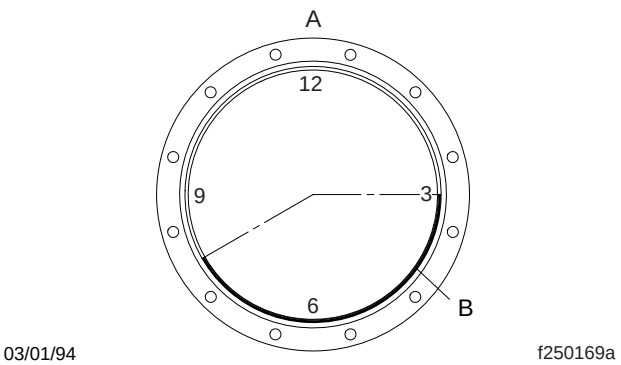
   The SAE maximum total runout for the flywheel housing pilot is 0.008 inch (0.2 mm). If readings are higher, replace the housing. For instructions, refer to the engine manufacturer's service manual.

   1.2 Measure the runout of the face of the flywheel housing. With the dial indicator secured to the flywheel (or crankshaft), move the finger to contact the face of the



1. Pilot
2. Engine Flywheel Housing
3. Transmission Clutch Housing

Fig. 5, Inspect for a Worn or Corroded Pilot



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

Fig. 6, Checking for Wear

housing. See **Fig. 9**. Mark the high and low points.

The SAE maximum total runout for the flywheel housing face is 0.008 inch (0.2 mm). If the readings are higher, replace the housing. For instructions, refer to the engine manufacturer's service manual.

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

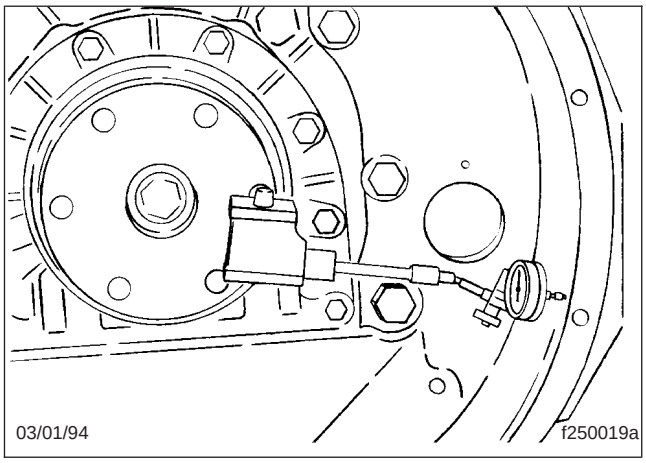
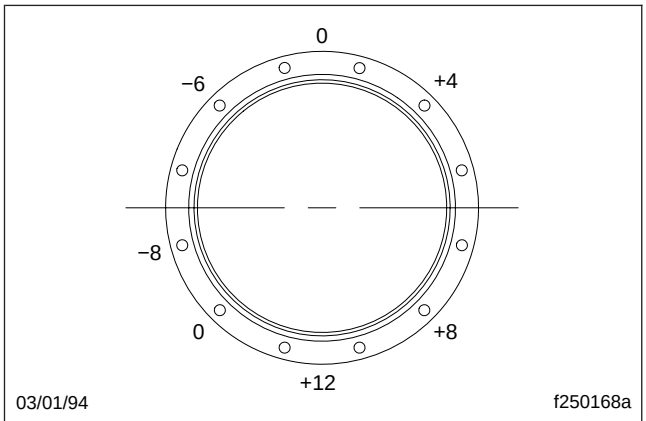


Fig. 7, Measure the Runout of the Pilot Bore



NOTE: Plus 0.012 inch (0.30 mm) and minus 0.008 inch (0.2 mm) gives the housing a total runout of 0.020 inch (0.51 mm).

Fig. 8, Calculating Runout

2. Measure the runout of the flywheel face. Secure the dial indicator to the flywheel housing, with the gauge finger against the face of the flywheel near the outer edge. See **Fig. 10**. Turn the flywheel to obtain readings.

   A 0.0005 inch (0.01 mm) runout or face wobble per inch of flywheel diameter is allowed. For example, on a 14-inch clutch, and if the readings are taken just off the outer edge of the clutch disc wear, the maximum tolerance would be 0.007 inch (0.2 mm). If the readings are higher, repair or replace the flywheel. Refer to the engine manufacturer's service manual for instructions.

Clutch Removal, Inspection, and Installation

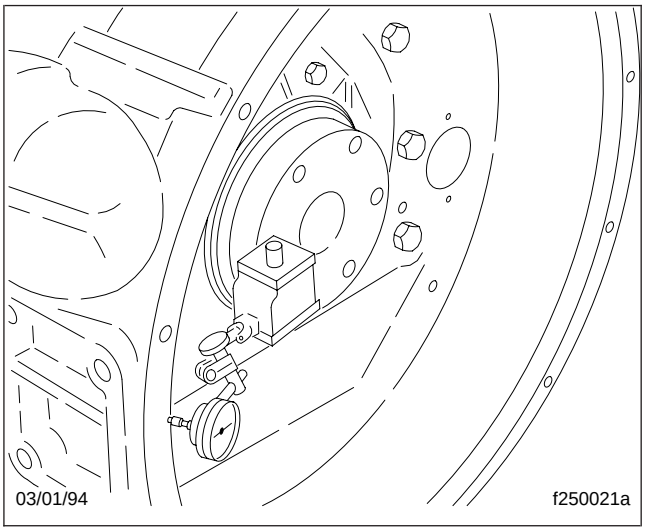


Fig. 9, Measure the Runout of the Flywheel Housing Face

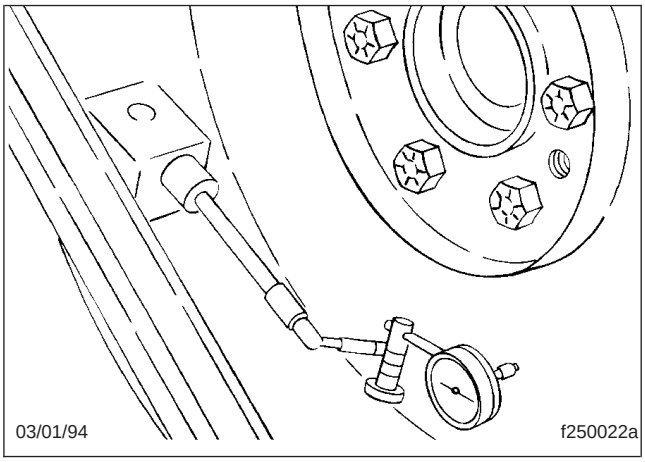


Fig. 10, Measure the Runout of the Flywheel Face

3. Measure the runout of the pilot-bearing bore of the flywheel. With the indicator secured to the flywheel housing, move the gauge finger to contact the pilot-bearing bore surface. See **Fig. 11**. Turn the flywheel to obtain the readings.

   The SAE maximum total runout for the pilot-bearing bore is 0.005 inch (0.1 mm). If the readings are higher, refer to the engine manufacturer's service manual for instructions.

4. Measure the runout of the transmission clutch-housing face and pilot.

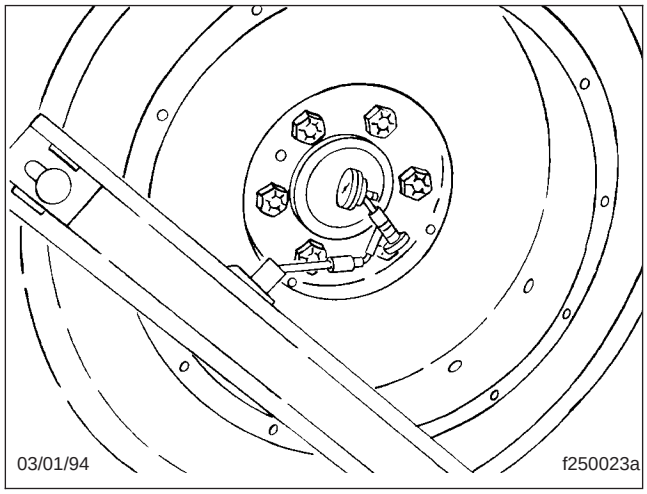


Fig. 11, Measure the Runout of the Pilot-Bearing Bore

NOTE: The clutch-housing face and pilot cannot be checked accurately unless you have a set of case-bore plugs and shaft. This set consists of plugs that are tapped into the front and rear bores of the transmission case, and have very close fits in the bores. A shaft runs through the center of the plugs, and extends to the front far enough to secure a dial indicator, and obtain a reading on the clutch housing.

The SAE maximum runout for the clutch-housing face and pilot is 0.008 inch (0.2 mm). If the readings are higher, replace the clutch housing; refer to the transmission manufacturer's service manual.

5. Remove the flywheel (refer to the engine manufacturer's service manual), and measure the runout of the flywheel crankshaft face. Secure the dial indicator to the flywheel housing, with the gauge finger against the crankshaft face, near the outer edge. See **Fig. 12**. Turn the crankshaft to obtain readings.

   Refer to the engine manufacturer's service manual for maximum runout, corrective measures, and flywheel installation instructions.

⚠ CAUTION

CAUTION: Misalignment of any parts described in the steps above will cause premature wear of drivetrain components.

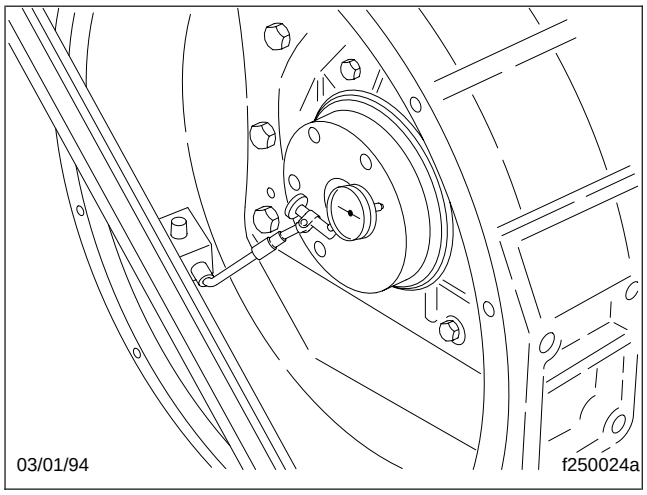


Fig. 12, Measure the Runout of the Flywheel Crankshaft Face

Installation

Pre-Installation Checks

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

1. Inspect the friction surface of the flywheel for smoothness, heat checks, scoring, and wear on the contact surface. Inspection for heat checks and scoring must be visual, and based on experience; however, measure the friction surface wear with a straightedge and feelers.

   Replace or repair the flywheel if the wear is extreme. For instructions, refer to the engine manufacturer's recommendations concerning flywheel replacement or rebuilding.

2. If the flywheel has been replaced, measure the runout of the face and pilot diameters to make sure the measurements are within the engine manufacturer's specifications.

3. Check the fit of the splined hubs of the front and rear friction discs by sliding them on the transmission input shaft splines. The hubs must slide freely so the clutch will release cleanly. If necessary, use a hand stone to dull the sharp edges of the splines. If the input shaft splines are badly worn or notched, replace the input shaft; for instructions, refer to the transmission manufacturer's service manual.

4. Check for wear on the fingers of the clutch release yoke, release shafts, and the release shaft bushings. Replace any worn parts.

Installing a Spicer Angle-Spring Plate Clutch

NOTE: Do the pre-installation checks in this section before installing the clutch.

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

2. If the clutch is new, remove the protective coating from the pressure plate.

3. If not already in place, install two 3/8-16 by 2-inch guide studs in two upper mounting holes of the flywheel. See **Fig. 13**.

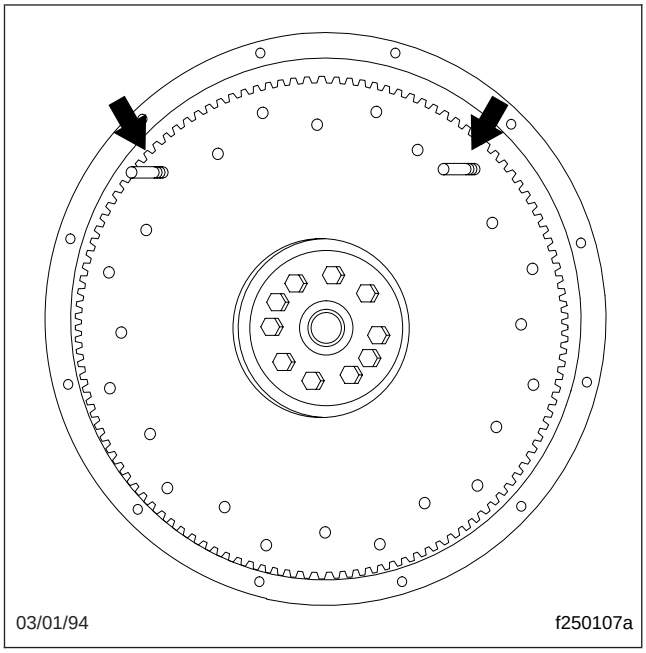


Fig. 13, Install the Guide Studs

4. Insert an aligning tool through the splines of the driven disc. Insert the aligning tool into the pilot bearing. See **Fig. 14**. Be sure the side marked *PRESSURE PLATE SIDE* faces the pressure plate. See **Fig. 15** for the driven disc installed position.

Clutch Removal, Inspection, and Installation

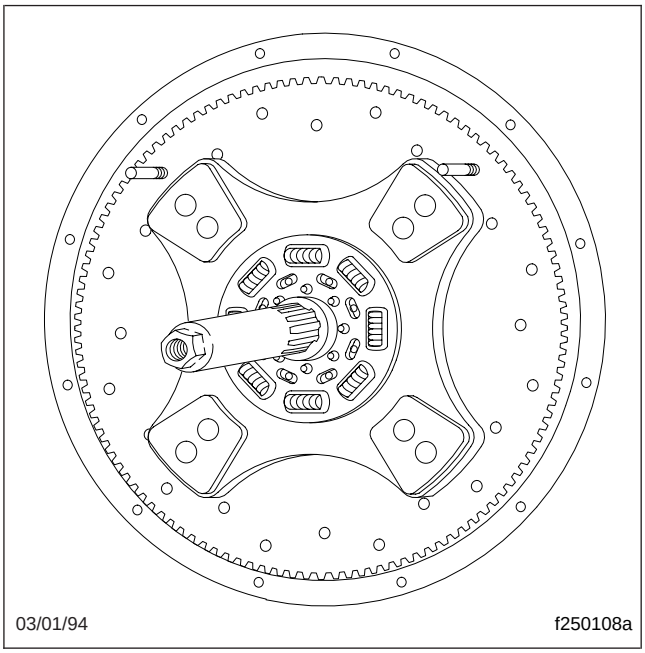


Fig. 14, Insert an Aligning Tool

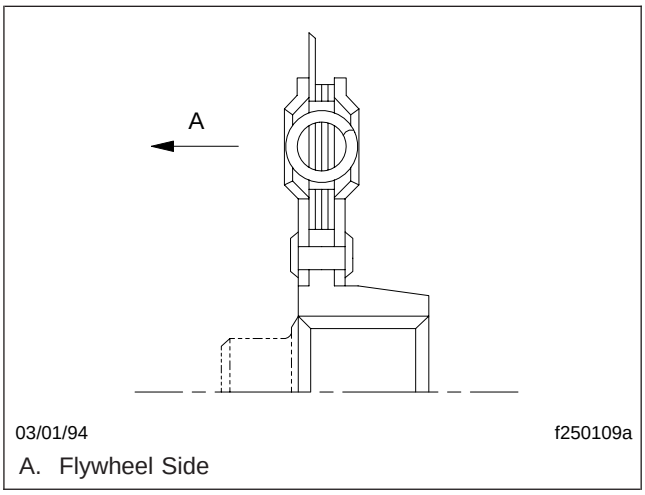


Fig. 15, Driven Disc Installed

WARNING

WARNING: The pressure plate and cover assembly is heavy and should be removed and installed with a lifting device. If the assembly is lifted incorrectly or dropped, it could cause serious personal injury.

5. With the aligning tool still in place, slide the cover assembly over the aligning tool. Align the lockstrap or self-adjuster with the access opening in the bell housing. See **Fig. 16**.

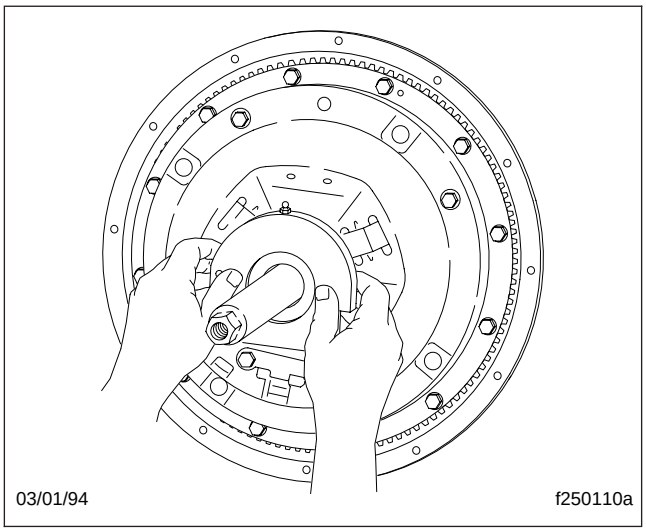


Fig. 16, Slide the Cover Assembly Over the Aligning Tool

6. Start ten 3/8-16 grade 8 capscrews with lockwashers in the cover plate. Tighten them snugly. Remove the guide studs. Install two 3/8-16 grade 8 capscrews with lockwashers. Then, following the sequence in **Fig. 17**, tighten the capscrews 35 to 40 lbf·ft (47 to 54 N·m).

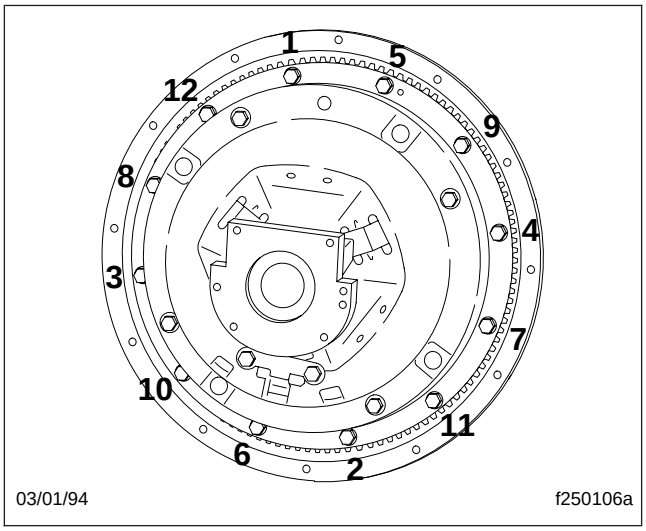


Fig. 17, Tightening Sequence

CAUTION

CAUTION: If the capscrews are not tightened in the sequence shown, clutch damage and an out-of-balance condition may result.

7. Remove the alignment tool. Remove the wooden spacer blocks.
8. Adjust the clutch and the clutch linkage after installing the clutch. Refer to the clutch linkage section in this group for procedures.

Installing a Spicer Angle-Spring Two Plate Clutch

NOTE: Do the pre-installation checks in this section before installing the clutch.

1. Install a new pilot bearing. Be sure that the pilot bearing has a press-fit in the flywheel.
2. If the clutch is new, remove the protective coating from the pressure plate.
3. Place the front disc in the bell housing with the side marked *FLYWHEEL SIDE* facing the flywheel. See **Fig. 18**.

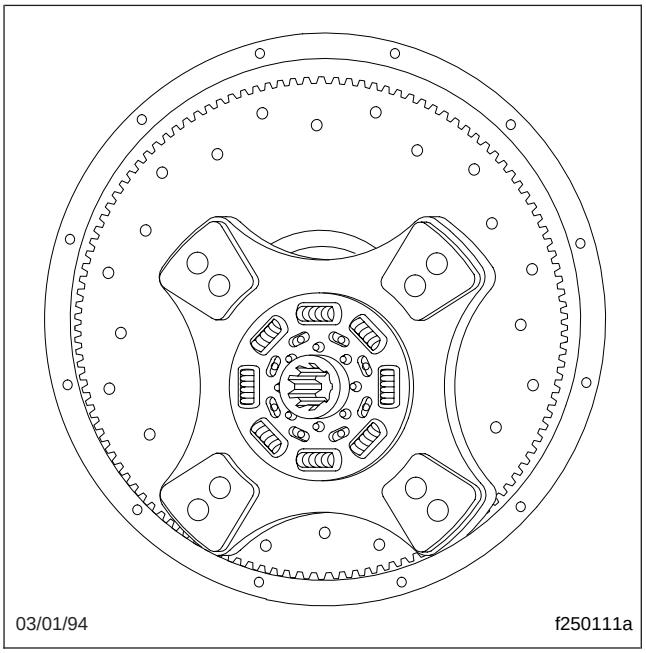


Fig. 18, Position the Front Disc

4. If not already in place, install two 3/8-16 by 2-inch guide studs in two upper mounting holes of the flywheel. See **Fig. 19**.

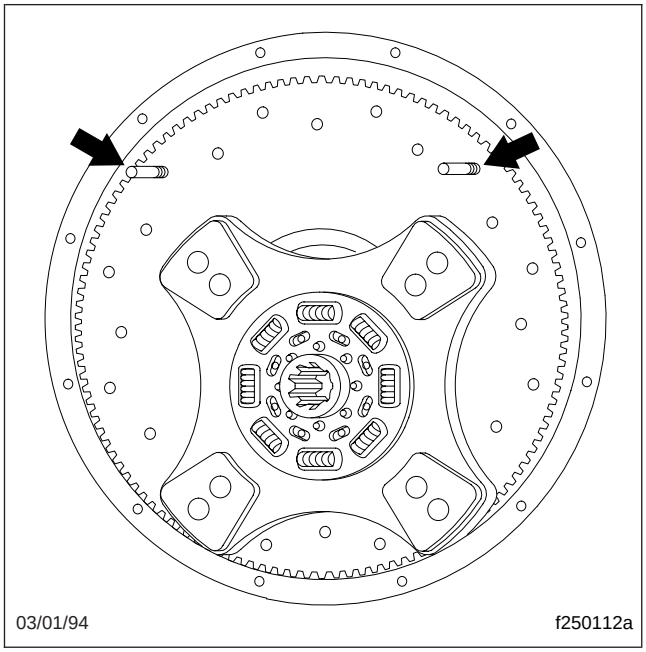


Fig. 19, Install the Guide Studs

5. Install the drivestrap intermediate plate over the guide studs. Make sure the side marked *FLYWHEEL SIDE* faces the flywheel. See **Fig. 20**.

IMPORTANT: The drivestraps of the intermediate plate must face the pressure plate.

NOTE: The four holes through the drivestraps are the pilot holes for the adapter ring.

6. Raise the front disc to fit into the intermediate plate opening.
7. Install an aligning tool through the splines of the rear disc. Install the rear disc by inserting the aligning tool into the pilot bearing. See **Fig. 21**. Be sure the side marked *PRESSURE PLATE SIDE* faces the pressure plate. See **Fig. 22** for driven disc installed position.

WARNING

WARNING: The pressure plate and cover assembly is heavy and should be removed and installed only with a lifting device. If the assembly is lifted

Clutch Removal, Inspection, and Installation

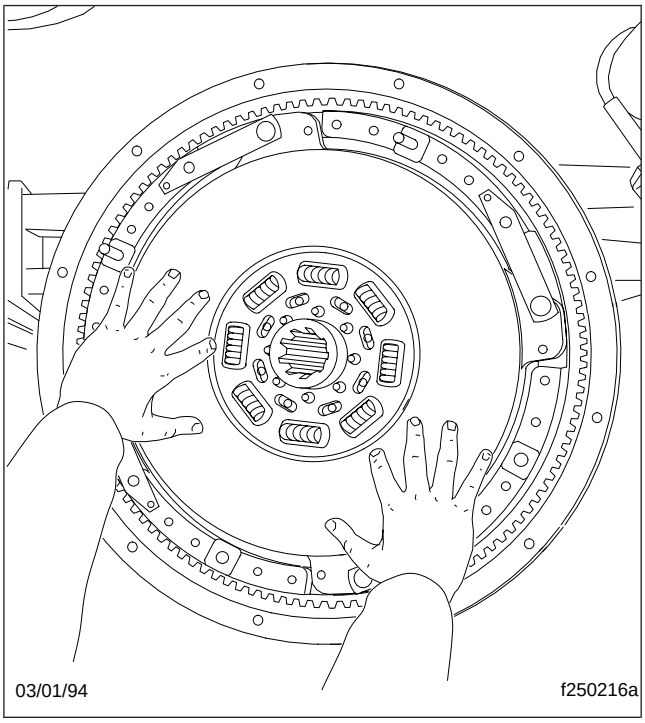


Fig. 20, Install the Drivestrap Intermediate Plate

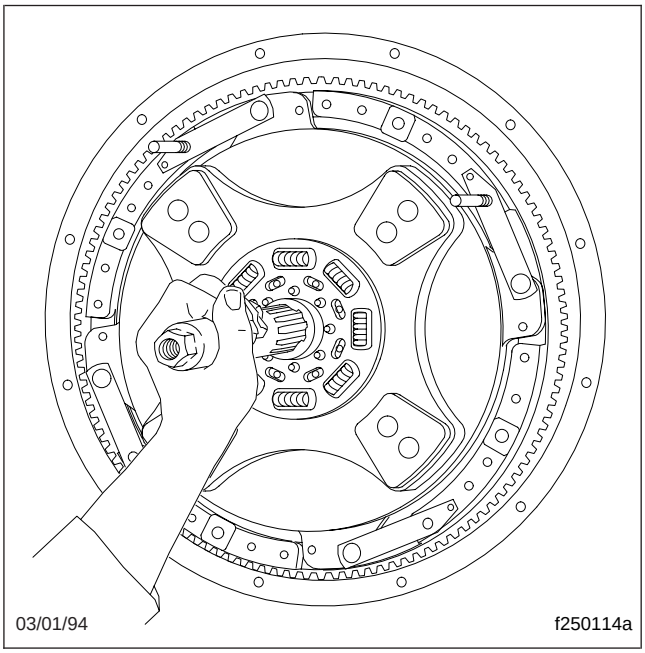


Fig. 21, Install an Aligning Tool

incorrectly or dropped, it could cause serious personal injury.

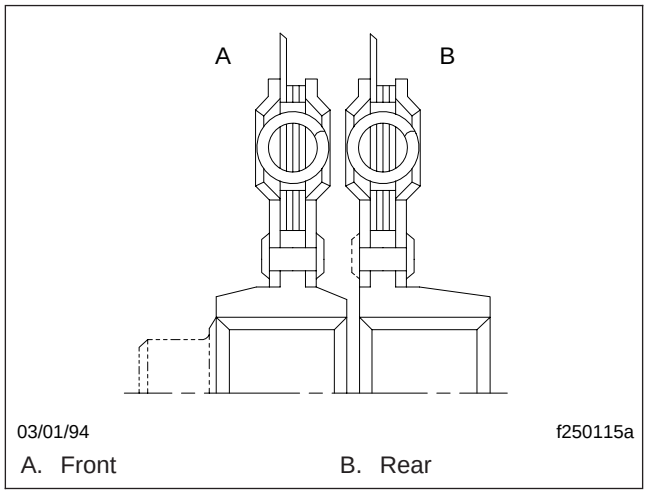


Fig. 22, Driven Disc Installed

8. With the aligning tool still in place, carefully slide the clutch assembly over the aligning tool. See **Fig. 23**. Align the lockstrap or self-adjuster with the access hole in the bell housing.

   Slide the clutch assembly over the guide studs and against the spacer ring.

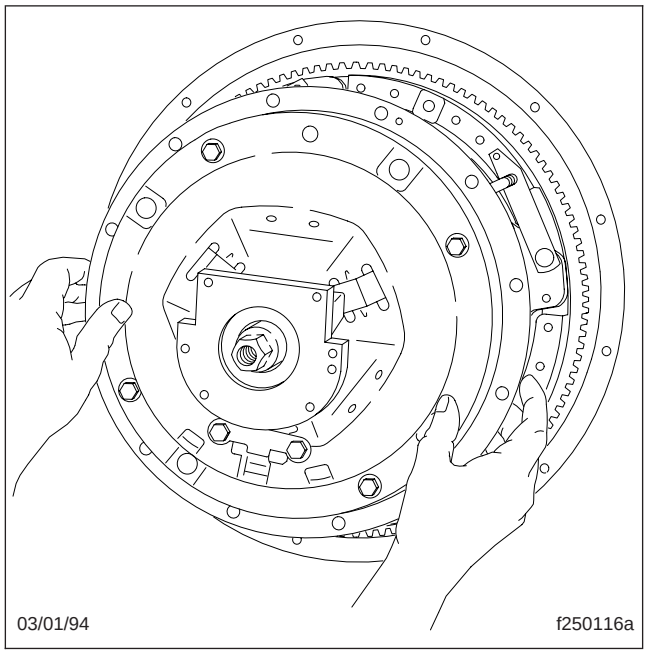


Fig. 23, Slide the Clutch Assembly Over the Aligning Tool

9. Start ten 3/8-16 grade 8 capscrews with lockwashers in the cover plate. Tighten them snugly. Remove the guide studs. Install two 3/8-16 grade 8 capscrews with lockwashers. Then, following the sequence in **Fig. 24**, tighten the capscrews 35 to 40 lbf·ft (47 to 54 N·m).

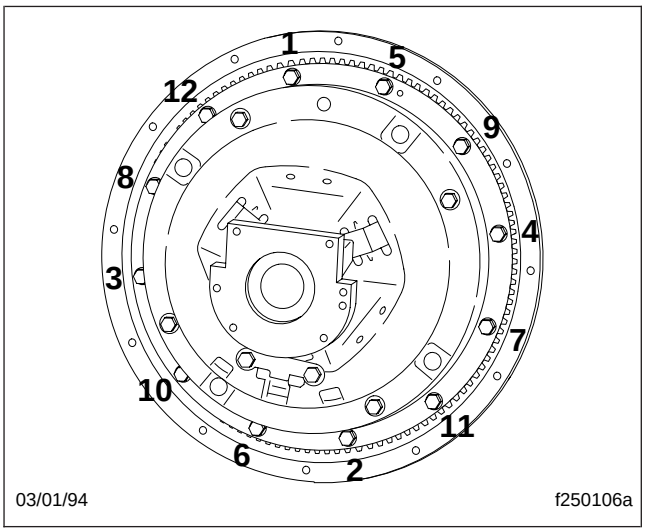


Fig. 24, Tightening Sequence

CAUTION

CAUTION: If the capscrews are not tightened in the sequence shown, clutch damage and an out-of-balance condition may result.

10. Remove the alignment tool. Remove the wooden spacer blocks.
11. Adjust the clutch and the clutch linkage after installing the clutch. Refer to the clutch linkage section in this group for procedures.

Troubleshooting Tables

Problem—Clutch Slipping

Problem—Clutch Slipping	
Possible Cause	**Remedy**
Lack of free-play is holding the clutch partially disengaged.	Adjust the clutch and linkage.
The clutch release mechanism is binding.	Check the clutch release mechanism and linkage. Lubricate as necessary, following the procedures in the vehicle maintenance manual.
Clutch facings are worn.	Replace the driven discs.
Grease or oil on the facings is allowing the discs to slip.	Replace the discs.
The clutch pressure springs are weak.	Replace the clutch.
The clutch is overloaded.	Check the vehicle specifications to ensure that the correct clutch has been specified and is installed.

Problem—Noisy Clutch

Problem—Noisy Clutch	
Possible Cause	**Remedy**
A dry or damaged clutch release bearing is making noise.	Lubricate the bearing using the instructions in the vehicle maintenance manual. If the bearing is damaged, replace it.
A dry or damaged flywheel pilot bearing is making noise.	Lubricate or replace the bearing, as needed.
The clutch release-bearing housing is striking the flywheel ring.	Adjust the clutch. Also, check for wear on the cross-shafts, cross-shaft bushings, and on the release yoke fingers. Replace worn parts, as needed.
There is incorrect clearance between the drive slots on the flywheel ring and the drive pins on the pressure plate (14-inch clutch, pot-type flywheel only).	The clearance should be no less than 0.006 inch (0.2 mm). Reinstall the drive pins if necessary.

Problem— Poor Clutch Release

Problem— Poor Clutch Release	
Possible Cause	**Remedy**
The clutch adjustment is incorrect.	Adjust the clutch.
The flywheel pilot bearing is too tight in the flywheel, or is too tight on the end of the drive gear.	Free the pilot bearing to a light push. If the bearing is rough, replace it.
A damaged release bearing is not allowing a smooth clutch release.	Replace the bearing. If the bearing is a greasable type, lubricate it, following the procedures in the vehicle maintenance manual.
If the clutch release shafts are projecting through the release yoke, they are interfering with the release bearing travel.	Relocate the release shafts so they don't project. Check the release shaft bushings, and the release yoke for wear. Replace worn parts, as needed.

Troubleshooting

Problem— Poor Clutch Release Possible Cause	Remedy
At the full clutch-release position, the release yoke is making contact with the cover assembly.	Replace the release yoke with the correct yoke.
The release yoke is not aligned with the release bearing.	Check the flywheel for resurfacing that exceeds the 0.060 inch (1.5 mm) recommendations. Replace the flywheel, if needed, following the procedures in the engine manufacturer's service manual.
The intermediate plate is sticking on the drive pins.	Check to see that the drive pins are 90 degrees square to the flywheel surface, and that there is a minimum 0.006 inch (0.2 mm) clearance between the drive pins and the intermediate-plate slots. Reinstall the drive pins if necessary.
The intermediate plate is binding (14-inch with flat flywheel only.)	Check to be sure that there is a minimum of 0.006 inch (0.2 mm) clearance between the drive lugs and the intermediate plate slots.
One or both driven discs is distorted.	The driven discs should be straight within 0.015 inch (0.04 mm). Replace the discs if they can't be straightened.
Worn splines on the input shaft of the transmission aren't allowing a smooth clutch travel.	Check the transmission input shaft and driven disc hubs for wear, and replace as needed.
Oil or grease has gummed the driven disc facings.	Replace the discs. Cleaning is not recommended. Check for and repair the leak causing the gumming.
The intermediate plate is broken.	Replace the entire intermediate-plate/driven-disc assembly. Damage such as this is almost always caused by abusive use of the clutch. Caution the operator on the correct clutch operation.

Description	inches (mm)
Flywheel-Housing Pilot Diameter	14.750/14.747 (374.7/ 374.6)
Flywheel-Housing Bolt Circle	15.500 (394)
Flywheel Pot Depth	2-15/16 (74.6)
Driven Disc and Facing Thickness	0.463/0.428 (11.8/10.9)
Disc Assembly, Maximum Runout	0.015 (0.38)
Driven Disc Assembly, Maximum Out of Flat	0.020 (0.5)
Hub Spline Size (inches, number of splines)	1-3/4-10 (44.45-10)
	2-10 (51-4)
Release-Sleeve Bushing Diameter (new)	1.754/1.750 (44.55/44/45)
	2.010/2.008 (51.05/51.0)
Intermediate Plates, Driving Pins to Slot Clearance (minimum new/maximum worn)	0.006/0.020 (0.15/0.5)
Pressure Plates, Driving Lugs to Slot Clearance (new/ maximum worn)	0.004-0.008/0.020 (0.10-0.20/0.5)
Intermediate Plates and Pressure Plates: Out of Flat	0.000-0.004 (0.000-0.10) Concave
Scoring: Maximum Depth That Can Be Re-Used	0.015 (0.38)
Release Sleeve Retainer, Driving Lugs to Slot Clearance (maximum worn)	0.020 (0.5)

Table 1, Spicer 14 and 15-1/2 Inch Standard and Super-Duty Clutch Specifications

Clutch Type	Spring Color Code	Facing	Recommended Maximum Engine Torque lbf·ft (N·m)
SAS 1401 (14-inch; single-plate)	Blue	Organic	350 (475)
	Purple	Organic	400 (542)
	Blue	Ceramic	500 (678)
	Purple	Ceramic	560 (759)
SAS 1402 (14-inch; two-plate)	Blue	Organic	560 (759)
	Green	Ceramic	800 (1085)
	Blue	Ceramic	800 (1085)
	Purple	Organic	800 (1085)
	Purple	Ceramic	800 (1085)

Table 2, Spicer Angle-Spring Clutch Capacity; Spring Color Codes

Specifications

Description	lbf·ft (N·m)
Cover-to-Flywheel	35–40 (47–54)

Table 3, Torque Values

General Description

The clutch linkage transfers the motion of the clutch pedal to the clutch release bearing.

Free-play in the clutch pedal is required to ensure that the fingers of the release bearing do not run against the release bearing. There should not be any play or looseness in the connections and joints of the clutch linkage.

Two types of clutches may be installed on the vehicle: pull or push.

- On push-type clutches, depressing the clutch pedal moves the release bearing toward the engine flywheel. As the clutch is depressed, the pressure plate moves away from the driven disc assembly, and the clutch is disengaged. As the clutch pedal is released, the release bearing and clutch levers move away from the engine flywheel causing the driven disc to be locked up between the friction surfaces of the pressure plate and the engine flywheel. The clutch is then engaged.
- On pull-type clutches depressing the clutch pedal pulls the release bearing away from the pressure plate, disengaging the clutch. As the clutch pedal is released, the pressure plate is forced toward the engine flywheel until the driving and driven discs turn at the same speeds, engaging the clutch.

IMPORTANT: On pull-type clutches, release bearing and release fork clearance are internal clutch adjustments, and *can not be adjusted* by adjusting the clutch linkage. Refer to the applicable clutch section in this group for internal clutch adjustments, or to the clutch manufacturer's service literature.

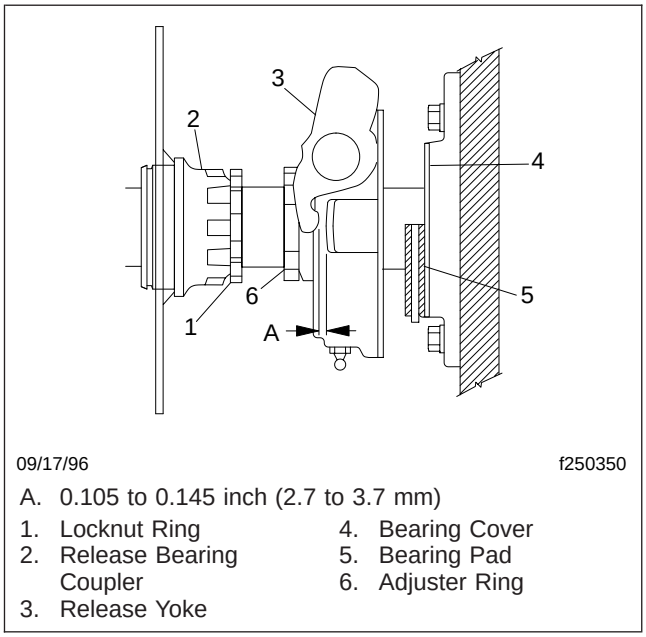
Clutch Linkage Adjustment

Pull-Type Clutch

1. Observe the following points before beginning clutch linkage adjustment:
   - If the clutch free pedal is less than one inch (25 mm), adjust the clutch internally, not at the linkage.
   - Be sure internal clutch adjustments are correct before making adjustments to the clutch linkage. For instructions, refer to the applicable clutch section in this group.
   - Adjust the clutch linkage only after repair or replacement of the clutch or clutch linkage components.
2. Tilt the hood.
3. Remove the clutch inspection cover from the bottom of the bell housing.
4. Be sure the clutch pedal is all the way up, against the upper stop.
5. Check the internal clutch adjustment (if applicable). Refer to the applicable clutch section in this group for instructions, and adjust if needed.
6. Measure the distance between the release yoke and the release bearing. See **Fig. 1**. If this measurement is 0.105 to 0.145 inch (2.7 to 3.7 mm), no further work is needed. If the measurement is incorrect, do all of the remaining steps.
7. Remove the cotter key and clevis pin that attach the clevis and cable assembly to the clutch relay lever (at the transmission). See **Fig. 2**. Remove the clevis and cable assembly from the clutch release lever.
8. Place a one-inch (25 mm) spacer between the clutch pedal and the plastic pedal stop. Block the pedal in this position.

IMPORTANT: Don't apply excessive force when pulling the clutch release lever forward as this could partially disengage the clutch.

9. Pull the clutch release lever forward until resistance is felt. The release yoke is now touching the release bearing.
10. Hold the clevis and cable assembly in the same position. Turn the clevis (in or out) until it lines up with the hole in the release lever. Install the clevis pin through the clevis and release lever. Install a new cotter key in the clevis pin.
11. Remove the spacer from the clutch pedal.
12. Measure the distance between the release yoke and the release bearing. If this measurement is 0.105 to 0.145 inch (2.7 to 3.7 mm), go to the next step. If the measurement is incorrect, repeat the previous steps.
13. Install the inspection cover on the bottom of the bell housing.
14. Check the clutch free pedal.



A. 0.105 to 0.145 inch (2.7 to 3.7 mm)

1. Locknut Ring
2. Release Bearing Coupler
3. Release Yoke
4. Bearing Cover
5. Bearing Pad
6. Adjuster Ring

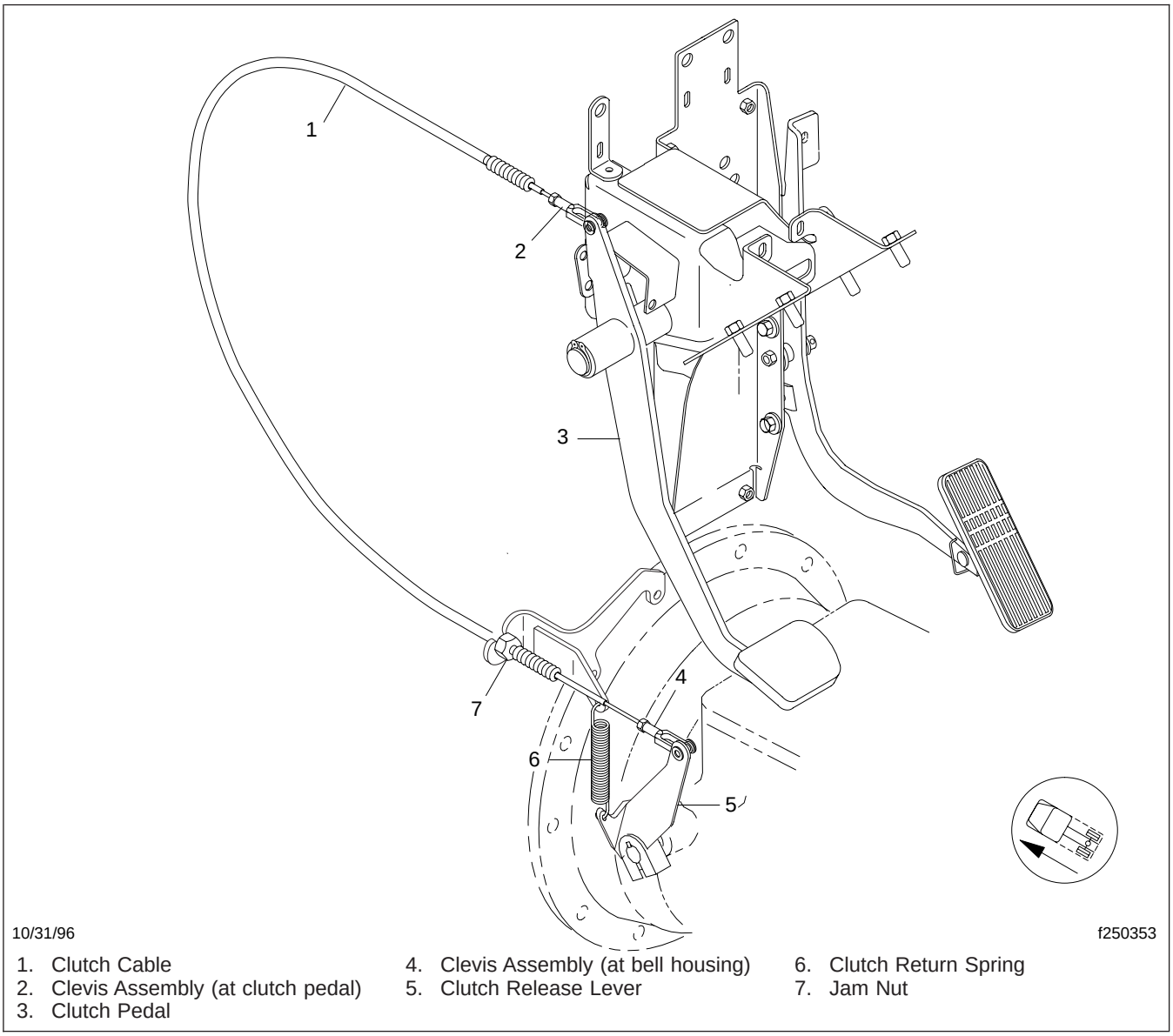
Fig. 1, Clutch Adjustment Specifications

Push-Type Clutch

IMPORTANT: If the clutch free pedal is less than one inch (25 mm), adjust the clutch at the linkage, not internally.

1. Tilt the hood.
2. Remove the cotter key and clevis pin that attach the clevis and cable assembly to the clutch relay lever (at the transmission). See **Fig. 2**.Remove the clevis and cable assembly from the relay lever.

Clutch Linkage Adjustment



1. Clutch Cable
2. Clevis Assembly (at clutch pedal)
3. Clutch Pedal
4. Clevis Assembly (at bell housing)
5. Clutch Release Lever
6. Clutch Return Spring
7. Jam Nut

Fig. 2, Clutch Cable Installation (push-type clutch shown)

3. Place a one-inch (25 mm) spacer between the clutch pedal and the plastic pedal stop. Block the pedal in this position.

IMPORTANT: Don't apply excessive force when pulling the clutch release lever forward as this could partially disengage the clutch.

4. Pull the clutch release lever forward until resistance is felt. The release yoke is now touching the release bearing.
5. Hold the clevis and cable assembly in the same position. Turn the clevis (in or out) until it lines up with the hole in the release lever. Install the clevis pin through the clevis and release lever. Install a new cotter key in the clevis pin.
6. Remove the spacer from the clutch pedal.

7. Measure the distance between the release yoke and the release bearing. If this measurement is 0.105 to 0.145 inch (2.7 to 3.7 mm), go to the next step. If the measurement is incorrect, repeat the previous steps.
8. Install the inspection cover on the bottom of the bell housing.
9. Check the clutch free pedal.

Clutch Pedal Removal and Installation

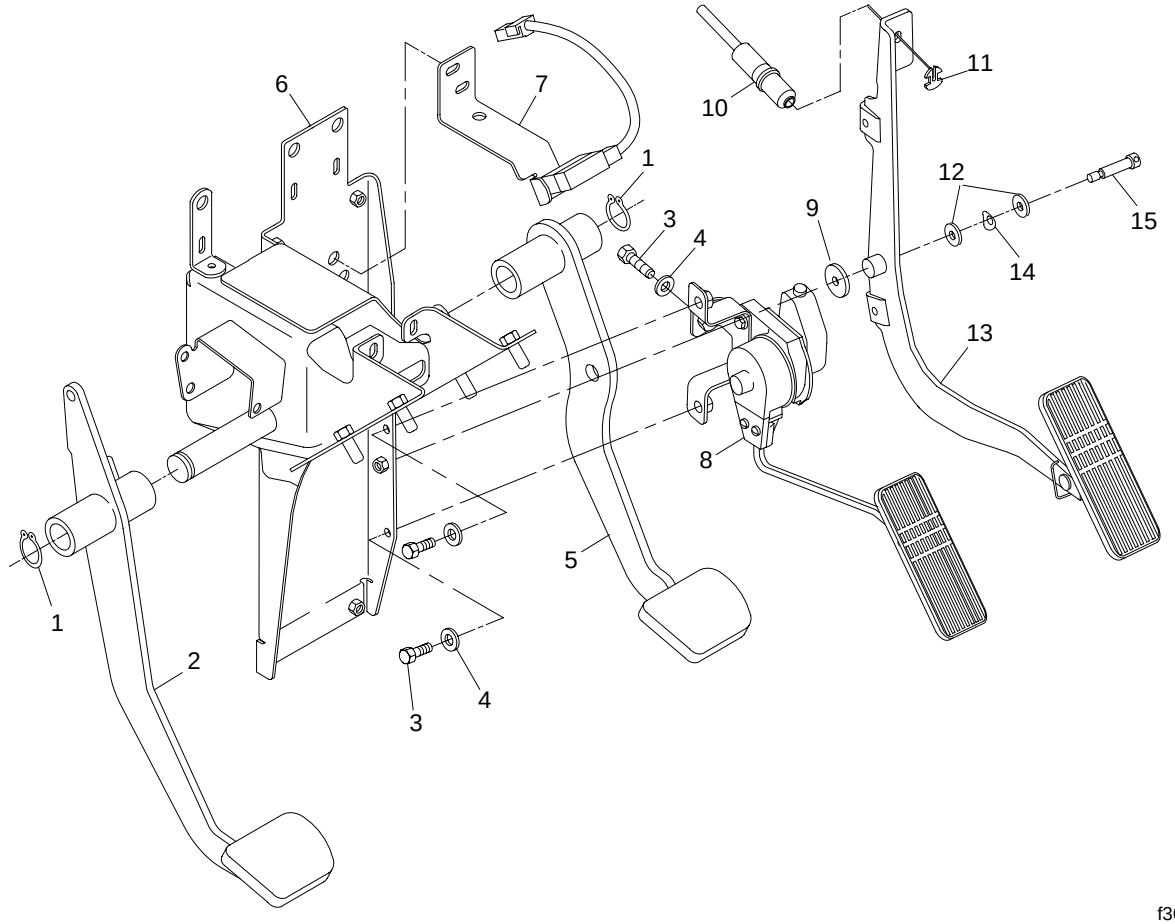
Removal

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Disconnect the batteries.
3. Remove the cotter pin from the clevis pin at the top of the pedal, and remove the clevis from the pedal.
4. Remove the snap ring and spacers that hold the pedal on its mounting bracket. Remove the pedal from the pedal bracket. See **Fig. 1**.

Installation

1. Position the clutch pedal on its mounting bracket.
2. Install the spacers and the snap ring to secure the pedal.
3. Using a new cotter pin, connect the clutch linkage cable clevis to the top of the clutch pedal.
4. Connect the batteries, lower the hood, and remove the chocks from the tires.
5. Test drive the vehicle.

Clutch Pedal Removal and Installation



09/18/96 f300257

NOTE: A vehicle will have either the electronic throttle pedal (item 8) or the mechanical pedal (item 13).

1. Snap Ring
2. Clutch Pedal
3. Capscrew, 5/16–18, Grade 5
4. Washer, 5/16
5. Brake Pedal
6. Steering Column Assembly
7. Brake Switch and Bracket
8. Electronic Throttle Pedal
9. Washer, 5/16 x 1-1/4
10. Throttle Cable
11. Throttle Cable Retainer
12. Washer, 3/8
13. Mechanical Throttle Pedal
14. Spring Washer
15. Shoulder Bolt, 3/8 x 1-1/4

Fig. 1, Pedal Installations

Removal

1. Chock the rear tires, and apply the parking brakes.
2. Remove the shift tower from the transmission.
   - 2.1 Place the transmission in high gear.
   - 2.2 Remove the four Torx®-head screws from the retainer ring holding the shift lever boot. See **Fig. 1**. Remove the ring and the boot.

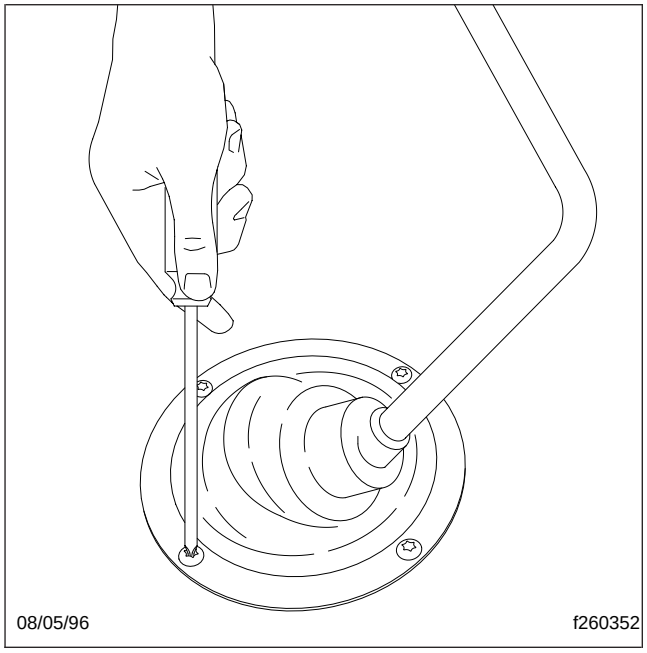
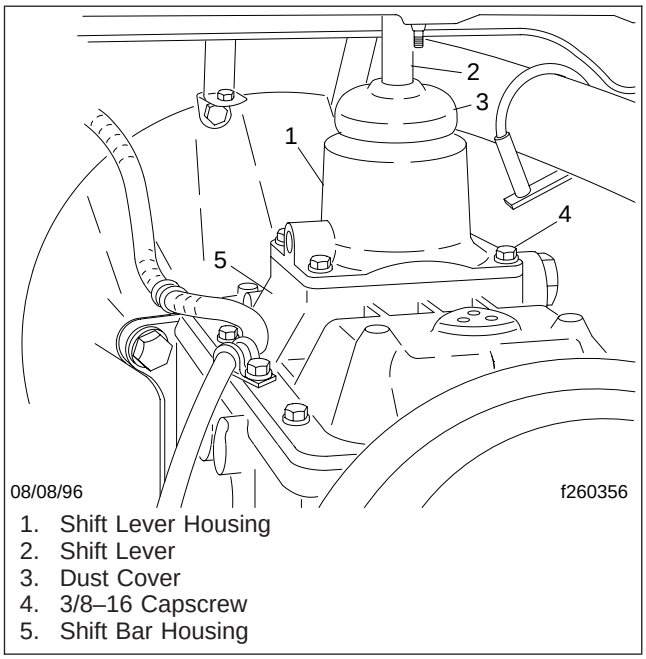


Fig. 1, Shift Lever Boot Retainer Ring

   - 2.3 Remove the four capscrews holding the shift lever housing to the shift bar housing (transmission top cover). See **Fig. 2**.
   - 2.4 Lift up on the shift tower and remove it. See **Fig. 3**.
   - 2.5 Cover the opening in the shift bar housing to prevent entry of dirt.
3. Disconnect the driveshaft from the transmission.
   - 3.1 If the vehicle is equipped with a driveline parking brake, remove the nuts on the brake flange. See **Fig. 4**.



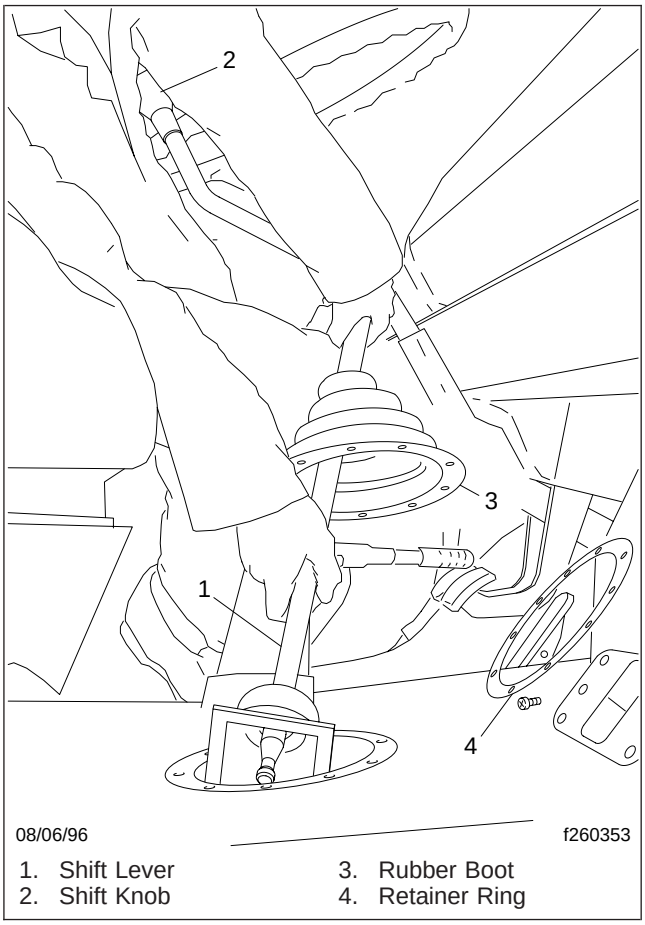
1. Shift Lever Housing
2. Shift Lever
3. Dust Cover
4. 3/8–16 Capscrew
5. Shift Bar Housing

Fig. 2, Shift Tower and Shift Bar Housing

   If the vehicle is not equipped with a driveline parking brake, remove the transmission yoke U-joint end caps.
   - 3.2 Loosen the bolts holding the midship bearing bracket so the driveshaft can slide to the rear. See **Fig. 5**.
   - 3.3 Slide the front of the driveshaft off the driveline brake flange or out of the transmission output yoke.

   NOTE: It may be necessary to remove the bolts from the midship bearing bracket so the driveshaft can be moved far enough back.
   - 3.4 Support the disconnected driveshaft or tie it out of the way.
4. Remove all electrical connections from the transmission.
   - 4.1 Disconnect the back-up light cables. See **Fig. 6**.
   - 4.2 Disconnect the electrical cable from the speedometer sensor. See **Fig. 7**.

Manual Transmission Removal and Installation



1. Shift Lever
2. Shift Knob
3. Rubber Boot
4. Retainer Ring

Fig. 3, Shift Tower Removal

4.3 Loosen the capscrews holding the speedometer sensor wiring harness to the transmission. Move the harness out of the way.

5. If the vehicle is equipped with a driveline parking brake, remove the cotter pin holding the clevis to the driveline brake lever. See **Fig. 8**. Remove the two bolts holding the driveline brake cable bracket to the transmission, then remove the bracket.

6. Disconnect the clutch cable.

   6.1 Disconnect the spring holding tension on the clutch lever.

   6.2 Detach the clutch cable from the clutch lever.

7. Support the transmission with a jack.

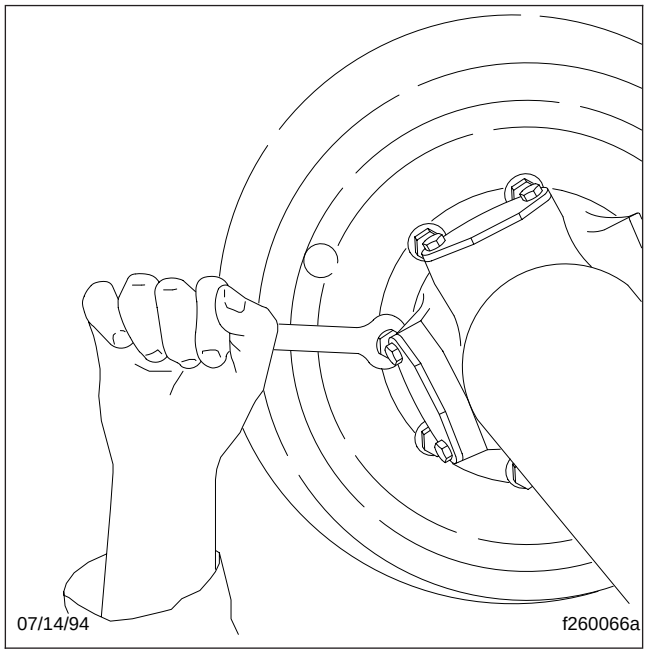


Fig. 4, Driveline Parking Brake

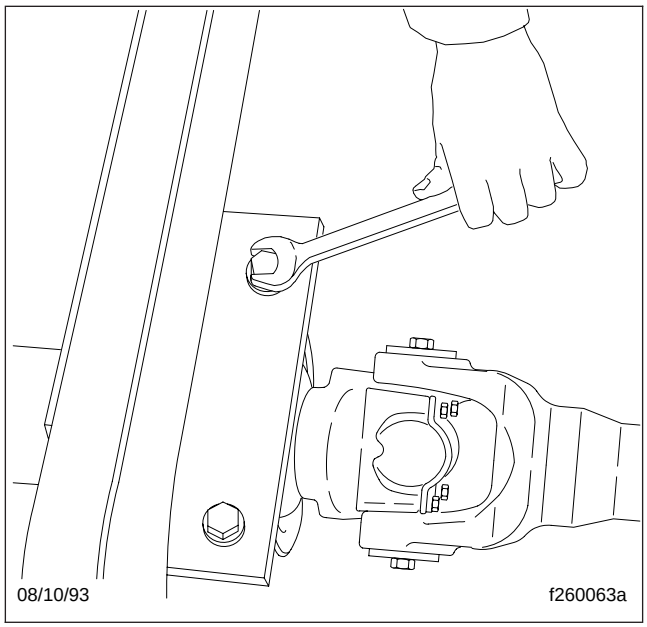


Fig. 5, Midship Bearing Bracket

7.1 Position a transmission jack under the transmission and raise its support plates against the bottom of the transmission.

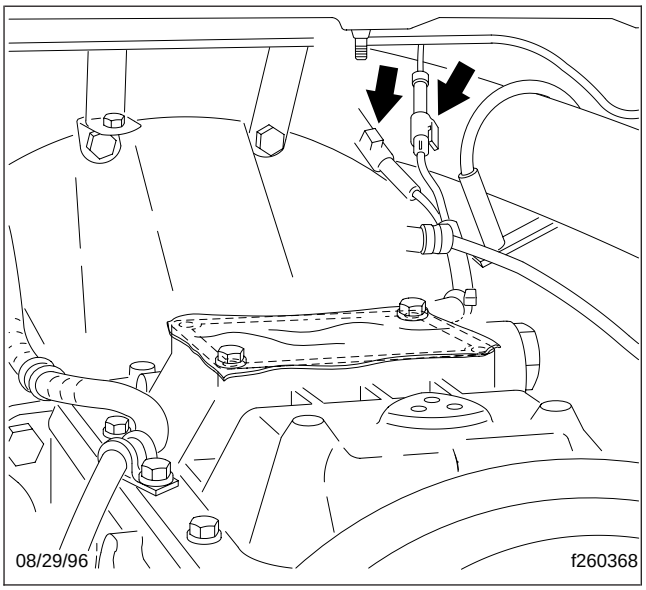


Fig. 6, Back-Up Light Cables

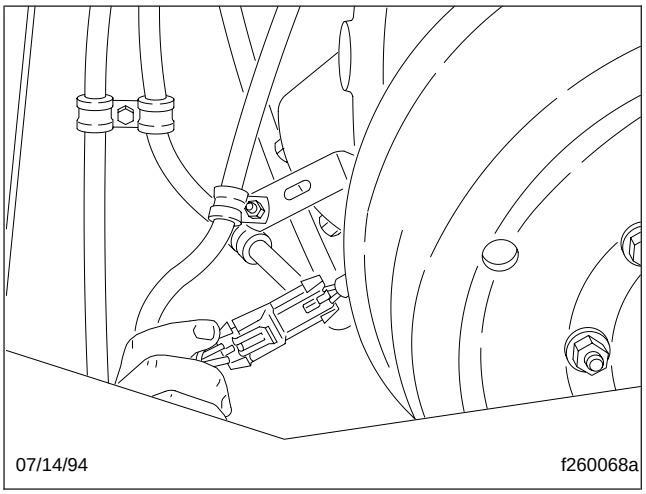


Fig. 7, Speedometer Sensor

7.2 Adjust the support plates to cradle the transmission.

7.3 Using a chain, secure the transmission to the jack.

8. Remove the transmission. See **Fig. 9**.

8.1 Remove the capscrews that hold the transmission to the clutch housing (bell housing).

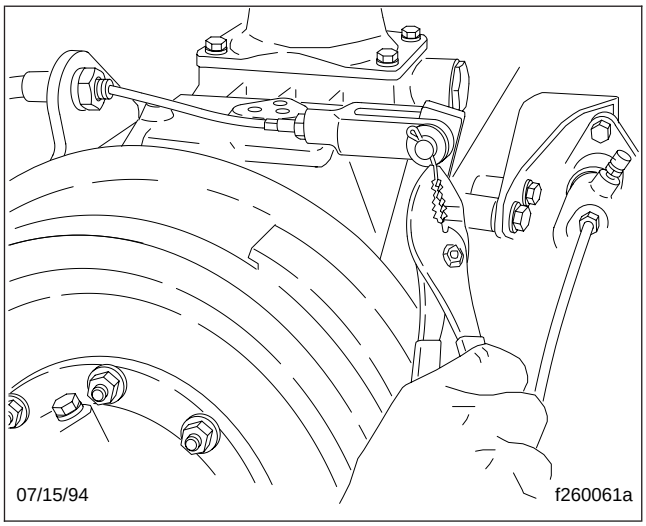
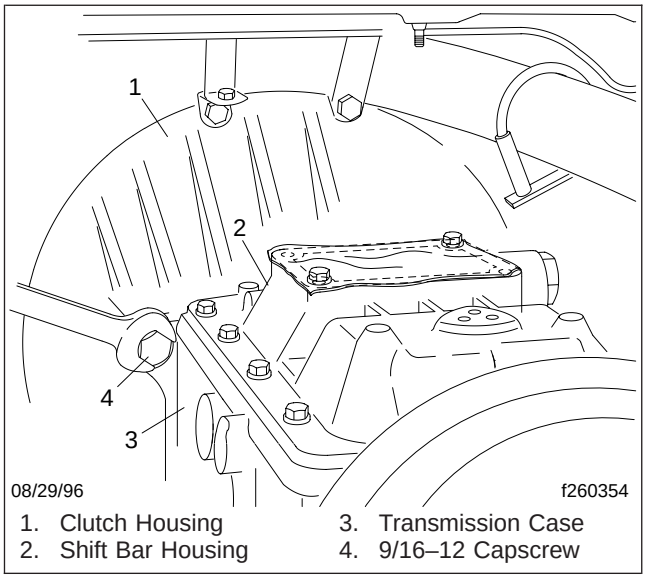


Fig. 8, Driveline Parking Brake Lever



1. Clutch Housing
2. Shift Bar Housing
3. Transmission Case
4. 9/16–12 Capscrew

Fig. 9, Removing the Transmission

8.2 Pull the transmission and jack straight back, until the transmission input shaft is clear of the clutch.

8.3 If required, lower the jack supporting the transmission. Raise the front of the truck and slide the transmission and jack out from under the truck.

Manual Transmission Removal and Installation

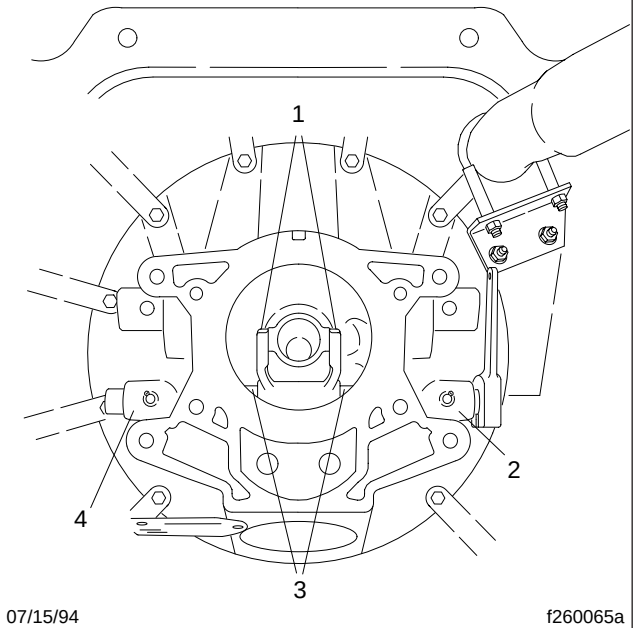
CAUTION

CAUTION: Do not let the rear of the transmission drop, and do not let the transmission hang unsupported in the splined hubs of the clutch disc(s). Keep the flange of the clutch housing parallel (all the way around) to the flange of the flywheel housing, until the input shaft is clear of the clutch. Taking these precautions will prevent damage to the clutch disc(s).

Installation

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

1. Check for wear on the fingers of the clutch release yoke, release shaft, and the release shaft bushings. Replace any worn parts, as needed. See **Fig. 10**.



1. Clutch Release Yoke Fingers
2. Release Shaft Bushing (R/H)
3. Clutch Release Shaft
4. Release Shaft Bushing (L/H)

Fig. 10, Clutch Wear Points

2. Install the transmission.

2.1 Shift the transmission into gear, so that the transmission input shaft can be rotated during assembly to line it up with the clutch driven-disc hub splines.

2.2 Align the jack and the transmission behind the engine. Raise the transmission, and adjust the angle of the jack until the clutch housing and the transmission input flange are parallel.

2.3 Push the transmission and jack straight forward making sure the flanges remain parallel.

2.4 Reach through the access hole in the bottom of the clutch housing and hold the throw-out bearing in place by hand. See **Fig. 11**.

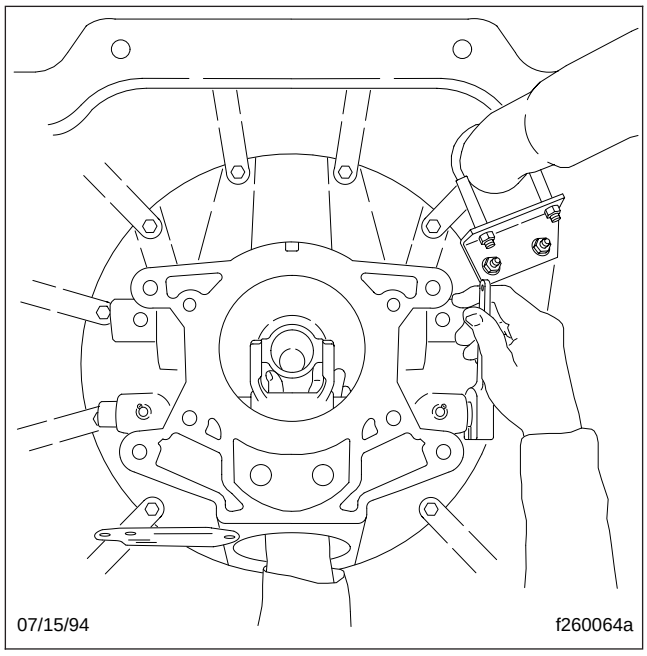


Fig. 11, Holding the Release Bearing In Place

2.5 Slide the splined input shaft into the clutch driven disc.

CAUTION

CAUTION: Use care to avoid springing the driven disc(s) when the transmission is being installed. Do not force the transmission into the clutch housing if it does not enter freely. Do not let the transmission drop or hang unsupported in

the driven disc(s). These practices can damage the clutch assembly.

2.6 Install the capscrews holding the transmission to the clutch housing. See **Fig. 9**. Tighten them 150 lbf·ft (203 N·m).

2.7 Remove the chain securing the transmission to the jack, then remove the jack.

3. Attach the clutch cable and install the spring on the clutch cable and lever.

4. If the vehicle is equipped with a driveline parking brake, mount the driveline brake cable bracket to the transmission. Install the two bolts, and tighten them 100 lbf·ft (136 N·m). Attach the clevis to the brake lever; then, insert and lock the cotter pin. See **Fig. 8**.

5. Connect all electrical lines to the transmission.

5.1 Connect the back-up light cables. See **Fig. 6**.

5.2 Connect the electrical cable to the speedometer sensor. See **Fig. 7**.

5.3 Install the speedometer sensor wiring harness. Install the capscrews fastening it to the transmission. Tighten them 40 lbf·ft (54 N·m).

6. Connect the driveshaft.

6.1 Slide the front of the driveshaft into the transmission output yoke, or onto the driveline parking brake flange (if so equipped).

6.2 On vehicles without a driveline parking brake, install the transmission yoke U-joint end caps. Tighten the bolts 45 lbf·ft (61 N·m).

On vehicles with a driveline parking brake, slide the driveshaft flange onto the studs in the parking brake.

Install the nuts, and tighten them 40 lbf·ft (54 N·m).

6.3 Install the capscrews and nuts on the midship bearing bracket. Tighten them 95 lbf·ft (129 N·m).

7. Install the shift tower.

7.1 Remove the covering from the opening in the shift tower.

7.2 Install the shift lever and shift lever housing. See **Fig. 3**.

7.3 Install the four capscrews in the shift lever housing. See **Fig. 2**. Tighten them 28 lbf·ft (38 N·m).

7.4 Install the rubber boot and the retainer ring. Install the four Torx-head screws. See **Fig. 1**.

8. Remove the chocks from the rear tires.

Specifications

Torque Values, Manual Transmission	
Description	**Torque: lbf·ft (N·m)**
Driveline Parking Brake Cable Bracket Mounting Capscrews	100 (136)
Driveline Parking Brake Stud Nuts	40 (54)
Midship Bearing Bracket Capscrews	95 (129)
Shift Lever Plate Capscrews	28 (38)
Transmission-to-Clutch-Housing Capscrews	150 (203)
U-Joint End Cap Bolts	45 (61)

Table 1, Torque Values, Manual Transmission

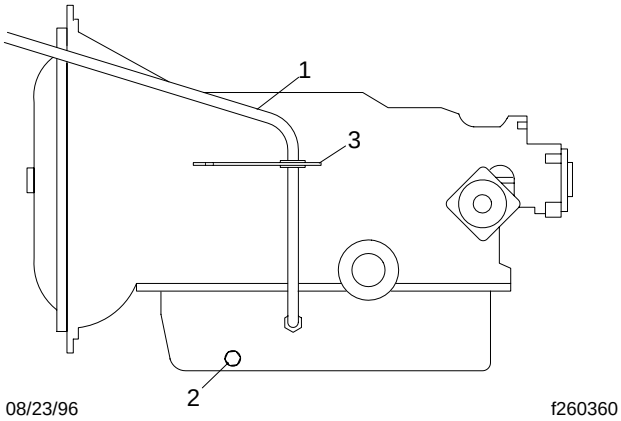
Automatic Transmission Removal and Installation, AT/MT Models

Removal

1. Apply the parking brake, chock the tires, and disconnect the batteries.

NOTE: For better drainage, do the next step when the transmission is warm.

2. Remove the transmission drain plug and drain the automatic transmission fluid (ATF). See **Fig. 1**. Install the drain plug and tighten it 15 to 20 lbf·ft (20 to 27 N·m).



1. Fill/Dipstick Tube
2. Drain Plug
3. Support Bracket

Fig. 1, Transmission Drain Plug (typical)

NOTE: On Model AT–542 transmissions, the drain plug is located on the right-hand side of the oil pan. On AT–545 and MT transmission models, it is on the left-hand side.

3. Support the driveline with a jack stand between the transmission output yoke and the midship bearing.

4. Disconnect the driveline from the transmission.

   4.1 Loosen the bolts holding the midship bearing bracket so the driveline can slide to the rear. See **Fig. 2**.

   4.2 If the vehicle is equipped with a driveline parking brake, remove the nuts on the brake flange. See **Fig. 3**.

   If the vehicle is not equipped with a driveline parking brake, remove the transmission yoke U-joint end caps or lock straps.

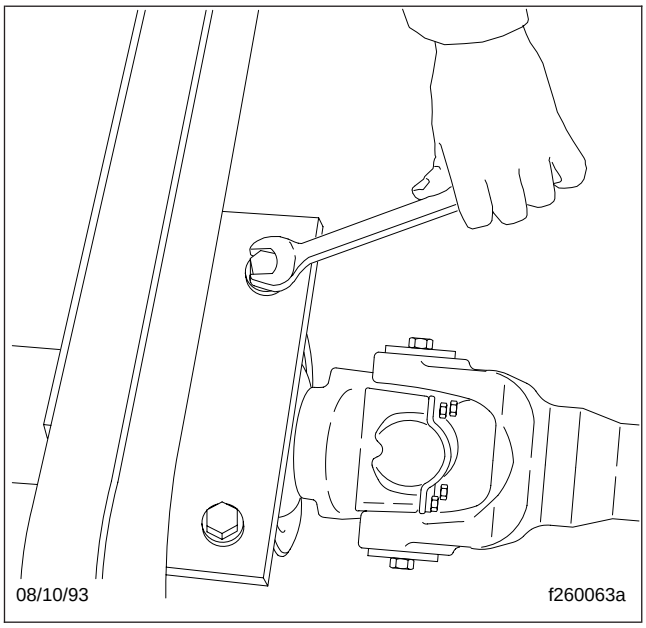


Fig. 2, Loosening the Midship Bearing Bracket Bolts

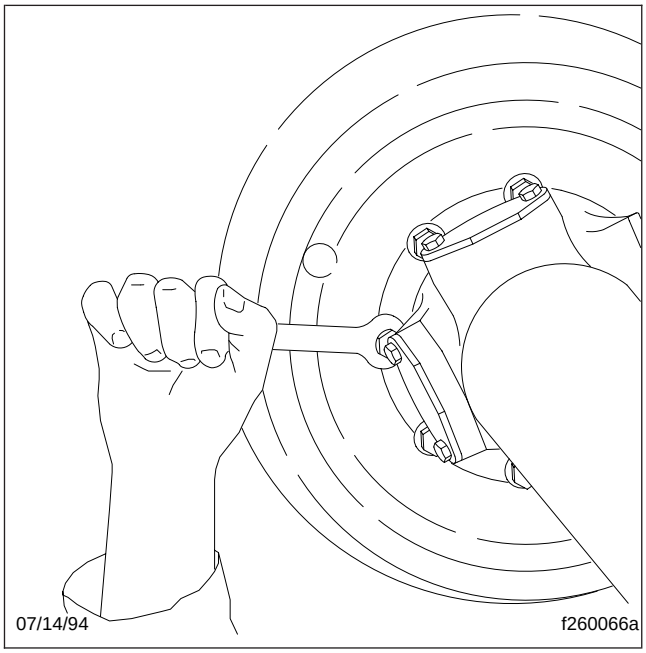


Fig. 3, Removing the Nuts on the Brake Flange

   4.3 Slide the front of the driveline off the driveline brake flange or out of the transmission output yoke.

Automatic Transmission Removal and Installation, AT/MT Models

NOTE: It may be necessary to remove the mounting bolts from the midship bearing bracket so the driveline can be moved back far enough.

4.4 Support the disconnected driveline and tie it to the frame rail.

5. Disconnect the three electrical connections to the transmission. The back-up light sensor (on the RH side) and the neutral start switch (on the LH side) are located low on the transmission case, above the oil pan. The vehicle speed sensor is located on the rear cover.

6. Remove the shift cable from the range selector lever. Tie back the cable and cover the threaded end.

7. If the vehicle is equipped with a driveline parking brake, release the brake cable.

   7.1 Release the parking brake.

   7.2 Remove and discard the cotter pin holding the clevis to the driveline brake lever.

   7.3 Remove the capscrews holding the driveline brake cable bracket to the transmission.

   7.4 Remove the bracket from the transmission case.

8. Remove the ATF fill/dipstick tube. See **Fig. 4**.

   8.1 Remove the forward standoff bracket holding the air line away from the transmission case.

   8.2 Remove the bolt and support bracket holding the fill/dipstick tube.

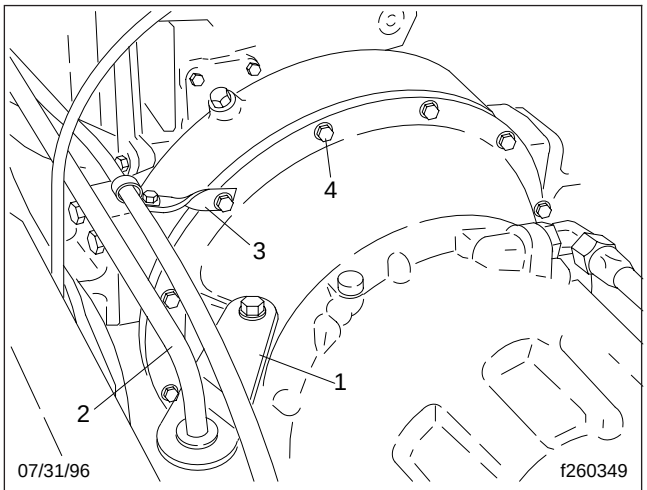
   8.3 Pull the fill/dipstick tube, with dipstick attached, out of the transmission case.

   8.4 Plug the hole with a clean rag to prevent entry of foreign material.

9. Disconnect the flexplate from the transmission. See **Fig. 5**.

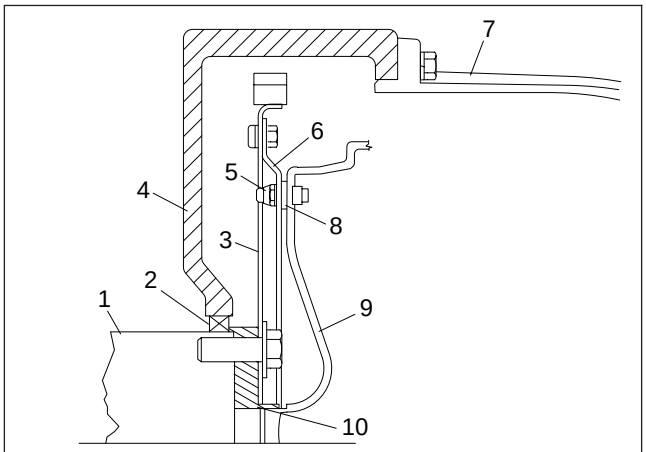
   9.1 Remove the capscrews holding the ring gear access cover. Then, remove the cover.

   9.2 Using a screwdriver, turn the ring gear until one of the flexplate drive capscrews holding the flexplate to the torque converter can be removed. Continue turning



1. Support Bracket
2. ATF Fill/Dipstick Tube
3. Forward Air Line Standoff Bracket
4. Flange Bolt

Fig. 4, Removing the Fill/Dipstick Tube



Viewed through the ring gear access cover

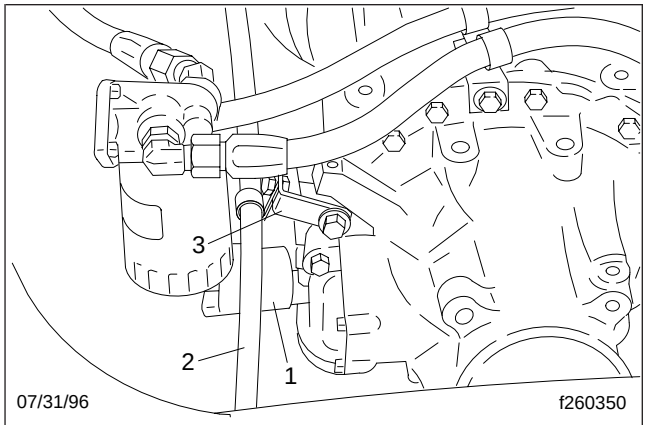
1. Engine Crankshaft
2. Double Lip Seal
3. Flexplate
4. Engine Flywheel Housing
5. Flexplate Drive Capscrew
6. Ring
7. Torque Converter Housing
8. Washer
9. Torque Converter
10. Flexplate Adapter

Fig. 5, Disconnecting the Flexplate

Automatic Transmission Removal and Installation, AT/MT Models

the ring gear and removing the cap-screws through the access hole until all twelve are removed.

10. Remove the electronic modulator (see **Fig. 6**) on the left-hand side of the transmission and disconnect the electrical connector. Remove the aft air line standoff bracket.



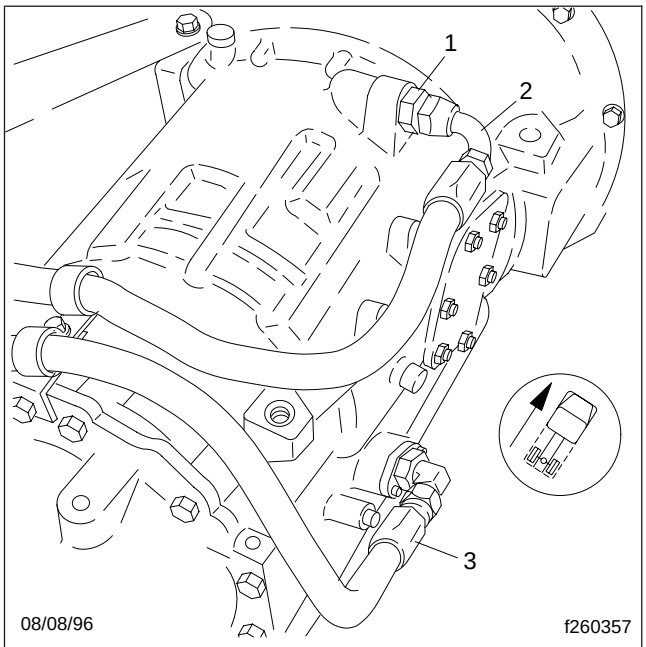
1. Electronic Modulator
2. Air Line
3. Aft Standoff Bracket

Fig. 6, Removing the Electronic Modulator

11. Disconnect the ATF cooler lines (see **Fig. 7**) from the transmission and drain the remaining ATF.

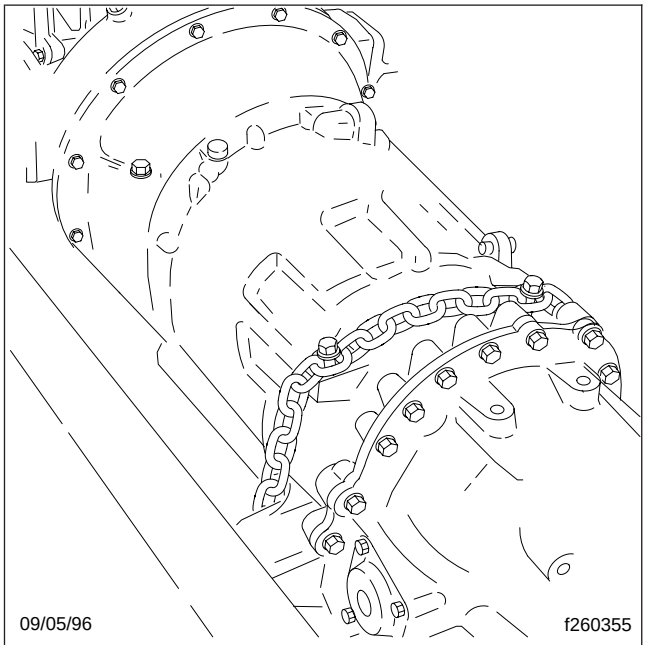
NOTE: On model AT transmissions, both ATF cooler lines are on the top of the case on the right-hand side, with the inlet line slightly to the rear.

12. Place a piece of plywood on a transmission jack to support the transmission.
13. Slide the jack into place under the transmission. Secure the transmission with a chain. Anchor the chain with bolts at the front lifting bosses on the top of the transmission. See **Fig. 8**.
14. Remove the twelve transmission flange bolts. See **Fig. 9**.
15. Move the transmission jack to the rear. Lower the jack and lift the front of the truck, as needed, so the transmission clears the frame rail and any attached components.
16. Place jack stands under the raised front of the vehicle.



1. Inlet Line
2. 90° Elbow
3. Outlet Line

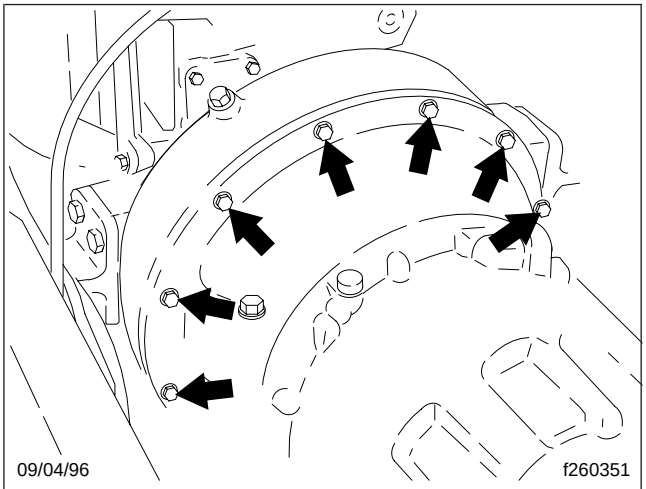
Fig. 7, ATF Cooler Lines (model MT shown)



Anchor the chain with bolts at the front lifting bosses.

Fig. 8, Securing the Transmission With Chain

Automatic Transmission Removal and Installation, AT/MT Models



There are twelve flange bolts to remove (not all are shown).

Fig. 9, Transmission Flange Bolts

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 transmission is securely chained to the transmission jack.

1. Raise the front of 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 front of the vehicle frame.
3. Align the transmission and flexplate.
   - 3.1 Raise the jack until the transmission lines up with the flexplate.
   - 3.2 Push the transmission toward the engine until it seats squarely against the engine flywheel housing with the bolt holes in the transmission housing aligned with those in the flywheel housing.

   NOTE: No force is required. If interference is encountered, move the transmission away from the engine and correct the problem.
   - 3.3 Install the transmission flange bolts finger-tight.
   - 3.4 Remove the chain holding the transmission to the transmission jack.
   - 3.5 Lower the transmission jack and remove it.
4. Connect the ATF cooler lines to the transmission. Tighten the fittings 45 lbf·ft (61 N·m). See **Fig. 7**.
5. Install the twelve flexplate adapter capscrews.

   NOTE: Be careful not to drop the capscrews inside the torque converter cover. The transmission must be removed to get them out.
   - 5.1 Turning the ring gear for access, install all the capscrews through the access hole. Don't tighten them now.

   IMPORTANT: To prevent cocking of the flexplate adapter, install all the capscrews before tightening any of them.
   - 5.2 Using a star pattern, tighten the capscrews 37 lbf·ft (50 N·m) until all twelve are tightened.
   - 5.3 Install the access cover and its capscrews.
6. Using a star pattern, tighten the twelve M10 transmission flange bolts (see **Fig. 9**) 41 lbf·ft (56 N·m).
7. Install the driveline parking brake, if removed.
   - 7.1 If the vehicle is equipped with a driveline parking brake, mount the driveline brake cable bracket to the transmission.
   - 7.2 Install the capscrews and tighten them 23 lbf·ft (31 N·m)
   - 7.3 Attach the clevis to the brake lever.
   - 7.4 Insert a new cotter pin and lock it.
   - 7.5 Apply the parking brake.
8. Connect the driveline.
   - 8.1 Slide the front of the driveline into the transmission output yoke or onto the

Automatic Transmission Removal and Installation, AT/MT Models

driveline parking brake flange, if so equipped.

8.2 On vehicles without a driveline parking brake, install the transmission yoke U-joint end caps or lock straps.

On vehicles with a driveline parking brake, slide the driveline flange onto the studs in the parking brake. Install the nuts, and tighten them 40 lbf·ft (54 N·m).

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

9. Install the shift cable onto the range selector lever.
   - 9.1 Put the shift lever in NEUTRAL.
   - 9.2 Thread the cable end into the swivel.
   - 9.3 Attach the swivel to the range selector lever with the pin and washer.
   - 9.4 Move the range selector lever up and down until it clicks into place.
10. Install the ATF fill/dipstick tube.
   - 10.1 Inspect the fill/dipstick tube seal. Replace it if damaged.
   - 10.2 Insert the fill/dipstick tube through the support bracket and into the transmission case.
   - 10.3 Install the fill/dipstick tube support bracket. Tighten the capscrew 28 lbf·ft (38 N·m).
11. Install the electronic modulator, as removed. Connect the electrical connector.
12. Install the forward and aft air line standoff brackets on the left side of the transmission.

    Make sure the air line and the wiring harness are securely attached to the standoff brackets.
13. Fill the transmission with ATF. Use Dexron II automatic transmission fluid. Add 16 quarts (15.1 liters).
14. Connect all electrical lines to the transmission.
   - 14.1 Connect the vehicle speed sensor to the port on the rear cover.
   - 14.2 Connect the neutral start switch to the port low on the transmission case, right-hand side.
   - 14.3 Connect the back-up light sensor to the port low on the transmission case, left-hand side.
   - 14.4 Using tie straps, secure the cables where necessary.
15. Connect the batteries and remove the chocks from the tires.
16. Start the engine, and check for any leaks. Repair leaks as needed.
17. Check the ATF level. Add fluid as needed.
18. Road test the vehicle, and check for correct transmission operation.

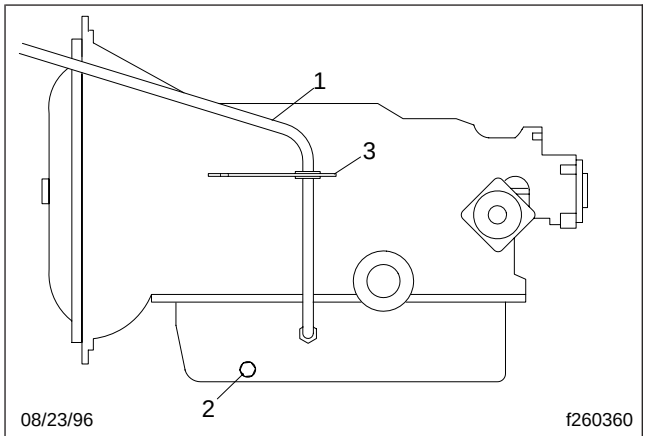
WTEC Electronic Transmission Removal and Installation

Removal

1. Apply the parking brake, chock the tires, and disconnect the batteries.

NOTE: For better drainage, do the next step when the transmission is warm.

2. Remove the transmission drain plug and drain the automatic transmission fluid (ATF). See **Fig. 1**. Install the drain plug and tighten it 15 to 20 lbf·ft (20 to 27 N·m).



1. Fill/Dipstick Tube
2. Drain Plug
3. Support Bracket

Fig. 1, Transmission Drain Plug (typical)

3. Support the driveline with a jack stand between the transmission output yoke and the midship bearing.
4. Disconnect the driveline from the transmission.
   - 4.1 Remove the bolts holding the midship bearing bracket so the driveline can slide to the rear. See **Fig. 2**.
   - 4.2 If the vehicle is equipped with a driveline parking brake, remove the nuts on the brake flange. See **Fig. 3**.

     If the vehicle is not equipped with a driveline parking brake, remove the transmission yoke U-joint end caps or lock straps.
   - 4.3 Slide the front of the driveline off the driveline brake flange or out of the transmission output yoke.

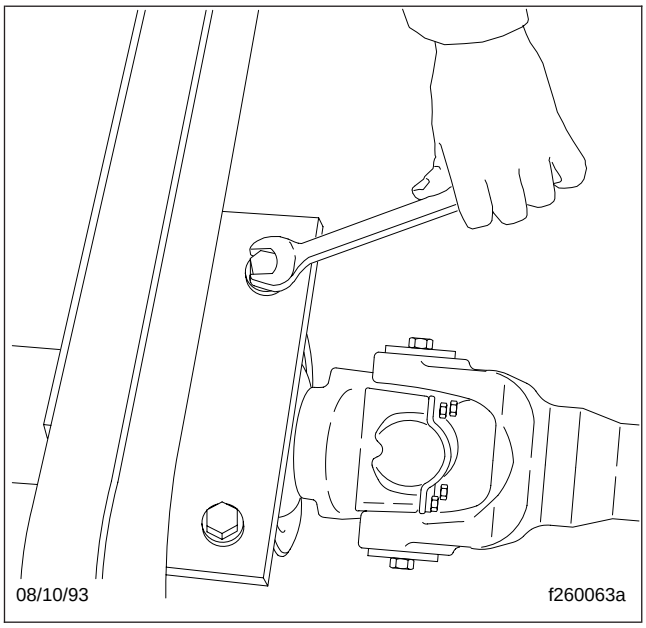


Fig. 2, Removing the Midship Bearing Bracket Bolts

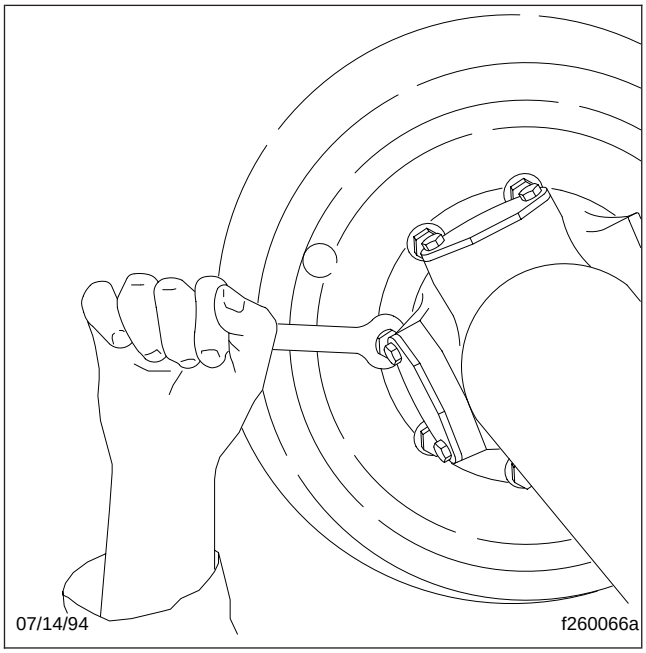


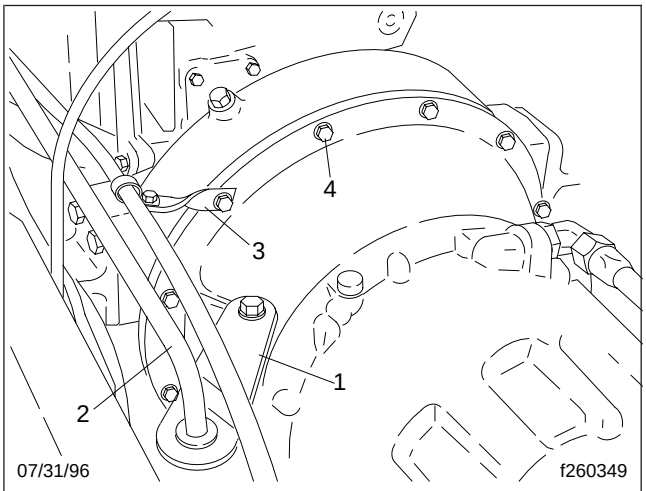
Fig. 3, Removing the Nuts on the Brake Flange

   - 4.4 Support the disconnected driveline and tie it to the frame rail.
5. Disconnect the output speed sensor (on the rear cover), the input sensor (located on the right side

WTEC Electronic Transmission Removal and Installation

of the torque converter housing), the oil temperature sensor (located on the transmission oil cooler line), and the feed through harness connector to the main wiring harness.

6. Remove the ATF fill/dipstick tube. See **Fig. 4**.



1. Support Bracket
2. ATF Fill/Dipstick Tube
3. Forward Air Line Standoff Bracket
4. Flange Bolt

Fig. 4, Removing the Fill/Dipstick Tube

6.1 Remove the forward standoff bracket holding the air line away from the transmission case.

6.2 Remove the bolt and support bracket holding the fill/dipstick tube.

6.3 Pull the fill/dipstick tube, with dipstick attached, out of the transmission case.

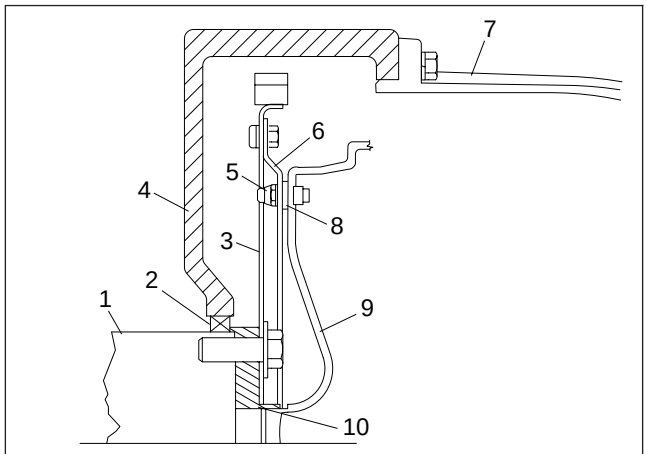
6.4 Plug the hole with a clean rag to prevent entry of foreign material.

7. Remove the turbo outlet pipe and the exhaust pipe back to the muffler.

8. Disconnect the flexplate from the transmission. See **Fig. 5**.

8.1 Remove the capscrews holding the ring gear access cover. Then, remove the cover.

8.2 Using a small crowbar, turn the ring gear until one of the flexplate drive capscrews holding the flexplate to the torque converter can be removed. Continue turning



1. Engine Crankshaft
2. Double Lip Seal
3. Flexplate
4. Engine Flywheel Housing
5. Flexplate Drive Capscrew
6. Ring
7. Torque Converter Housing
8. Washer
9. Torque Converter
10. Flexplate Adaptor

Fig. 5, Disconnecting the Flexplate

the ring gear and removing the capscrews through the access hole until all twelve are removed.

9. Disconnect the ATF cooler lines from the transmission and drain the remaining ATF.

10. Slide the jack into place under the transmission. Secure the transmission with a chain. Anchor the chain with bolts at the front lifting bosses on the top of the transmission. See **Fig. 6**.

11. Remove the twelve transmission flange bolts. See **Fig. 7**.

12. Move the transmission jack to the rear. Lower the jack and lift the front of the vehicle, as needed, so the transmission clears the frame rail and any attached components.

13. Place jack stands under the raised front of the vehicle.

14. Roll the transmission jack back and remove the transmission.

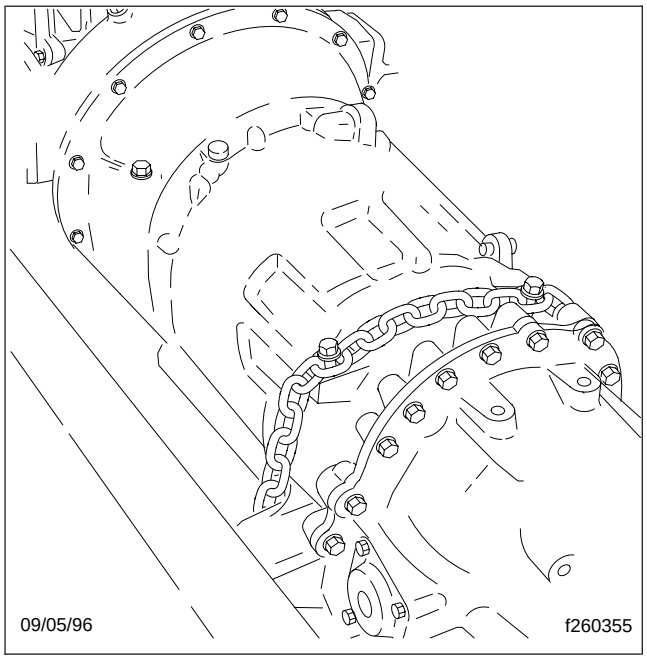


Fig. 6, Securing the Transmission With a Chain

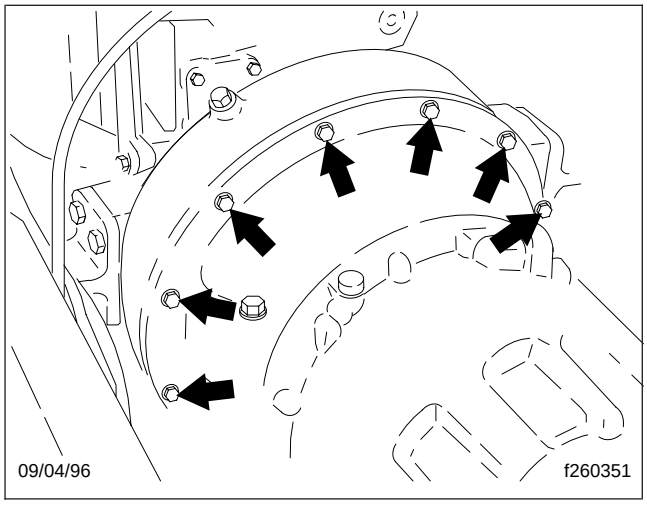


Fig. 7, Transmission Flange Bolts

Installation

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

1. Raise the front of 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 front of the vehicle frame.
3. Align the transmission and flexplate.
   - 3.1 Raise the jack until the transmission lines up with the flexplate.
   - 3.2 Push the transmission toward the engine until it seats squarely against the engine flywheel housing with the bolt holes in the transmission housing aligned with those in the flywheel housing.

   NOTE: No force is required. If interference is encountered, reposition the transmission away from the engine and correct the problem.
   - 3.3 Install the transmission flange bolts finger-tight.
   - 3.4 Remove the chain holding the transmission to the transmission jack.
   - 3.5 Lower the transmission jack and remove it.
4. Connect the ATF cooler lines to the transmission. Tighten the fittings 45 lbf·ft (61 N·m).
5. Install the twelve flexplate adaptor capscrews.

   NOTE: Be careful not to drop the capscrews inside the torque converter cover. The transmission must be removed to get them out.
   - 5.1 Turning the ring gear for access, install all the capscrews through the access hole. Don't tighten them now.

   IMPORTANT: To prevent cocking of the flexplate adaptor, install all the capscrews before tightening any of them.
   - 5.2 Using a star pattern, tighten the capscrews 37 lbf·ft (50 N·m) until all twelve are tightened.
   - 5.3 Install the access cover and its capscrews.

WTEC Electronic Transmission Removal and Installation

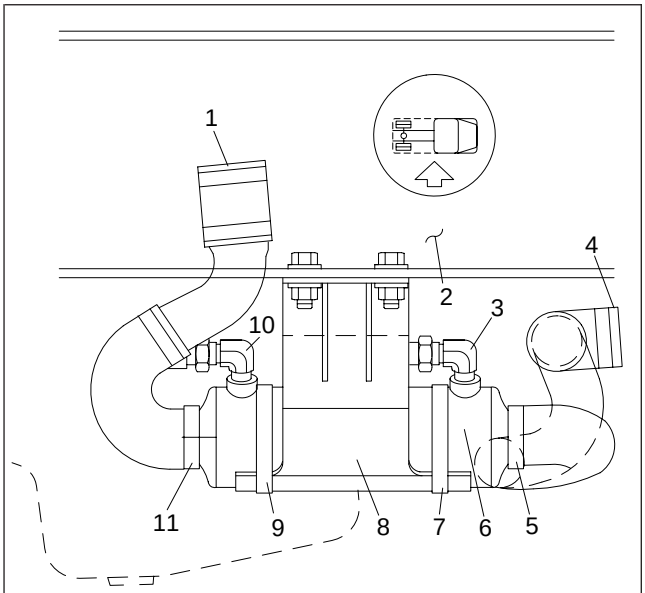
6. Using a star pattern, tighten the twelve M10 transmission flange bolts 41 lbf·ft (56 N·m). See **Fig. 7**.
7. Connect the driveline.
   - 7.1 Slide the front of the driveline into the transmission output yoke or onto the driveline parking brake flange, if so equipped.
   - 7.2 On vehicles without a driveline parking brake, install the transmission yoke U-joint end caps or lock straps.

     On vehicles with a driveline parking brake, slide the driveline flange onto the studs in the parking brake. Install the nuts, and tighten them 40 lbf·ft (54 N·m).
   - 7.3 Install the midship bearing bracket bolts and nuts. Tighten the nuts 95 lbf·ft (129 N·m).
8. Install the exhaust from the turbo outlet to the muffler.
9. Install the ATF fill/dipstick tube.
   - 9.1 Inspect the fill/dipstick tube seal. Replace it if damaged.
   - 9.2 Insert the fill/dipstick tube through the support bracket and into the transmission case.
   - 9.3 Install the fill/dipstick tube support bracket. Tighten the capscrew 28 lbf·ft (38 N·m).
10. Install the forward and aft air line standoff brackets on the left side of the transmission.

    Make sure the air line and the wiring harness are securely attached to the standoff brackets.
11. Fill the transmission with ATF. Use Dexron III automatic transmission fluid, or equivalent. Add 16 quarts (15.1 liters).
12. Connect all electrical wires to the transmission.
    - 12.1 Connect the input speed sensor to the port on the rear cover.
    - 12.2 Connect the output speed sensor
    - 12.3 Connect the temperature sensor.
    - 12.4 Connect the main wiring harness to the feed through harness connector.
    - 12.5 Using tie straps, secure the wires where necessary.
13. Connect the batteries, and remove the chocks from the tires.
14. Start the engine, and check for any leaks. Repair leaks as needed.
15. Check the ATF level. Add fluid as needed.
16. Road test the vehicle, and check for correct transmission operation.

ATF Cooler Removal and Installation

Removal



06/06/97 f260431

1. Coolant Return Hose
2. Frame Rail
3. ATF Supply Line
4. Coolant Supply Hose
5. Coolant Clamp
6. ATF Cooler
7. T-Bolt Clamp
8. ATF Cooler Mounting Bracket
9. T-Bolt Clamp
10. ATF Return Line
11. Coolant Clamp

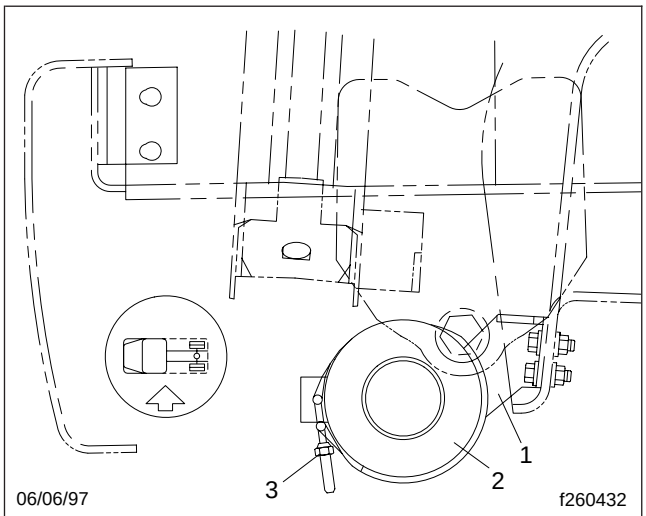
Fig. 1, ATF Cooler (frame-mounted)

1. Apply the parking brakes and chock the tires.

⚠ WARNING

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

2. With the engine cool, loosen the surge tank cap to release cooling system pressure.
3. Place a suitable container under the radiator. Open the drain petcock at the bottom of the radiator and drain the cooling system. Close the drain petcock.
4. Disconnect the coolant hoses from the fittings at both sides of the automatic transmission fluid (ATF) cooler. See **Fig. 1** and **Fig. 2**. When the coolant stops draining, secure the ends of the hoses to prevent leakage.



06/06/97 f260432

1. ATF Cooler Mounting Bracket
2. ATF Cooler
3. T-Bolt Clamp

Fig. 2, ATF Cooler (transverse-mounted)

5. Disconnect the ATF hoses from the fittings at both sides of the ATF cooler. Catch the ATF by directing the disconnected end of each hose into a drain pan. When the ATF stops draining, plug the hoses and cap the fittings.
6. Remove the two hexnuts and washers that attach the ATF cooler to the T-bolt mounting bracket assembly, and remove the ATF cooler. Drain the ATF cooler into a drain pan.

Installation

1. Hold the ATF cooler in place; then install the hexnuts and washers on the T-bolt mounting bracket assembly. Tighten 28 lbf·ft (38 N·m).
2. Attach the coolant hoses to the fittings at both sides of the ATF cooler, as removed.
3. Remove the plugs from the ATF hoses and the caps from the fittings. Attach the ATF hoses to the fittings at both sides of the ATF cooler. Tighten the fittings 40 to 50 lbf·ft (54 to 68 N·m).
4. Fill the coolant system and install the surge tank cap.

ATF Cooler Removal and Installation

5. Start the engine and operate the transmission for one or two minutes, then add the correct ATF to the transmission as needed. For instructions and lubricant specifications, see Group 26 in the *School Bus Chassis Maintenance Manual*.
6. Run the engine until operating temperature is reached and check for leaks in the coolant system or ATF cooler. Repair leaks as needed.
7. Check the coolant level and add as needed.
8. Remove the tire chocks.

Troubleshooting

Follow the steps in the procedure below to diagnose transmission fluid overheating.

IMPORTANT: Transmission fluid normal operating temperatures are 180 to 220°F (82 to 104°C) and below. Temperature spikes up to 300°F (149°C) under load with high ambient temperatures are not abnormal. However, the temperature should decrease as the load decreases.

⚠ CAUTION

If excessive temperature is indicated by the transmission fluid temperature gauge, stop the vehicle as soon as possible and shift to N (neutral). Accelerate the engine to 1200 to 1500 rpm and allow the temperature to return to normal (two or three minutes) before resuming operation.

1. Check and confirm that the transmission temperature gauge has a red line of 300°F (149°C).

NOTE: The transmission temperature gauge could be indicating an overheating condition when the transmission temperature is actually within specifications.

2. Check and confirm that the transmission temperature gauge and the sender are operating properly and are not faulty.
3. Check the transmission fluid level with the transmission at operating temperature. The fluid should be at the full mark on the dipstick and not over the full mark.

⚠ CAUTION

Transmission fluid overheating can result from checking the transmission fluid level when the transmission is cold and then adding fluid.

NOTE: High oil temperature can be caused by fluid aeration from an overfull fluid level.

4. Ensure that the cooling fan is operating properly and drawing air through the radiator toward the engine.
5. Check the electronic modulator and ensure that it is connected and working properly as specified in Allison *SIL 21TR02*.

IMPORTANT: Engine modulation trigger points (throttle counts) should be set at a 60/45 parameter. This 60/45 parameter is the default setting for electronic control modules (ECMs) of engines provided to FCCC after August 1, 1999. If this parameter is incorrect, the transmission will shift to high gear rapidly, and will cause the torque converter to build excessive heat and will not circulate the fluid quickly enough for adequate cooling.

6. If the vehicle is equipped with radiator shutters, the transmission temperature may be high until the shutters open and the coolant begins circulating.

NOTE: Normally this occurs when the ambient temperature is below 20°F (–7°C). Driving conditions will determine how long it takes for the engine to reach 190°F (88°C) and for the thermostat to open. The transmission cooler is located in the bottom of the radiator and any condition causing engine coolant overheating (such as a sticking thermostat or faulty water pump) will also affect transmission fluid temperature.

7. Inspect the cooler lines for restriction or damage that would impede flow.
8. If the vehicle was delivered after May 1999, determine from an Allison dealer if the transmission serial number is affected by the Allison torque converter campaign of May 2000 (transmissions manufactured between April 1999 to April 2000).
9. If an overheating condition or erratic shifting persists after making the checks above, contact an Allison dealer and determine if valve body modifications specified in Allison *SIL 21TR02* apply to the vehicle transmission.

Specifications

For a schematic of the electronic modulator wiring, see **Fig. 1**.

For a diagram of the modulator engine harness, see **Fig. 2**.

For a diagram of the modulator cab harness, see **Fig. 3**.

Torque Values, Automatic Transmission, AT/MT Models	
Description	**Torque: lbf·ft (N·m)**
ATF Cooler Hoses	45 (61)
Drain Plug	15–20 (20–27)
Driveline Parking Brake Cable Bracket Mounting Capscrews	23 (31)
Driveline Parking Brake Stud Nuts	40 (54)
Fill/Dipstick Tube Support Bracket Capscrew	28 (38)
Flexplate Adaptor Capscrews	37 (50)
Midship Bearing Bracket Capscrews	95 (129)
Transmission Flange Bolts	41 (56)

Table 1, Torque Values, Automatic Transmission, AT/MT Models

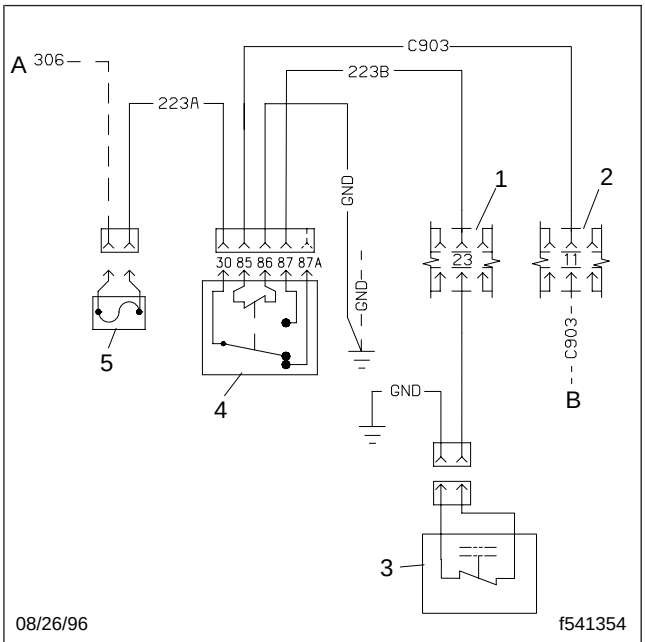
Torque Values, Electronic Transmission, WTEC Model	
Description	**Torque lbf·ft (N·m)**
Transmission Drain Plug	136 (184)
ATF Cooler Hose Fittings	40–50 (54–68)
Flexplate Adaptor Capscrews	18–21 (24–29)
Transmission Flange Bolts	38–45 (51–61)
Driveline Parking Brake Cable Bracket Mounting Nuts	23 (31)
Driveline Parking Brake Stud Nuts	40 (54)
Midship Bearing Bracket Nuts	95 (129)
Exhaust Pipe-to-Turbocharger Mounting Bolts	60 (81)
ATF Fill/Dipstick Tube Support Bracket Capscrews	80 (108)
ATF Fill/Dipstick Tube Clamp Capscrews	12 (16)
ATF Fill/Dipstick Tube-to-Bracket U-Bolt Nuts	8 (11)

Table 2, Torque Values, Electronic Transmission, WTEC Model

Torque Values, ATF Cooler Installation		
Description	**Torque: lbf·ft (N·m)**	**Torque: lbf·in (N·cm)**
ATF Cooler Line Fittings	18 (24)	—
ATF Cooler Mounting T-Bolt Nuts	—	84 (940)

Table 3, Torque Values, ATF Cooler Installation

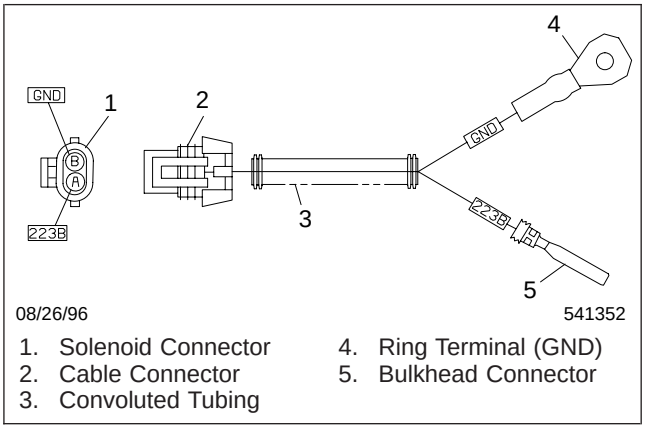
Specifications



A. From Ignition Keyswitch
B. From Engine ECU

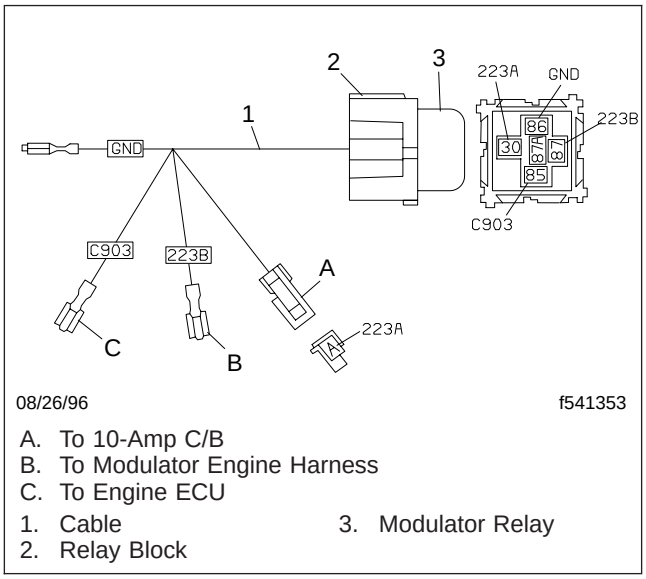
1. Bulkhead Connector
2. Engine ECU Harness Connector
3. Shift Modulator
4. Modulator Relay
5. 10-Amp C/B (Location B13)

Fig. 1, Modulator Schematic



1. Solenoid Connector
2. Cable Connector
3. Convoluted Tubing
4. Ring Terminal (GND)
5. Bulkhead Connector

Fig. 2, Modulator Engine Harness



A. To 10-Amp C/B
B. To Modulator Engine Harness
C. To Engine ECU

1. Cable
2. Relay Block
3. Modulator Relay

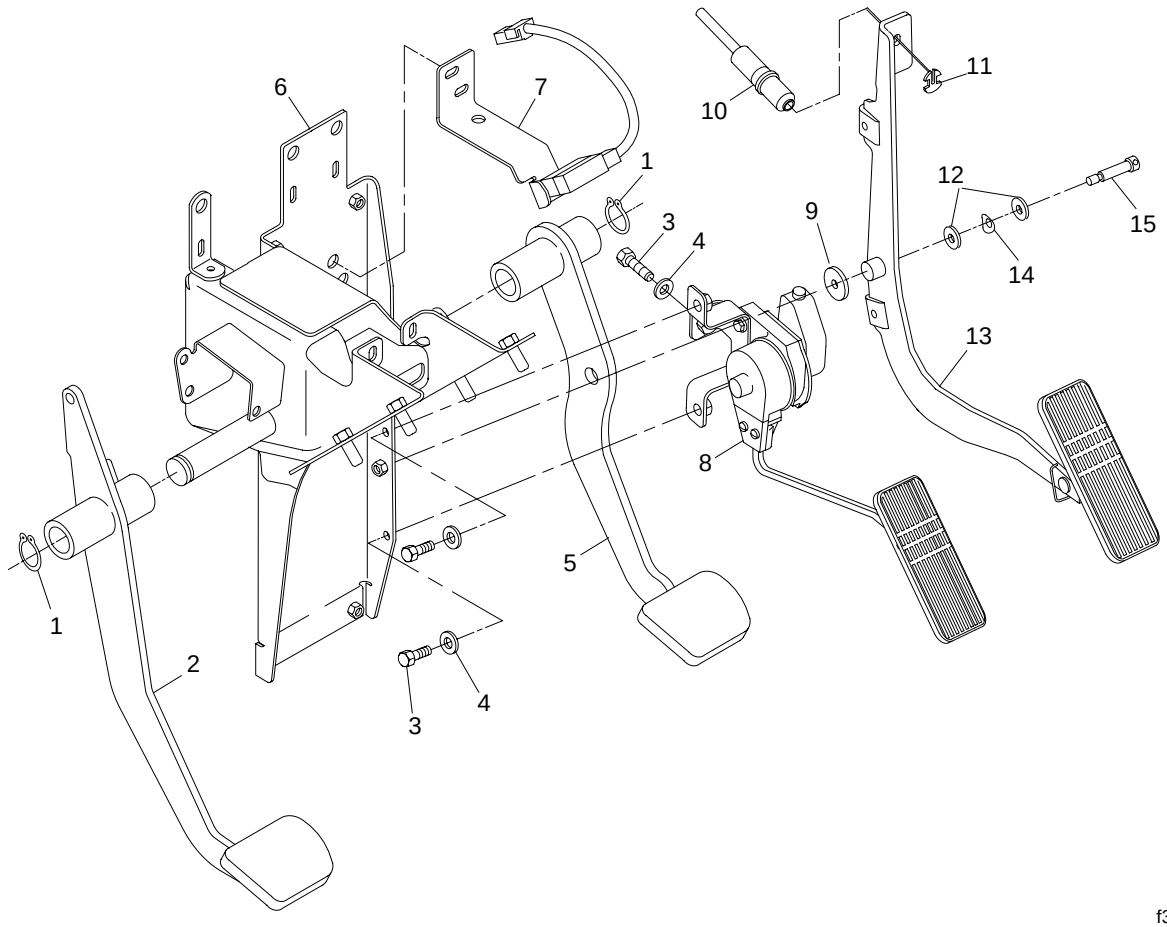
Fig. 3, Modulator Cab Harness

General Information

Your vehicle can be equipped with either a mechanical or an electronic throttle pedal. If you have a Caterpillar CFE engine, a Cummins ISB, or ISC engine, your vehicle uses a Williams electronic suspended throttle pedal. See **Fig. 1**. If you have a Cummins B or C series engine, your vehicle uses a mechanical throttle pedal and cable.

With electronic pedals, the suspended pedal assembly mounts to the steering column assembly and the inside of the cab bulkhead, and communicates with the engine through a wiring harness.

As the driver presses the pedal, the drive lever is forced downward, rotating the pinion gear which meshes with the pedal sensor (sometimes called the "potentiometer"). As the drive lever moves down and



NOTE: A vehicle will have either the electronic throttle pedal (item 8) or the mechanical pedal (item 13).

1. Snap Ring
2. Clutch Pedal
3. Capscrew, 5/16–18, Grade 5
4. Washer, 5/16
5. Brake Pedal
6. Steering Column Assembly
7. Brake Switch and Bracket
8. Electronic Throttle Pedal
9. Washer, 5/16 x 1-1/4
10. Throttle Cable
11. Throttle Cable Retainer
12. Washer, 3/8
13. Mechanical Throttle Pedal
14. Spring Washer
15. Shoulder Bolt, 3/8 x 1-1/4

Fig. 1, Throttle Pedal Installations

rotates the pinion gear, the sensor, attached to the

General Information

inboard side of the assembly, monitors how far the pinion gear rotates. Depending on how much the driver presses the pedal—and the pedal rotates the pinion gear—the sensor tells the electronic engine control how much fuel to deliver to the engine.

When the driver stops pressing the pedal, return springs within the pedal assembly lift the pedal back to the original idle position.

Only the pedal sensor is serviceable. If any other part of the pedal malfunctions, replace the entire pedal assembly.

Cummins B and C series engines use a cable to connect the mechanical throttle pedal to the throttle lever on the engine. See **Fig. 2**. The cable runs from the pedal, through the frontwall, and directly to the engine throttle lever. Return springs return the throttle lever to the idle position when pressure on the throttle pedal is released.

When depressed, the throttle pedal pulls the cable, and the cable pulls the engine throttle lever up to increase fuel delivery to the engine. The cable length enables the throttle pedal to operate the throttle lever through its full range, from idle to full throttle. The cable conduit prevents any interference with, or wear on, the throttle cable.

The throttle lever consists of two parts held in alignment by a breakover spring. The rear half of the lever connects to the throttle cable. The forward half connects to a shaft which controls the fuel injection pump rack. As the throttle cable pulls the lever up or releases it down, the lever rotates the shaft to increase or decrease fuel delivery to the fuel injectors.

When the throttle cable pulls the rear half of the throttle lever as far up as the injection pump shaft will rotate, additional force applied at the throttle pedal overcomes the breakover spring in the throttle lever. This allows the rear portion of the throttle lever to continue rotating upward as the throttle cable pulls, but the injection pump shaft is not forced to rotate beyond its rotation limit.

A throttle pedal stop prevents the cable from pulling the throttle lever beyond the breakover range.

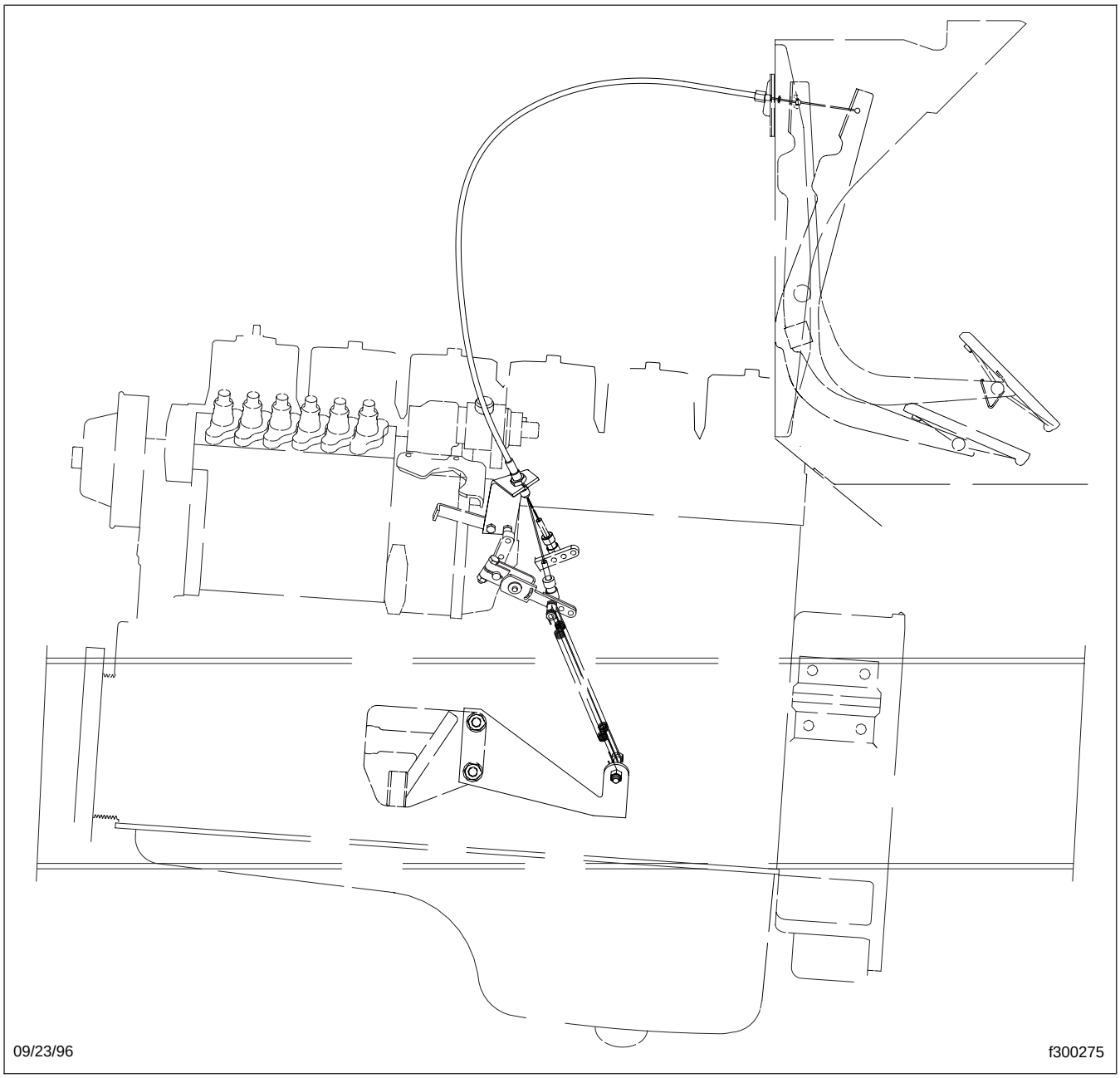


Fig. 2, Adjustable Throttle Cable, Cummins Engine

Throttle Cable Removal and Installation

Removal

1. Lift the throttle pedal to get some slack in the throttle cable as it comes through the bulkhead. See **Fig. 1**.
2. Pry out the plastic bushing which holds the cable end in the throttle pedal lever. Take the bushing off the cable, and remove the cable from the pedal lever.

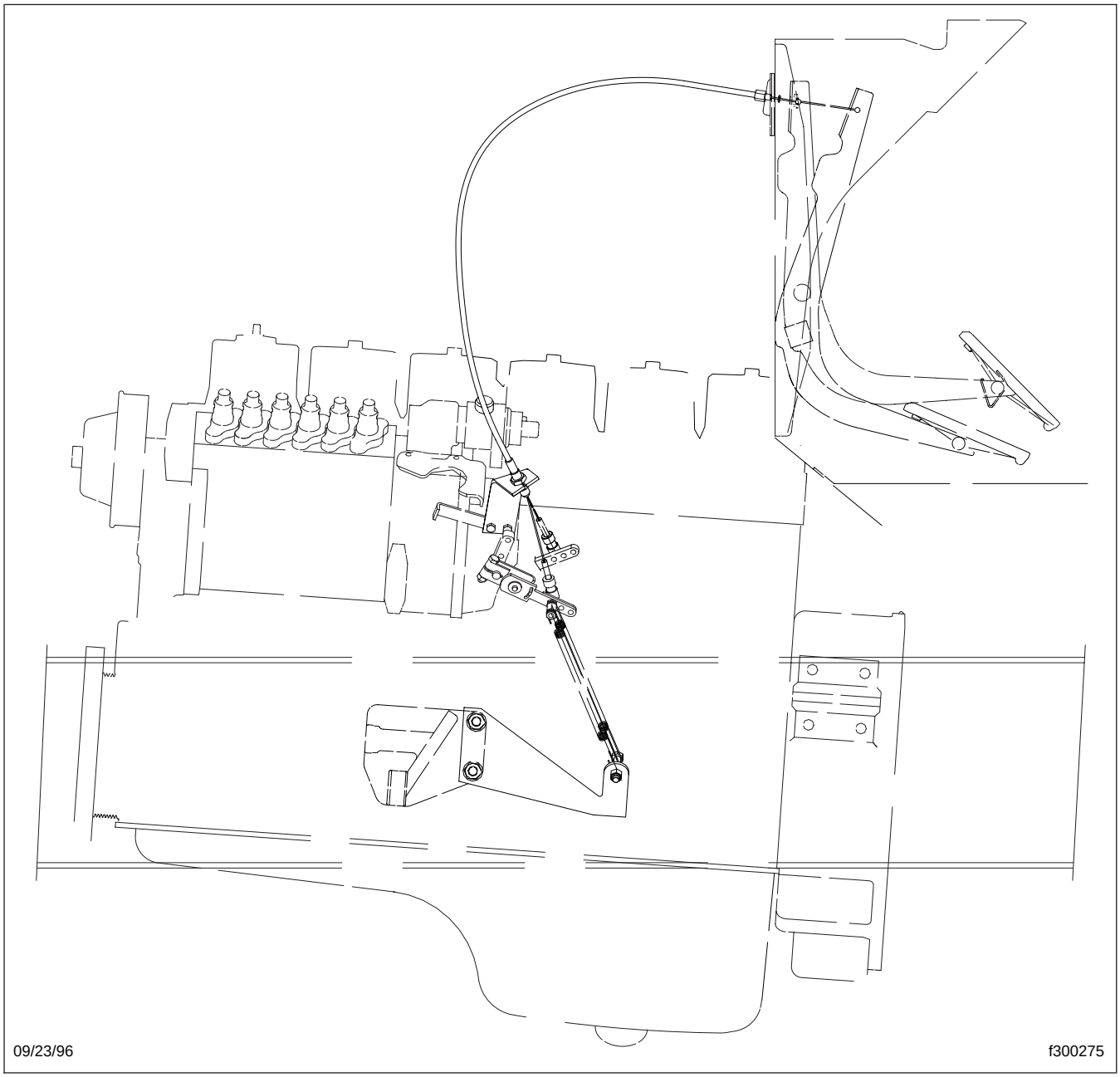


Fig. 1, Throttle Cable, Cummins Engine

Throttle Cable Removal and Installation

3. Remove the four screws that hold the throttle cable assembly plate to the firewall, and pull the throttle cable and plate away from the firewall.
4. Remove the split nylon ring holding the throttle cable to the plate assembly.
5. Remove the cable end from the ball stud on the throttle lever.
6. Remove the cable from the cable bracket.

Installation

1. Push the throttle cable bulkhead end through the throttle cable plate assembly, and install the plate assembly on the firewall.
2. Pass the throttle cable ball end through the top hole, labeled "THRT", of the pedal arm. Place the cable into the slot of the retainer, then press the retainer into the pedal arm hole until it snaps into place.
3. Thread the cable through the cable bracket hole, and assemble the cable end on the ball stud.
4. Position the cable in the throttle bracket, and secure it.

   Adjust the throttle cable in the bracket as necessary to assure firm throttle lever contact with the idle stop when no force is on the throttle pedal.

   Also position the cable in the bracket so there is visible throttle lever breakover when the throttle pedal is pressed against the pedal stop. Throttle breakover should not exceed 15 degrees.

Electronic Throttle Pedal Removal and Installation

Caterpillar CFE and Cummins ISB and ISC electronic engines use a Williams brand electronic throttle pedal. See **Fig. 1**. This is a hanging pedal with an electronic sensor connected by wiring to the engine control module.

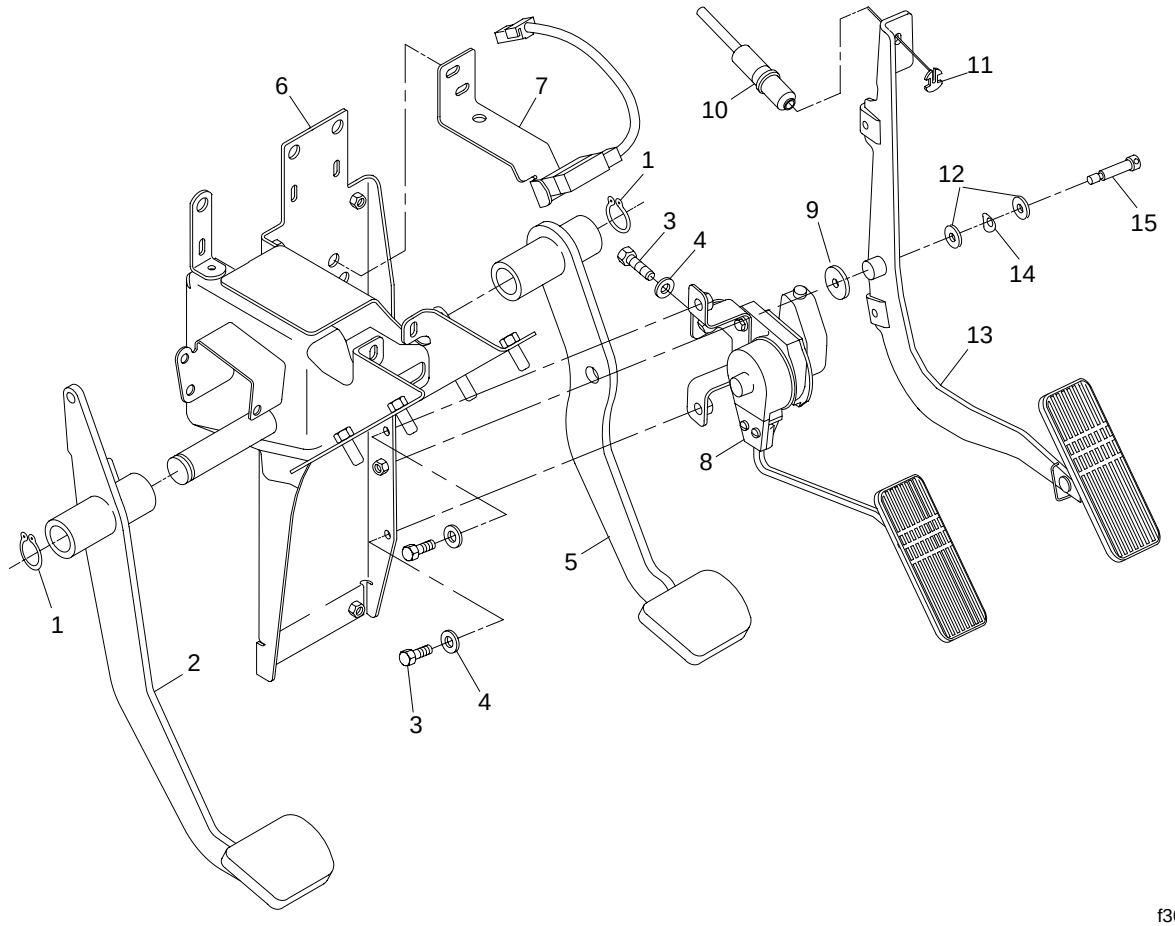
Removal

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Disconnect the batteries.
3. Disconnect the wiring harness from the throttle pedal.
4. Remove the throttle pedal assembly from the vehicle. See **Fig. 1**.
   - 4.1 Remove the three capscrews and washers that secure the mounting plate to the steering column assembly and the bulkhead.
   - 4.2 Remove the pedal assembly from the steering column assembly.

Installation

1. Install the throttle pedal assembly.
   - 1.1 Position the pedal assembly on the steering column assembly.
   - 1.2 Secure the pedal assembly with three capscrews and washers, and tighten the capscrews 10 lbf·ft (13 N·m).
2. Connect the wiring harness to the throttle pedal.
3. Connect the batteries, lower the hood, and remove the chocks from the tires.
4. Test drive the vehicle.

Electronic Throttle Pedal Removal and Installation



09/18/96 f300257

NOTE: A vehicle will have either the electronic throttle pedal (item 8) or the mechanical pedal (item 13).

1. Snap Ring
2. Clutch Pedal
3. Capscrew, 5/16–18, Grade 5
4. Washer, 5/16
5. Brake Pedal
6. Steering Column Assembly
7. Brake Switch and Bracket
8. Electronic Throttle Pedal
9. Washer, 5/16 x 1-1/4
10. Throttle Cable
11. Throttle Cable Retainer
12. Washer, 3/8
13. Mechanical Throttle Pedal
14. Spring Washer
15. Shoulder Bolt, 3/8 x 1-1/4

Fig. 1, Throttle Pedal Installations

Electronic Throttle Pedal Sensor Replacement

Replacement

1. Apply the parking brakes, and chock the tires.
2. Disconnect the batteries.

NOTE: The sensor is not a serviceable part. If the sensor is malfunctioning, replace it.

3. Remove the sensor.
   - 3.1 Disconnect the wiring harness from the throttle pedal sensor.
   - 3.2 Remove the two screws that hold the sensor to the throttle base.
4. Install the sensor.
   - 4.1 Align the sensor with the pinion gear.
   - 4.2 Rotate the sensor so the mounting holes line up, then secure the sensor with the mounting screws, and tighten the screws fingertight.
   - 4.3 Check the sensor output. For instructions, see **Subject 120**.
   - 4.4 After the sensor is adjusted to the correct specifications, tighten the two sensor screws 15 to 20 lbf·in (169 to 226 N·cm).
   - 4.5 Connect the wiring harness to the sensor.
5. Connect the batteries and remove the chocks from the tires.
6. Test drive the vehicle.

Sensor Timing

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Loosen the two screws that hold the sensor to the throttle base.
3. For Caterpillar engines, connect the Caterpillar Digital Diagnostic Tool to the vehicle's electronic data link. With the pedal in the idle position, adjust the sensor by rotating its housing until the reader displays the correct output of 10 to 22 percent of duty cycle.
4. For Cummins engines, check and adjust sensor timing by measuring voltage with a voltmeter at both closed and open throttle positions. See the latest Cummins instruction bulletin.

IMPORTANT: Cummins allows 125 ohms resistance in the idle validation switch. Do not replace a sensor unless the idle validation switch resistance exceeds 125 ohms while the pedal is in motion.

⚠ CAUTION

Do not overtighten the sensor screws. Overtightening the screws can damage the sensor.

5. After the sensor is adjusted to the correct specifications, tighten the two sensor screws 15 to 20 lbf·in (169 to 226 N·cm).
6. Tighten the wiring harness clamps.
7. Remove the chocks from the tires.

General Information

IMPORTANT: This service manual *does not cover* the procedures and calculations necessary to perform frame modifications. Before modifying the frame, be sure to consult with the Freightliner Engineering Department.

The main body of the frame is two non-heat-treated steel frame rails secured together by crossmembers. See **Fig. 1**. The frame assembly is supported on the front and rear axles, and supports the rest of the chassis and body.

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 for protection of the wires and tubing that are routed from one side of the vehicle to the other.

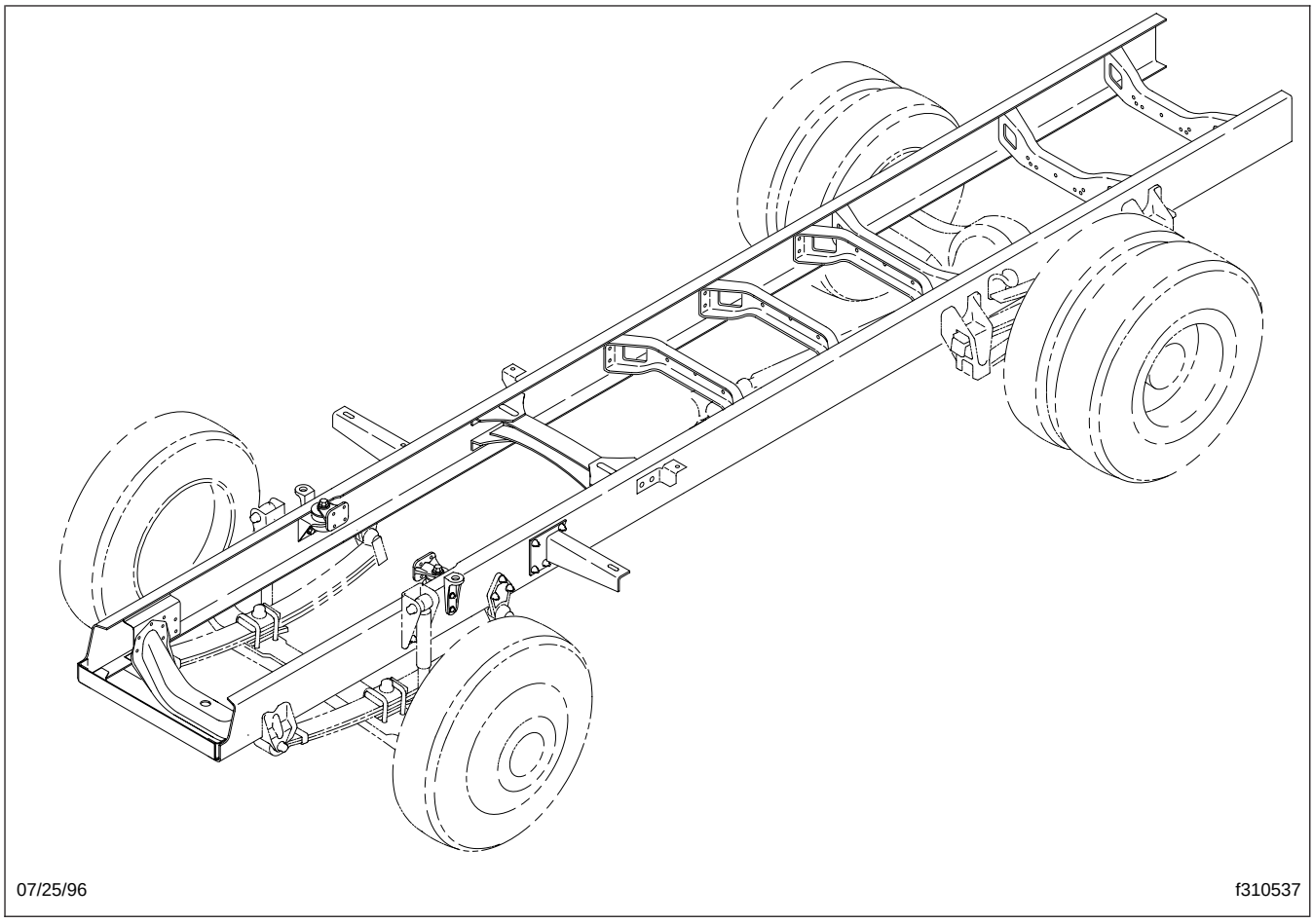


Fig. 1, Frame Assembly

Both frame rails have identical specifications. Each has an upper flange, lower flange, and web (the surface area between the flanges). The inside area of the frame rail is called the channel. See **Fig. 2**.

General Information

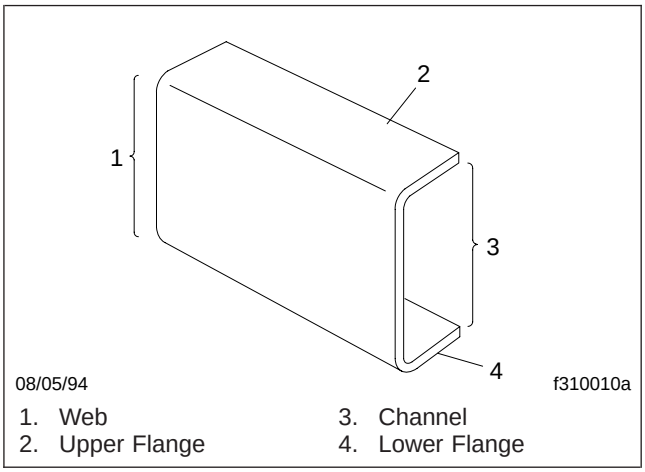


Fig. 2, Frame Terminology

General Handling

Whenever the frame rails are lifted or moved, take care to avoid anything that may scratch, cut, or damage the exposed frame assembly. Cushion all chain hoists or cable slings with a section of heavy hose. If the frame rail is raised with a jack, place a block of wood between the jack and the frame rail.

Never heat the frame rails for straightening purposes; such work should be done cold.

⚠ CAUTION

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.

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.

⚠ CAUTION

CAUTION: Before performing any electric welding on a vehicle, disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Freightliner vehicle components that typically use ECUs include electronic engine, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect its ground terminal from the chassis ground, and disconnect its power terminal from the battery positive post. Or else disconnect the main connection at the ECU.

Apply Alumilastic® Compound or a paintable, air-cured synthetic rubber or moisture-cured polyurethane, flexible weather-sealant between any dissimilar metal surfaces that contact each other (except nuts, bolts, and zinc or cadmium plated washers), regardless of whether the surfaces are primed or painted.

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.

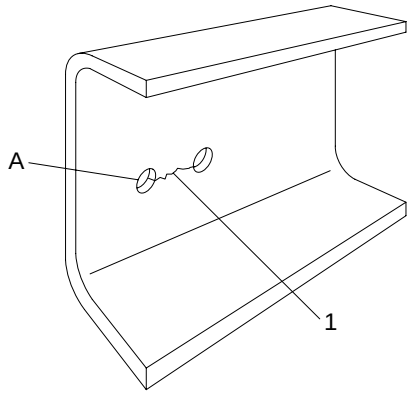
CAUTION

Before performing any electric welding on a vehicle, disconnect the battery power and ground cables and any electronic control units (ECUs) installed on the vehicle. Electric currents produced during electric welding can damage various electrical components on the vehicle, such as alternator diodes and ECUs.

Vehicle components that typically use ECUs include electronic engines, electronic automatic transmission, and ABS (antilock braking system).

For any ECU with a battery power harness, disconnect the ground terminal from the chassis ground and the power terminal from the battery positive post, or disconnect the main connection at the ECU.

1. Drill a 1/8 inch (3 mm) diameter hole at each end of the crack to prevent further spreading. See **Fig. 1**.

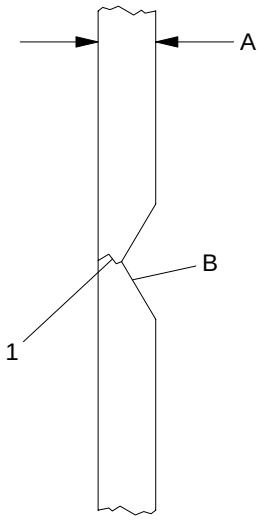


09/19/2003 f310012c

A. 1/8 inch (3 mm) Diameter Hole
1. Crack

Fig. 1, Preventing Cracks from Spreading

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



08/14/95 f310013a

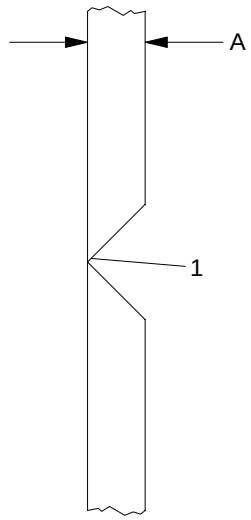
A. Frame Rail Thickness
B. Grind a v-groove to two-thirds the depth of the stock thickness.
1. Crack

Fig. 2, Cross-Section View

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.
4. Grind the weld flush with the frame rail. See **Fig. 5**.
5. Cut a deep enough v-groove on the opposite side of the frame rail to reach the weld metal. See **Fig. 6**.
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**.

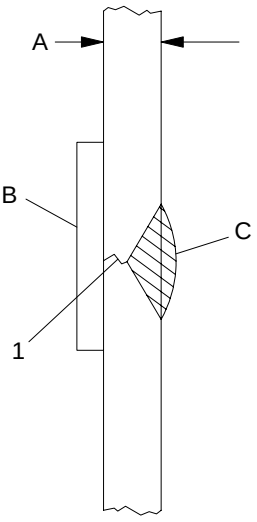
Frame Rail Repair



08/14/95 f310014a

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

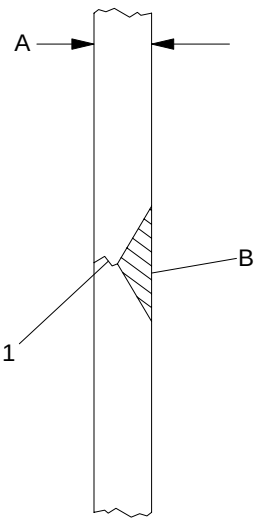
Fig. 3, Full Depth Groove



08/14/95 f310015a

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

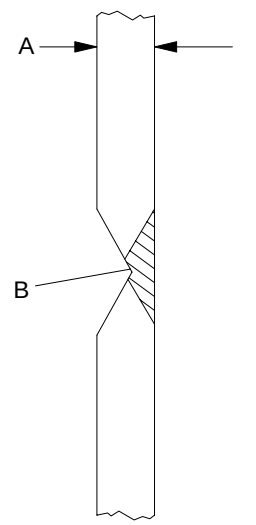
Fig. 4, Using a Chill Strip



08/15/95 f310016a

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

Fig. 5, Weld Ground Flush



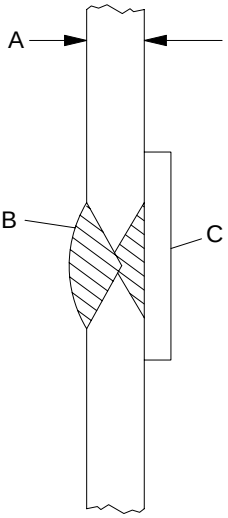
08/15/95 f310017a

A. Frame Rail Thickness
B. Grind a v-groove deep enough to reach the weld.

Fig. 6, Cross-Section View

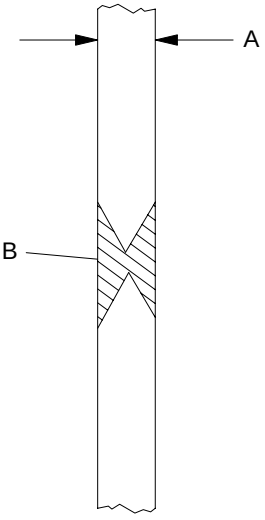
Filling Unused Holes

1. Fill all unused holes in the frame assembly with the applicable nut, washer, and bolt combination.



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

Fig. 7, Second Weld



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

Fig. 8, Second Weld Ground Flush

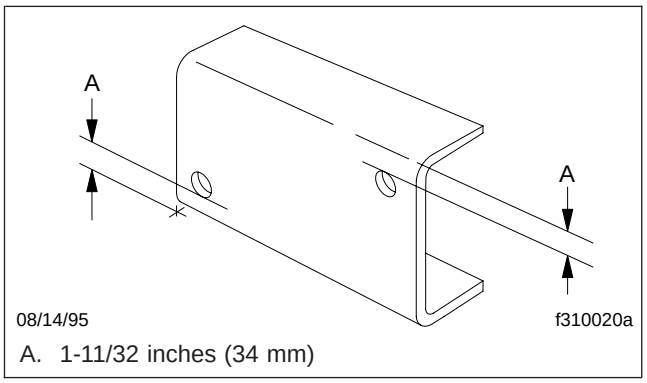
2. If the diameter of a hole is less than 3/8 inch (1 cm), enlarge it to 3/8 inch (1 cm), and fill it with the applicable nut, washer, and bolt combination.
3. Tighten the fasteners to the applicable torque value. For proper frame fastening instructions, refer elsewhere in this group.

Drilling Holes

During vehicle manufacture, holes are drilled or punched in the frame rail only as specified on the vehicle frame drilling chart. If any additional holes need to be drilled, contact your regional service representative for approval.

A single exception to this rule is that holes may be drilled for tubing clips and the like through the web portion of the channel only, with the following restrictions:

- The *edge* (not the center) of the hole must be no closer than 1-11/32 inches (34 mm) from the outer face of the flange. See **Fig. 9** for the minimum distance to the flanges that holes can be placed on the web.
- Material between the centerline of the hole and the outside of the upper or lower flange must be at least 2-13/32 inches (60 mm).
- Minimum material between hole centerlines must be 2 inches (50 mm).
- All attaching fasteners must be Grade 8. Flat washers must be made with high strength steel.
- The minimum material between the rear suspension bracket and the end of the frame must be at least 2 inches (50 mm).
- Holes between the front axle centerline and the rear axle centerline cannot exceed 3/4 inch (19 mm).

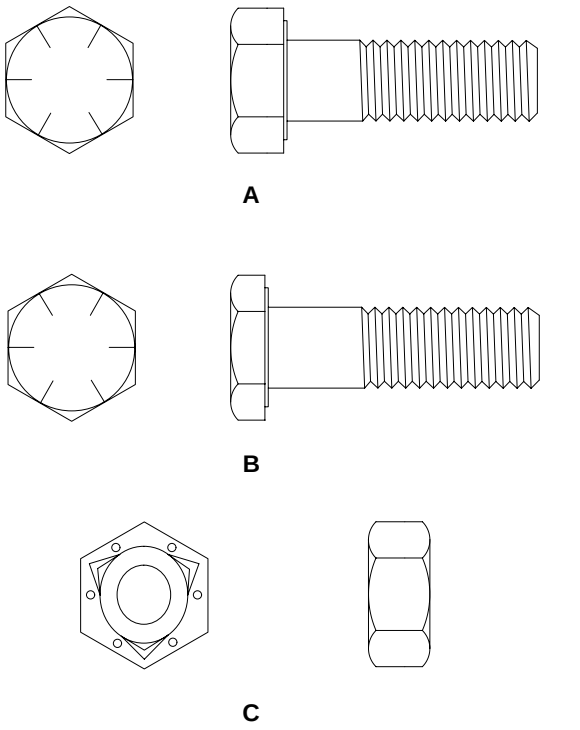


A. 1-11/32 inches (34 mm)

Fig. 9, Minimum Distance for Drilling Holes

General Information

Grade 8 hexhead bolts and grade C prevailing torque locknuts are used for frame attachments. For attachments where clearance is minimal, low-profile hexhead bolts and grade C prevailing torque locknuts are used. See **Fig. 1**. Prevailing torque locknuts of both bolt types have distorted sections of threads to provide torque retention.



A. Grade 8 Hexhead Bolt
B. Grade 8 Low-Profile Hexhead Bolt
C. Grade C Prevailing Torque Locknut

Fig. 1, Hexhead Fasteners

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 the 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

Replace hexhead bolts with identical fasteners. Refer to the Freightliner Parts Book for fastener specifications.

Apply Alumilastic® compound, or an equivalent, to all surfaces where steel and aluminum parts contact each other.

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.

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 four inches (102 mm), allow a minimum of 3 threads and a maximum of 3/4-inch (19-mm) bolt length.

If it is necessary to remove rivets, always replace them with grade 8 hexhead bolts and grade C prevailing torque locknuts of the next larger size. For example, replace 3/8-inch (9.5-mm) diameter rivets with 7/16-inch (11-mm) fasteners.

FRAME FASTENER TIGHTENING

CAUTION

Tighten standard frame fasteners periodically. Continued vehicle operation with loose fasteners could result in component, bracket, and frame damage.

Tighten hexhead bolts and locknuts periodically to offset the effects of "bedding in" (seating). See the Maintenance Schedule and Group 31 of the *School Bus Chassis Maintenance Manual* for intervals.

Frame Fasteners

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, refer to the general information section in the chassis maintenance manual.

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.

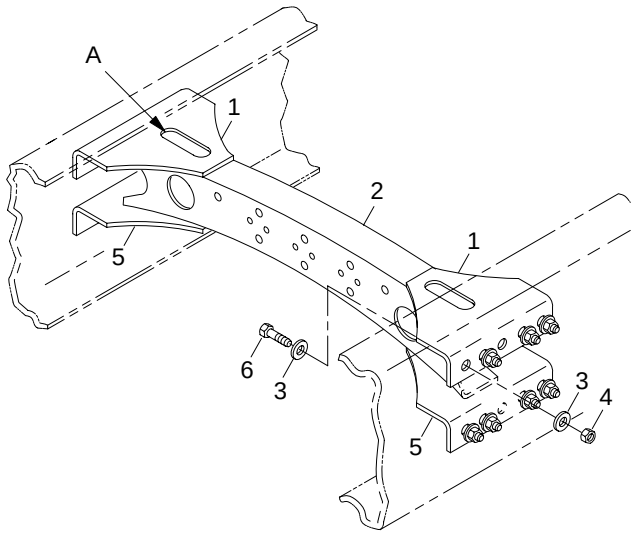
IMPORTANT: Before removing any crossmember, note the direction, size, and type, of all fasteners that attach the crossmember to the frame rail, and that attach other parts to the crossmember. Also note which direction the open channel of the crossmember is facing, for installation reference.

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. See **Fig. 1**.



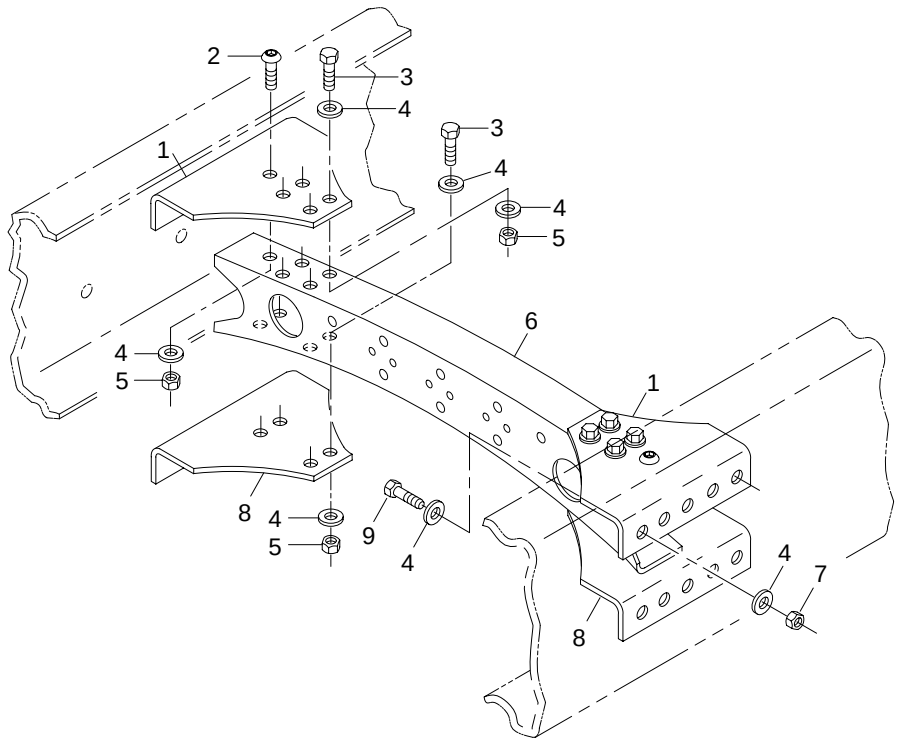
02/26/2001 f310538

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

5. Remove the fasteners that attach the crossmember halves to the frame rails, and remove the crossmember.

Crossmember Removal and Installation



08/05/94 f310243a

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

REAR-CLOSING CROSSMEMBER

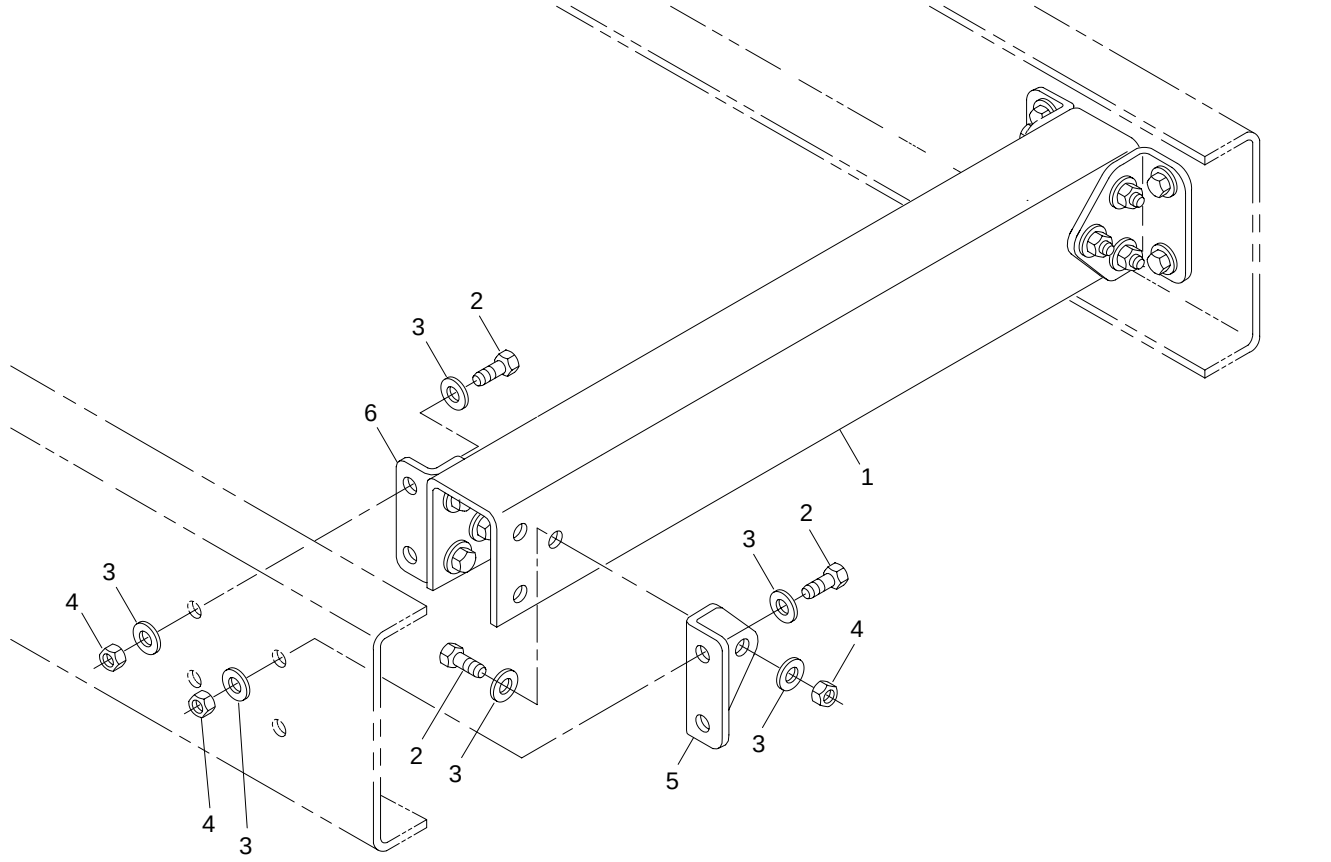
1. Apply the parking brakes, then chock the tires on both the front and rear axles.
2. If so equipped, remove the backup alarm from the crossmember.

   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.
3. Remove the fasteners that attach the crossmember to the front angle brackets. See **Fig. 3**.
4. If rear suspension brackets are attached to the frame rails with the same fasteners that attach the angle brackets, support the rear of the frame at its normal ride height, using safety stands.
5. Remove the fasteners that attach the rear angle brackets to each frame rail; then remove, as an assembly, the rear brackets and the crossmember.
6. If needed, remove the front angle brackets and their fasteners. If applicable, after removing the fasteners, remove the rear suspension brackets from the springs.

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.



1. Rear Closing Crossmember
2. 5/8–11 Grade 8 Bolt
3. Hardened Steel Flatwasher
4. 5/8–11 Locknut
5. Rear Angle Bracket
6. Front Angle Bracket

Fig. 3, Rear Closing Crossmember Installation

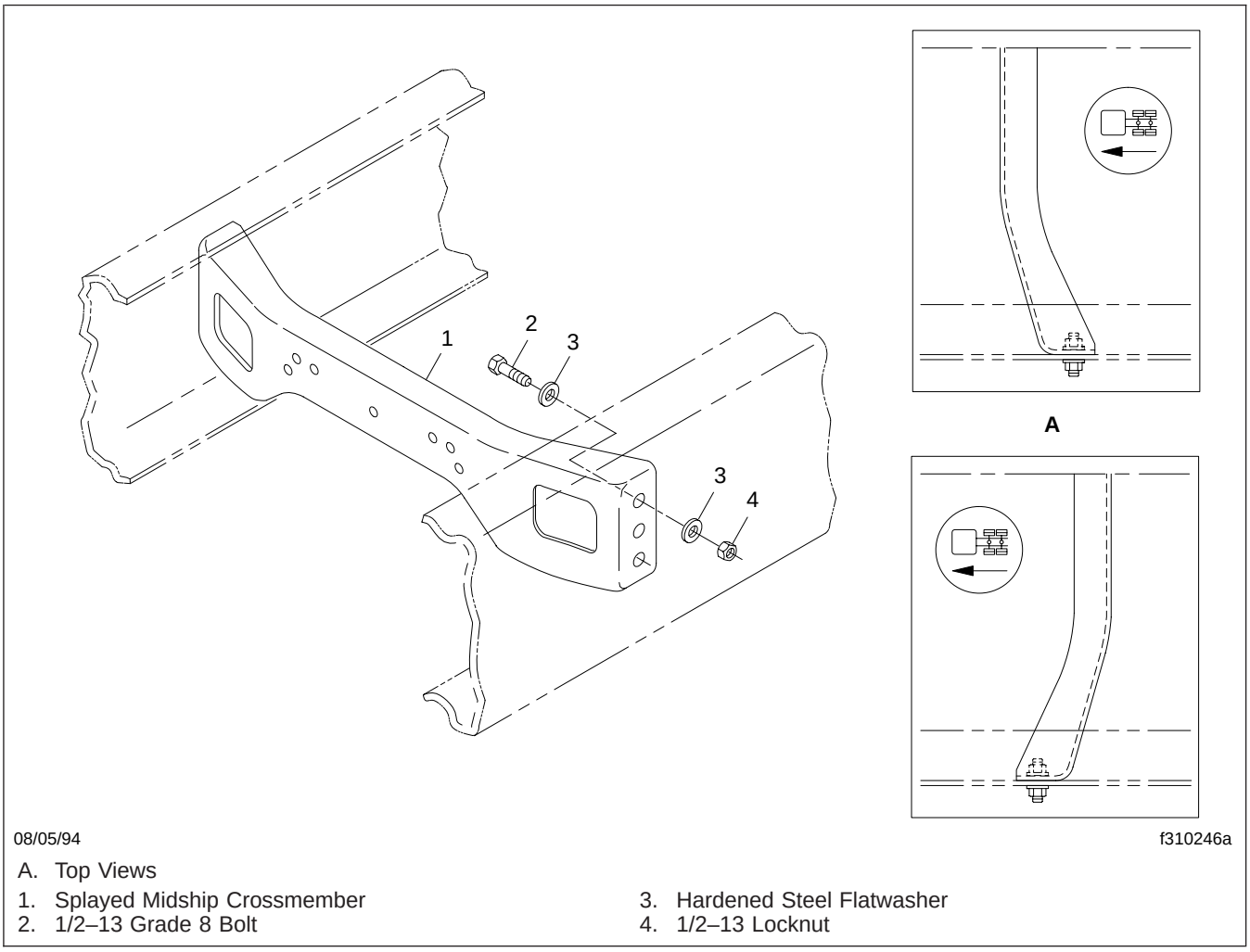
3. Unbolt the crossmember from both frame rails. See **Fig. 4**.
4. At one end of the crossmember, use a deadblow hammer to tap against its curved side (the closed side of the channel), until the crossmember is no longer wedged in the frame. Remove the crossmember.

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.

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. 4, Splayed Crossmember

3. Attach the other upper gusset to the crossmember channel; tighten the fasteners snug, but not to their final torque value.
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.

REAR-CLOSING CROSSMEMBER

1. If they were removed, install the front angle brackets and their fasteners, but don't tighten the fasteners at this time. If applicable, install the rear suspension brackets on the springs. See **Fig. 3**.
2. Slide the crossmember into the opening at the rear of the frame rails, then turn it upright, to position it against the front angle brackets.
3. Attach the rear angle brackets to the frame rails, but don't tighten the fasteners at this time.
4. Install but do not tighten the fasteners that attach the crossmember to the front angle brackets.
5. If they were removed from the rear-closing crossmember, install any air brake valves, and securely tighten the fasteners.

   If so equipped, install the backup alarm.

   Install any clamps that attach air lines or wiring to the crossmember.
6. Tighten the fasteners that attach the angle brackets to the frame rails, then tighten the fasteners that attach the crossmember to the angle brackets. Tighten all fasteners 136 lbf·ft (184 N·m).
7. 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 at one end of the crossmember with the holes in the frame rail. See **Fig. 4**.

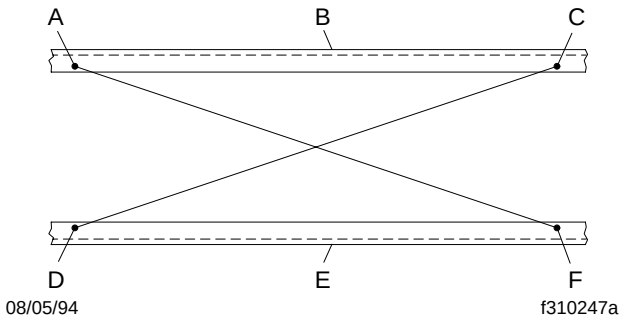
NOTE: With the crossmember not straight across in the frame rails, and the holes not aligned on the opposite end, the holes at that end will be in approximate alignment.

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** in this manual.
6. Remove the chocks.

Alignment

Frame rail alignment is checked by measuring the distances from two sets of points on the upper (or lower) flanges of the frame rails. See **Fig. 1**. The rear set of points must be as far back as possible from the forward set of points. There must be no interference, along or between the frame rails, that would prevent measuring from any one of the four points to the other three points. If the upper flanges are being used for the measurements, the fifth wheel and deck plate (as equipped) must be removed.

There are no marks or bolt holes in the upper or lower flanges of the frame rails. Therefore, the points must be projected from the frame station marks, manufacturing holes, or component attachment holes in the frame rail webs.



A. Right Forward Point
B. Right Frame Rail
C. Right Rear Point
D. Left Forward Point
E. Left Frame Rail
F. Left Rear Point

Fig. 1, Frame Rail Squaring

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

1. Apply the parking brakes, then chock the tires.
2. For each frame rail, project the exact vertical centerline of the 5/8-inch (16-mm) manufacturing hole at frame station 2628.4, from the frame web to the upper (or lower) flange, and mark it with a line across the flange.

   If, because of interference, the manufacturing hole at frame station 2628.4 cannot be used, choose and mark another matched set of points, as follows:

   2.1 Determine how far forward that the upper (or lower) flanges of both frame rails are clear.

   2.2 Find a matched set of bolt holes on the frame rail webs, that are aligned with, or just rearward of, the front of the clear area on the flanges. The bolt holes must be in exactly the same location in each frame rail.

   2.3 Project the exact vertical centerline of each bolt hole, and mark a line across the upper (or lower) flange of its respective frame rail.
3. Find the exact center of the width of each flange, and mark the point on each projected line. This will be the forward set of points. The forward points must be in identical locations on both frame rails.
4. Measure along each frame rail, to find a set of holes *at least* 72 inches (180 cm) rearward from the forward set of points. The holes must be in exactly the same location in each frame rail.

IMPORTANT: If, because of interference, the distance must be less than 72 inches (180 cm), the distance must be the maximum that is possible.

5. Project the exact vertical centerline of each bolt hole, and mark a line across the upper (or lower) flange of its respective frame rail.
6. Along each line, measure and mark a point 2 inches (5 cm) inboard from the outside face of its respective frame rail. The rear points must be in identical locations on both frame rails.
7. Measure the distance from the forward point on one frame rail to the rear point on the opposite frame rail. See **Fig. 1**. Then measure the distance from the other forward point to the rear point on its opposite frame rail. Compare the two measurements.

Frame Rail Alignment

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

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.

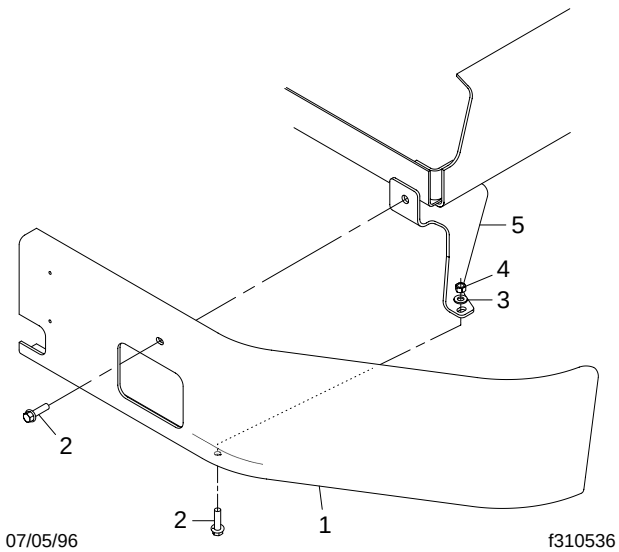
8. Loosen *all* of the frame fasteners enough to allow movement of the parts when force is applied.

IMPORTANT: To align the frame rails, the frame must have all of the crossmembers in place, but the attachment fasteners should *not* be tightened.

9. Using a large hammer and a large wooden block, place the block against the rear end of the frame rail that had its rear 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.
10. Tighten all of the frame fasteners, starting at the middle of the frame and working alternately toward both ends. Tighten all fasteners to their applicable torque values; refer to Specifications in **Section 00.03**.
11. Again, check the frame rail alignment.
12. If the frame rails needed aligning, check the axle alignment; refer to the appropriate suspension section in **Group 32** for instructions.
13. Remove the chocks.

Bumper Removal and Installation

Removal



NOTE: Road lights not shown.

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

1. Park the vehicle on a level surface; then apply the parking brakes. Chock the tires.
2. If equipped with road lights, remove them from the bottom of the bumper.
   - 2.1 Disconnect the wiring from each road light.
   - 2.2 Remove the fasteners that attach the road light mounting bracket to the bottom of the bumper; then remove the road light and its mounting bracket. See **Fig. 1**.
3. Support the bumper. On one side of the vehicle, remove first the lower, then the upper 1/2–13 fasteners that attach the bumper to the frame rail bracket.
4. 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. If removed, install the road lights onto the bumper.
   - 3.1 Line up the hole in the road light mounting bracket with that in the bottom edge of the bumper.
   - 3.2 Install the fasteners; then tighten them finger tight.
   - 3.3 Turn the light to correctly align it; then tighten the mounting bracket fasteners firmly.
   - 3.4 Connect the wiring.
   - 3.5 Repeat the procedure on the other side of the vehicle.
4. Remove the chocks from the tires.

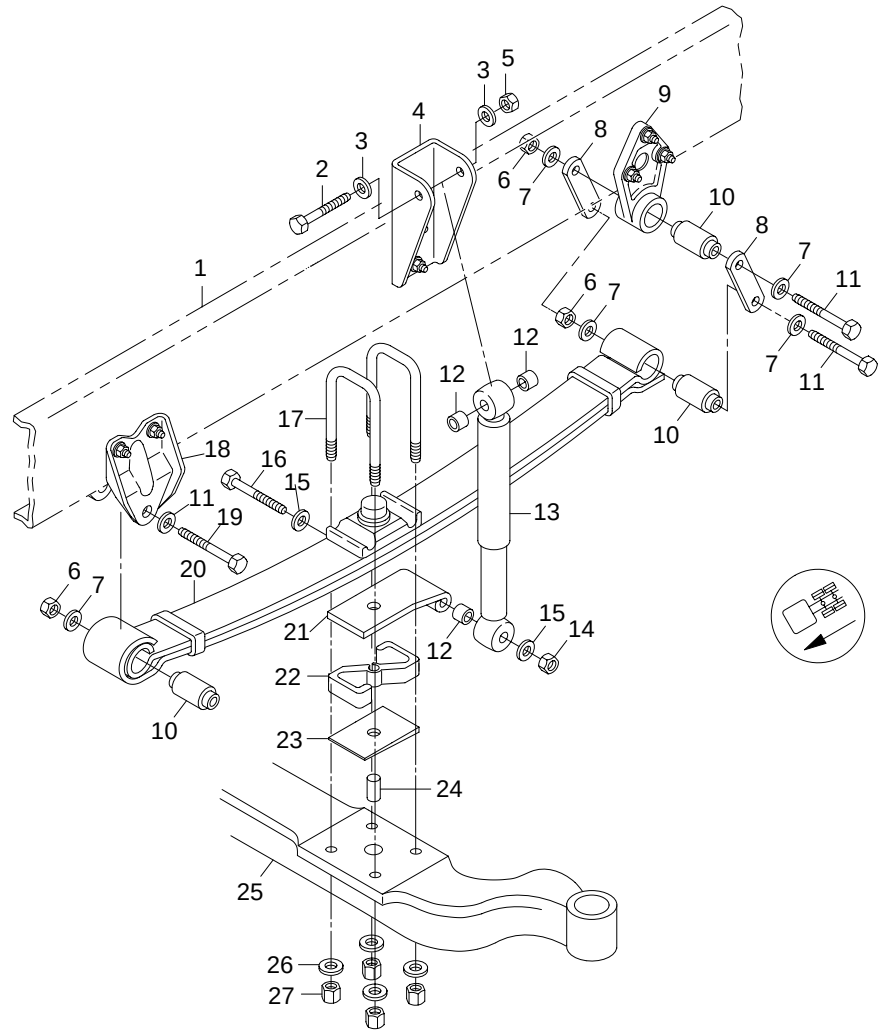
General Information

Freightliner front suspensions use either a taperleaf or a flatleaf assembly. The taperleaf suspensions are available in varying capacities from 6,000-pound (2 722 kg) to 12,000-pound (5 443 kg). Shock absorbers are standard.

The spring assemblies are attached to the axle with U-bolts, hardened washers, and high nuts. See **See Fig. 1** and **Fig. 2**. The forward end of each spring mounts to a stationary front spring bracket. The rear of each spring mounts to a spring shackle suspended from a frame-mounted bracket. The shackle allows for variations in spring length as the spring flexes.

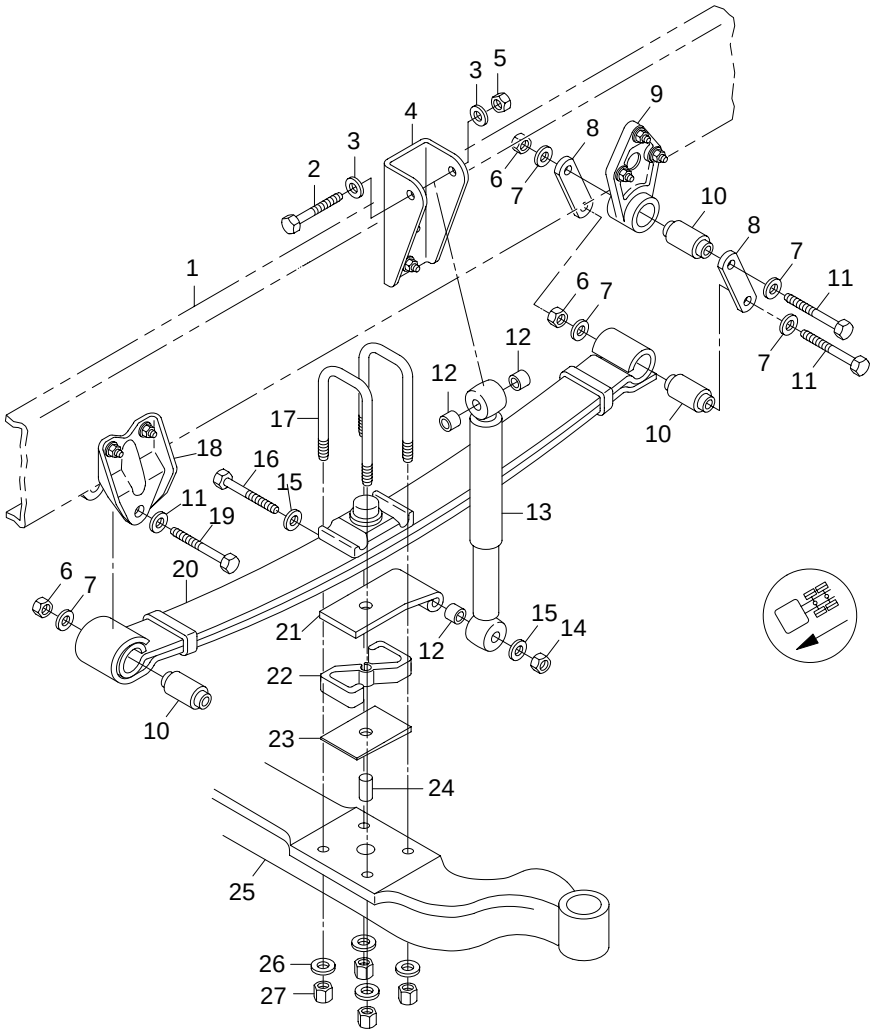
The leaf spring assembly absorbs and stores energy over bumps, releasing it at a controlled rate to smooth the ride. Individual spring leaves are held together by a center bolt. Alignment clips limit the sideways spread and vertical separation of the individual leaves.

General Information



1. Frame Rail
2. Shock Absorber Upper Mounting Bolt
3. Hardened Washer
4. Shock Absorber Upper Mounting Bracket
5. Hexnut
6. Hexnut, 3/4–10, Grade C
7. Hardened Washer
8. Spring Shackle
9. Shackle Bracket
10. Bushing
11. Spring Shackle Bolt, 3/4–10 x 6.5
12. Spacer
13. Shock Absorber
14. Hexnut
15. Hardened Washer
16. Shock Absorber Lower Mounting Bolt
17. U-Bolt, 5/8–18
18. Front Spring Bracket
19. Front Spring Mounting Eye Bolt, 3/4–10 x 6
20. Spring Assembly
21. Shock Absorber Lower Mounting Bracket
22. Spacer
23. Caster Adjustment Shim
24. Dowel Pin
25. Axle
26. Hardened Washer
27. High Hexnut, 5/8–18

Fig. 1, Standard Taperleaf Front Suspension (6,000-pound shown)



03/25/96 f320253a

1. Frame Rail
2. Shock Absorber Upper Mounting Bolt
3. Hardened Washer
4. Shock Absorber Upper Mounting Bracket
5. Hexnut
6. Hexnut, 3/4–10, Grade C
7. Hardened Washer
8. Spring Shackle
9. Shackle Bracket
10. Bushing
11. Spring Shackle Bolt, 3/4–10 x 6.5
12. Spacer
13. Shock Absorber
14. Hexnut
15. Hardened Washer
16. Shock Absorber Lower Mounting Bolt
17. U-Bolt, 3/4–16
18. Front Spring Bracket
19. Front Spring Mounting Eye Bolt, 3/4-10 x 6
20. Spring Assembly
21. Shock Absorber Lower Mounting Bracket
22. Spacer
23. Caster Adjustment Shim
24. Dowel Pin
25. Axle
26. Hardened Washer
27. High Hexnut, 3/4–16, Grade C

Fig. 2, Standard Taperleaf Front Suspension (12,000-pound shown)

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

Removal

1. Apply the parking brakes, chock the rear tires, and tilt the hood.
2. Remove the front bumper. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
3. Remove the half-fender. For instructions, see **Group 88**.
4. Using a floor jack, lift the front of the vehicle by the frame until all weight is off the spring being removed.
5. Support the frame and axle with safety stands.

⚠ WARNING

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.

6. Remove the leaf spring assembly.

   6.1 Remove the U-bolt high nuts and washers; then, remove the U-bolts. See **Fig. 1**.

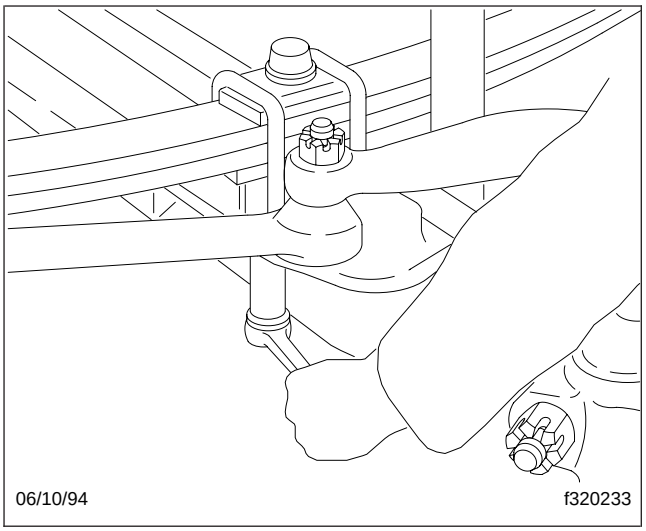
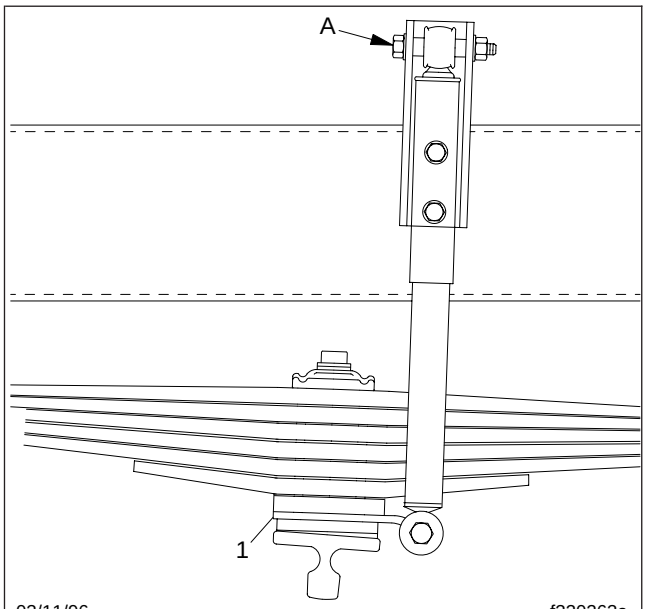


Fig. 1, U-Bolt Removal

   6.2 Loosen the shock absorber upper mounting bolt. Swing the shock absorber and attached lower mounting bracket out of the way. See **Fig. 2**.



A. Loosen the shock absorber upper mounting bolt.
1. Shock Absorber Lower Mounting Bracket

Fig. 2, Shock Absorber Lower Mounting Bracket Removal

   6.3 Remove the spring shackle lower bolt. See **Fig. 3**.

   6.4 Remove the front spring mounting eye bolt. See **Fig. 4**.

NOTE: If removing the driver's side spring, the steering must be at right full-lock so the bolt can clear the drag link.

   6.5 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

WARNING: The spring assembly is heavy. To prevent bodily injury, always use two people to remove it.

   6.6 Remove the spring by sliding it toward the front of the vehicle. See **Fig. 5** .

7. Remove the shackle upper bolt and nut. See **Fig. 6**. Press out the bushing. Remove the fas-

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

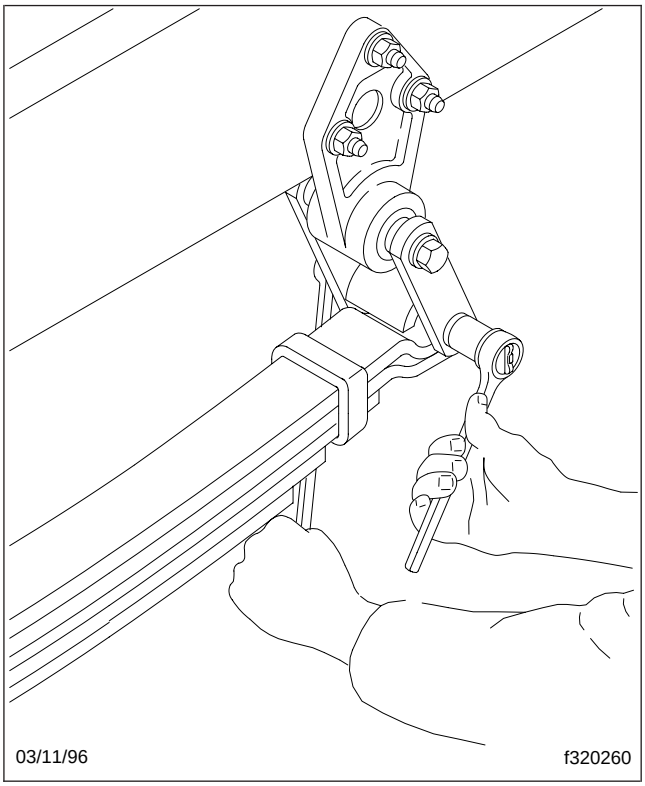


Fig. 3, Spring Shackle Lower Bolt Removal/Installation

teners holding the shackle bracket to the frame. See **Fig. 7**. Then, remove the bracket.

Cleaning and Inspection

1. Using a wire brush and solvent or steam cleaning equipment, wash all parts to remove dirt, grease, and scale.
2. Inspect all components for damage.
   - 2.1 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.*

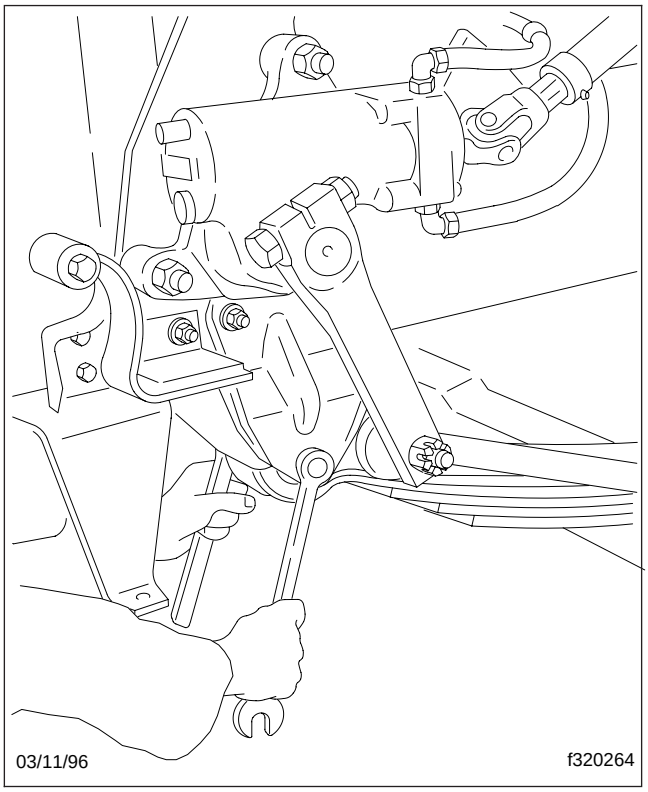


Fig. 4, Spring Eye Bolt Removal/Installation

⚠ WARNING

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, the cleaned areas can be painted with a rust-inhibiting paint. If rusting or corrosion is severe, replace the spring assembly.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

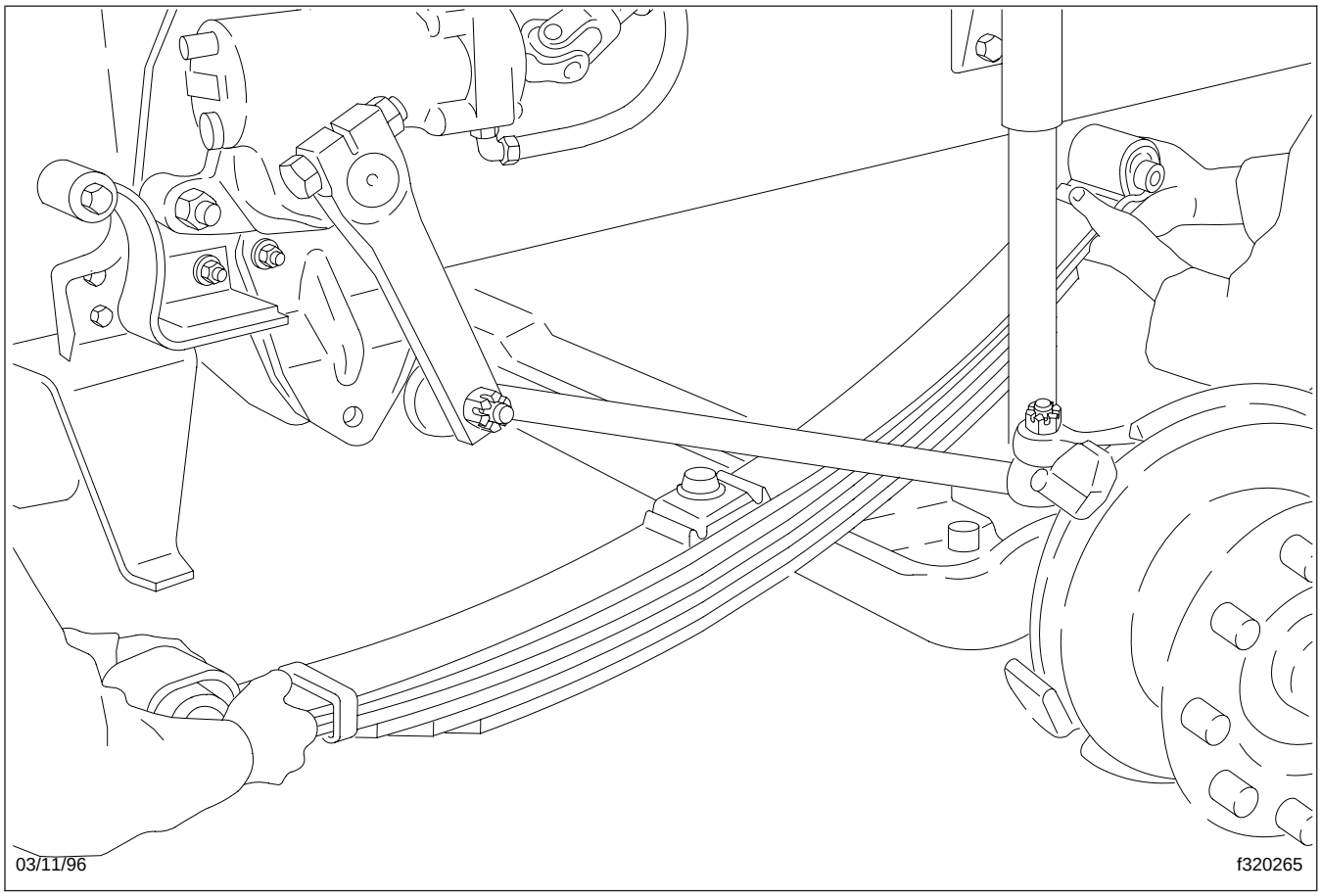


Fig. 5, Spring Removal/Installation

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. See **Fig. 7**. Tighten the mounting bolts 135 lbf·ft (183 N·m).

NOTE: All suspension bracket (frame) fasteners require periodic retightening. Refer to the vehicle 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

WARNING: The spring assembly is heavy. To prevent bodily injury, always use two people to install it.

3. Install the spring assembly.

   3.1 Lift the spring into position. See **Fig. 5**. Install the spring eye bolt at the front of the spring and the lower bolt in the shackle at the rear of the spring. See **Fig. 4** and **Fig. 3**.

Leaf Spring and Components Removal, Cleaning and Inspection, and Installation

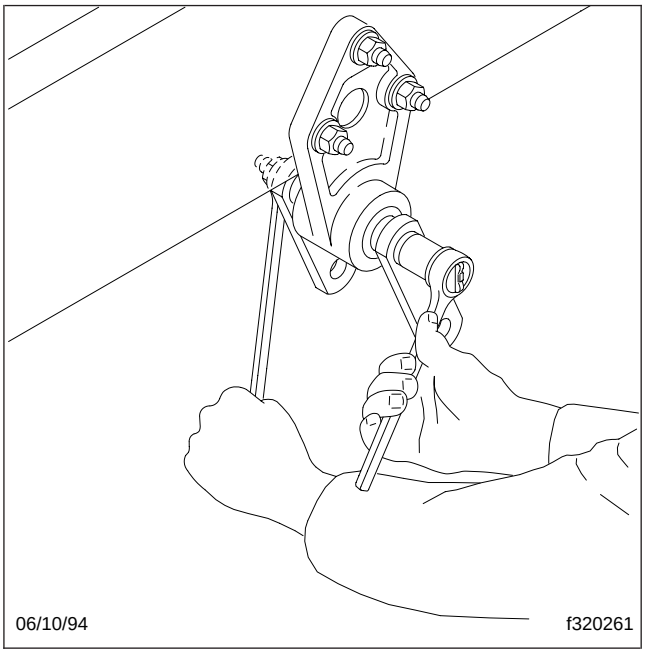


Fig. 6, Spring Shackle Bushing Removal

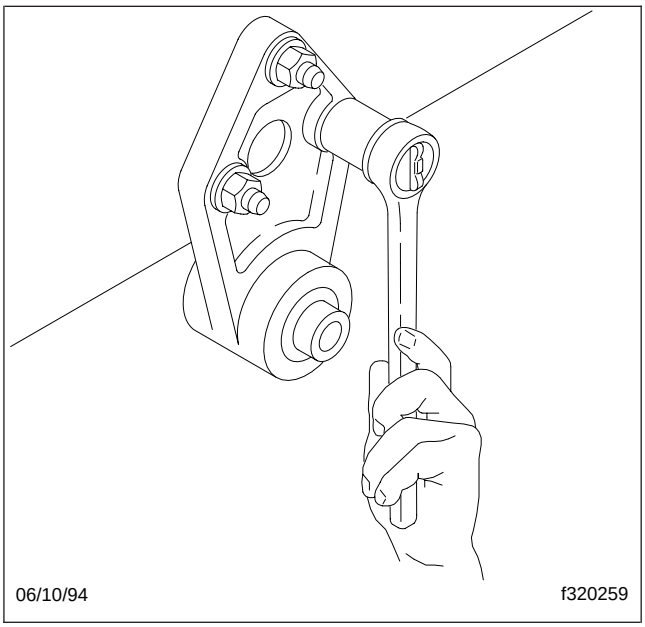


Fig. 7, Shackle Bracket Installation

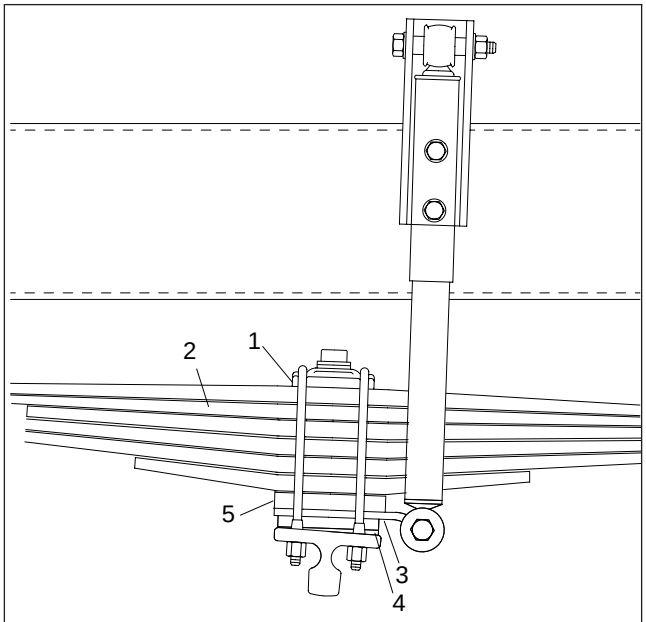
3.2 Tighten the spring eye bolt and the bolts at the top and bottom of the shackle 240 lbf·ft (325 N·m).

3.3 Apply Alumilastic® or a similar compound to the top and bottom of the spring spacer and any caster adjustment shims.

⚠ CAUTION

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.

3.4 Place the caster adjustment shim and spring spacer on the axle. See **Fig. 8**.



1. U-Bolt Pad
2. Leaf Spring
3. Shock Absorber Lower Mounting Bracket
4. Caster Adjustment Shim
5. Spring Spacer

Fig. 8, Caster Adjustment Shim Location

3.5 Place the U-bolt pad in position on the leaf spring.

3.6 Using a jack, lift the axle into position.

3.7 If so equipped, position the shock absorber lower mounting bracket between the leaf spring and the spring spacer.

3.8 Install the U-bolts over the spring leaves, shock absorber lower mounting bracket, spring spacer, caster adjustment shims, and through the front axle.

3.9 Install the high-nuts on the U-bolts and hand tighten them initially. Then tighten them in a diagonal pattern and in stages as follows:

5/8–18 UNF: Tighten the nuts 60 lbf·ft (80 N·m); then tighten them 200 lbf·ft (270 N·m); then tighten them to a final torque of 205 lbf·ft (278 N·m).

3/4–16 UNF: Tighten the nuts 60 lbf·ft (80 N·m); then tighten them 200 lbf·ft (270 N·m); then tighten them to a final torque of 300 lbf·ft (407 N·m).

4. Remove the floor jack and safety stands.
5. Install the half-fender. See **Group 88** for instructions.
6. Install the wheel and tire. See **Group 40** for instructions. Install the front bumper.
7. Lower the hood, and remove the chocks from the tires.

Shackle Bracket Bushing Replacement

1. Apply the parking brakes, chock the rear tires, and tilt the hood.
2. Remove the front bumper. Remove the wheel and tire for access to the leaf spring. For instructions, see **Group 40**.
3. Remove the half-fender. For instructions, see **Group 88**.
4. Remove the shackle bracket from the vehicle. See **Fig. 1**.
   - 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.
   - 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.
    - 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 half-fender. For instructions, see **Group 88**.
12. Install the wheel and tire. For instructions, see **Group 40**. Install the front bumper.
13. Lower the hood and remove the chocks from the tires.

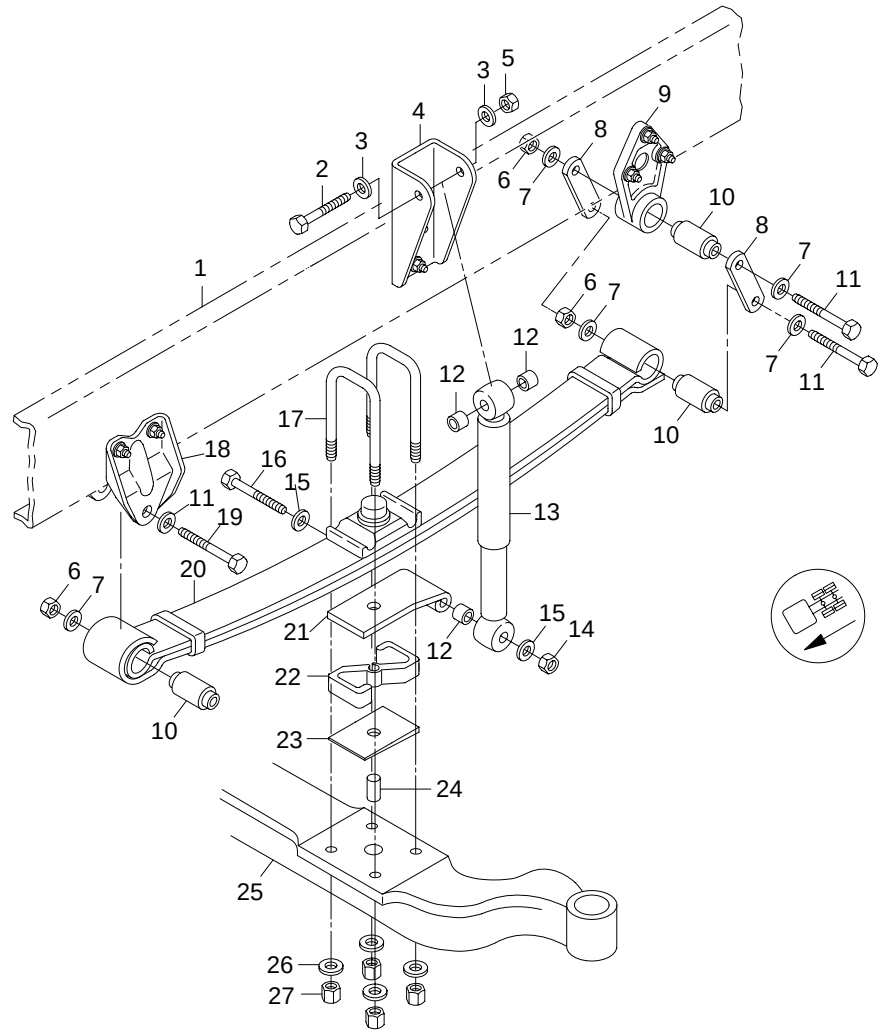
Spring Bushing Replacement

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.

Bushing Replacement

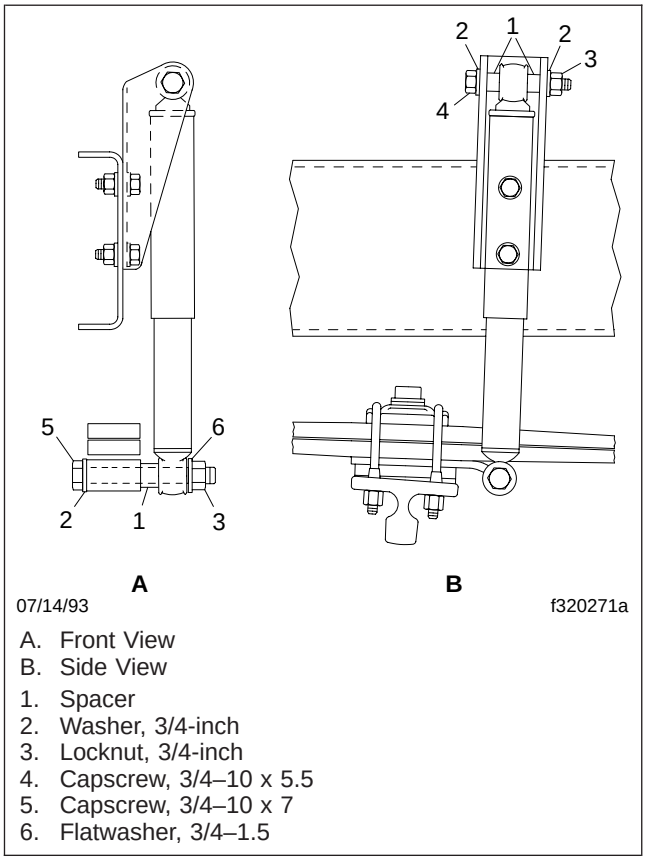


1. Frame Rail
2. Shock Absorber Upper Mounting Bolt
3. Hardened Washer
4. Shock Absorber Upper Mounting Bracket
5. Hexnut
6. Hexnut, 3/4–10, Grade C
7. Hardened Washer
8. Spring Shackle
9. Shackle Bracket
10. Bushing
11. Spring Shackle Bolt, 3/4–10 x 6.5
12. Spacer
13. Shock Absorber
14. Hexnut
15. Hardened Washer
16. Shock Absorber Lower Mounting Bolt
17. U-Bolt, 5/8–18
18. Front Spring Bracket
19. Front Spring Mounting Eye Bolt, 3/4–10 x 6
20. Spring Assembly
21. Shock Absorber Lower Mounting Bracket
22. Spacer
23. Caster Adjustment Shim
24. Dowel Pin
25. Axle
26. Hardened Washer
27. High Hexnut, 5/8–18

Fig. 1, Standard Taperleaf Front Suspension (6,000-pound shown)

Replacement

1. Apply the parking brake, chock the rear tires, and tilt the hood.
2. Remove the shock absorber.
   - 2.1 Remove the locknut from the shock absorber upper mount; then, remove the capscrew, washers, and spacers.
   - 2.2 Remove the locknut from the shock absorber lower mount; then, remove the capscrew, washers, and spacers.
   - 2.3 Remove the shock absorber.
3. Install the new shock absorber. See **Fig. 1**. Make sure the flatwasher (Ref. 6) is on the lower shock absorber mounting bushing and toward the outside. Tighten the locknuts 67 to 87 lbf·ft (90 to 118 N·m).
4. Lower the hood, and remove the chocks from the tires.



A. Front View
B. Side View
1. Spacer
2. Washer, 3/4-inch
3. Locknut, 3/4-inch
4. Capscrew, 3/4–10 x 5.5
5. Capscrew, 3/4–10 x 7
6. Flatwasher, 3/4–1.5

Fig. 1, Shock Absorber Mounting

Troubleshooting Chart

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.
Installed spring does not match the specified load capacity.	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** in this manual.
Caster is incorrect.	Install correct caster shims. Refer to **Group 33** in this manual for specifications.
Steering gear is not centered.	Adjust steering using the instructions in **Group 46** in this manual.
Drive axles are out of alignment.	Align the drive axles using the instructions in **Group 35** in this manual.

Problem—Vehicle Bottoms Out

Problem—Vehicle Bottoms Out	
Possible Cause	**Remedy**
Excessive weight on the vehicle is causing an overload.	Reduce the loaded vehicle weight to the maximum spring capacities.
One or more spring leaves are broken.	Replace the spring assembly.
The spring assembly is weak or fatigued.	Replace the spring assembly.

Problem—Frequent Spring Breakage

Problem—Frequent Spring Breakage	
Possible Cause	**Remedy**
The vehicle is overloaded or operated under severe conditions.	Reduce the loaded vehicle weight to the maximum spring capacities. Caution the driver on improper vehicle handling.
There is insufficient torque on the U-bolt high nuts.	Torque the U-bolt high nuts to the value listed in the torque table in **Specifications, 400.**
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. Tighten 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. Tighten the fasteners to the values listed in the torque table under **Specifications, 400**.
Worn or damaged spring pins are allowing spring end-play.	Replace any worn or damaged spring pins.

Specifications

Description	Size	Torque lbf·ft (N·m)
Shackle Bracket Bolt	3/4–10	135 (183)
Shackle Bracket Mounting Bolt	5/8–11	135 (183)
Spring Eye Bolt	3/4–10	135 (183)
Shock Absorber Mounting Capscrews	3/4–10	67 to 87 (90 to 118)
U-Bolt High Nut	5/8–18	Stage 1: Hand tighten Stage 2: 60 (80) * Stage 3: 200 (270) * Stage 4: 205 (278) *
	3/4–16	Stage 1: Hand tighten Stage 2: 60 (80) * Stage 3: 200 (270) * Stage 4: 300 (407) *

* Tighten in a diagonal pattern.

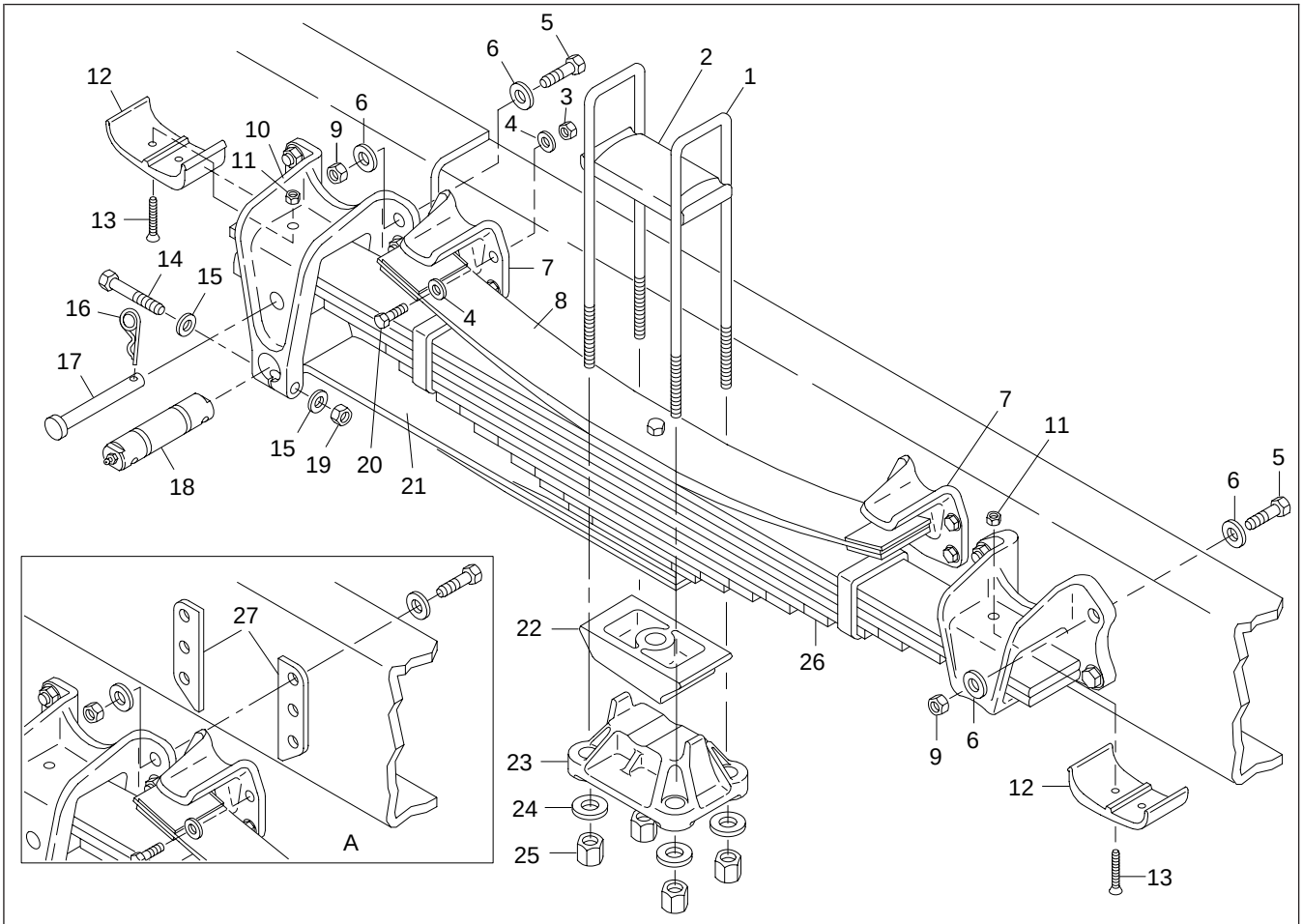
Table 1, Torque Values

General Information

The rear leaf spring suspension uses a slip spring design with varying capacities. See **Fig. 1**. Optional helper leaves provide a progressive spring rate and additional roll stability. The spring ends ride in cast iron brackets mounted on the frame rails. Each spring bracket holds a replaceable wear pad. The spring assemblies are attached to the axle with U-bolt assemblies. A radius leaf attaches each spring assembly to its forward spring bracket and holds the axle in alignment.

Shock absorbers are optional with all suspension capacities.

General Information



NOTE: Spacers are used when there is no frame rail reinforcement.

1. U-Bolt
2. U-Bolt Pad
3. Helper Spring Bracket Locknut
4. Washer
5. Helper Spring Bracket Locknut
6. Washer
7. Helper Spring Bracket
8. Helper Spring
9. Spring Bracket Mounting Locknut
10. Front Spring Bracket
11. Wear Pad Mounting Screw Locknut
12. Wear Pad
13. Allen-Head Screw
14. SPring Eye Pin Pinch Bolt
15. Pinch Bolt Washer
16. Spring Retainer Pin Clip
17. Spring Retainer Pin
18. Spring Eye Pin
19. Pinch Bolt Locknut
20. Helper Spring Bracket Mounting Capscrew
21. Radius Leaf
22. Spring Steel
23. U-Bolt Retainer
24. Hardened Washer
25. U-Bolt High Nut
26. Leaf Spring
27. Spacers

Fig. 1, Leaf Spring Suspension

Replacement

1. Lift the rear axle and support it with safety stands. Lift the vehicle frame to take weight off the rear springs.
2. Remove the U-bolt high nuts; then, remove the U-bolts. See **Fig. 1**.

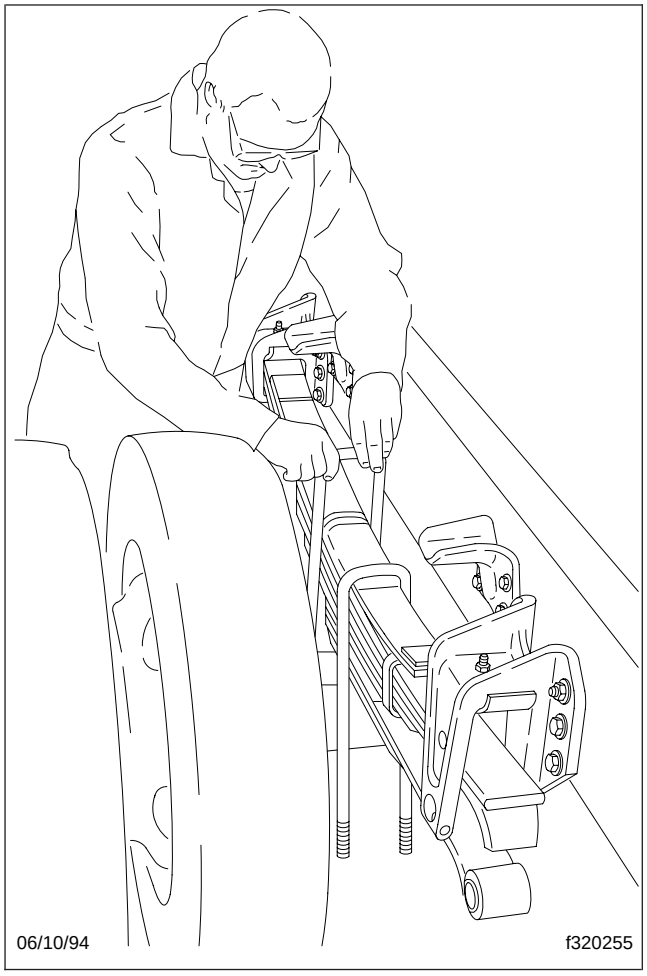


Fig. 1, U-Bolt Removal

3. Remove the spring eye pin that attaches the radius leaf to the front spring bracket.
   - 3.1 Using a C-clamp, take the load off the radius leaf. See **Fig. 2**.

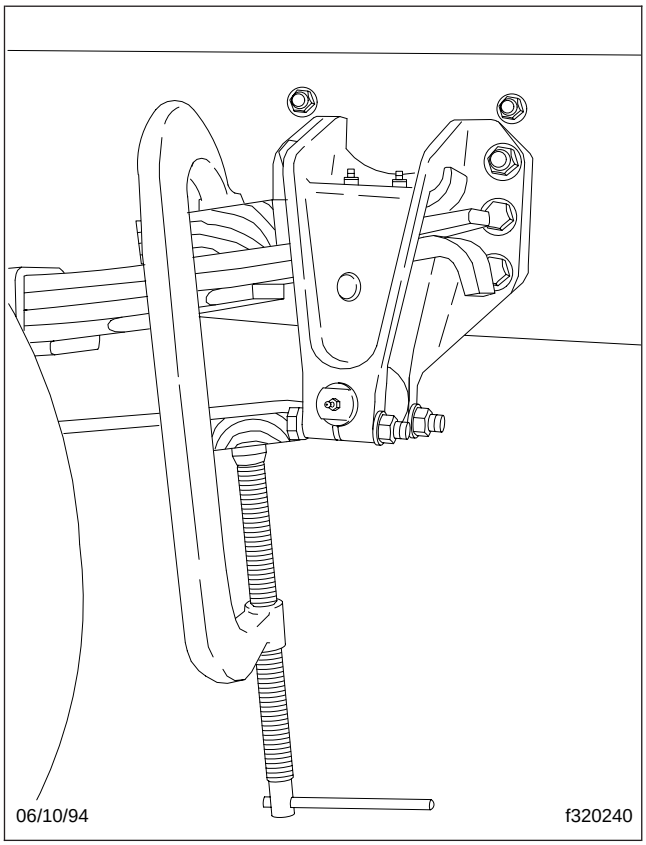


Fig. 2, Radius Leaf Clamping

WARNING

WARNING: Failure to use a C-clamp may cause components to be forcibly ejected, possibly causing serious personal injury.

   - 3.2 Remove the pinch bolts. See **Fig. 3**.
   - 3.3 Using a brass hammer and drift, tap the eye pin out. See **Fig. 4**.

4. Remove the clip and the spring retainer pin. See **Fig. 5** and **Fig. 6**.

WARNING

WARNING: The leaf spring assembly is heavy. Always use two people when moving it to avoid personal injury.

5. Remove the spring assembly.

Spring Assembly Replacement

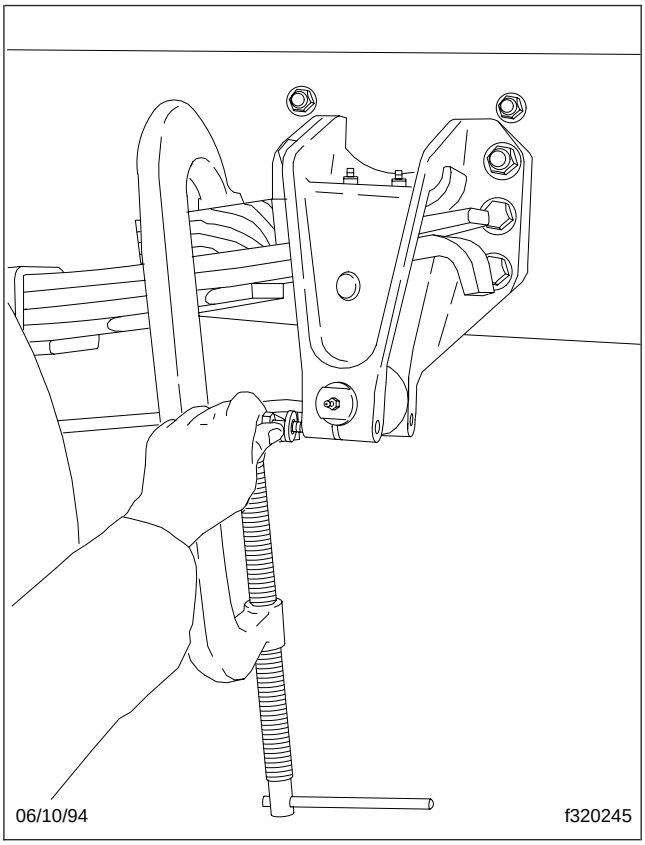


Fig. 3, Pinch Bolt Removal

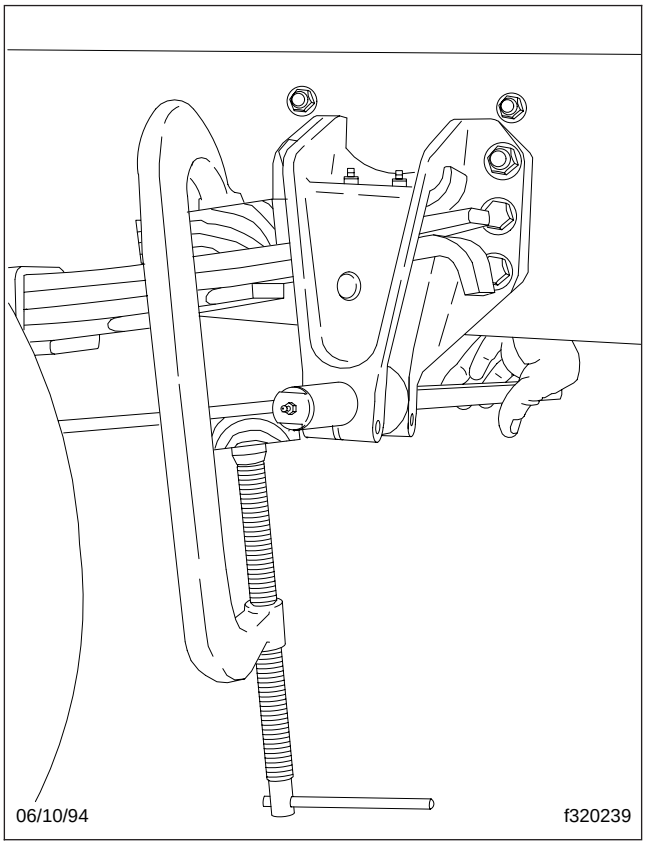


Fig. 4, Eye Pin Removal

5.1 If the vehicle is equipped with the optional helper spring, lift it off. See **Fig. 7**.

5.2 Slide the leaf spring assembly forward and remove it from the vehicle. See **Fig. 8**.

6. Inspect the wear pads for wear. Replace them if needed. For instructions, see **Subject 130**.

7. Install the new spring assembly.

7.1 Position the new spring on the axle seat.

NOTE: It may be necessary to raise the frame slightly.

7.2 Lower the frame until the spring is properly located between the spring brackets.

7.3 If equipped with the optional auxiliary spring, place it on the main spring.

8. Install the U-bolts and the U-bolt retainer. The taller end of the retainer must be towards the front of the vehicle. See **Fig. 9**.

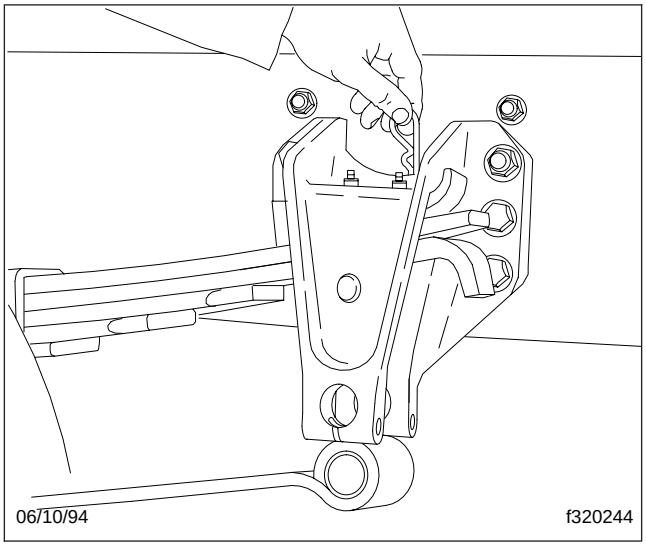


Fig. 5, Clip Removal

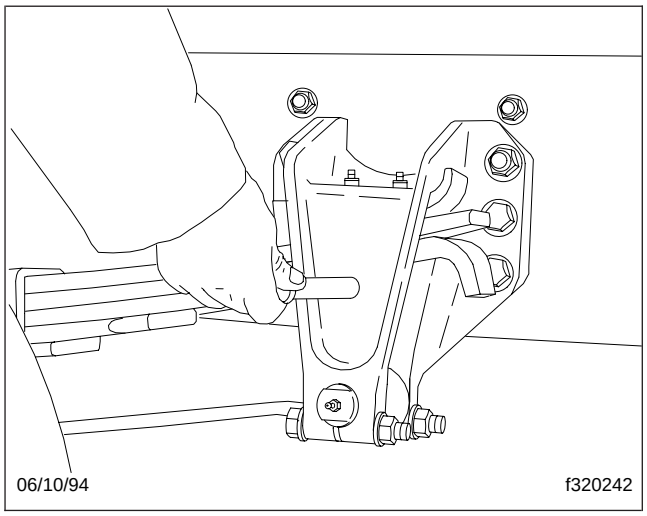


Fig. 6, Spring Retainer Pin

9. Install the U-bolt high nuts , but don't tighten them now.
10. Lift the spring above the hole for the spring retainer pin in the front spring bracket; then, insert the retainer pin.
11. Install the clip on the pin.
12. Install the spring eye pin.
    - 12.1 Using a C-clamp, compress the spring until the front spring eye pin can be installed. **See Fig. 2.**
    - 12.2 Inspect the pin for wear or damage. Replace it with a new pin if necessary.
    - 12.3 Using a brass hammer, tap the pin into position.
    - 12.4 Install the pinch bolts and nuts. Tighten the nuts 32 lbf·ft (43 N·m).
    - 12.5 Remove the C-clamp.
13. Tighten the U-bolt high nuts diagonally to the torque values in the torque table in **Specifications, 400**.
14. Remove the jack or safety stands from the rear axle and the frame.

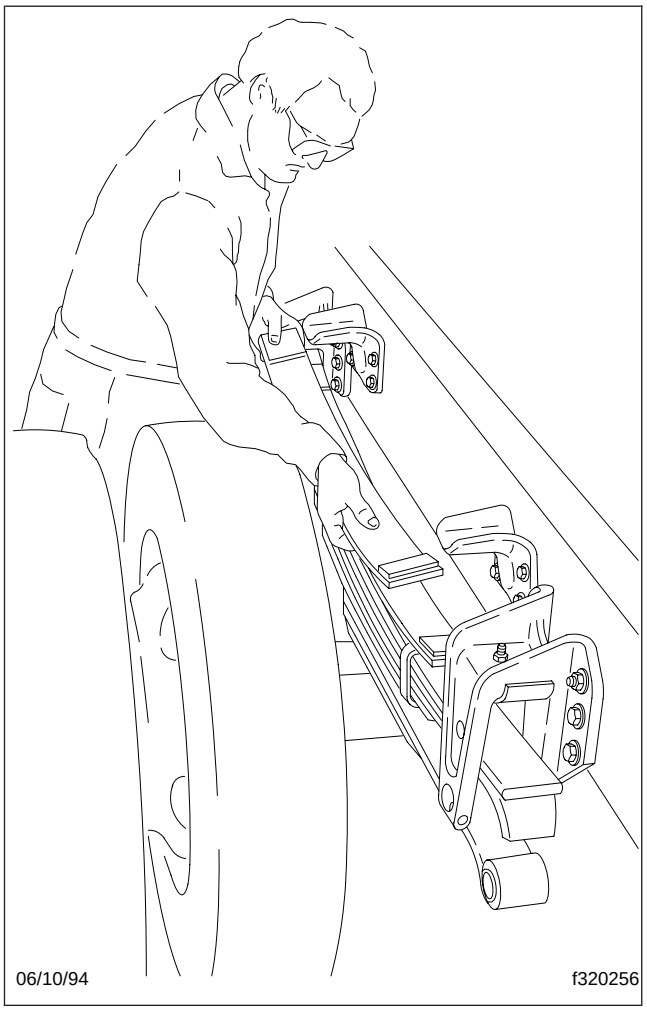


Fig. 7, Helper Spring Removal

Spring Assembly Replacement

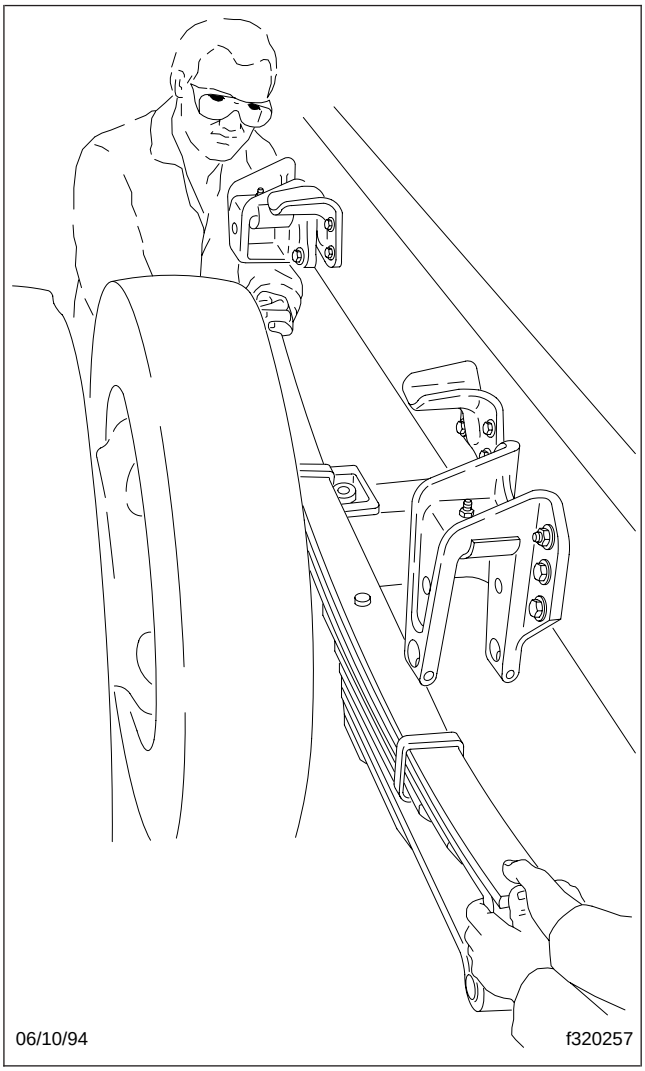
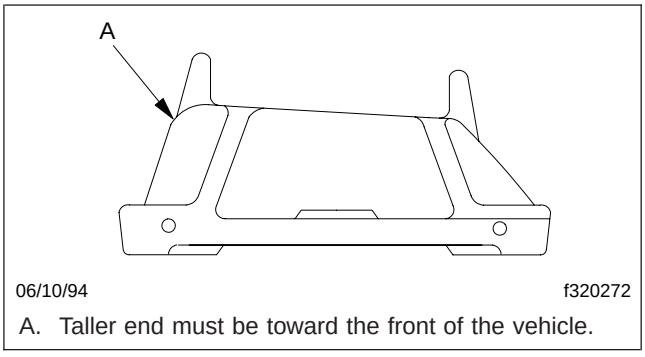


Fig. 8, Leaf Spring Assembly Removal



A. Taller end must be toward the front of the vehicle.

Fig. 9, Retainer Positioning

Rear Spring Bracket Replacement

1. Park the vehicle and chock the front tires.
2. Jack up the frame rail at the rear of the vehicle until the leaf spring is floating free in the rear spring bracket.
3. Remove the fasteners holding the rear spring bracket to the frame rail. See **Fig. 1**.
4. Slide the spring bracket off the end of the leaf spring assembly. See **Fig. 2**.
5. Check the wear pad for wear. Replace it if needed. For instructions, see **Subject 130**.
6. Slide the new spring bracket into position.
7. Install the fasteners and tighten them 135 lbf·ft (184 N·m).
8. Lower the frame rail and remove the chocks from the tires.

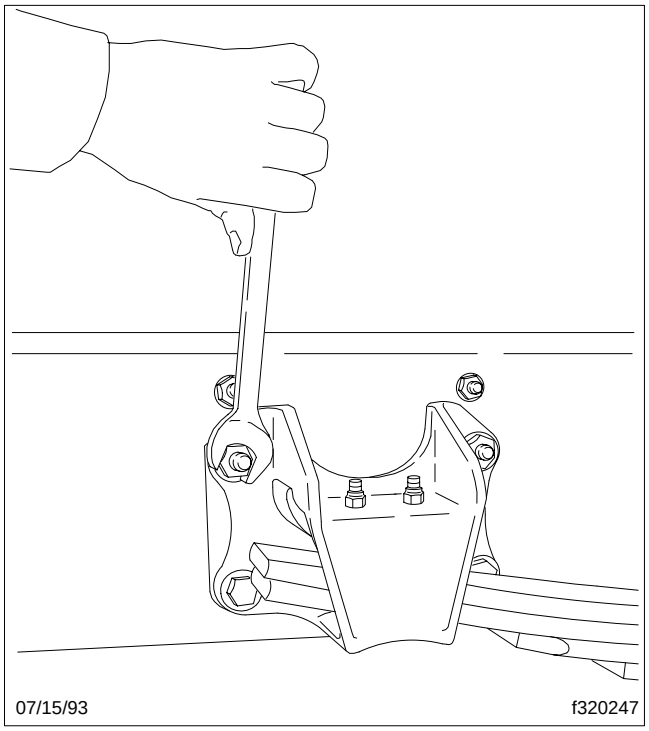


Fig. 1, Rear Spring Bracket Fastener Removal

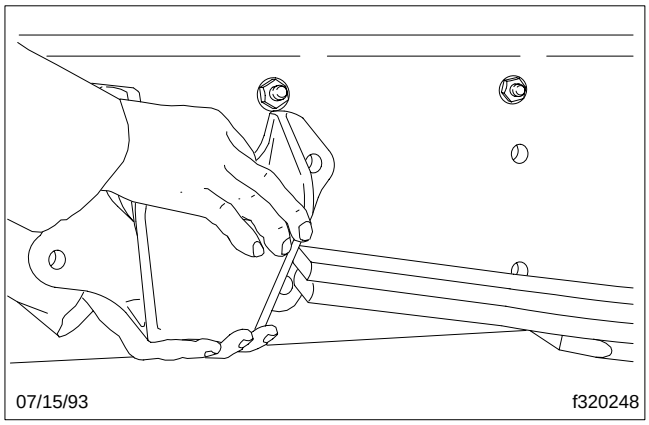


Fig. 2, Sliding Bracket From Leaf Spring Assembly

Forward Spring Bracket Replacement

1. Park the vehicle and chock the front tires.
2. Jack up the frame rail at the rear of the vehicle until the weight is removed from the leaf spring.
3. Remove the spring bracket.
   - 3.1 Using a C-clamp, take the load off the radius leaf. See **Fig. 3**.
   - 3.2 Remove the pinch bolts holding the spring eye pin. See **Fig. 4**.
   - 3.3 Using a hammer and drift, tap out the spring eye pin. See **Fig. 5**.
   - 3.4 Remove the clip and the spring retainer pin. See **Fig. 6** and **Fig. 7**.
   - 3.5 Remove the fasteners holding the front spring bracket to the frame rail.
   - 3.6 Slide the spring bracket off the front of the leaf spring assembly.
4. Install a new spring bracket.
   - 4.1 Slide a new spring bracket into position.
   - 4.2 Install the fasteners and tighten them 240 lbf·ft (325 N·m).
   - 4.3 While lifting the spring, install the spring retainer pin and clip. See **Fig. 7**.
   - 4.4 Using a brass hammer, drive in the spring eye pin. See **Fig. 8**.

Spring Bracket Replacement

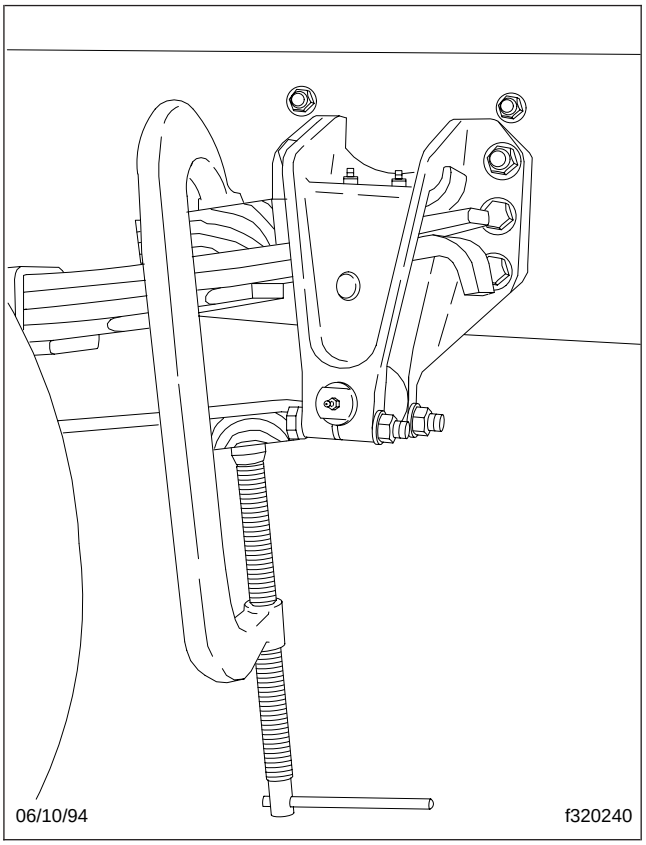


Fig. 3, Clamping Radius Leaf

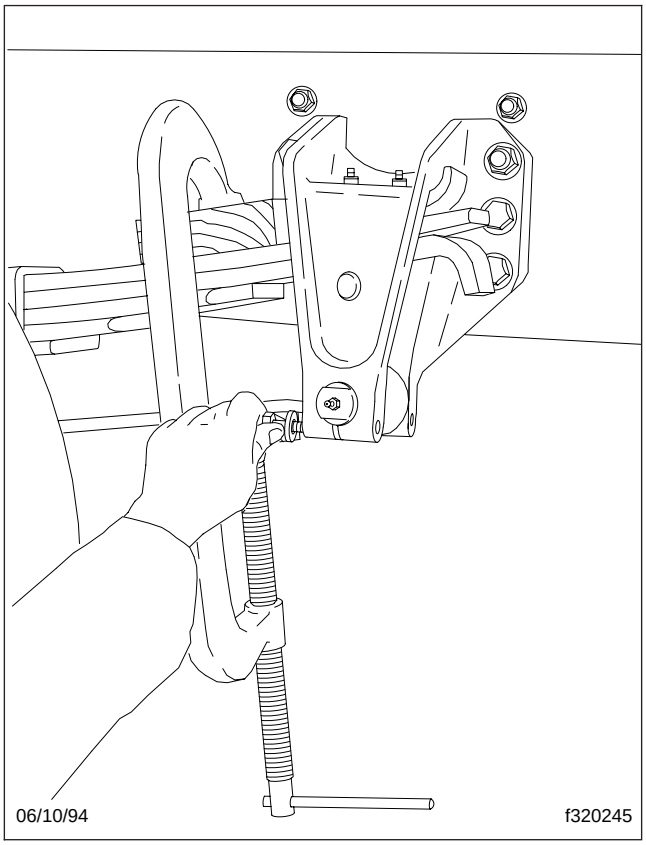


Fig. 4, Removing Pinch Bolts

4.5 Install the pinch bolts and nuts. Tighten the nuts 32 lbf·ft (43 N·m).

5. Lower the frame rail and remove the chocks from the tires.

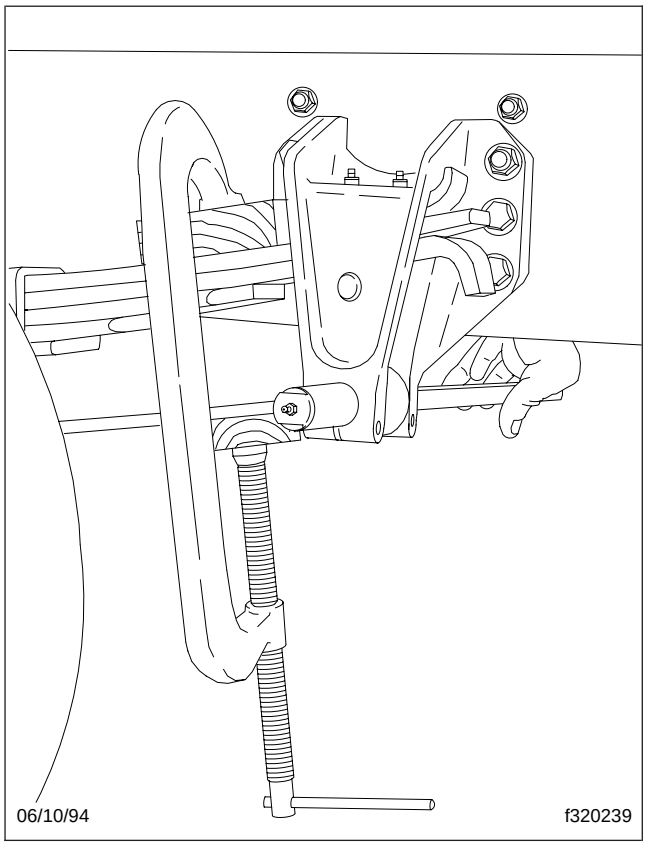


Fig. 5, Tapping Out the Spring Eye Pin

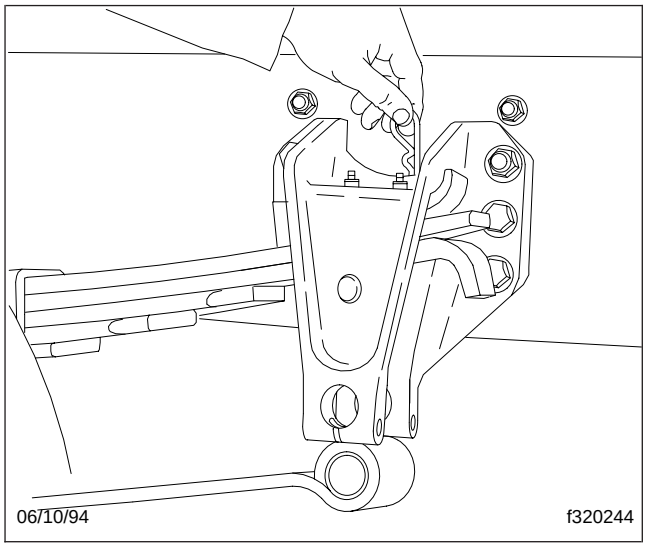


Fig. 6, Clip Removal

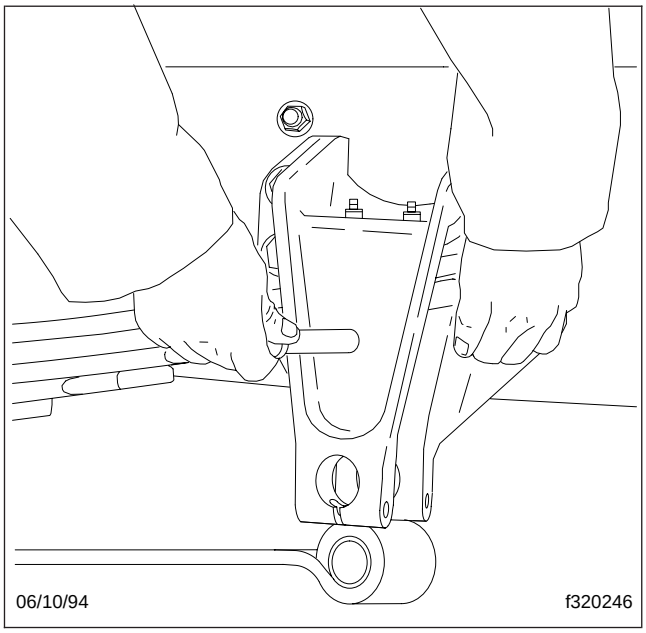


Fig. 7, Spring Retainer Pin Removal

Spring Bracket Replacement

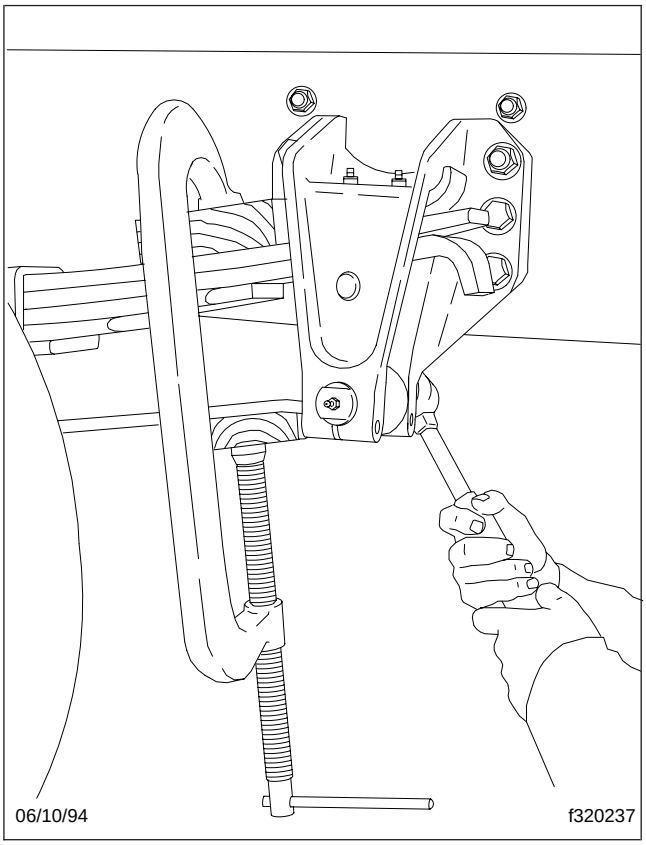


Fig. 8, Spring Eye Pin Installation

Replacement

1. Using a floor jack, lift the frame rail to take weight off the spring.
2. Using a C-clamp, take the load off the radius leaf. See **Fig. 1**.

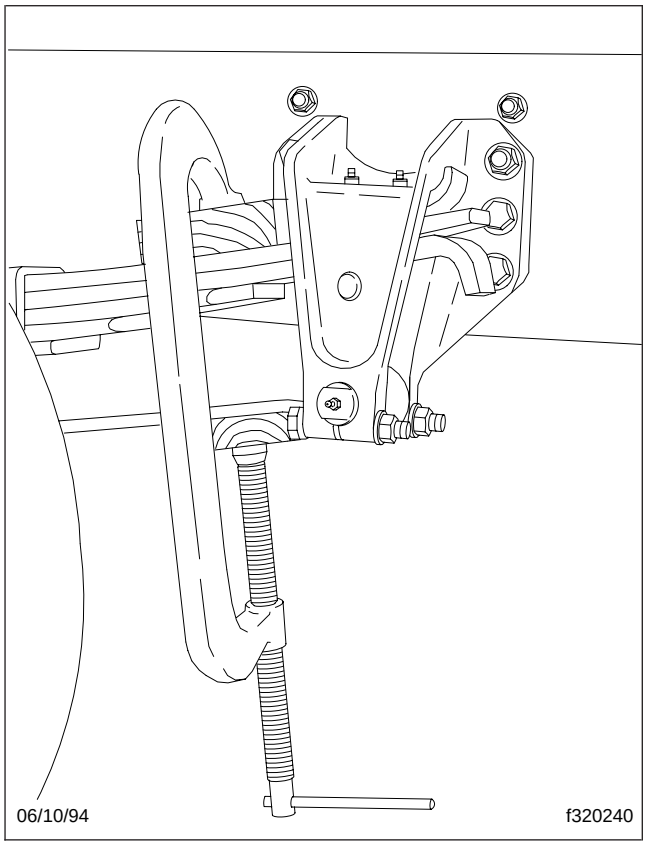


Fig. 1, Clamping the Radius Leaf

3. Loosen and remove the pinch bolts. See **Fig. 2**.
4. Using a hammer and a drift, tap the pin out. See **Fig. 3**.
5. Grease the outer surface of a new pin and insert it. See **Fig. 4**. Drive it in using a brass hammer. See **Fig. 5**.
6. Install the pinch bolts and nuts. See **Fig. 2**. Tighten the nuts 32 lbf·ft (43 N·m).
7. Install a new zerk fitting and the spring eye pin.
8. Remove the C-clamp and lower the jack.

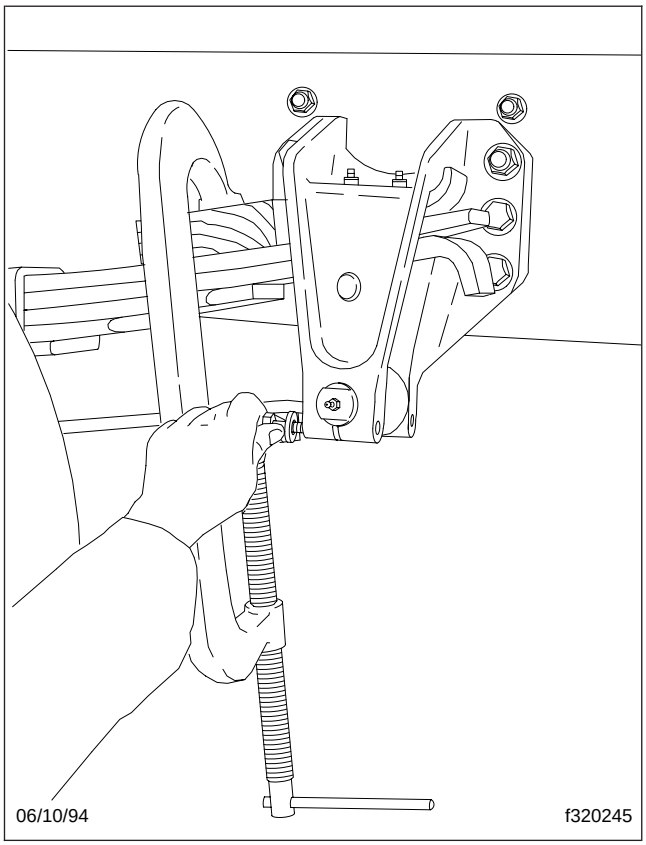


Fig. 2, Pinch Bolt Removal

NOTE: When replacing the pin, if the spring has shifted, loosen the U-bolt nuts so the spring can be shifted fore and aft.

Spring Eye Pin Replacement

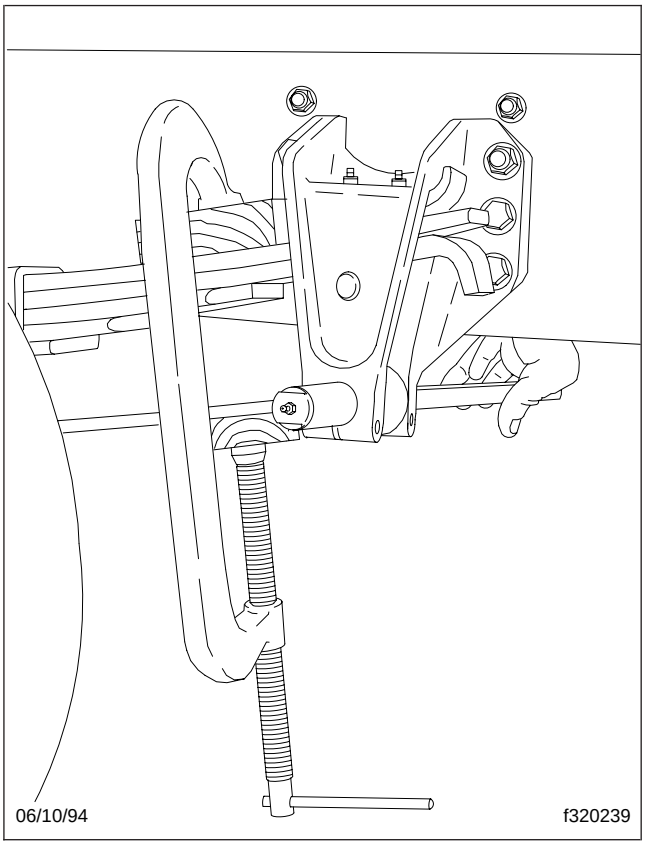


Fig. 3, Spring Eye Pin Removal

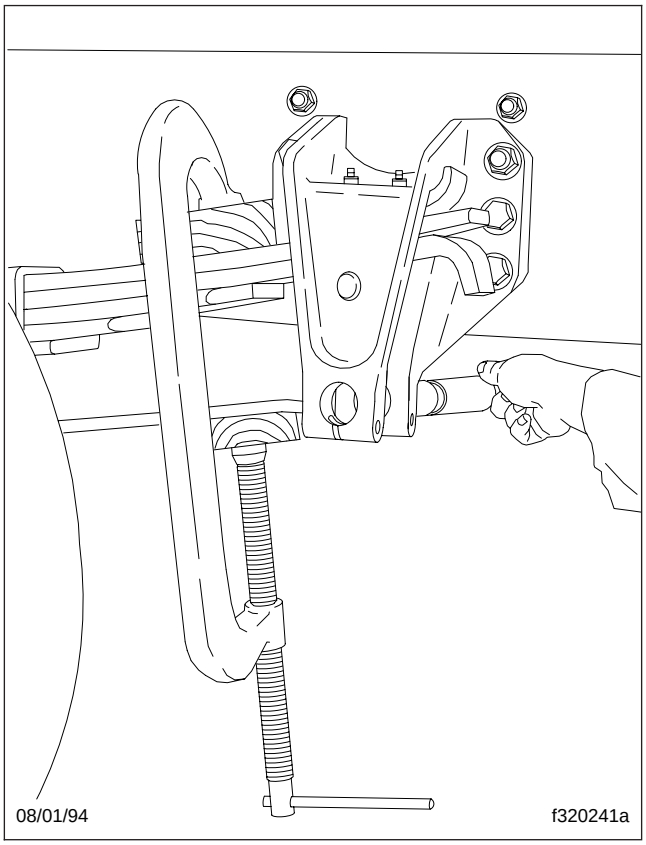


Fig. 4, Spring Eye Pin Insertion

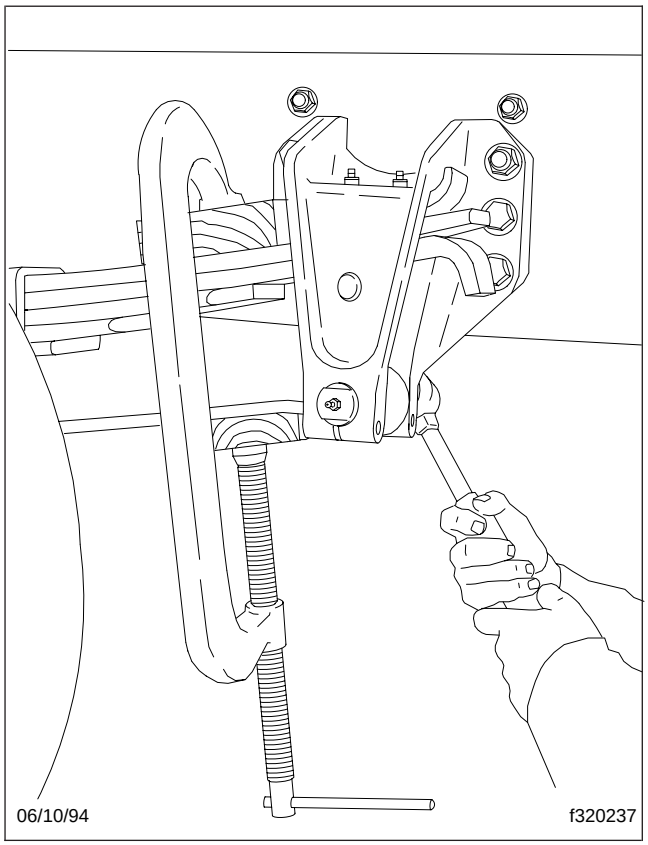


Fig. 5, Spring Eye Pin Installation (tapping)

Replacement

NOTE: Wear pads can be replaced without removing the leaf spring assemblies.

1. Park the vehicle and chock the front tires.
2. For front wear pad replacement, remove the clip and the spring retainer pin. See **Fig. 1** and **Fig. 2**.
3. 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.
4. Remove the allen-head screws attaching the wear pad to the spring bracket. See **Fig. 3** for the front wear pad, **Fig. 4** for the rear wear pad. Remove and discard the wear pad.
5. Install the new wear pad so that the thicker portion of the pad is toward the axle. See **Fig. 5** for the front wear pad. While holding it in place, install and tighten the allen-head screws until snug.
6. If removed, install the spring retainer pin and its clip.
7. Lower the frame rail.

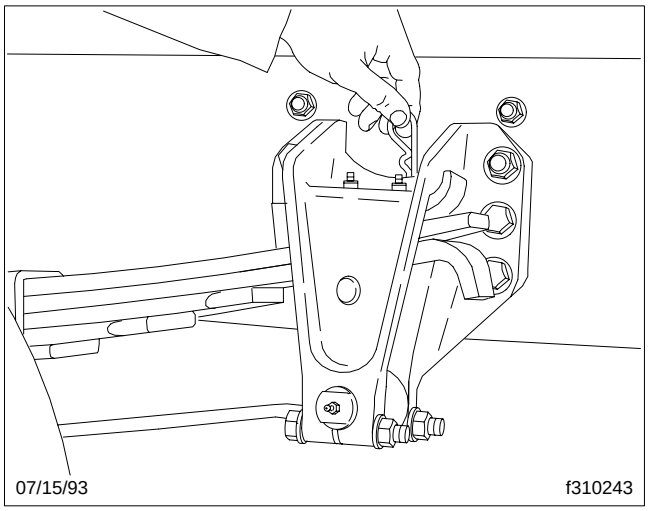


Fig. 1, Clip Removal

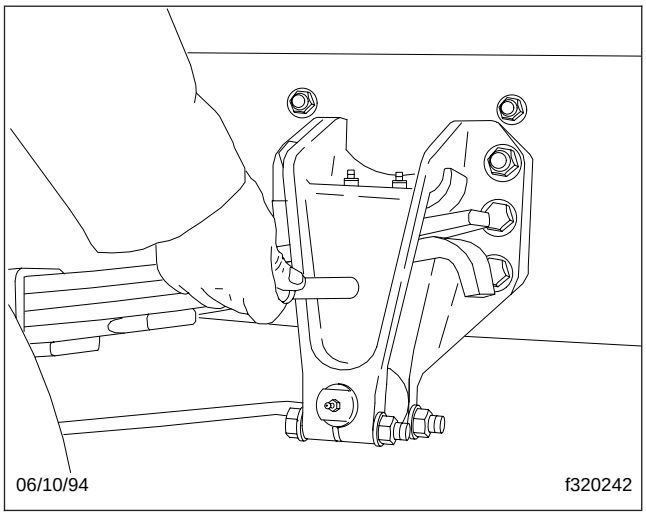


Fig. 2, Spring Retainer Pin Removal

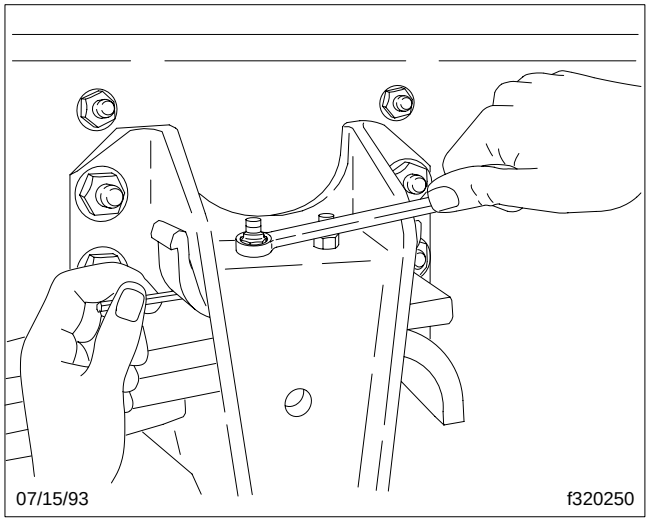
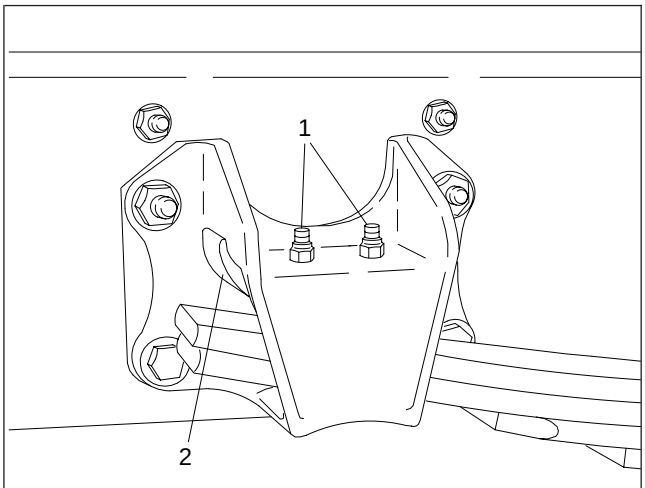


Fig. 3, Front Wear Pad Removal

Wear Pad Replacement



1. Allen-Head Screws
2. Wear Pad

Fig. 4, Rear Wear Pad Assembly

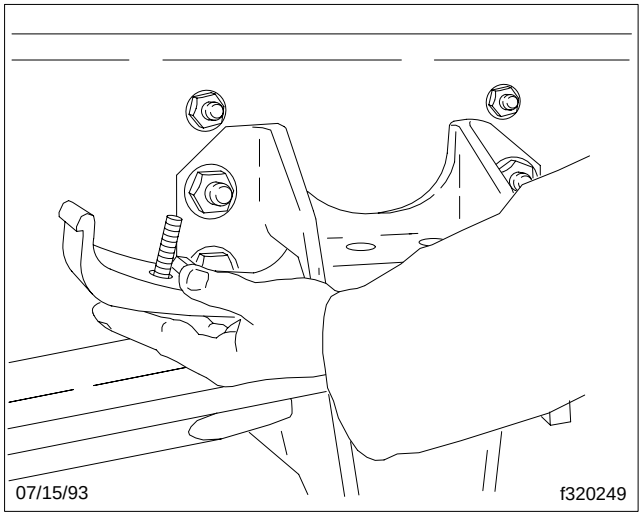


Fig. 5, Front Wear Pad Positioning

Replacement

1. Chock the tires and apply the parking brakes.
2. Remove the locknut, retainers, and bushings from the shock absorber lower mount.
3. Remove the locknut, capscrew, and washers from the shock absorber upper mount.
4. Remove the shock absorber.
5. Install the replacement shock absorber.
6. Install the capscrew and locknut in the upper mount. Hand tighten them at this time.
7. Install the replacement bushings, retainers, and locknut. See **Fig. 2**.

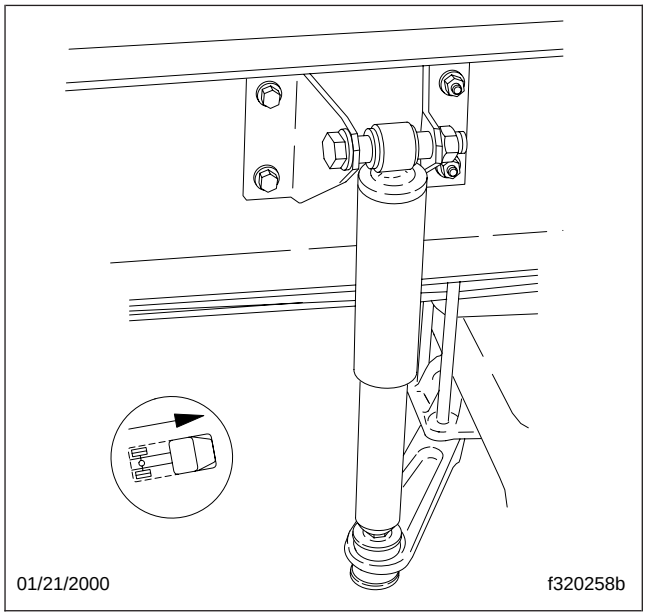
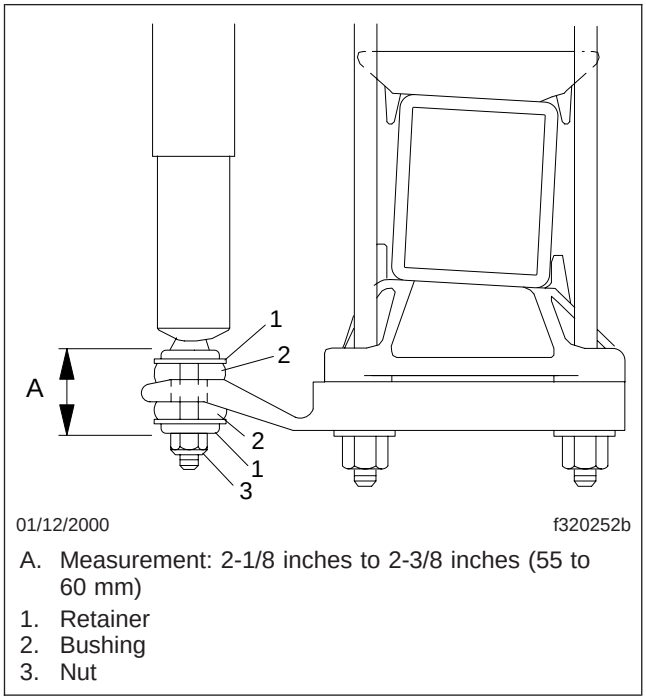


Fig. 1, Shock Absorber Installation

WARNING

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 167 lbf·ft (226 N·m).
9. Tighten the shock absorber lower mounting nut to compress the bushings to the dimension shown in **Fig. 2**.



A. Measurement: 2-1/8 inches to 2-3/8 inches (55 to 60 mm)
1. Retainer
2. Bushing
3. Nut

Fig. 2, Compressing the Bushing for Tightening

Specifications

Description	Size	IFI Grade	Torque lbf·ft (N·m)
Forward Spring Bracket-to-Frame Rail Locknut *	3/4–10	C	240 (325)
Rear Spring Bracket-to-Frame Rail Locknut *	5/8–11	C	135 (184)
Axle U-Bolt High Nuts	5/8–18	C	Stage 1: Hand tighten Stage 2: 100 (136) † Stage 3: 200 (270) † Stage 4: 300 (407) † Stage 5: 420 (569) †
	3/8–16	C	Stage 1: Hand tighten Stage 2: 100 (136) † Stage 3: 200 (270) † Stage 4: 300 (407) † Stage 5: 420 (569) †
Spring Eye Pin Pinch Bolts	7/16–14	C	37 (50)
Shock Absorber Upper Locknut	—	C	167 (226)

* Cadmium-plated, wax-coated nuts, and grade 8 hexbolts with phosphate- and oil-coated threads; both used with hardened washers.
† Tighten in a diagonal pattern.

Table 1, Torque Values

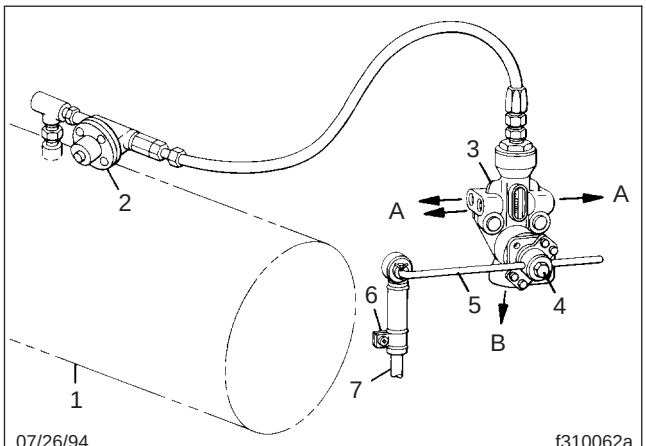
General Information

The Freightliner AirLiner Suspension is a single axle or tandem axle suspension that uses a combination of air and leaf springs. The suspension is manufactured at numerous weight ratings. 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. The axle housing is fastened to the leaf spring assembly by U-bolts. A control rod, mounted between the axle housing and the frame rail, can be used to help locate the assembly laterally.

The air springs compensate for changes in road conditions and vehicle load, maintaining vehicle height. The air springs also absorb road shock.

A height control valve regulates the air flow into or out of all the air springs. 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.

The pressure holding valve, located in the air line to the height control valve, is preset to maintain a minimum pressure of 65 psi (448 kPa) in the vehicle secondary air system if a leak should occur in the air suspension system. See **Fig. 1**. If a leak does occur, solid rubber bumpers in the air springs will support the vehicle.



A. To Air Springs
B. To Atmosphere
1. Secondary Air Reservoir
2. Pressure Holding Valve
3. Height Control Valve
4. Adjusting Locknut
5. Overtravel Lever
6. Linkage Adjustment Clamp
7. Height Control Valve Linkage

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 the vehicle maintenance manual for maintenance operations.

⚠ CAUTION

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 and the suspension section in the vehicle maintenance manual.

General Information

Adjust the suspension height with the vehicle on a level surface.

⚠ CAUTION

CAUTION: Failure to adjust the suspension height could adversely affect driveline angles. Also, if the air springs are set too high, the driver may have difficulty (or be prevented from) backing the vehicle under a trailer. If the air springs are set too low, rapid wear of suspension parts will result.

The height control valve installation is adjustable. See **Fig. 1**. The suspension height is changed by tilting the height control valve up or down.

Adjustment, Vehicles Equipped with Adjustable Leveling Valve

IMPORTANT: Before checking the AirLiner suspension height, make sure there is no load on the chassis.

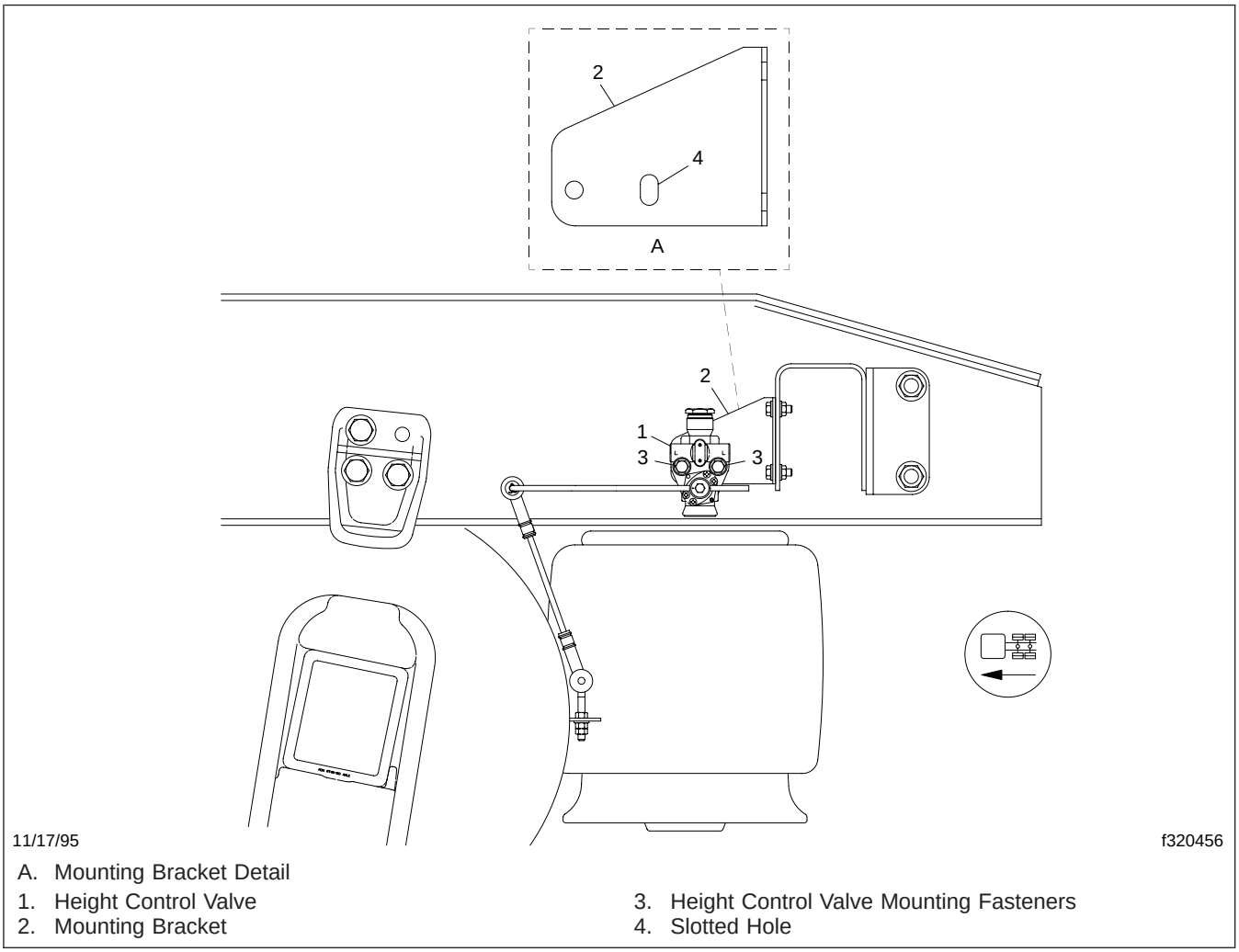
1. Park the vehicle on a level surface, using a light application of the brakes. Do not apply the parking brakes. Put the transmission in neutral. Build the secondary air pressure to at least 100 psi (690 kPa). Shut down the engine.
2. Mark the location of the front and rear tires on the floor; then chock the tires on one axle only to allow the slight movement needed for the drivetrain length change.
3. Check the length of the overtravel lever between its pivot points. See **Fig. 2**. The length should be 8 inches (203 mm). If needed, adjust the length of the overtravel lever.
   - 3.1 Loosen the adjustment locknut on the control shaft.
   - 3.2 Move the overtravel lever fore or aft until the length between the pivot points is 8 inches (203 mm).
   - 3.3 Tighten the adjustment locknut 62 lbf·in (700 N·cm).
4. Measure the distance from the bottom of the left forwardmost axle stop to the top of the axle U-bolt pad. See **Fig. 3**. If the distance is between 2-3/8 and 2-7/8 inches (60 to 73 mm) it is correct, and nothing more needs to be done. Apply the parking brakes and remove the chocks from the tires.

NOTE: If height adjustment is needed, use 2-3/8 inches (60 mm) as the target value.

5. Loosen the two fasteners attaching the leveling valve to the mounting bracket.
6. Rotate the leveling valve clockwise (as you are facing it from the driver's side of the vehicle). Let the air exhaust from the valve until the distance from the bottom of the left forwardmost axle stop to the top of the axle U-bolt pad is 2 inches (51 mm) or less.
7. Rotate the leveling valve counterclockwise, and raise the suspension height to 2-3/8 inches (60 mm). Stop the air flow to the air bag by rotating the leveling valve back clockwise.
8. Center the leveling valve.
   - 8.1 Rotate the valve very slightly clockwise and counterclockwise. You will notice a "dead" band where no air enters the valve or is exhausted from it. Don't rotate the valve too much, or you will change the suspension height.
   - 8.2 Rotate the valve so it's in the center of the "dead" band.
   - 8.3 Tighten the leveling valve mounting fasteners firmly.
9. 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.
10. Check the adjusted distance between the bottom of the left forwardmost axle stop and the top of the axle U-bolt pad. See **Fig. 3**. The correct distance is between 2-3/8 and 2-7/8 inches (60 to 73 mm).

Suspension Height Adjustment



A. Mounting Bracket Detail
1. Height Control Valve
2. Mounting Bracket
3. Height Control Valve Mounting Fasteners
4. Slotted Hole

Fig. 1, Height Control Valve Installation

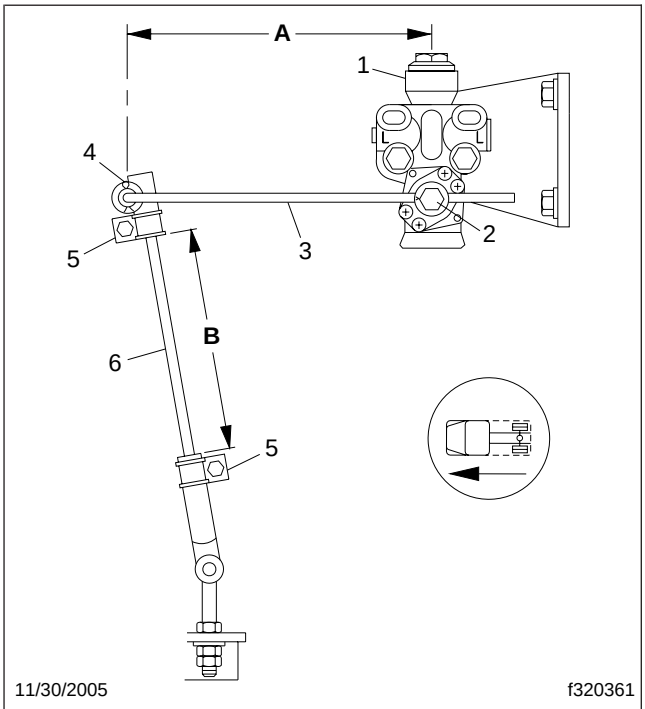
11. If the distance isn't right, repeat the adjustment procedure.
12. Apply the parking brakes; then remove the chocks from the tires.

Adjustment, Vehicles Equipped with Fixed Leveling Valve

IMPORTANT: Before checking the AirLiner suspension height, make sure there is no load on the chassis. For tractors, unhitch the trailer.

Trucks are to be empty. In order to adjust the suspension height, you must change the length of the linkage rod using the following procedure. The previous method of centering the control valve and then adjusting the linkage no longer applies.

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.



A. Measure the length of the overtravel lever between these two points.
B. Measure the length of the linkage rod between these two points.

1. Leveling Valve
2. Adjustment Locknut
3. Overtravel Lever
4. Cotter Pin
5. Linkage Adjustment Clamp
6. Linkage Rod

Fig. 2, Overtravel Lever and Linkage Rod Measurement

3. Check the length of the suspension overtravel lever between its pivot points. See **Fig.2**. The overtravel lever should be from 5-3/4 inches to 6-1/4 inches (146 to 159 mm) long.

   If the length is acceptable, go to the step for measuring the suspension height.

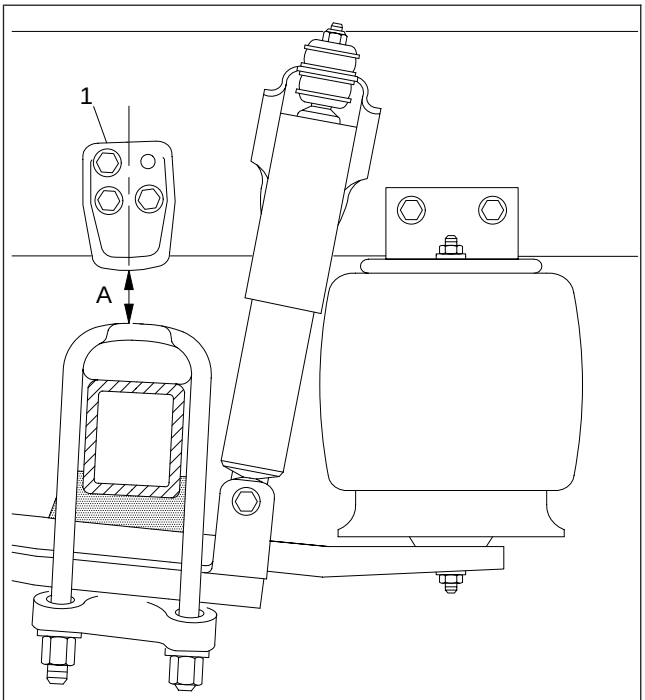
   If the length is not acceptable, go to the next step.

4. Adjust the length of the overtravel lever.

   4.1 Loosen the adjustment locknut on the control shaft.

   4.2 Move the overtravel lever fore or aft until it is the correct length.

   4.3 Tighten the adjustment locknut 62 lbf·in (700 N·cm).



A. Measure height here.
1. Left Forwardmost Axle Stop

Fig. 3, Axle Stop Measurement

5. Measure the distance from the bottom of the left forwardmost axle stop to the top of the axle U-bolt pad. See **Fig.3** . The correct distance is between 2-3/8 and 2-7/8 inches (60 to 73 mm).

   If the distance is correct, nothing more needs to be done. Apply the parking brakes; then remove the chocks from the tires.

   If the distance isn't correct, go to the next step.

NOTE: If height adjustment is needed, use 2-3/8 inches (60 mm) as the target value.

6. Determine how much the suspension height needs to be changed so that the distance is 2-3/8 inches (60 mm). Then, using **Table 1**, find the amount the length of the linkage rod needs to be changed. See **Fig.1**.

Suspension Height Change in Inches (mm)	Vertical Linkage Length Change in Inches (mm)
1/16 (2)	1/16 (2)

Suspension Height Adjustment

Suspension Height Change in Inches (mm)	Vertical Linkage Length Change in Inches (mm)
1/8 (3)	3/16 (5)
3/16 (5)	1/4 (6)
1/4 (6)	5/16 (8)
5/16 (8)	3/8 (10)
3/8 (10)	1/2 (13)
7/16 (11)	9/16 (14)
1/2 (13)	5/8 (16)
9/16 (14)	3/4 (19)
5/8 (16)	13/16 (20)
11/16 (17)	7/8 (22)
3/4 (19)	1 (25)
13/16 (20)	1-1/16 (27)
7/8 (22)	1-3/16 (30)
15/16 (24)	1-1/4 (31)
1 (25)	1-5/16 (33)

Table 1, Vertical Linkage Rod Lengths

7. Adjust the length of the linkage rod as needed, adding or subtracting the amount shown in **Table 1** .

   NOTE: If the linkage rod is too short, replace it with a new rod, part number 16–13485–000. (The linkage rod should be long enough so that at least 1/2 inch (13 mm) of it fits into both flexible end-sections of the linkage.)

   7.1 Mark the existing length of the linkage rod between the upper and lower flexible end-sections of the linkage. See **Fig. 2**.

   7.2 Loosen both linkage adjustment clamps.

   7.3 Slide the flexible end-sections of the linkage over the linkage rod until the rod is the correct length.

   To increase the suspension height, lengthen the linkage rod; to decrease the suspension height, shorten the rod.

   7.4 Tighten the adjustment clamps.

8. 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. Don't apply the parking brakes.

9. Again, check the distance between the bottom of the left forwardmost axle stop and the top of the axle U-bolt pad. The correct distance is between 2-3/8 and 2-7/8 inches (60 to 73 mm).

10. If the distance isn't right, repeat the adjustment procedure.

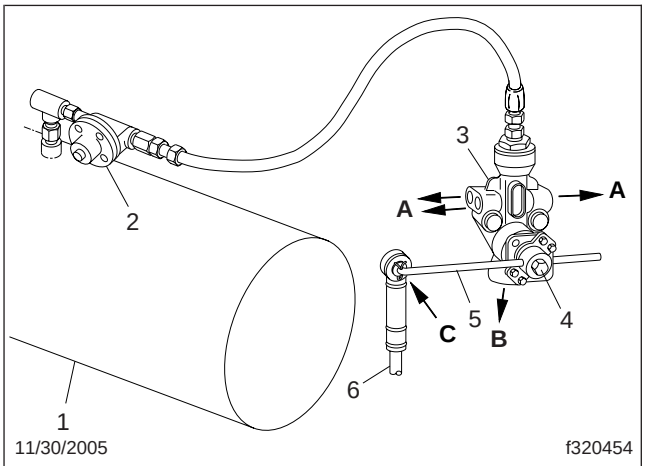
11. Apply the parking brakes; then remove the chocks from the tires.

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**.

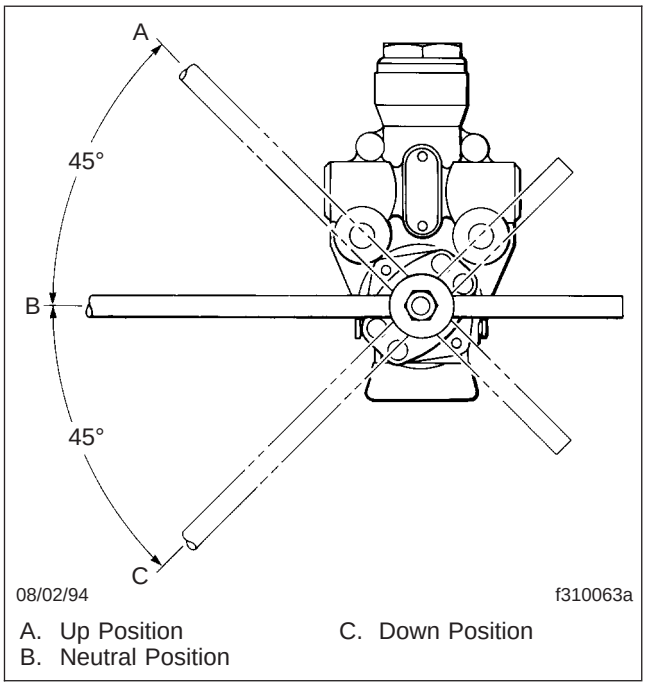


A. to air springs
B. to atmosphere
C. Disconnect the linkage here.

1. Secondary Air Reservoir
2. Pressure Protection Valve
3. Height Control Valve
4. Adjusting Locknut
5. Overtravel Lever
6. Height Control Valve Linkage

Fig. 1, Height Control Valve

2. Pull the overtravel lever up about 45 degrees. See **Fig. 2**. If air passes through the valve, that section of the valve is working.
3. Return the valve to the neutral position. See **Fig. 2**. Air should stop flowing. If so, that section of the valve is working.
4. Push the overtravel lever down about 45 degrees. See **Fig. 2**. 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.



A. Up Position
B. Neutral Position
C. Down Position

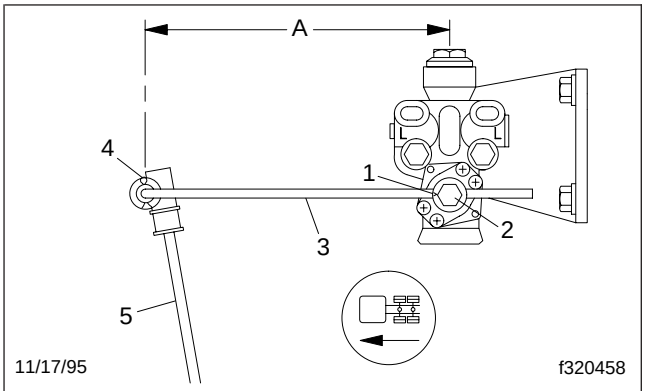
Fig. 2, Overtravel Lever Positions

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**.

Height Control Valve Replacement

1. Chock the tires, and drain the air reservoirs.
2. Disconnect the linkage from the overtravel lever. See **Fig. 1**. Exhaust all air from the air springs by moving the overtravel lever down.



A. Measure the length of the overtravel level between these two points.

1. V-Shaped Mark
2. Adjustment Locknut
3. Overtravel Lever
4. Cotter Pin
5. Linkage Rod

Fig. 1, Height Control Valve Linkage Measurement

3. 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.
4. Remove the height control valve mounting bolts and nuts, and remove the height control valve from the bracket.
5. Remove the overtravel lever from the height control valve.
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. Connect the height control valve linkage to the overtravel lever. Secure the linkage with a cotter pin.
9. Connect the overtravel lever to the height control valve. Insert the overtravel lever into the valve at the hole with the V-shaped mark. See **Fig. 1**. Be sure the length between pivot points is 8 inches (20.3 cm). See **Fig. 1**.
10. Close the drain cocks on all reservoirs.
11. Build up normal operating pressure in the air system. Check all air lines and connections for leaks. Eliminate all leaks.
12. Adjust the height control valve. For instructions, refer to **Subject 110**.

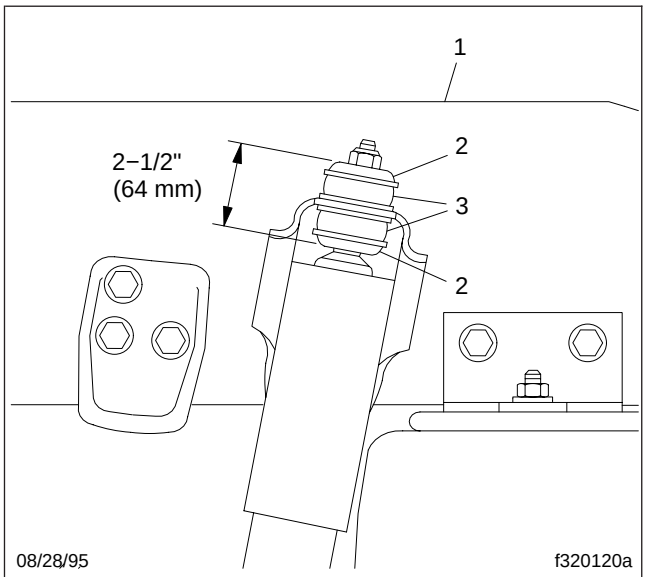
Shock Absorber Replacement

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 retainer, and upper bushing from the top of the shock absorber.
4. Pull the shock absorber out of the upper mounting bracket, and remove the retainer and bushing.
5. Install the replacement shock absorber, making sure the new bushings and retainers are correctly positioned. See **Fig. 1**.

⚠ WARNING

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**.

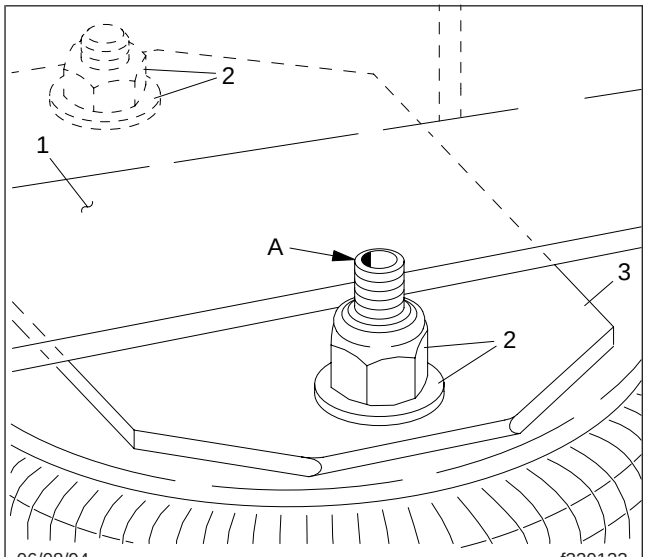


1. Frame Rail
2. Bushings
3. Retainer

Fig. 1, Shock Absorber Installation

Air Spring Replacement

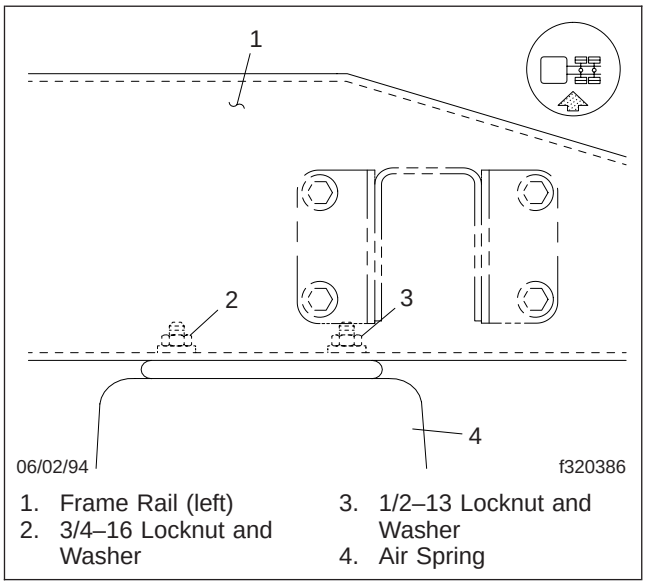
1. Chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs. The leveling valve automatically releases air from the air springs when all weight is removed from the suspension.
2. Disconnect the air supply line,including the brass tee, 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**.
5. Place the new air spring on the rear of the leaf spring, and install the washer and locknut that hold the air spring 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).



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

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

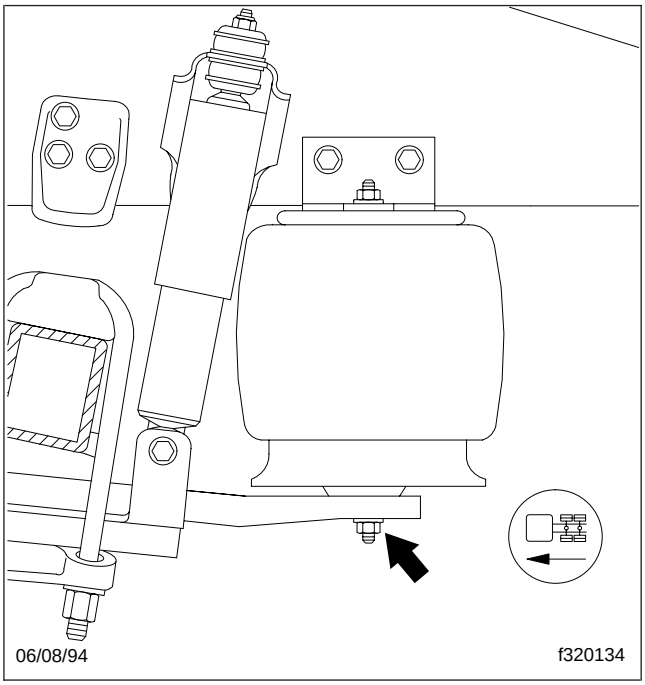


Fig. 3, Locknut and Washer Connecting Leaf Spring and Air Spring

Replacement

1. Chock the front tires. Raise the vehicle frame and support it with safety stands to remove all weight from the air springs.

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.

NOTE: When space is limited (such as at the forward axle of tandem axles) it may be easier to remove the piston from the leaf spring and assemble the bag and piston on a workbench. Secure the bag and piston in a fixture; do not try holding them by hand during inflation.

8. 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).
9. 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.
10. 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**.
11. Fold the air spring bag so the bead is fully parallel with the piston lip. See **Fig. 2**.
12. Apply an approved tire lubricant to the bead and piston lip.
13. 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 button hole. See **Fig. 3**.
14. 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.

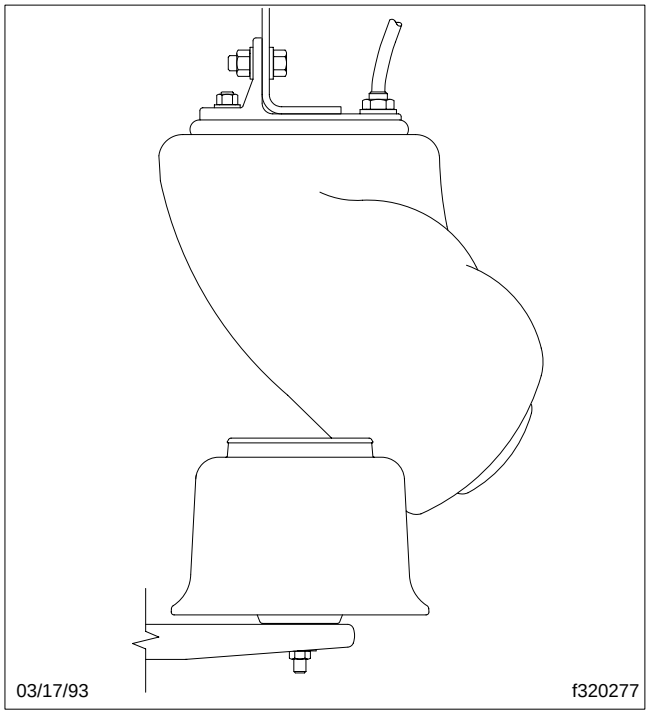


Fig. 1, Air Spring Bag Extended

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 Spring Bag Replacement

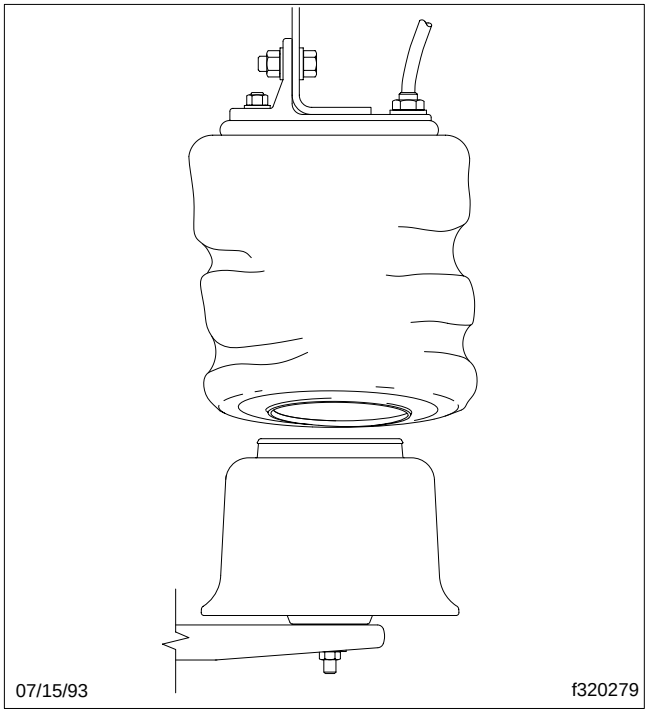


Fig. 2, Air Spring Bag Folded and Aligned with Piston

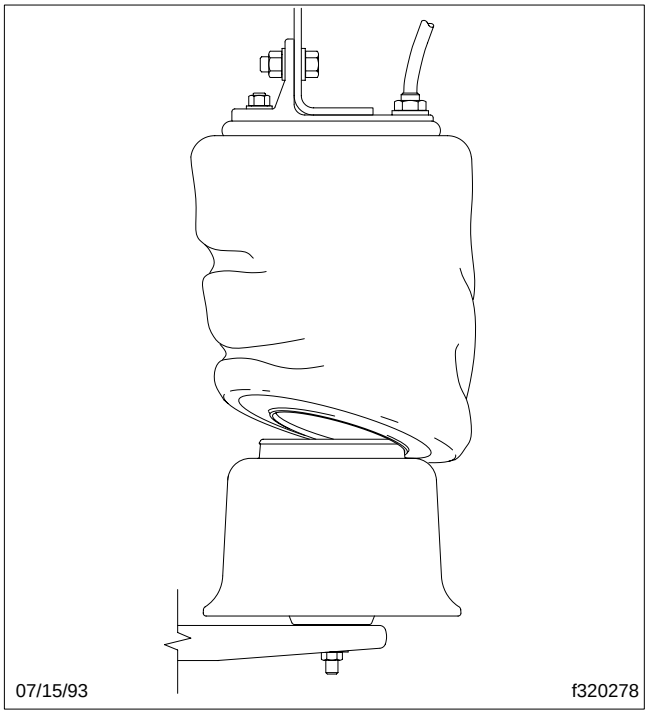


Fig. 3, Front of Air Spring Bag Over Piston Lip

air pressure and realign the air bag bead and piston. Then, try again to seat the bag using air pressure.

15. 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** .
16. Check the suspension ride height. See **Subject 110** for instructions.
17. Remove the safety stands, and lower the vehicle. Remove the chocks from the tires.

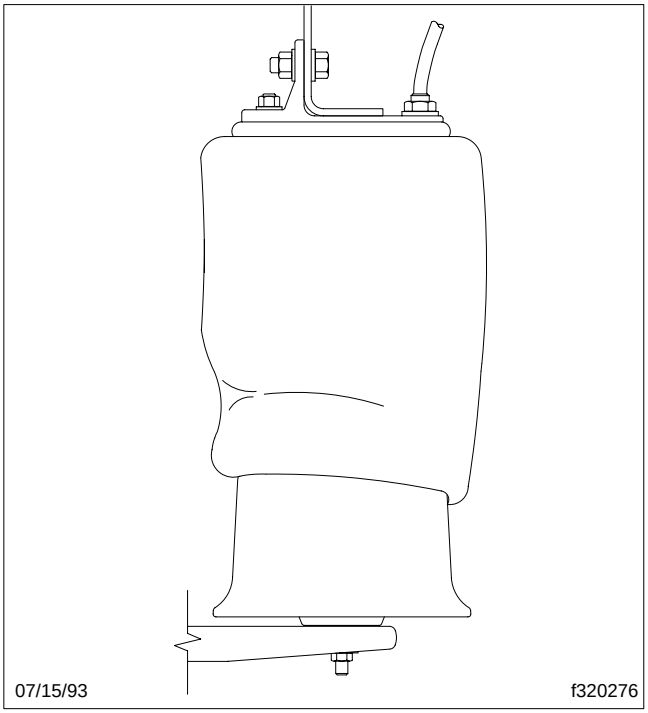


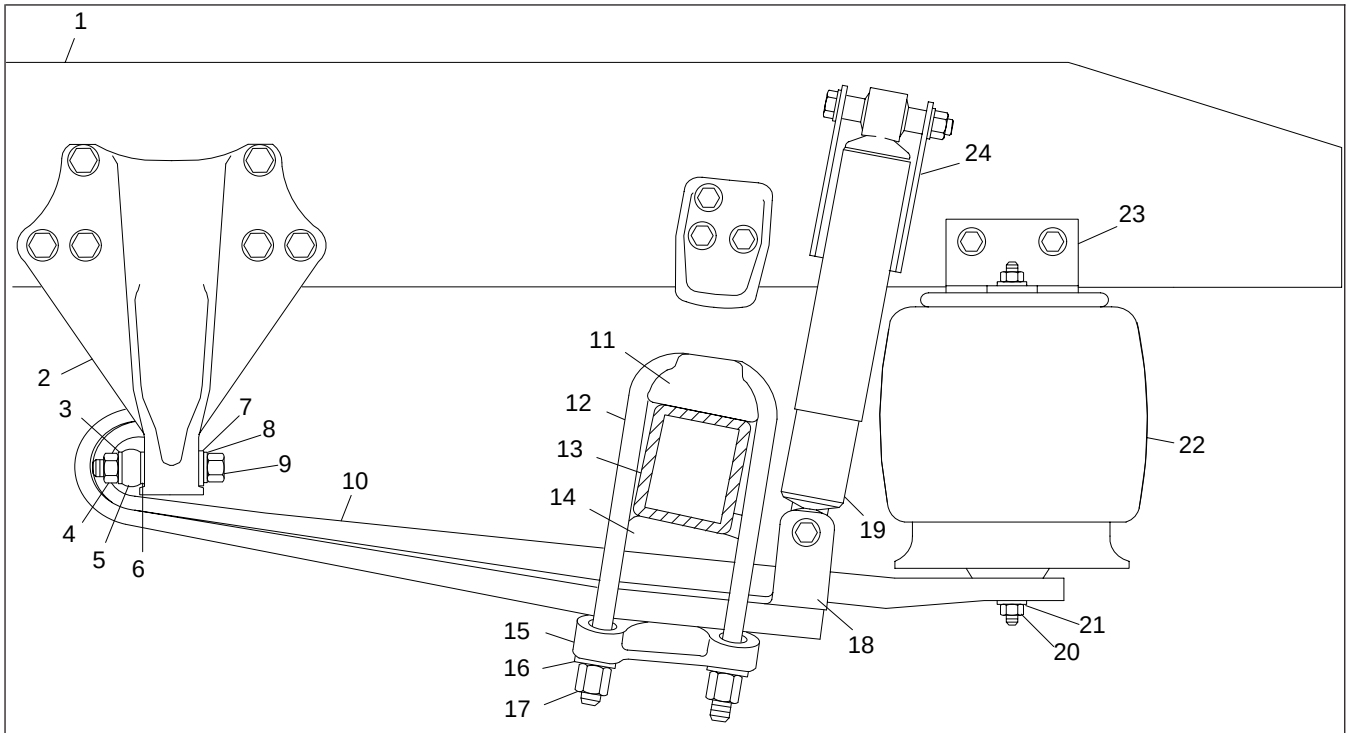
Fig. 4, Air Spring Bag Rolling Onto Piston

Leaf Spring Replacement

WARNING

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** in this manual 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



11/17/95 f320462

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. 1, AirLiner Leaf Spring Assembly

Leaf Spring Replacement

each U-bolt. Support the leaf spring assembly with a jack. See **Fig. 1**.

4. Disconnect the bottom of the air spring from the leaf spring.
5. Note the number and position of the alignment shims on the spring mounting bolt. See **Fig. 1**.
6. Remove the hexnut, washers, alignment shim(s), spring mounting bolt, and wear shoe clip from the spring hanger. See **Fig. 1**.

⚠ WARNING

WARNING: The leaf spring assembly is heavy. Use care when handling it to prevent injury.

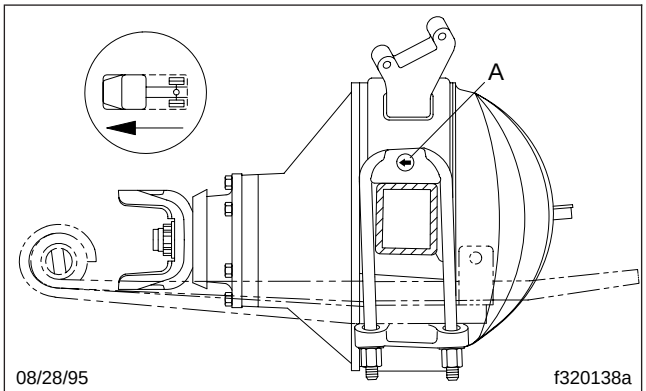
7. Remove and discard the leaf spring assembly.
8. While supporting a new leaf spring assembly with a jack, position the assembly on the spring hanger. Install the bolts, wear shoe clips, washers, alignment shims, and hexnuts. Tighten the bolts just enough to hold the leaf spring assembly in place.
9. 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 cross bar, attach the cross bar to the leaf spring assembly. The longer capscrews attach in the forwardmost holes; the shorter capscrews 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.

NOTE: On single-drive axles angled 5 degrees, the arrow on the U-bolt pads must point to the front of the axle housing. See **Fig. 2**. On single-drive 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. 3**.

With both 5- and 3-degree single-drive axle angles, the arrow on the bottom of the axle clamp must point toward the rear of the vehicle. See **Fig. 1**.

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).
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).
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, see **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 170**.



A. Arrow on U-Bolt Pad

Fig. 2, U-bolt Pad Arrow Positioning

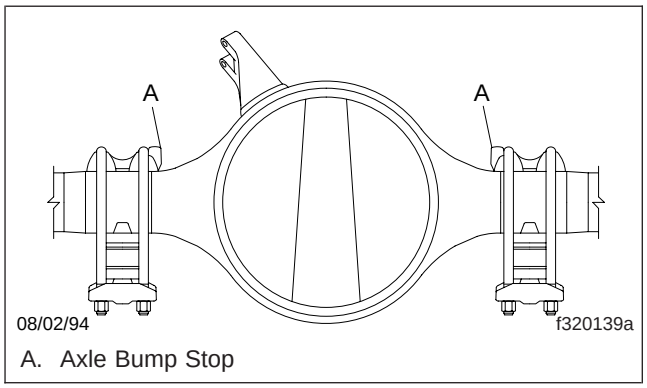
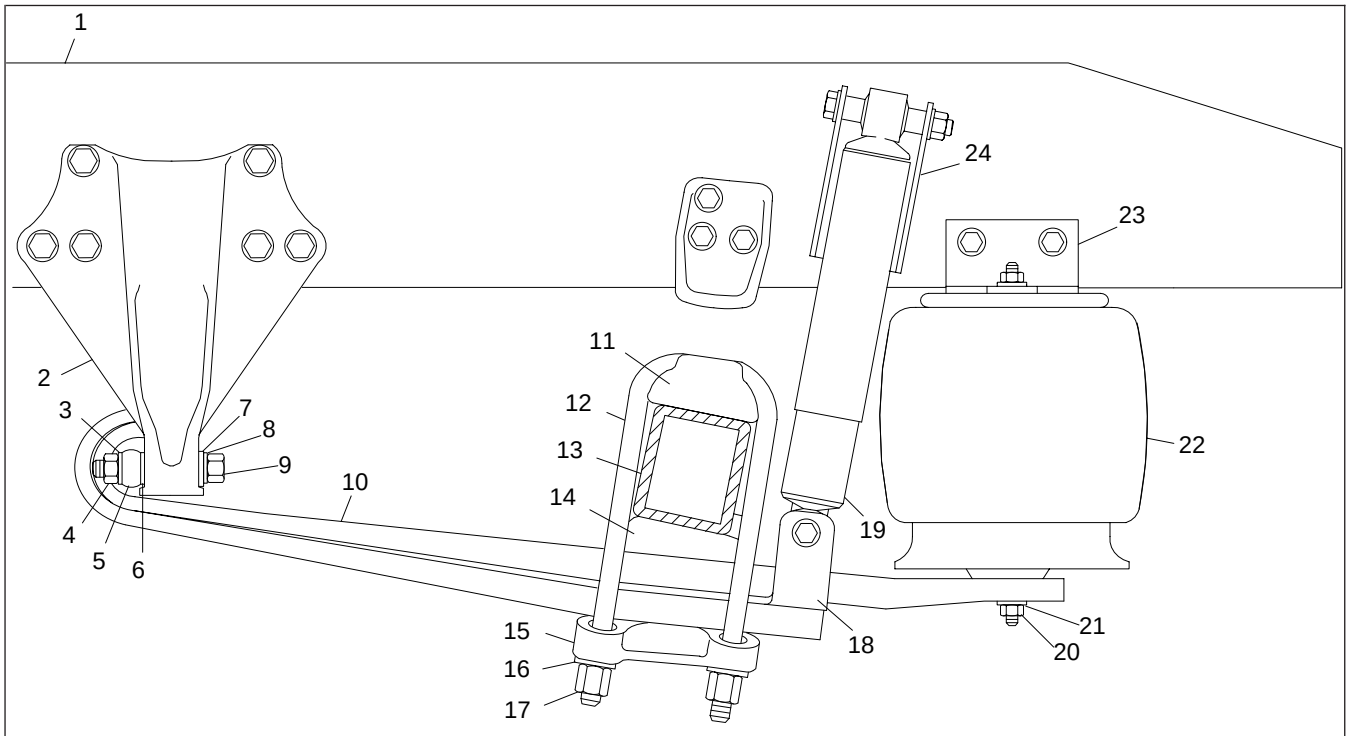


Fig. 3, Axle Bump Stop Positioning

Rear Axle Alignment Adjusting

Follow the instructions in the rear axle section in this manual to see if rear axle alignment adjustment is needed. If adjustment is needed, proceed as follows:



1. 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

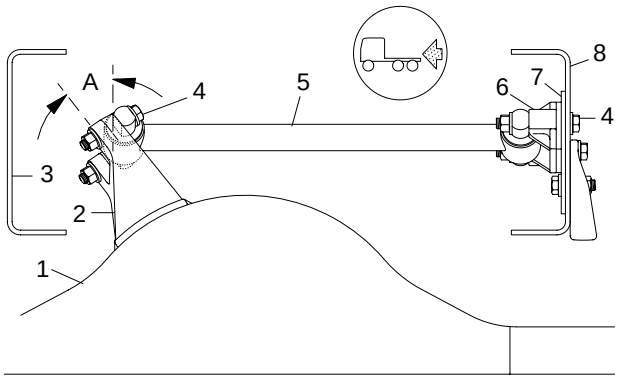
1. Loosen the spring pinch bolts so that the forward end of the leaf spring can slide fore and aft in the spring hanger. See **Fig. 1**.
2. Move the axle forward or backward until it is aligned within the tolerances in the rear axle alignment checking section in this manual.
3. When the axle is in alignment, 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.

Replacement

1. Park the vehicle. Shut down the engine, and apply the brakes.
2. Chock the tires. Raise the vehicle. Support the frame rails with jack stands.
3. Remove the fasteners holding the control rod to the frame rail bracket. Remove the shims, and set the shims aside.
4. Remove the control rod.
5. Position the new control rod so that the end with the fasteners angled up at 35 degrees is installed in the axle housing bracket. See **Fig. 1**.



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 chocks.

Specifications

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	7/8–14	Stage 1: Hand tighten	—
		Stage 2: 60 (80) *	—
		Stage 3: 200 (270) *	—
		Stage 4: 460 (624) *	—
Air Spring Upper Mounting Bracket	5/8–11	136 (184)	—
Spring Hanger Mounting Locknuts	3/4–10	240 (325)	—

* Tighten in a diagonal pattern.

Table 1, Torque Values

General Information

The Hendrickson HAS suspension is a single axle drive that uses two air-filled springs in place of leaf springs to lessen road shocks. See **Fig. 1**.

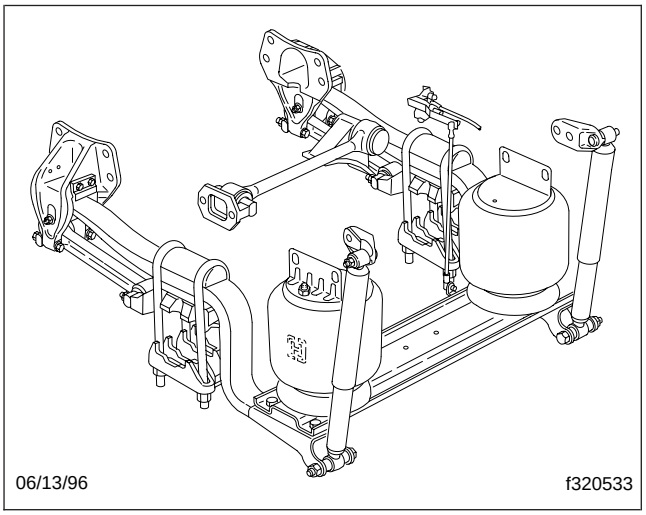


Fig. 1, Hendrickson HAS suspension

The HAS suspension ride height is controlled by a height control valve. A time delay is built into the valve to avoid leveling action while the suspension oscillates during normal operation.

A pressure protection valve is located at the vehicle's air storage tanks, and protects the vehicle's primary air system should a failure occur.

All suspension fasteners require periodic tightening. For suspension inspecting, lubricating, and fastener torque checking instructions, see Group 32 of the *School Bus Chassis Maintenance Manual*.

⚠ WARNING

Torque all suspension fasteners periodically as recommended. Failure to periodically torque the suspension fasteners could result in damage to the frame hangers or separation of components. This could cause a loss of vehicle control, resulting in personal injury or property damage.

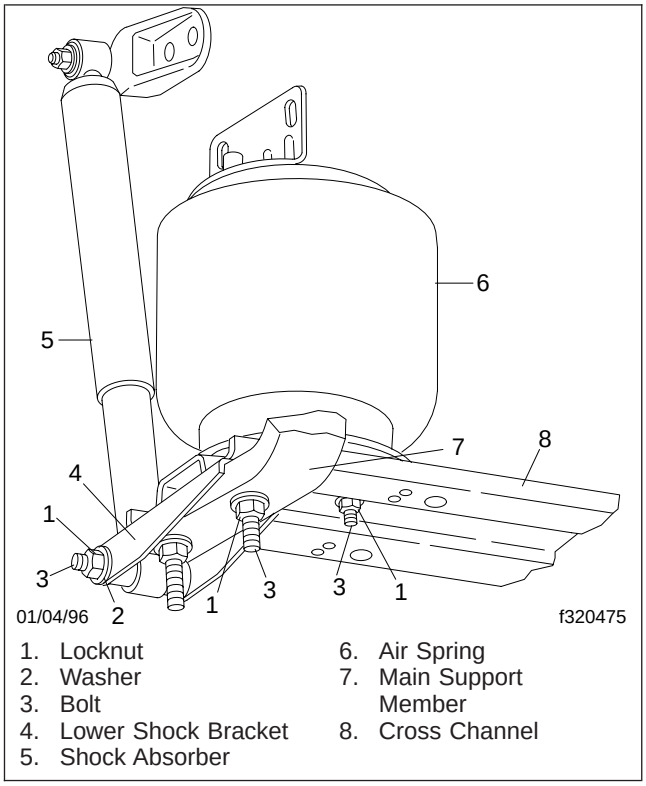
Removal

NOTE: Operation of the HAS suspension will result in wear between the main support member and the spring hanger slipper pad. In normal use, these components will function satisfactorily even though they show some wear. Premature wear may occur, however, and requires the replacement of one or both parts. A main support member should be replaced if it has 3/8-inch (9.5 mm) or more wear at the spring hanger cam contact area.

1. Chock the front tires.
2. Support the axle with a jack stand.
3. Drain the vehicle's air system.
4. Remove the height control valve. Refer to **Subject 120**.
5. Raise the rear of the frame enough to remove the load from the main support member. Support with safety stands.
6. Remove the U-bolt locknuts and washers, then remove the U-bolts.
7. Remove both locknuts and washers connecting the cross channel to both main support members.
8. Lift the cross channel from the main support member with jacks.
9. Remove the main support assembly.

Installation

1. Position the main support member on the axle seat, or on the spacer plate if the vehicle is so equipped, with the main support member center dowl sliding into the hole in the axle seat or spacer plate. The Delrin liner must be positioned on the top of the main support member.
2. Attach the top pad, the U-bolts, the bottom cap, and the washers and locknuts, but do not tighten the U-bolt locknuts.
3. Position the torque rod mounting bolts of the center springs toward the front of the vehicle.
4. Lower the air spring and cross channel mounting bolts into the main support members.
5. Attach the washers and locknuts that connect the cross channel to the main support members. Tighten the locknuts 280 lbf·ft (380 N·m). See **Fig. 1**.



1. Locknut
2. Washer
3. Bolt
4. Lower Shock Bracket
5. Shock Absorber
6. Air Spring
7. Main Support Member
8. Cross Channel

Fig. 1, Main Support Member Assembly

6. Lower the frame until the spring hangers engage the main support member. Fill the system with air, and center the main support member between the spring hanger legs.
7. Tighten evenly the U-bolt locknuts 425 lbf·ft (576 N·m). While doing so, rap with a hammer the top of the U-bolts, and then retighten to 425 lbf·ft (576 N·m).

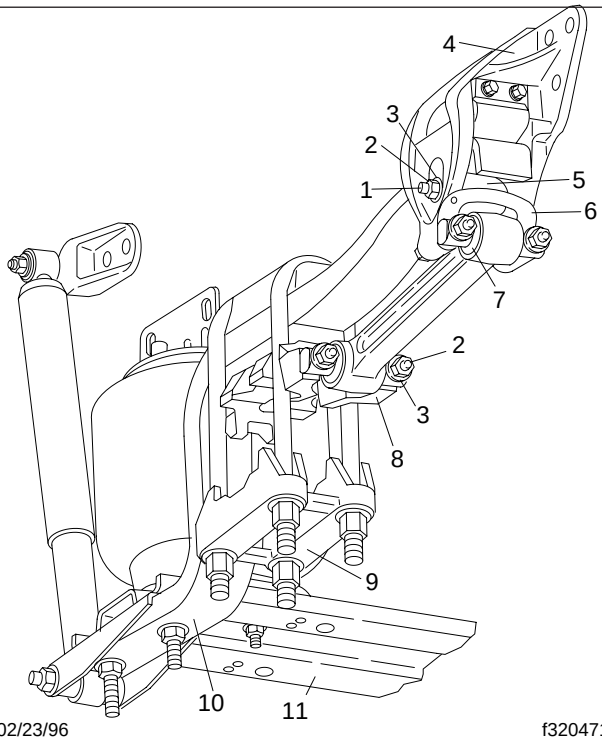
IMPORTANT: Do not exceed the specified torque on the U-bolt locknuts.

8. Attach the spring hangers. Tighten the locknuts 60 lbf·ft (81 N·m).
9. Attach the height control valve link, and tighten 125 lbf·ft (169 N·m).
10. Check alignment after the new main support members are installed.

Replacement

Use the following information to replace the spring seats, if required.

1. Chock the front tires.
2. Raise the rear axle, and support it with a jack stand.
3. Drain the vehicle's air system.
4. Remove the height control valve. See **Subject 120**.
5. Raise the rear of the frame enough to remove the load from the main support member.
6. Remove the U-bolt locknuts and washers, and remove the U-bolts.
7. Remove both locknuts and washers attaching the cross channel to both main support members.
8. Lift the cross channel from the main support member with jacks.
9. Remove the main support assembly.
10. Remove the spring seat.
11. If the spring seat stud on the axle needs replacement, remove it with a stud puller.
12. Install the new stud with a stud driver. The stud should be inserted from the dog point end (tap end) first, and then bottom out in the threaded hole of the spring seat. Tighten the stud 65 lbf·ft (88 N·m).
13. Replace the spring seat, the main support member, and the U-bolts.
14. Assemble the torque rod straddle mount bushing to the spring seat, and tighten locknuts 175 lbf·ft (237 N·m). See **Fig. 1**.
15. Check all fasteners for proper torque before moving the vehicle.
16. Build up pressure in the air system, and remove the jack stand.



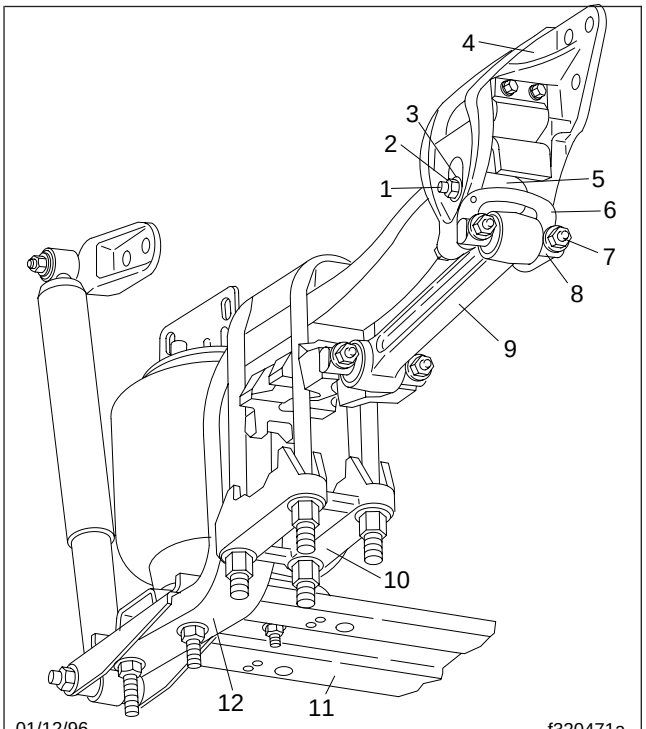
1. Rebound Bolt
2. Locknut
3. Washer
4. Spring Hanger
5. Rebound Roller
6. Alignment Shim(s)
7. Straddle Mount Bar Pin
8. Spring Seat
9. Bottom Cap
10. Main Support Member
11. Cross Channel

Fig. 1, Spring Seat Installation

Replacement

Use the following procedure to replace the torque rod bushing. See **Fig. 1**.

1. Chock the front tires, and the tires of the drive axles.
2. Remove the straddle mount bar pin locknuts and washers at the axle end of the torque rod. See **Fig. 1.**



01/12/96 f320471a

1. Rebound Bolt
2. Locknut
3. Washer
4. Spring Hanger
5. Rebound Roller
6. Alignment Shim(s)
7. Bolt
8. Straddle Mount Bar Pin
9. Torque Rod
10. Bottom Cap
11. Cross Channel
12. Main Support Member

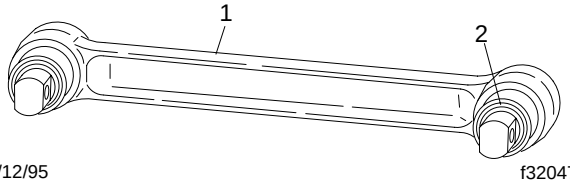
Fig. 1, Torque Rod Installation

3. Loosen the rebound bolt locknut in the spring hanger.
4. Remove the straddle mount bar pin locknuts, bolts and washers, and any alignment shims at the spring hanger ends of the torque rod. Note the number of shims, as the shims must be reinstalled in the same manner to avoid affecting the vehicle's alignment.
5. Push out the old bushings. Use a vertical shop press with a capacity of at least 10 tons. A 5-inch (127 mm) piece of 2-inch (5 cm) by 1/4-inch (6 mm) wall steel tubing receiving tool is required. The bushings are not cartridge type bushings, and do not have outer metals.
6. Support the torque rod end on the receiving tool with the end tube of the torque rod centered on the tool.
7. Push directly on the bushing straddle mount bar pin until the bushing is clear of the torque rod end tube.

⚠ WARNING

WARNING: Do not use heat or a cutting torch to remove the bushings from the torque rod. The use of heat will weaken the torque rod, which could cause the rod to break. This could result in a loss of vehicle control and personal injury, or property damage.

8. Clean and inspect the torque rod ends. Remove any nicks with an emery cloth.
9. Lubricate the torque rod ends and the new rubber bushings with a vegetable-based oil. Do not use a petroleum-based or soap-based lubricant.
10. Press in the new bushings while supporting the torque rod end on the receiving tool with the end tube of the torque rod centered on the receiving tool. The straddle mount bar pin bushings must have mounting flats positioned zero degrees to the shank of the torque rod. See **Fig. 2**.



12/12/95 f320472

1. Torque Rod
2. Straddle Mount Bar Pin Bushing

Fig. 2, Mounting Flats Positioning

11. Press directly on the straddle mount bar pin of the bushings, which must be centered within the

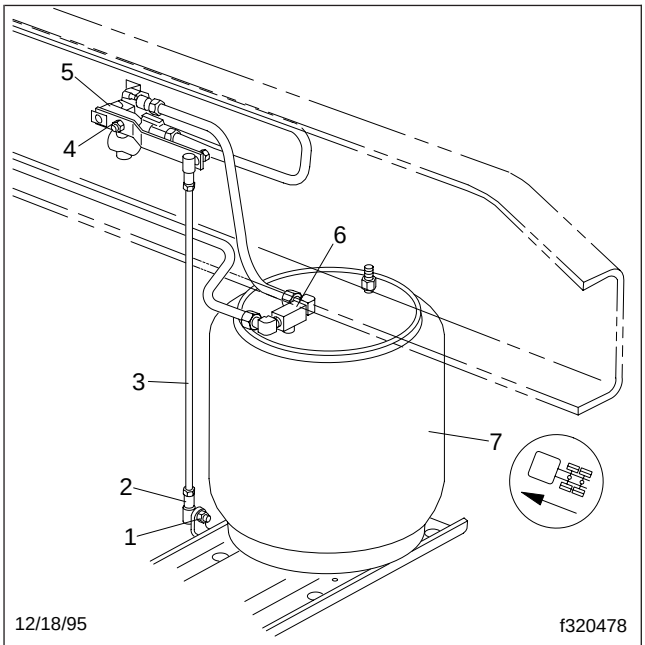
Torque Rod Bushing Replacement

torque rod end tubes. When pressing in the new bushings, overshoot the final position by approximately 3/16-inch (5 mm).

12. Press the bushing again from the opposite side to center the bushing within the torque rod end.
13. Position the new or rebushed torque rod into the spring seat, and attach it with the washers and locknuts. Handtighten the locknuts.
14. Position the torque rod onto the forward face of the spring hanger legs. Assemble the bolts, washers and locknuts, and any alignment shims. Tighten locknut 175 lbf·ft (237 N·m). See **Fig. 1**.
15. Tighten locknuts at the axle end of the torque rods 175 lbf·ft (237 N·m).
16. Tighten rebound bolt locknuts 60 lbf·ft (81 N·m).

Removal

1. Chock the front tires.
2. Drain the vehicle's air system.
3. Remove the height control valve threaded extension rod from the valve arm by removing the nut and lock washer.
4. Remove the air lines attached to the height control valve. See **Fig. 1**.



1. Locknut
2. Extension Arm
3. Threaded Extension Arm
4. Leveling Arm Locknut
5. Height Control Valve
6. Brass Air Fitting
7. Air Spring

Fig. 1, Height Control Valve System

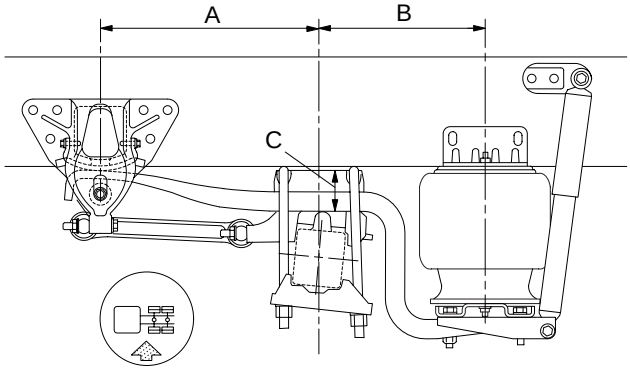
5. Remove the locknuts, washers, and bolts that attach the height control valve to the frame.
6. Remove the brass air fittings from the height control valve.

Installation

1. Attach the brass air fittings to the height control valve.
2. Install the bolts, washers, and locknuts that attach the valve to the frame rail.
3. Attach the air lines to the height control valve.
4. Attach the height control valve threaded extension rod to the height control valve arm, and attach the lock washer and nut. See **Fig. 1**.
5. Return air to the system.
6. Adjust the height control valve for proper ride height.

Adjustment

Spring seats of equal thickness are installed on the rear axle. The seats are designed to keep frames parallel to the ground, and this results in a zero-degree frame slope. The intent is to maintain a 4-1/4 inch (108 mm) main support member height on the axle. See **Fig. 1**. Maintaining the ensures equal loading on the axle, as well as a correct pinion angle.



06/13/96 f320468a

A. Measurement: 20 inches (508 mm)
B. Measurement: 15-1/4 inches (387 mm)
C. Measurement: 4-1/4 inches (108 mm)

Fig. 1, Adjustment Measurements

If the chassis frame slope is in excess of one degree it could be detrimental to the ride of the vehicle.

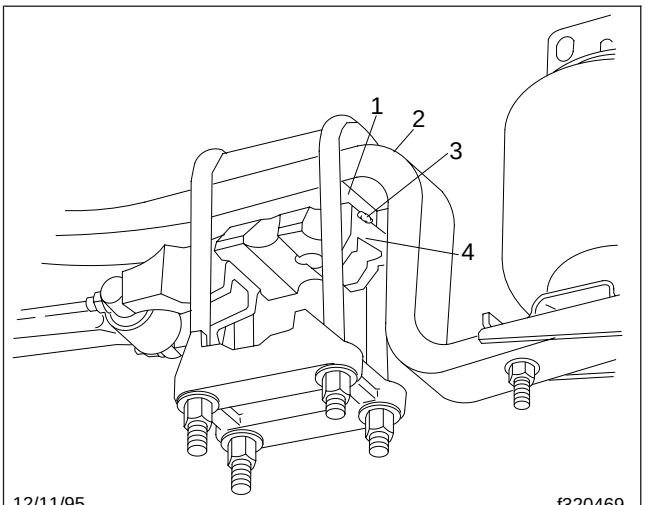
When installing spacer plates, position each plate on the center of the spring seat, and then tack-weld the spacer to the rear edge of the spring seat casting. Use stainless steel welding rod. See **Fig. 2**.

Longer U-bolts will be need to accommodate the spacer plates.

If the frame slope is excessive or greater than what can be corrected with a 1-1/2 inch (38 mm) spacer, it should be corrected at a Freightliner dealership.

WARNING

WARNING: Do not make changes to the steering axle. Changes could alter steering characteristics, possibly resulting in loss of vehicle control, and personal injury or property damage.



12/11/95 f320469

1. Spacer
2. Main Support Member
3. Tack Weld
4. Spring Seat

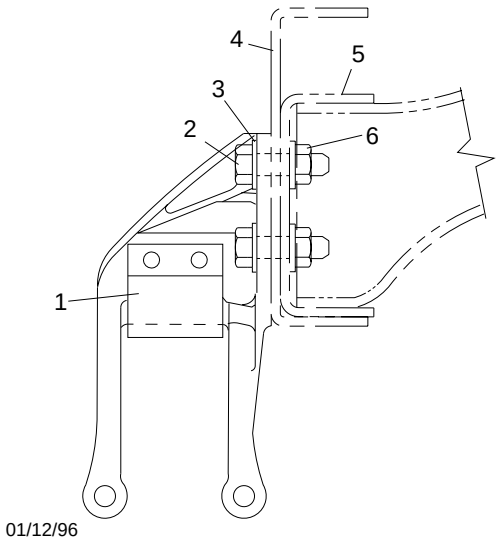
Fig. 2, Spacer Plate Installation

Spring Hanger/Slipper Pads Removal and Installation

Removal

NOTE: Operation of the HAS suspension will result in wear between the main support member and the spring hanger slipper pad. In normal use, these components will function satisfactorily even though the components indicate some wear.

If the slipper pads require replacement, inspect the pads and identify how they are attached. See **Fig. 1**.



1. Slipper Pad
2. Bolt
3. Hardened Flatwasher
4. Frame Rail
5. Crossmember
6. Locknut

Fig. 1, Spring Hanger/Slipper Pad Installation

1. Chock the front tires.
2. Raise and support the frame with jack stands.
3. Drain the vehicle's air system.
4. Apply an upward force on the cross channel with a jack or a pry bar. This will cause the tips of the main support members to drop away from the slipper pad.

IMPORTANT: Do not nick or gouge the cross channel.

5. Remove the fasteners, and the slipper pad. In some instances, the screws may have to be drilled out.
6. For hexhead fasteners, remove the rebound roller (in some instances) to disassemble the slipper pad. Loosen the rebound bolt locknut, remove the washer, the bolt, and the rebound roller.
7. For structural blind rivets, remove the four 1/4-inch (6 mm) structural blind rivets by grinding away the excess head. With a drift pan, punch through the hole, and remove the slipper pad.

Installation

1. Position the slipper pad and retainer plate on the frame hanger.
2. Tighten the hexhead self-tapping screws 25 lbf·ft (34 N·m).
3. Or, install the structural blind rivets using an air gun or a hand gun.
4. Remove the jack stands, and build up pressure in the air system.

Cross Channel Removal and Installation

Removal

1. Chock the front tires.
2. Raise and support the axle with jack stands.
3. Drain the vehicle's air system.
4. Remove the height control valve. See **Subject 120**.
5. Raise the rear of the frame enough to remove the load from the main support member.
6. Remove the locknuts and washers that attach the air spring to the cross channel and to both main support members.
7. Remove the cross channel.

Installation

1. Attach the cross channel to both air springs, then lower the frame, piloting the bolt holes onto the main support member.
2. Attach the washers and locknuts that connect the cross channel to the main support member.
3. Tighten the locknuts 290 lbf·ft (393 N·m).
4. Assemble the height control valve link, and tighten it 125 lbf·ft (169 N·m).
5. Build up pressure in the air system.

Checking and Adjustment

Use the following procedure after all repairs to the suspension:

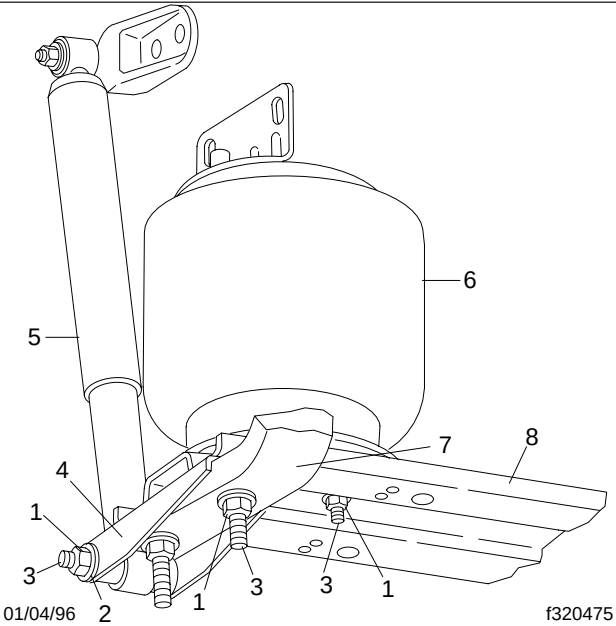
1. Park vehicle on a level surface. Free and center all suspension joints by slowly moving the vehicle back and forth several times without applying the brakes.
2. Chock the front tires, and the tires of the rear axle.
3. Release the brakes.
4. C-clamp a nine-foot (2.74 m) piece of straight bar stock or angle iron across the frame. Select a location as far forward of the axle as possible where components will not interfere.
5. To determine the proper alignment of the bar stock or angle, place a square straight edge onto the frame using a carpenter's square.
6. Use a trammel bar or its equivalent to measure from the straight edge to the center line of the rear axle on both sides of the vehicle. If both sides measure within 3/16-inch (5 mm) of being the same, the alignment of the rear axle is acceptable. If the sides differ by more than 3/16-inch (5 mm), first loosen the rebound locknut, and then adjust the axle by loosening up the torque rod bar pin locknuts on the spring hangers. Add or remove drop-in shims as needed.

NOTE: The torque rod bar pin must always be mounted adjacent to the forward face of the spring hanger legs. No more than four shims may be used (for a maximum thickness of 1/4-inch (6 mm).

7. Snug the torque rod bar pin locknuts but do not torque to specification.
8. Move the vehicle back and forth several times prior to removing the straight edge from the frame. Recheck the alignment.
9. Tighten the torque rod bar pin locknuts 180 lbf·ft (244 N·m), and tighten rebound bolt locknuts 180 lbf·ft (244 N·m).

Replacement

1. Chock the front tires.
2. Raise the axle, and support the axle with jack stands.
3. Drain the vehicle's air system. See **Fig. 1**.
4. Remove the height control valve. See **Subject 120**.
5. Raise the rear of the frame enough to remove the load from the main support member.
6. Remove the locknuts and washers that attach the air spring to the cross channel.
7. Disconnect the air lines to the air spring.
8. Remove the brass air fittings from the air spring.
9. Remove the locknuts and washers that attach the air spring to the upper air spring frame hanger.
10. Remove the air spring.
11. Attach the new air spring to the air spring frame hanger by inserting the studs into the appropriate holes.
12. Attach the air spring to the cross channel. Tighten fasteners 25 lbf·ft (34 N·m).
13. Tighten the outboard locknut that attaches the air spring to the air spring frame hanger 25 lbf·ft (34 N·m).
14. Attach the brass fittings to the air spring using a Teflon thread seal.
15. Connect the air lines to the air spring.
16. Lower the vehicle.
17. Build up pressure in the air system.



1. Locknut
2. Washer
3. Bolt
4. Lower Shock Bracket
5. Shock Absorber
6. Air Spring
7. Main Support Member
8. Cross Channel

Fig. 1, Air Spring Installation

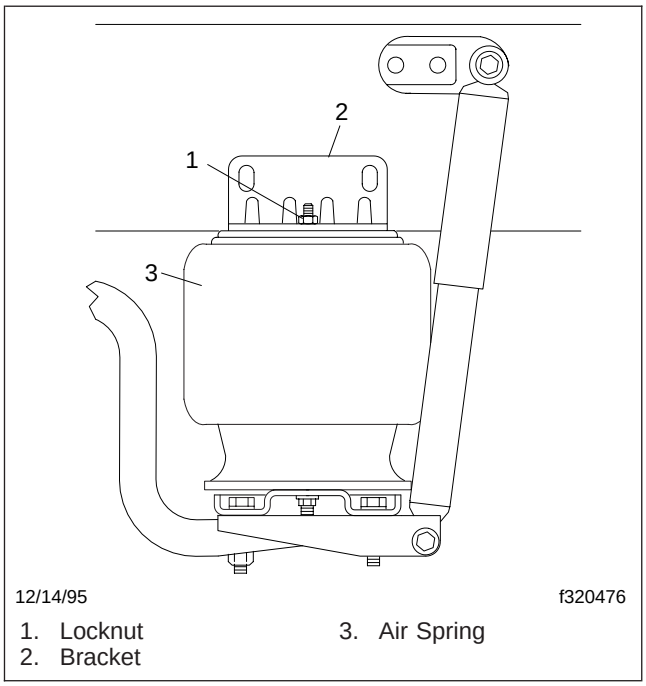
Stamped Air Spring Frame Hanger Removal and Installation

Removal

1. Chock the front tires.
2. Drain the vehicle's air system.
3. Raise the rear of the frame enough to remove the load from the suspension. Support with jack stands.
4. Disconnect the air lines from the air spring.
5. Remove the brass air fittings from the air spring.
6. Remove the locknuts and washers that attach the air spring bracket to the frame rail, and then the air spring to the air spring bracket. See **Fig. 1**.
7. Remove the air spring bracket.

Installation

1. Attach the air spring bracket to the top of the air spring.
2. Attach the frame hanger to the frame.
3. Attach the air spring to the air spring frame hanger. Tighten evenly the outboard locknut 25 lbf·ft (34 N·m).
4. Attach the brass air fittings to the air spring using Teflon thread seal.
5. Connect the air lines to the air spring.
6. Lower the vehicle.
7. Build up pressure in the air system.



1. Locknut
2. Bracket
3. Air Spring

Fig. 1, Air Spring Installation

Shock Absorber Outboard Frame Hanger Bracket and Lower Bracket Removal and Installation

Removal

1. Chock the front tires.
2. Drain the vehicle's air system.
3. Raise the rear of the frame enough to remove the load from the suspension. Support with jack stands.
4. Remove the shock absorber. See **Subject 170**.
5. Remove the shock absorber frame hanger bracket from the frame.
6. Remove the fasteners that attach the cross channel to the main support member.
7. Remove the lower bracket by sliding the bracket to the rear.

Installation

1. Attach the frame hanger bracket to the frame.
2. Position the lower bracket between the cross channel and the main support member.
3. Tighten the locknuts attaching the cross channel to the main support member 290 lbf·ft (393 N·m).
4. Install the shock absorber. Install the washers at both sides of each shock bushing for a total of four washers per shock absorber.
5. Tighten shock absorber locknuts 60 lbf·ft (81 N·m).
6. Lower the vehicle.
7. Build up pressure in the air system.

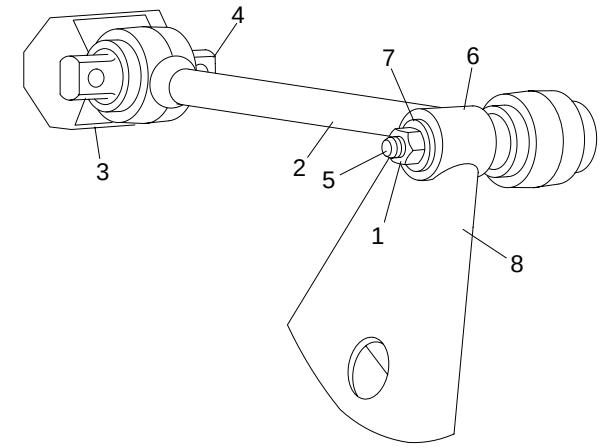
Removal

NOTE: This procedure is recommended for replacement of a transverse rod with a tapered stud at the axle connection and a straddle mount end at the frame bracket end. Some installations have straddle mounts at both ends of the transverse rod.

1. Chock the front tires.
2. Drain the vehicle's air system.
3. Disconnect the transverse rod where it is attached to the frame. See **Fig. 1**.
4. Disconnect the transverse rod where it is attached to the axle bracket.
5. Remove the tapered stud from the axle bracket by hitting only the axle bracket with a hammer.
6. Remove the torque rod bushing from the bracket.

Installation

1. Clear the tapered hole in the axle bracket of all foreign matter.
2. Insert the tapered stud and torque rod bushing into the bracket.
3. Attach the washer and locknut to the stud. Tighten 200 lbf·ft (271 N·m).
4. After tightening, hit only the axle bracket with a hammer to seat the tapered stud. Retighten.
5. Position the straddle mount end of the torque rod at the transverse rod frame bracket, and tighten 200 lbf·ft (271 N·m).
6. Build up pressure in the air system.



04/13/99 f320477

1. Locknut
2. Transverse Rod
3. Frame Bracket
4. Straddle Mount End
5. Tapered Stud End
6. Top of Transverse Rod Axle Bracket
7. Washer
8. Transverse Rod Axle Bracket

Fig. 1, Transverse Rod Assembly

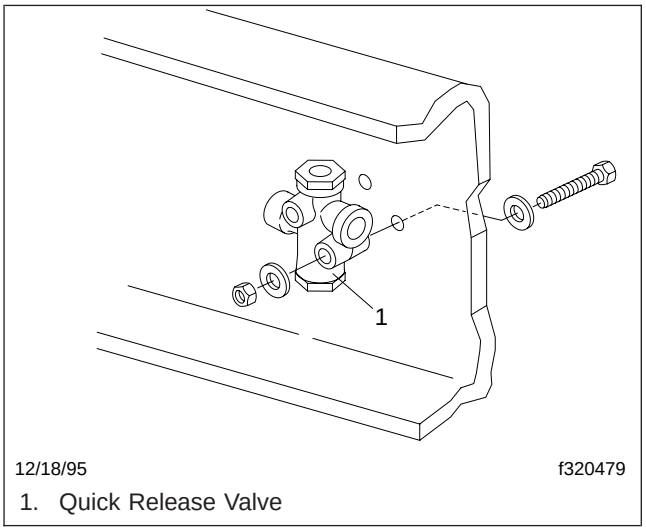
Replacement

NOTE: Shock absorbers are 1.375 inches (35 mm) in diameter with a compressed length of 18.34 inches (466 mm) and an extended length of 30 inches (762 mm).

1. Chock the front tires.
2. Remove the fasteners that attach the shock absorber to the frame hanger bracket.
3. Remove the fasteners that attach the shock absorber to the lower bracket.
4. Remove the shock absorber.
5. Install the new shock absorber, attaching it with fasteners to the lower bracket and the frame hanger bracket. Install washers at both sides of each shock bushing, that is four washers per shock absorber.
6. Tighten the fasteners 60 lbf·ft (81 N·m).

Replacement

1. Chock the front tires.
2. Drain the vehicle's air system.
3. Disconnect the air lines from the quick release valve. Identify the air line at the top of the valve. See **Fig. 1**.
4. Remove the quick release valve from the frame or cross member.
5. Remove the brass air fittings from the valve.
6. Attach the brass air fittings to the replacement quick release valve.
7. Attach the valve to the frame or cross member.



1. Quick Release Valve

Fig. 1, Quick Release Valve Installation

8. Connect the air lines to the valve, making sure to attach the identified line to the top of the valve.
9. Build up pressure in the air system.

Specifications

Description	Size	Torque: lbf·ft (N·m)
U-bolt Locknut	7/8–14	425 (576)
Torque Rod Bar Pin Locknut	5/8–11	180 (244)
Spring Seat Stud	5/8–11	65 (88)
Rebound Bolt Locknut	1/2–13	60 (81)
Shock Absorber Locknut, Upper	1/2–13	60 (81)
Shock Absorber Locknut, Lower	3/4–10	60 (81)
Cross Channel to Main Support Member Locknut	3/4–10	290 (393)
Air Spring to Frame Hanger Locknut	1/2–13	25 (34)
Air Spring to Cross Channel Locknut	1/2–13	25 (34)
Transverse Rod Locknut	1-1/4–12	200 (271)
Extension Arm Jam Nut	5/16–24	125 (169)
Extension Arm Locknut	5/16–24	125 (169)

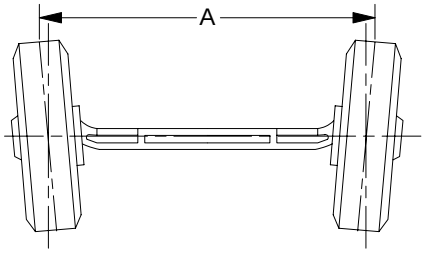
Table 1, Torque Values

General Description

Correct front axle wheel alignment is needed to ensure long tire life, ease of handling, and steering stability.

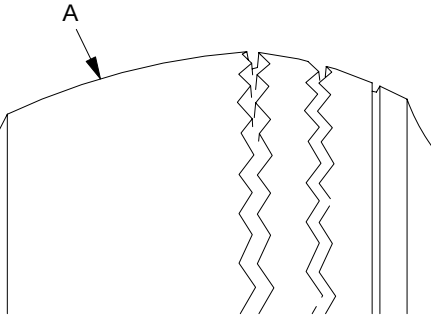
Three factors are involved in wheel alignment: camber angle, caster angle, and wheel toe-in.

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 in the same direction that the negative-camber wheel is on, wearing the inboard side of the tire tread. If camber angles are not correct, the tires will wear smooth around the edge on one side. See **Fig. 2**.



A. Camber (Positive)

Fig. 1, Camber Angle



A. One side of the tread is worn excessively.

Fig. 2, Tire Damage Due to Excessive Camber

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.

Wheel toe-in is the distance in inches that the front of the wheels are closer together than the rear of the wheels, as viewed from the top. 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**.

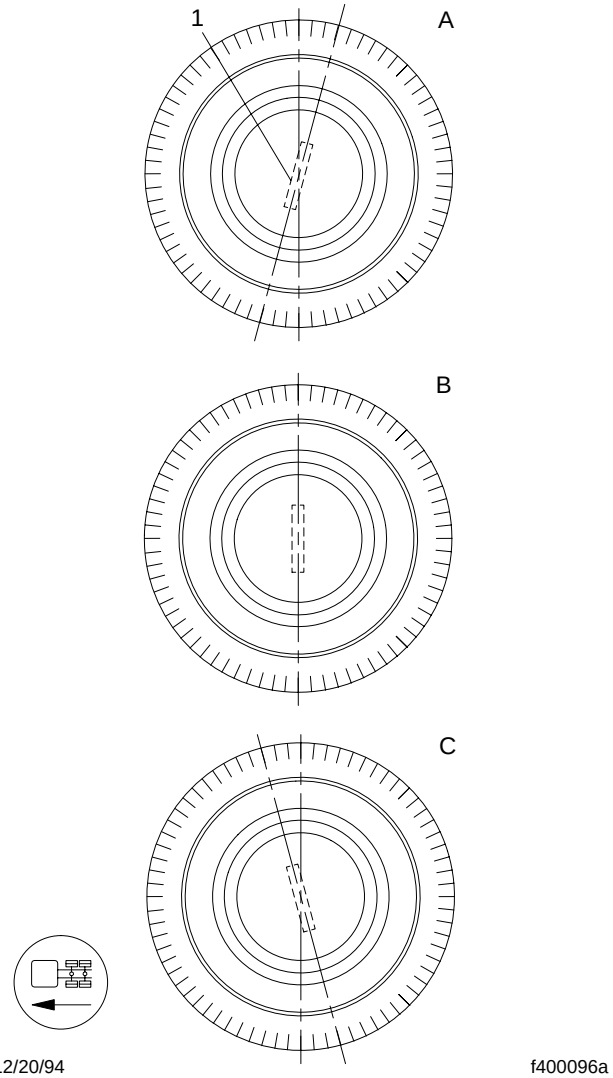
Advanced wear patterns can be seen, but less severe wear patterns are detected only by rubbing the palm of your hand flat across the tire tread.

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** for other possible causes.

If excessive tire tread wear has resulted from incorrect wheel alignment, replace the damaged tires. For minimum tread wear specifications, refer to the wheels and tires section in the vehicle maintenance manual.

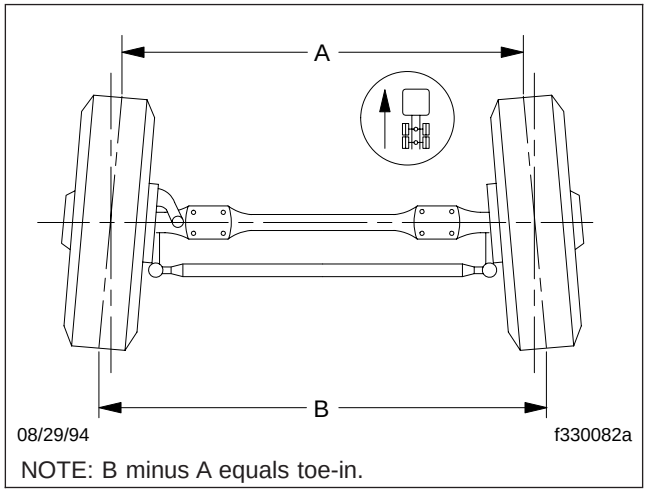
General Description



1. Knuckle Pin (King Pin)

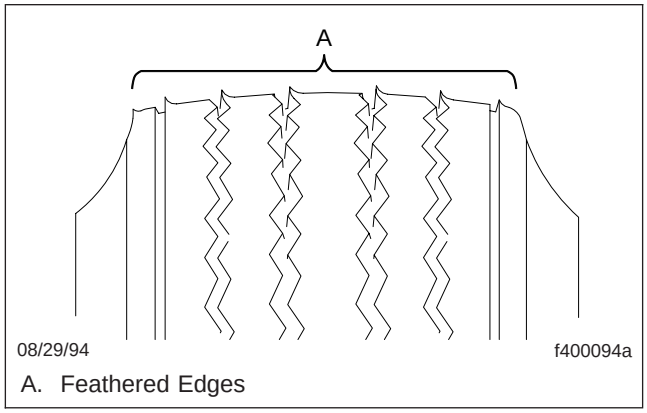
A. Positive Caster
B. Zero Caster
C. Negative Caster

Fig. 3, Caster Angle



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

1. Steering axle wheel assemblies should be balanced, especially for vehicles that travel at sustained speeds of more than 50 mph (80 km/h). Off-balance wheel assemblies cause vibrations that result in severely shortened life for tires, and steering suspension parts.
2. Do not mix tires of different size, type, or weight. Tire wear should be even and not worn to limits exceeding government specifications. See **Group 40** of this manual and Group 40 of the *School Bus Chassis Maintenance Manual* for more information. Replace any tire that is excessively worn.
3. Check the inflation pressure of the tires. Refer to the wheels and tires section 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**.

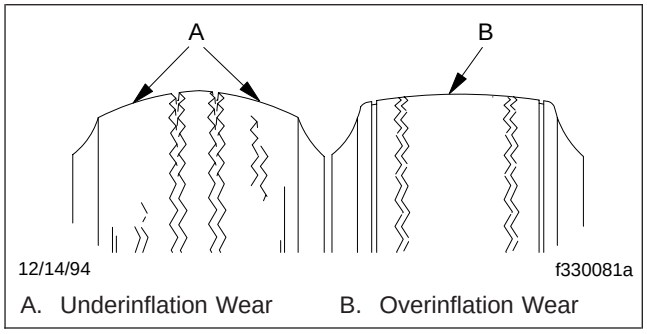
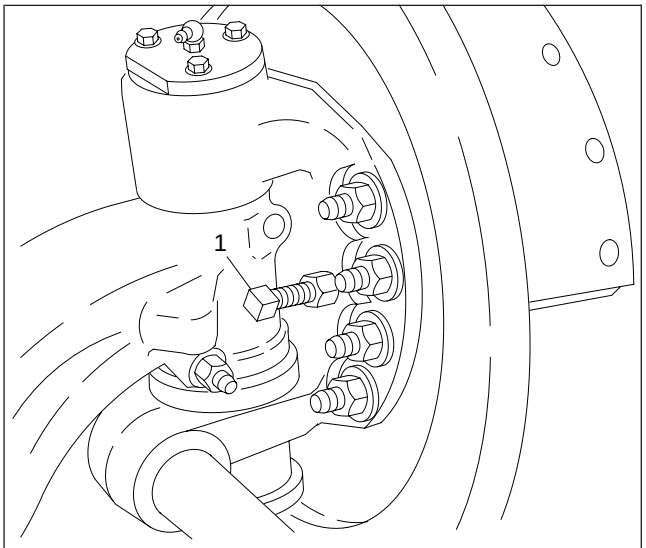


Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

4. Check for out-of-round wheels, 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 the suspension section in 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 the steering section in this manual.
8. Check the steering angle, and adjust the axle steering stops, as needed. See **Subject 110**.

Checking and Adjusting

Steering (or turning) angle is the degree of front wheel movement from a straight-ahead position to either an extreme right or left position. Although front wheel movement can be limited by the amount of internal travel in the steering gear, it generally depends on how much clearance there is between chassis components and the tire and wheel assemblies. All axles have adjustable stopscrew-and locknut-type axle stops, 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. Freightliner 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 the steering section in this manual. Bottoming of the steering gear must not occur when making an extreme right or left turn.
2. If using stationary turn-plates or turntables, 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.

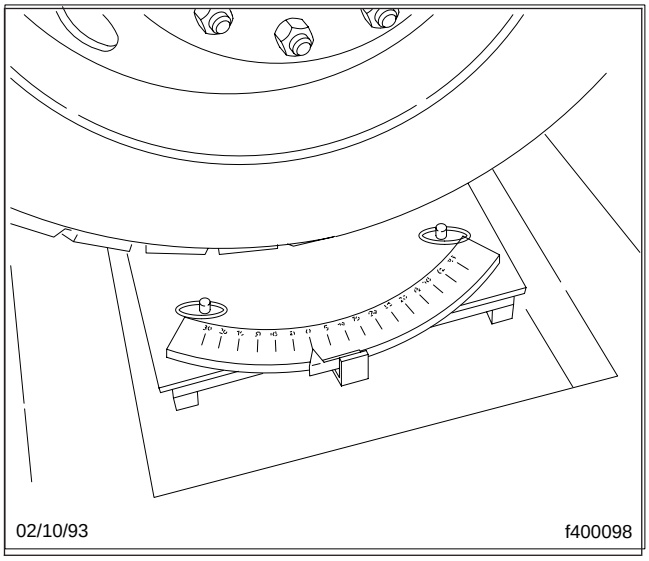


Fig. 2, Turn-Plate (Turntable), Stationary Type

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** in this manual.
7. Drive the vehicle off the turn-plates or turntables, or remove them from under the tires and lower the vehicle.

Checking

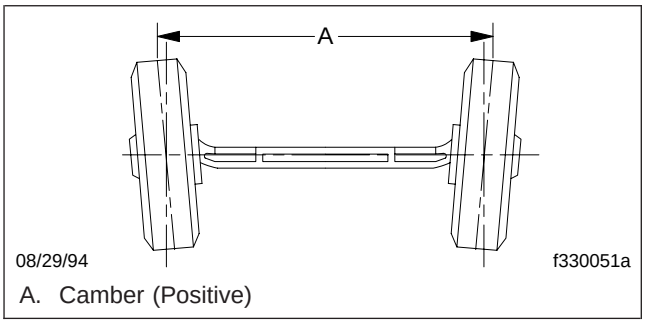


Fig. 1, Camber Angle

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. Freightliner 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. See **Fig. 1**. 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.
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.

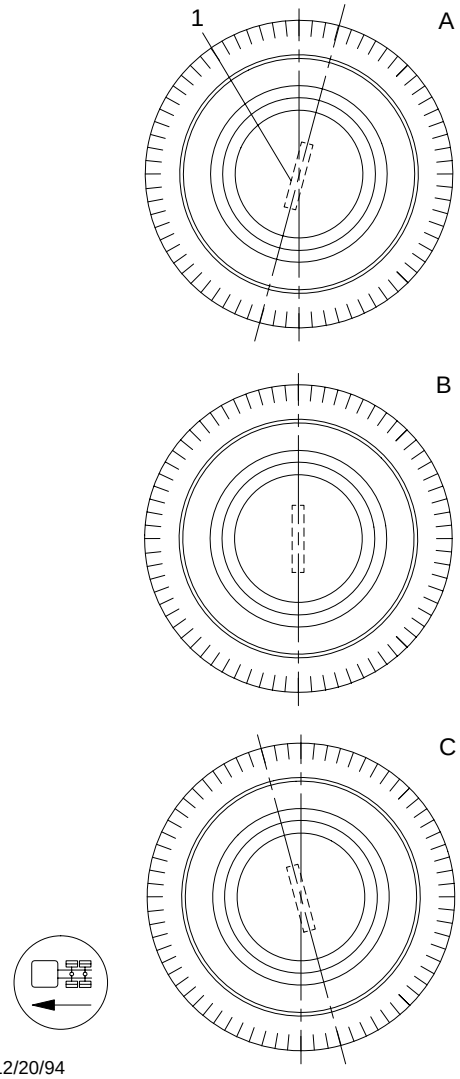
   Incorrect camber angles could be caused by damage in one or more of the following front axle components: the knuckle pin, the knuckle pin bushings, the axle spindle, or the axle beam. Replace twisted or otherwise damaged components. Don't try to straighten twisted or bent components; replace them with 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

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.

Checking and Adjusting



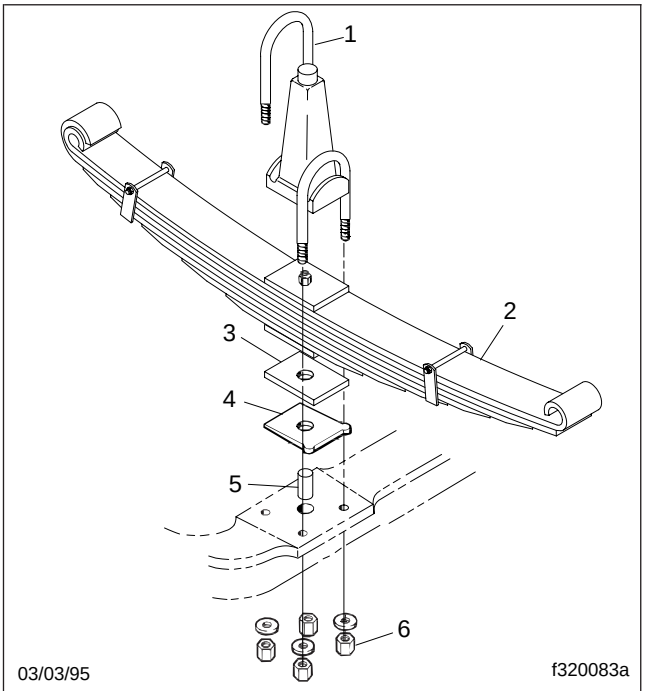
A. Positive Caster
B. Zero Caster
C. Negative Caster
1. Knuckle Pin (Kingpin)

Fig. 1, Caster 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. Freightliner dealers must have proof of this calibration history.

Using the alignment equipment manufacturer's operating instructions, measure the front wheel caster. See **Fig. 1**.

Compare the caster angles with those shown the appropriate table in **Specifications, 400**. If needed, adjust the caster angle by placing wedge-shaped shims between the axle spacer and the axle beam, as follows. See **Fig. 2**:



1. Axle Spring U-Bolt
2. Leaf Spring Assembly
3. Spacer
4. Front Caster Shim
5. Dowel Pin
6. U-Bolt High Nut

Fig. 2, Axle Spring Installation

IMPORTANT: Extreme angle shims cannot be used to correct caster angles that vary by more than 2 degrees from the values in the table. Weak or broken leaf springs, or worn shackle bushings, can cause extreme deviations to caster angles. Replace damaged parts before doing caster adjustments.

Caster Angle Checking and Adjusting

1. Apply the parking brakes, and chock the front and rear tires.
2. Back off the U-bolt nuts from the U-bolts on one side of the front axle. See **Fig. 2**.
3. Raise the spring away from the axle enough to allow removal of the front caster shim.
4. Remove the shim, and install one that will provide the correct caster angle, as specified in the table in **Specifications, 400**. Install the dowel pin and check penetration.

IMPORTANT: Place front caster shims between the axle beam and the axle spacer, or between the axle beam and the shock absorber bracket. See **Fig. 2**.

5. Lower the vehicle onto the axle.
6. Coat the threaded ends of the U-bolts with chassis lube or an antiseize compound, such as Loctite® 242. Tighten the U-bolt nuts to the value in the appropriate table in **Specifications, 400**.

   U-bolt nuts need periodic retightening. Refer to the suspension section in the vehicle maintenance manual for recommended intervals.

⚠ CAUTION

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. Remove the chocks from the tires. Do a final caster angle check.

Checking and Adjusting

Using the alignment equipment manufacturer's operating instructions, measure the wheel toe-in. Compare the measurement with that shown in the appropriate table in **Specifications, 400**. If corrections are needed, go to the applicable (tie rod adjustment) step below. See **Fig. 1**.

IMPORTANT: For vehicle alignment to be accurate, the shop floor must be level in every direction. The turn plates for the front wheels must rotate freely without friction, and the alignment equipment must be calibrated every three months by a qualified technician from the equipment manufacturer. Freightliner dealers must have proof of this calibration history.

1. Apply the parking brakes, and chock the rear tires.
2. Raise the front of the vehicle until the tires clear the ground. Place safety stands under the axle. Make sure the stands will support the weight of the cab, axle, and frame.
3. Using spray paint or a piece of chalk, mark the entire center rib of each front tire.
4. Place a scribe or pointed instrument against the marked center rib of each tire, and turn the tires. The scribes must be held firmly in place so that a single straight line is scribed all the way around each tire.
5. Place a turn-plate or turntable under each tire. Remove the safety stands from under the axle, then lower the vehicle. Remove the lockpins from the gauges; make sure the tires are exactly straight ahead.

NOTE: If turn-plates or turntables are not available, lower the vehicle. Remove the chocks from the rear tires and release the parking brakes. Move the vehicle backward and then forward about six feet (2 meters).

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.

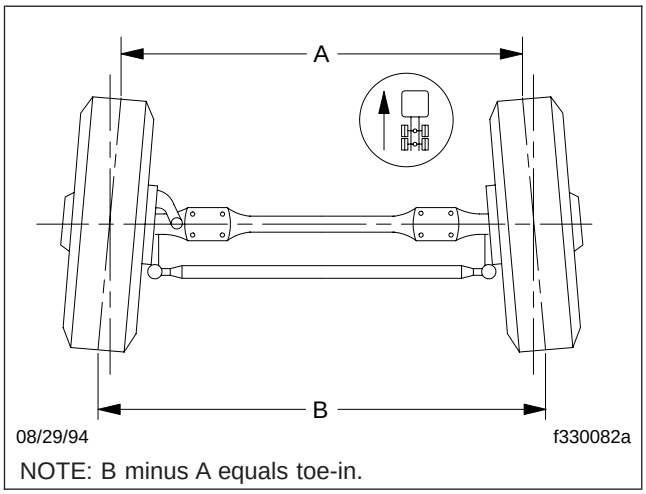


Fig. 1, Wheel Toe-In (Overhead View)

7. Place the trammel bar at the front of the tires as shown in **Fig. 2**. Adjust the scale end so that the pointers line up with the scribe lines. See **Fig. 3**.
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 six feet (two 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.

   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.

Wheel Toe-In Checking and Adjusting

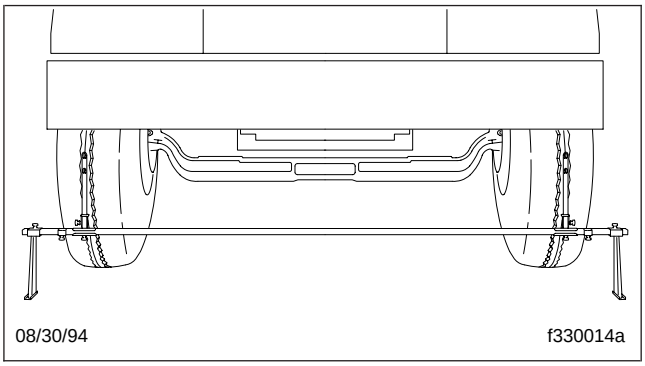


Fig. 2, Trammel Bar Positioning

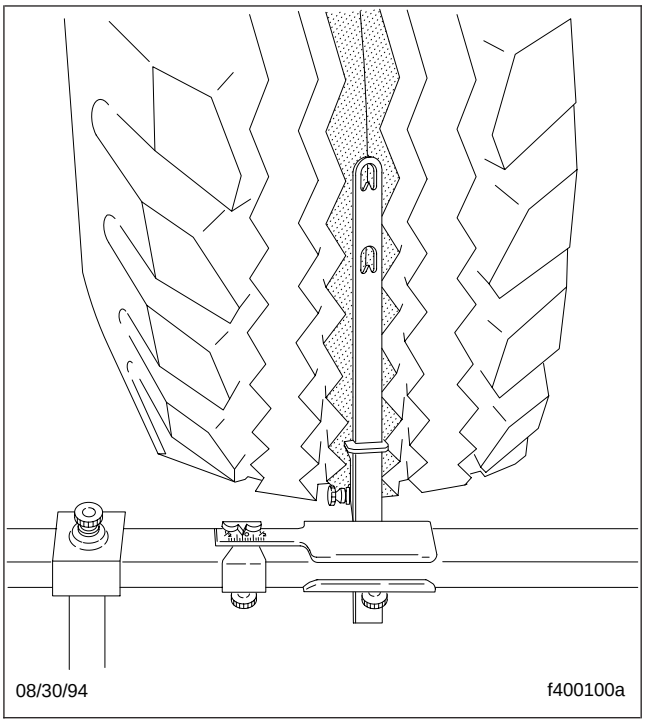


Fig. 3, Calculating Wheel Toe-In

Specifications

IMPORTANT: When aligning the front axle, it is essential that the rear axle(s) be checked for correct alignment at the same time. Alignment of the rear axle(s) has a direct impact on how the vehicle tracks. See **Section 35.00**, Specifications 400.

Camber and Toe-In					
Axle Manufacturer	**Axle Model**	**Left Camber (deg)**	**Right Camber (deg)**	**Toe-In Limits in (mm)**	**Toe-In Target in (mm)**
Meritor	FC–941 FF–961 FC–965 FD–965	Axles built before September 1992: * +1/2 ± 7/16 Axles built from September 1, 1992: * 0 ± 7/16	0 ± 7/16	0 to +1/8 † (0 to +3.175)	+1/16 (+1.5785)

* A manufacturer's code tag is riveted to the front of the axle beam for identification. Tags with no date code, or with a date code followed by the letter "P" (for example "24592P"), were manufactured before September 1, 1992.
† If adjustment is required, set the toe-in as close as possible to +1/32 inch.

Table 1, Camber and Toe-In

Caster				
Axle Model	**Bee Line Except LC 4000 (deg)**	**Bee Line LC 4000 Models (deg)**	**Hunter**	**Target, All Models (deg)**
Meritor	Manual Steering: +1-3/4 to +3-1/4	Manual Steering: +1-1/4 to +2-1/4	Manual Steering: +1-1/4 to +2-1/2	+3-1/2 to +4
Meritor	Power Steering: +3 to +6-1/2	Power Steering: +2-1/4 to +4-3/4	Power Steering: +1-1/2 to +5	+3-1/2 to +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 T lbf·ft (N**
Meritor	FC–941, FF–961, FC–965, FD–965	5/8–11	40–60 (54–81)	40–60 (5
Meritor	FC–941, FF–961, FC–965, FD–965	5/8–18	40–60 (54–81)	40–55 (5

* 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	
Description	**Torque lbf·ft (N·m)**
U-Bolt Nuts 7/8–14	400 (542)
Meritor Stopscrew Locknut	50–65 (68–88)

Table 4, Miscellaneous Torque Values

General Information

The front axle full-floating wheel hub assembly is made up of four major components: tapered wheel bearings, the wheel hub, wheel studs, and the brake drum or rotor. See **Fig. 1**.

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. 2**. 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. The bearing setting is locked in place on the axle spindle (steering knuckle) by an adjusting nut and jam nut. See **Fig. 3**.

WHEEL HUB

The wheel and the brake drum or rotor are mounted on a steel 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.

Spoke wheels combine the wheel and hub into a single unit.

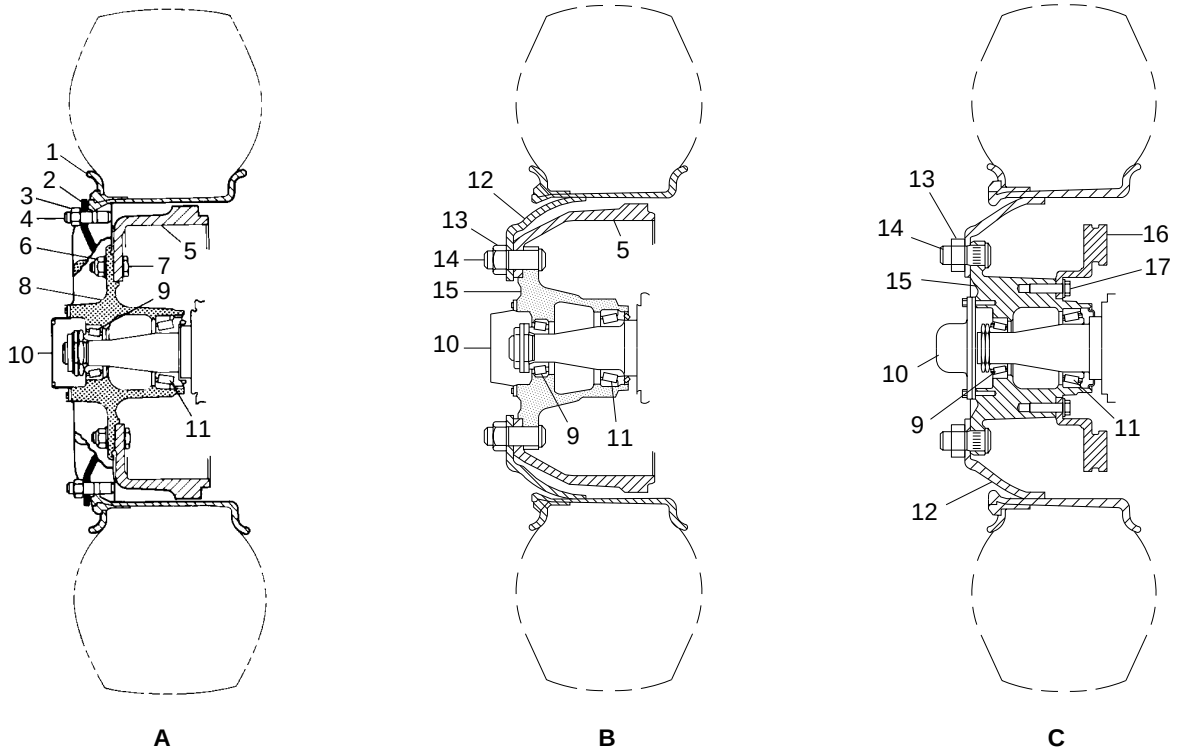
WHEEL STUDS

A headed wheel stud is used on front axle disc wheel hub assemblies and has serrations on the stud body to prevent the stud from turning in the wheel hub. See **Fig. 5**.

The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the driver's side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the passenger's side of the vehicle.

Spoke wheels have rim studs. Rim studs are threaded on both ends, with a non-threaded section midway along the shaft of the stud. The studs are coated with an anaerobic locking compound.

General Information

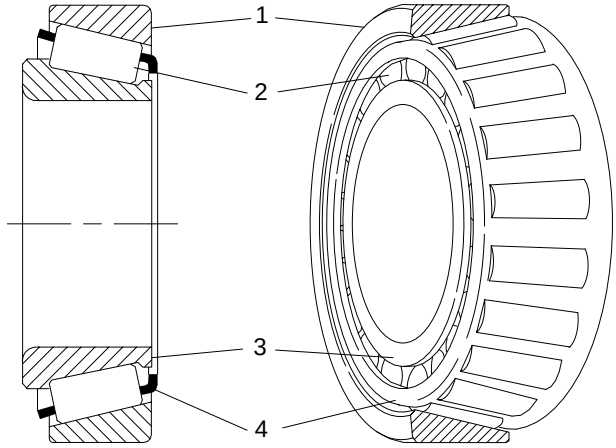


06/20/95 f330067a

A. Spoke Wheel Assembly with Drum Brakes
B. Disc Wheel Assembly with Drum Brakes
C. Disc Wheel Assembly with Disc Brakes

1. Rim
2. Rim Clamp
3. Rim Stud Nut
4. Rim Stud
5. Brake Drum
6. Brake Drum Nut
7. Brake Drum Bolt
8. Spoke Wheel
9. Outer Wheel Bearing
10. Hub Cap
11. Inner Wheel Bearing
12. Disc Wheel
13. Wheel Nut
14. Wheel Stud
15. Hub
16. Brake Rotor
17. Rotor Bolt

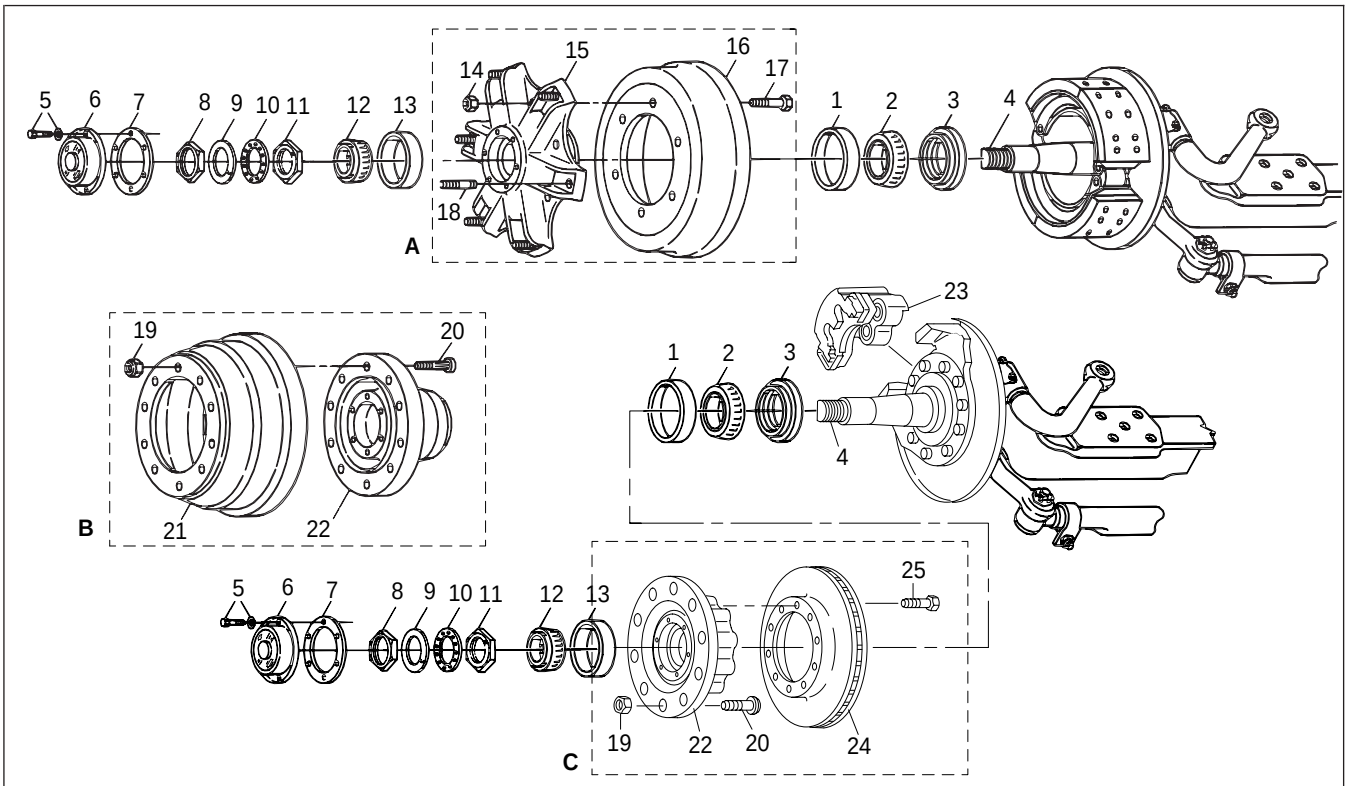
Fig. 1, Hub and Wheel Assemblies



1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Wheel Bearing

General Information



06/13/94 f330069a

A. Spoke Wheel and Inboard-Mounted Drum Assembly
B. Disc Wheel, Hub, and Outboard-Mounted Drum Assembly
C. Disc Brake Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub
23. Brake Caliper
24. Brake Rotor
25. Rotor Bolt

Fig. 3, Typical Front Axle Assembly

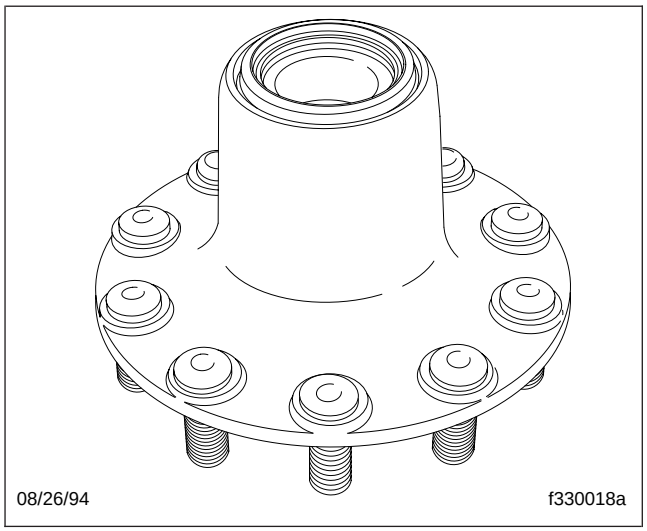
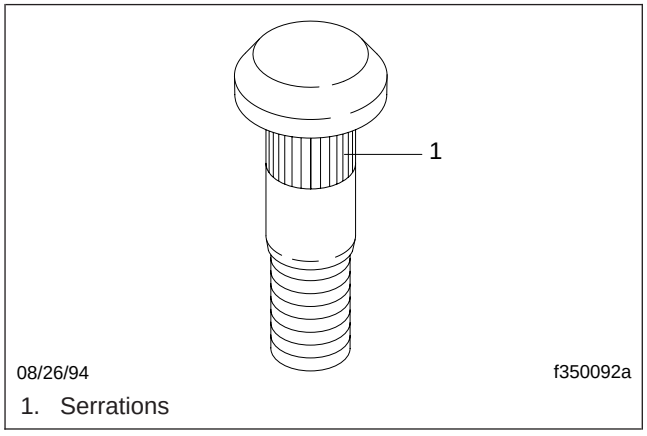


Fig. 4, Front Axle Wheel Hub



1. Serrations

Fig. 5, Wheel Stud

Hub Assembly Removal and Installation, Disc Wheels

Removal

1. Apply the parking brakes, and chock the rear tires to prevent vehicle movement.
2. Raise the front of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. On vehicles equipped with air brakes, back off the slack adjuster to release the front axle brake shoes. For instructions, refer to the applicable slack adjuster section in **Group 42**.
4. Remove the wheel and tire assembly. See **Group 40** for instructions.

⚠ WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

5. To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. See **Fig. 1**. 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.
6. Remove the brake drum (air brakes) or brake caliper (hydraulic brakes). For instructions, see **Group 42**.

NOTE: On vehicles equipped with oil-lubricated bearings, 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. Dispose of the oil safely.

7. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket.
8. Remove the axle spindle (steering knuckle) jam nut, lockwasher, and lockring or cotter pin. See **Fig. 2** or **Fig. 3**.
9. Back off the wheel bearing adjusting nut about two turns, or enough to allow the weight of the hub to be lifted from the wheel bearings.
10. Lift the hub until all weight is removed from the wheel bearings; remove the adjusting nut.

⚠ 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.

11. 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).
12. Carefully remove the outer wheel bearing. Handle the bearing assembly with clean, dry hands; wrap all bearing assembly parts in clean oil-proof paper or lint-free rags.

⚠ CAUTION

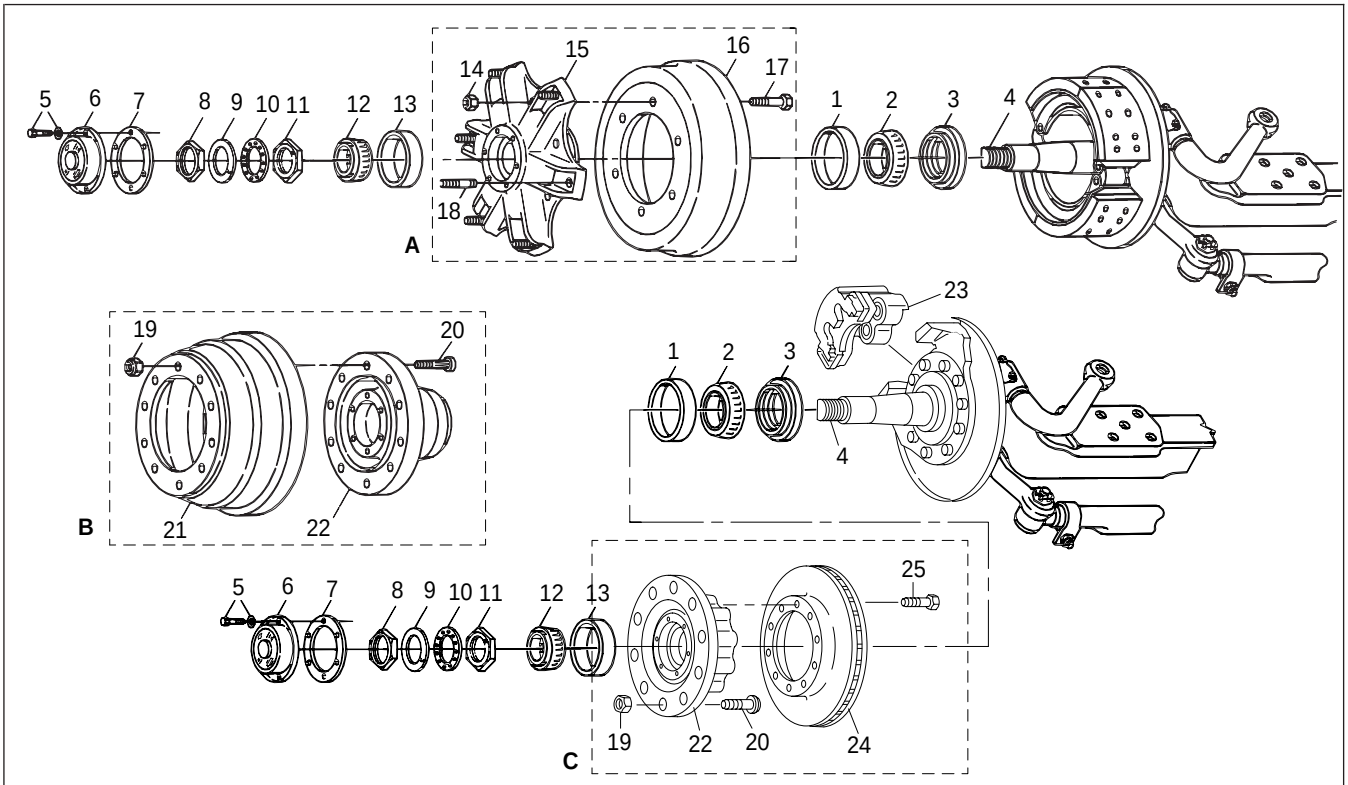
Do not spin the bearing rollers at any time. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

13. Remove the hub from the axle spindle. Be careful not to damage the axle spindle threads as the assembly is removed.
14. Remove the oil or grease seal from the hub with a seal removal tool.
15. Remove the inner wheel bearing from the hub. Handle the bearing assembly with clean, dry hands.

    If the bearing isn't easy to remove, place a protective cushion to catch it. Then, use a hardwood drift and a light hammer to gently tap the bearing (and seal, if needed) out of the cup. Wrap all bearing assembly parts in clean, oil-proof paper or lint-free rags.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

Hub Assembly Removal and Installation, Disc Wheels



06/13/94 f330069a

A. Spoke Wheel and Inboard-Mounted Drum Assembly
B. Disc Wheel, Hub, and Outboard-Mounted Drum Assembly
C. Disc Brake Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub
23. Brake Caliper
24. Brake Rotor
25. Rotor Bolt

Fig. 1, Typical Front Axle Assembly

16. Using an emery cloth or file, remove all burrs from the hub shoulder. See **Fig. 4** or **Fig. 5**.

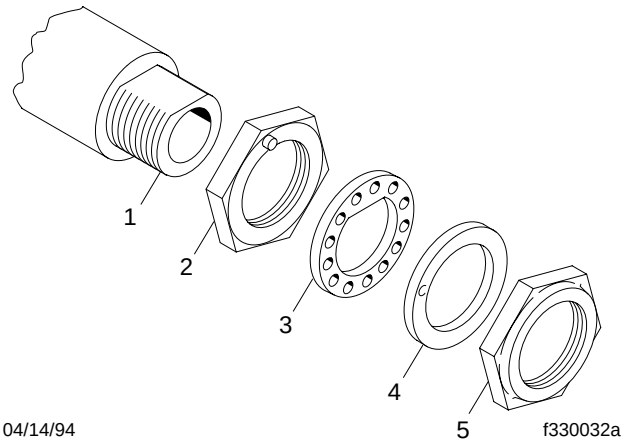
    Clean any metal filings from the parts. For instructions, see **Subject 110**.

Installation

⚠ WARNING

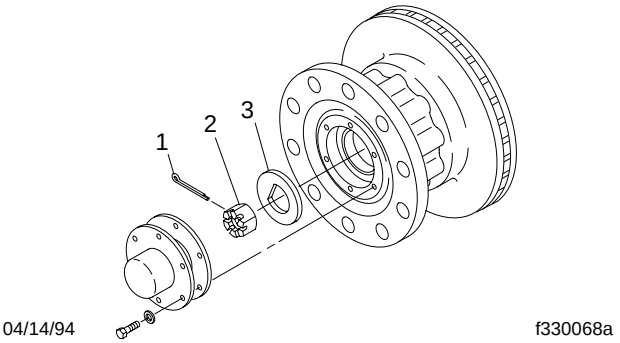
Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a res-

Hub Assembly Removal and Installation, Disc Wheels



1. Axle Spindle
2. Adjusting Nut
3. Lockring
4. Lockwasher
5. Jam Nut

Fig. 2, Axle With Jam Nut and Lockring

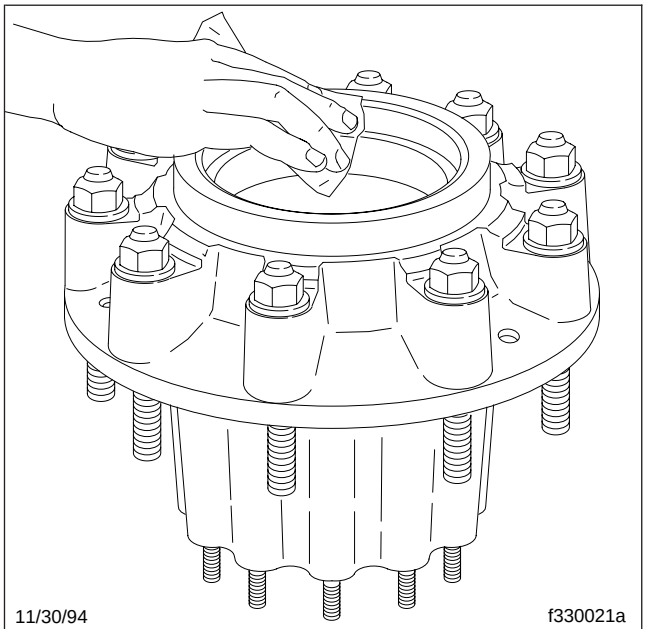


1. Cotter Pin
2. Adjusting Nut
3. Thrustwasher ("D" Washer)

Fig. 3, Single Nut Adjustment Hub Assembly, With Disc Brakes Shown

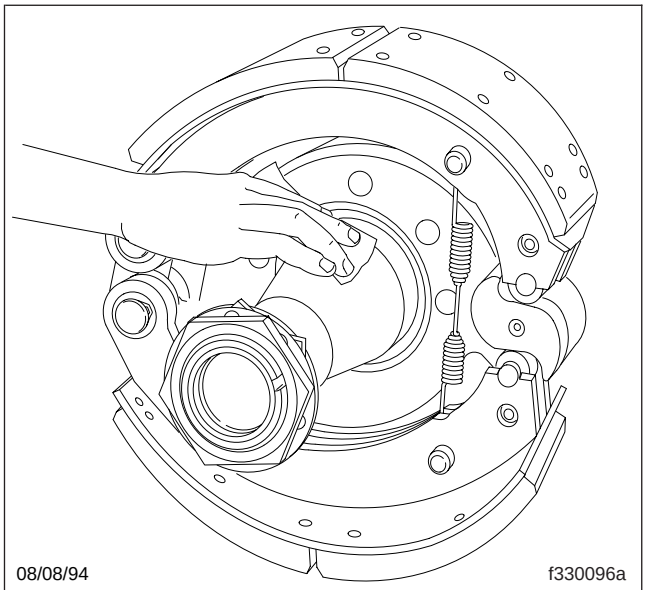
pirator at all times when servicing the brakes, continuing through installation of the wheels.

1. Using clean solvent, remove the old oil or grease from the axle spindle (steering knuckle) and the disassembled parts. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper.
2. Wrap a protective layer of friction tape on the axle spindle threads.



NOTE: Typical application.

Fig. 4, Clean the Hub Shoulder



NOTE: Typical application.

Fig. 5, Clean the Spindle

Hub Assembly Removal and Installation, Disc Wheels

CAUTION

When coating the bearing assemblies with oil or grease, do not use old lube, which could be contaminated with dirt or water. Both are corrosives, and could damage the wheel bearings and hub.

3. If the axle is equipped with oil-lubricated bearings, coat them with fresh oil; if equipped with greased bearings, pack them using a pressure packer, if possible. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For lubricant specifications, see **Specifications, 400**.

   Install the inner wheel bearing and oil or grease seal. Handle the bearing assembly with clean, dry hands.

4. Depending on the type of bearing lubricant used on the axle, wipe a film of axle oil or grease on the axle spindle, to prevent rust from forming behind the inner wheel bearing.

5. Install the new oil or grease seals.

   5.1 Seat the small outer edge of the seal in the recess of the tool adaptor. See **Fig. 6**. The correct adaptor is identified on the box.

   5.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 7**. The plug prevents cocking of the seal in the bore.

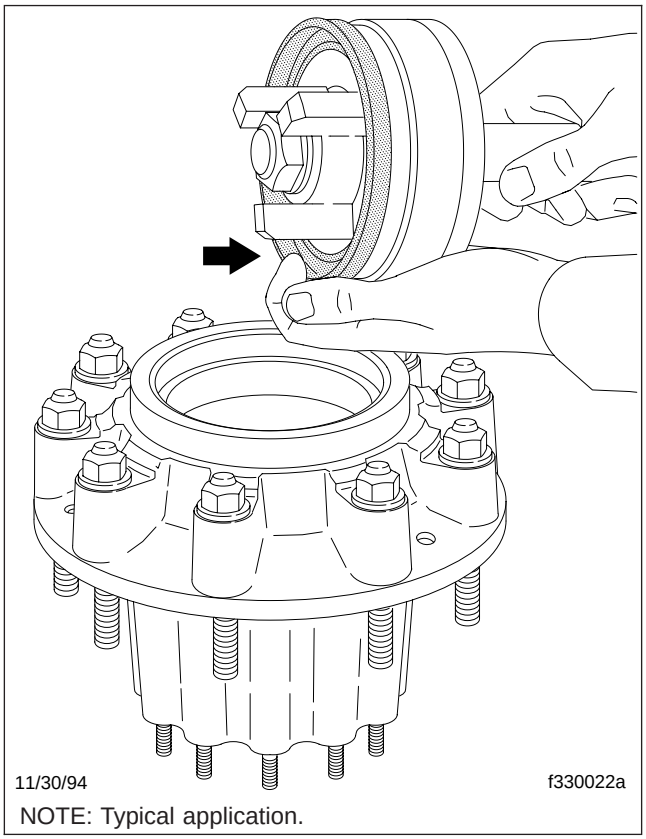
   5.3 Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms out. See **Fig. 8**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

   5.4 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.

6. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.

7. If the axle is equipped with oil-lubricated bearings, fill the hub cavity with oil; if equipped with greased bearings, pack the hub between the bearing cups with lubricant to the level of the smallest diameter of the cups. See **Fig. 9**.

   Install the outer wheel bearing. Handle the bearing assembly with clean, dry hands. Use care not to damage the bearing while seating it in the cup. Remove the friction tape from the axle spindle threads.



NOTE: Typical application.

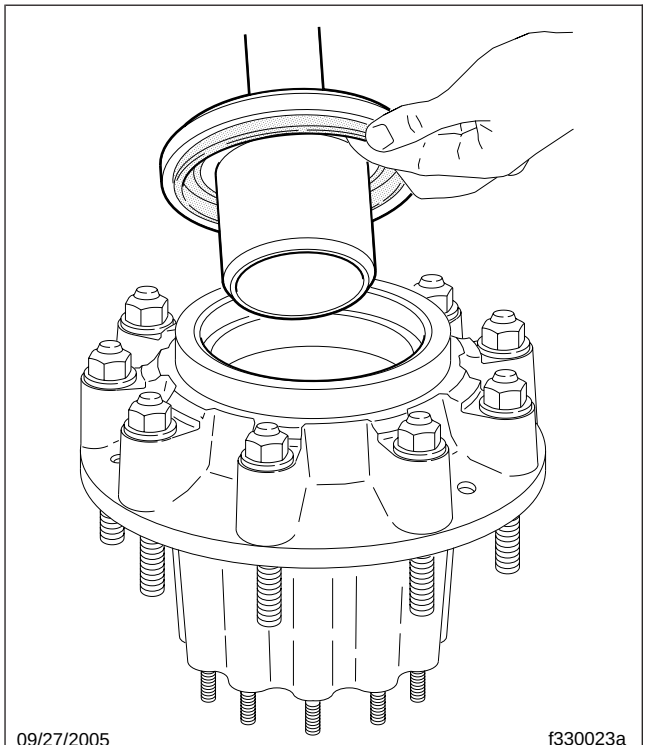
Fig. 6, Seat the Seal in the Tool

8. Install the wheel bearing adjusting nut. Tighten the nut finger-tight. Adjust the bearings. See **Fig. 2** or **Fig. 3**.

   IMPORTANT: Be sure there is sufficient clearance between the brake shoe and the brake drum, so brake shoe drag will not interfere with bearing adjustment.

   8.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 200 lbf·ft (271 N·m) while rotating the wheel hub assembly.

Hub Assembly Removal and Installation, Disc Wheels



NOTE: Typical application.

Fig. 7, Insert the Tool

8.2 Back off the inner nut one full turn.

8.3 Tighten the inner nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.

8.4 Back off the inner nut one quarter turn.

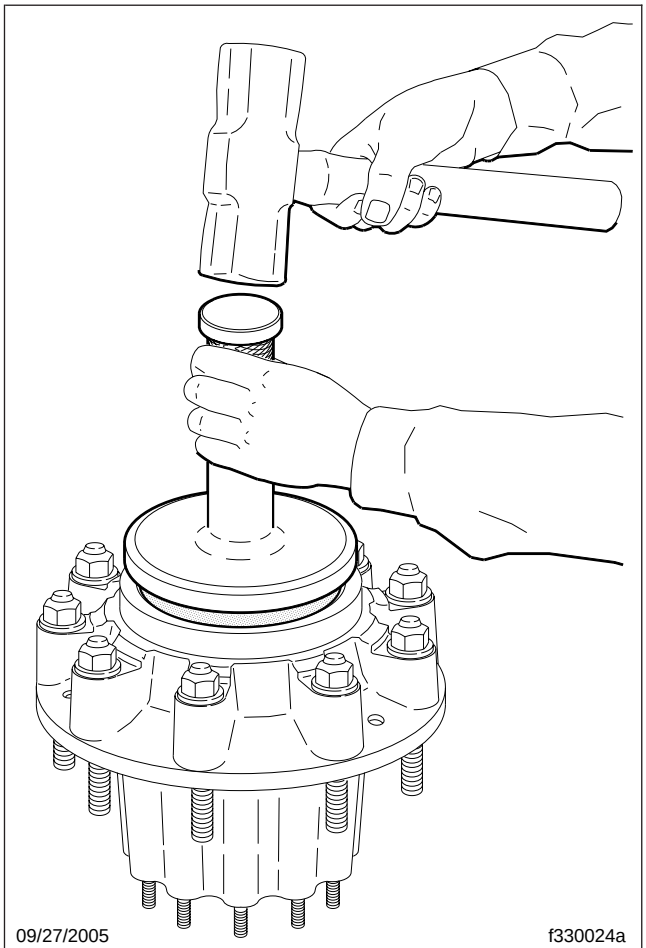
8.5 On applicable assemblies, install a new cotter pin, or install the jam nut and locking device as follows. See **Fig. 3**.

NOTE: If you're securing the wheel bearings with a pierced lockring and 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.

8.6 Install the locking device:

- Tanged nut-lock
- Lockring
- Lockwasher *and* a lockring
- Nut-lock *and* a lockring

Then install the jam nut, and tighten it to the applicable torque in **Table 1**.



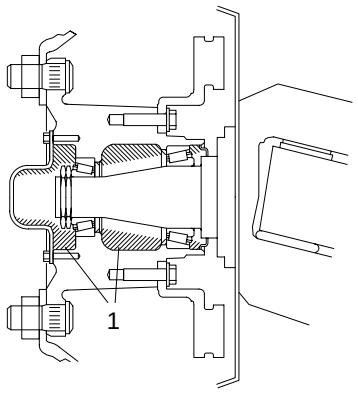
NOTE: Typical application.

Fig. 8, Strike the Tool

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.

8.7 With the jam nut installed and tightened, attach a dial indicator to the hub and set the point of the indicator in line with the end of the axle spindle.

Hub Assembly Removal and Installation, Disc Wheels



1. Lubricate here.

Fig. 9, Lubricate the Bearings

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.

8.8 Release the brakes if you used them to hold the drum while installing it.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then push the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then pull the hub (and drum, if applicable). Read the dial indicator, and note the end play.

Push the hub back in to confirm that the needle of the dial indicator returns to zero.

The end play must be between 0.001 and 0.005 inch (0.025 and 0.127 mm).

9. If the end play is not within this range, remove the jam nut and locking device, and back off or tighten the inner (adjusting) nut to adjust the end play. Keep the following in mind:

If you're using a nut-lock: turning the inner nut 1/4 turn will change the end play about 0.014 inch (0.355 mm).

If you're using a lockring: turning the inner nut one lockring hole will change the end play about 0.005 inch (0.127 mm). If you take the lockring off and reverse it, then turn the inner nut to the next hole, this will change the end play about 0.0025 inch (0.0635 mm).

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 (0.025 and 0.127 mm), adjust the inner (adjusting) nut, again.

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

Hub Assembly Removal and Installation, Disc Wheels

10. Once the end play is correct, bend the nut-lock or lockwasher as applicable to lock the jam nut and/or adjusting nut in place.
11. Rotate the wheel in both directions. It should turn freely with no dragging or binding.
12. If the axle is equipped with grease-packed bearings, pack the hub between the bearing cups with lithium-based wheel bearing grease to the level of the smallest diameter of the cups. See **Fig. 9**.
13. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews to the torque value in the torque table in **Specifications, 400**.

    If the axle is equipped with oil-lubricated bearings, add fresh oil to the wheel hub to the level shown on the hub cap. Refer to **Specifications, 400** for recommended axle lubricants.

⚠ 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. See Fig. 10. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury due to loss of vehicle control.

14. Install the brake drum or caliper on the wheel hub. See **Group 42** for instructions.
15. Install the wheel and tire assembly. See **Group 40** for instructions.

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, and the wheel hub flange is probably damaged. In this case, replace it with a new wheel hub assembly. Failure to replace the wheel hub assembly when these conditions exist could result in the loss of a wheel or loss of vehicle control, and possible personal injury.

16. Adjust the front axle brakes. For instructions, see **Group 42** of the *School Bus Chassis Maintenance Manual*.

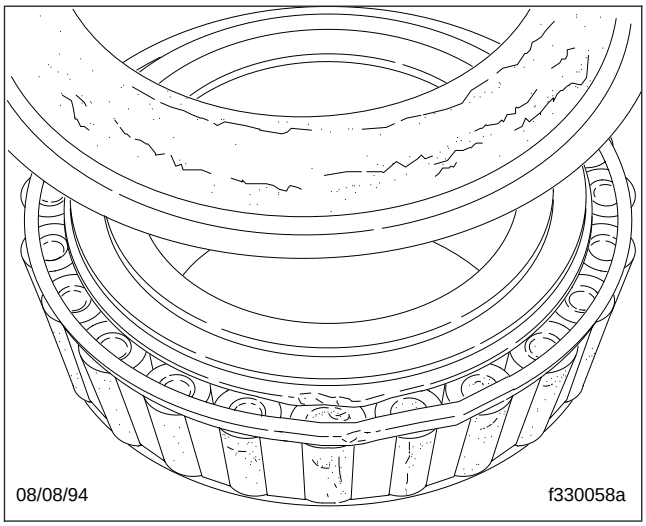
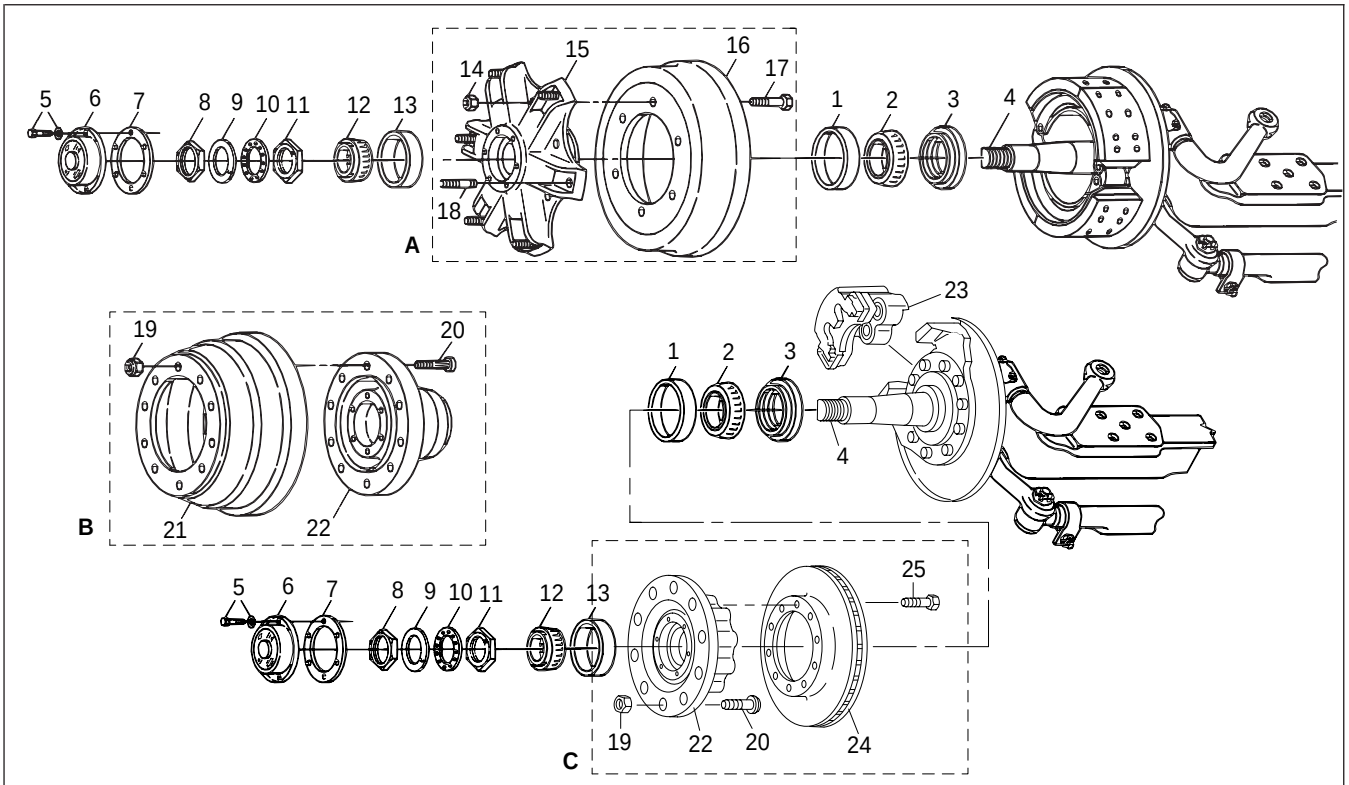


Fig. 10, Bearing Damage Resulting from Inadequate Lubrication

17. Remove the safety stands from under the axle; lower the vehicle.
18. Remove the chocks from the rear tires.

Hub Assembly Removal and Installation, Spoke Wheels

Removal



06/13/94 f330069a

A. Spoke Wheel and Inboard-Mounted Drum Assembly
B. Disc Wheel, Hub, and Outboard-Mounted Drum Assembly
C. Disc Brake Assembly

1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle (Steering Knuckle)
5. Hub Cap Capscrew and Washer
6. Hub Cap
7. Hub Cap Gasket
8. Jam Nut
9. Lockwasher
10. Lockring
11. Wheel Bearing Adjusting Nut
12. Outer Wheel Bearing
13. Outer Wheel Bearing Cup
14. Brake Drum Nut
15. Spoke Wheel
16. Brake Drum, Inboard-Mounted
17. Brake Drum Bolt
18. Rim Stud
19. Wheel Nut
20. Wheel Stud
21. Brake Drum, Outboard-Mounted
22. Wheel Hub
23. Brake Caliper
24. Brake Rotor
25. Rotor Bolt

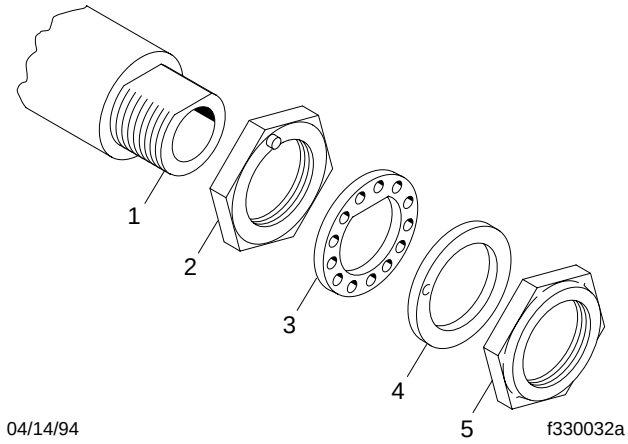
Fig. 1, Typical Front Axle Assembly

1. Apply the parking brakes, and chock the rear tires to prevent vehicle movement.
2. Raise the front of the vehicle until the tires clear the ground; place safety stands under the axle. Position a jack or wheel-and-tire dolly under the tire.
3. On vehicles equipped with air brakes, back off the slack adjuster to release the front axle brake shoes. For instructions, refer to the applicable slack adjuster section in **Group 42**.
4. Remove the rim and tire assembly. See **Group 40** for instructions.

Hub Assembly Removal and Installation, Spoke Wheels

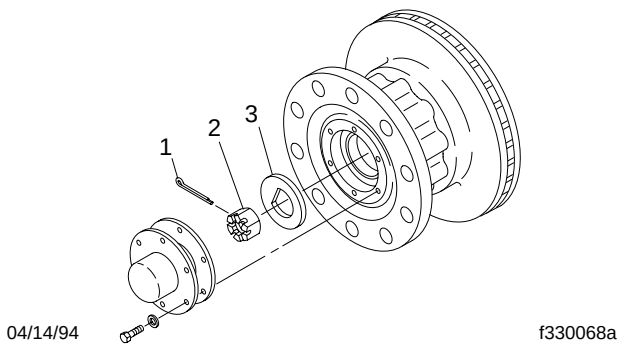
NOTE: On axles equipped with oil-lubricated bearings, oil will spill as the hub cap is removed. Place a suitable container under the wheel to catch any spilled oil. Dispose of the oil safely.

5. Remove the capscrews, washers, and hub cap. Remove and discard the hub cap gasket and oil. See **Fig. 1**.
6. Remove the axle spindle (steering knuckle) jam nut, lockwasher, and lockring or cotter pin. See **Fig. 2** or **Fig. 3**.



1. Axle Spindle
2. Adjusting Nut
3. Lockring
4. Lockwasher
5. Jam Nut

Fig. 2, Axle With Jam Nut and Lockring



1. Cotter Pin
2. Adjusting Nut
3. Thrustwasher ("D" Washer)

Fig. 3, Single Nut Adjustment Hub Assembly, With Disc Brakes Shown

7. Back off the wheel bearing adjusting nut about two turns, or enough to allow the weight of the wheel and drum assembly to be lifted from the wheel bearings.
8. Using an adjustable wheeled support, raise the wheel and drum assembly until all weight is removed from the bearings. Remove the adjusting nut.
9. Carefully remove the outer wheel bearing. Handle the bearing assembly with clean, dry hands. If the bearing hasn't loosened from the cup, move the wheel assembly about 1/2 inch (13 mm) to jar loose the outer wheel bearing. Be careful to not drop the bearing. Wrap all bearing assembly parts in clean oil-proof paper or lint-free rags.

CAUTION

Do not spin the bearing rollers at any time. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

10. Using the wheeled support, pull the wheel assembly away from the vehicle. Be careful not to damage the axle spindle threads as the assembly is removed.

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.

11. To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Don't use compressed air or dry brushing to clean the brake assembly.

Hub Assembly Removal and Installation, Spoke Wheels

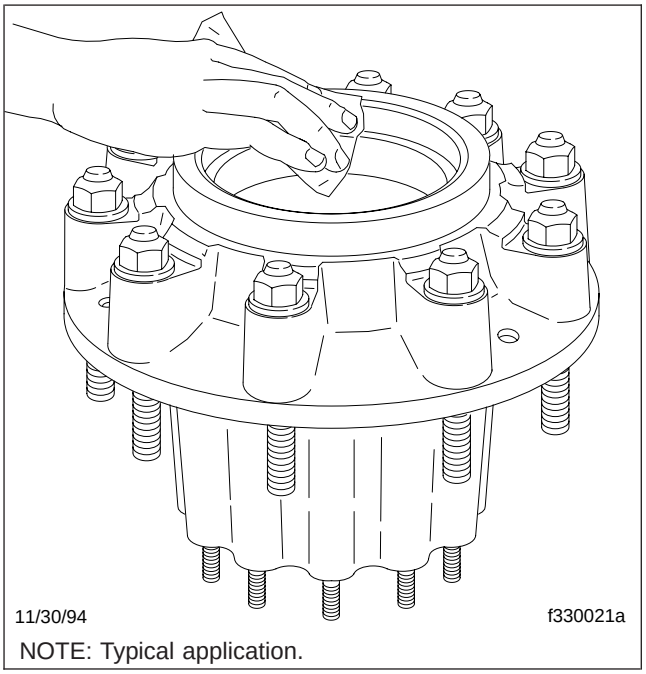
12. Remove the brake drum or rotor nuts and detach the brake drum or rotor from the wheel. See **Fig. 1**.
13. Remove the oil or grease seal using a seal removal tool.
14. Remove the inner wheel bearing from the hub. Handle the bearing assembly with clean, dry hands.

    If the bearing isn't easy to remove, place a protective cushion to catch it. Then, use a hardwood drift and a light hammer to gently tap the bearing (and seal, if needed) out of the cup. Wrap all bearing assembly parts in clean, oil-proof paper or lint-free rags.

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

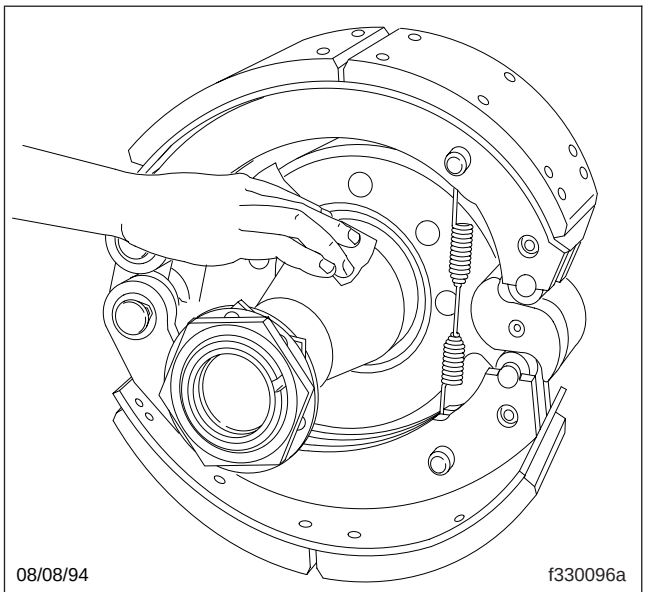
15. Using an emery cloth or file, remove all burrs from the hub shoulder. See **Fig. 4** or **Fig. 5**.

    Clean any metal filings from the parts. For instructions, see **Subject 110**.



NOTE: Typical application.

Fig. 4, Clean the Hub Shoulder



NOTE: Typical application.

Fig. 5, Clean the Spindle

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, starting with removal of the wheels and continuing through assembly.

1. Using clean solvent, remove the old oil or grease from the axle spindle (steering knuckle) and the disassembled parts. Inspect and clean the wheel hub cavity and the wheel bearings as instructed under **Subject 110**. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper.
2. Wrap a protective layer of friction tape on the axle spindle threads.
3. If it was removed, attach the brake drum or rotor to the hub. Install the bolts and nuts, then tighten the nuts 240 lbf·ft (325 N·m) for drum brakes and 130 lbf·ft (175 N·m) for disc brakes.

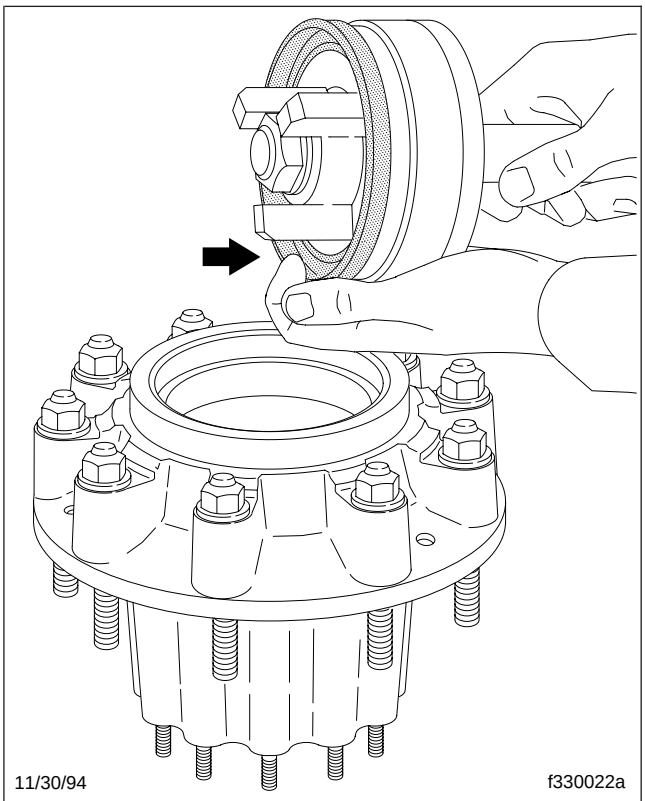
Hub Assembly Removal and Installation, Spoke Wheels

4. If the axle is equipped with oil-lubricated bearings, coat them with fresh oil; If equipped with greased bearings, pack them using a pressure packer, if possible. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For lubricant specifications, refer to **Specifications, 400**.

   Install the inner wheel bearing. Handle the bearing assembly with clean, dry hands.

5. Install the new oil or grease seals.

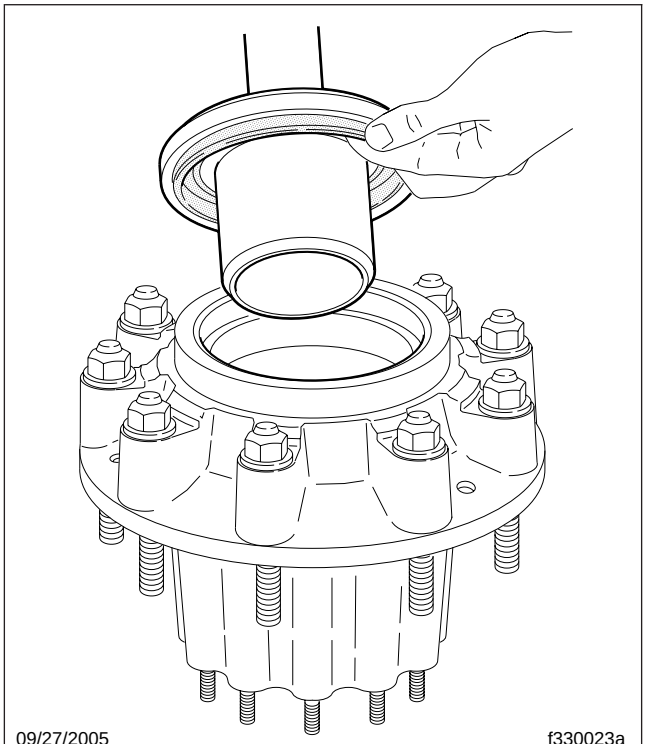
   5.1 Seat the small outer edge of the seal in the recess of the tool adaptor. See **Fig. 6**. The correct adaptor is identified on the box.



NOTE: Typical application.

Fig. 6, Seat the Seal in the Tool

   5.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 7**. The plug prevents cocking of the seal in the bore.



NOTE: Typical application.

Fig. 7, Insert the Tool in the Cone

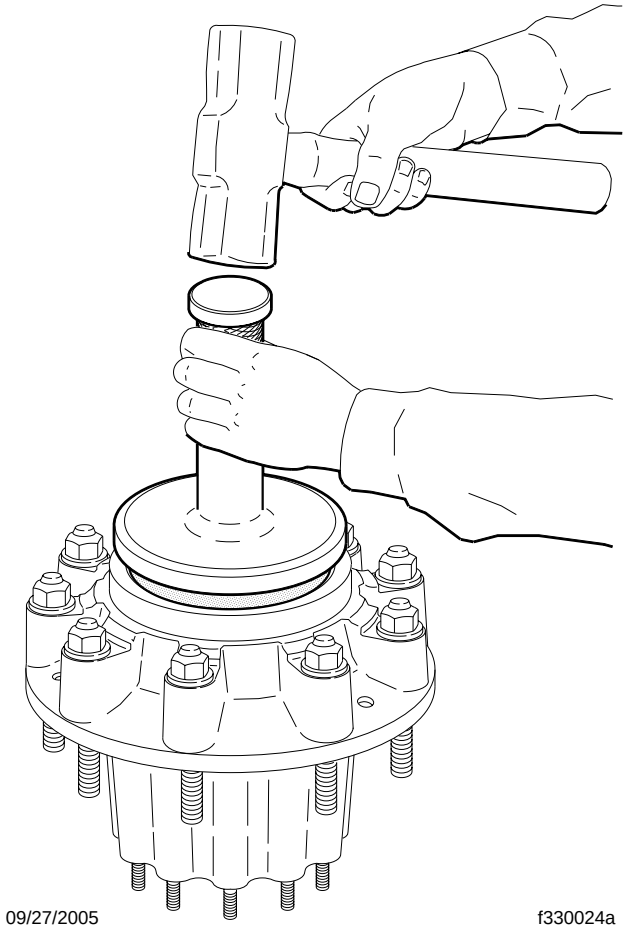
   5.3 Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms out. See **Fig. 8**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

   5.4 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.

6. Depending on the type of bearing lubricant used on the axle, wipe a film of axle oil or grease on the axle spindle, to prevent rust from forming behind the inner wheel bearing.

7. Using a wheeled support, mount the wheel and drum assembly on the axle spindle; be careful not to unseat the bearing or seal.

Hub Assembly Removal and Installation, Spoke Wheels



NOTE: Typical application.

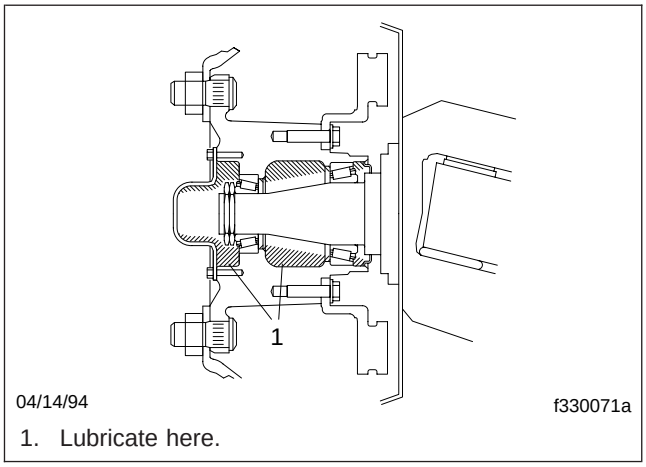
Fig. 8, Strike the Tool

8. If the axle is equipped with oil-lubricated bearings, fill the hub cavity with oil; if equipped with greased bearings, pack the hub between the bearing cups with lubricant to the level of the smallest diameter of the cups. See **Fig. 9**.

   Install the outer wheel bearing. Handle the bearing assembly with clean, dry hands. Use care not to damage the bearing while seating it in the cup. Remove the friction tape from the axle spindle threads.

9. Install the wheel bearing adjusting nut. Tighten the nut finger-tight. Adjust the bearings. See **Fig. 2** or **Fig. 3**.

   IMPORTANT: Be sure there is sufficient clearance between the brake shoe and the brake drum, so brake shoe drag won't interfere with bearing adjustment.



1. Lubricate here.

Fig. 9, Lubricate the Bearings

9.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 200 lbf·ft (271 N·m) while rotating the wheel hub assembly.

9.2 Back off the inner nut one full turn.

9.3 Tighten the inner nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.

9.4 Back off the inner nut one quarter turn.

9.5 On applicable assemblies, install a new cotter pin, or install the jam nut and locking device as follows. See **Fig. 3**.

NOTE: If you're securing the wheel bearings with a pierced lockring and 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.

9.6 Install the locking device:

- Tanged nut-lock
- Lockring
- Lockwasher *and* a lockring
- Nut-lock *and* a lockring

Hub Assembly Removal and Installation, Spoke Wheels

Then install the jam nut, and tighten it to the applicable torque in **Table 1**.

Dual-Nut Wheel Bearing Lock Torque Values		
Application	**Size**	**Torque: lbf·ft (N·m)**
Adjusting Nut	—	Stage 1: Tighten to 100 (135)
		Stage 2: Back Off Completely
		Stage 3: Tighten to 20 (25) While Rotating Hub
		Stage 4: Back Off 1/3 Turn
Jam Nut (with Wheel Bearing Nut, Pierced Lockwasher, and 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: 325 (440) Permissible Range: 250–400 (340–540)

Table 1, Dual-Nut Wheel Bearing Lock Torque Values

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.

9.7 With the jam nut installed and tightened, 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.

9.8 Release the brakes if you used them to hold the drum while installing it.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then push the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then pull the hub (and drum, if applicable). Read the dial indicator, and note the end play.

Push the hub back in to confirm that the needle of the dial indicator returns to zero.

The end play must be between 0.001 and 0.005 inch (0.025 and 0.127 mm).

10. If the end play is not within this range, remove the jam nut and locking device, and back off or tighten the inner (adjusting) nut to adjust the end play. Keep the following in mind:

If you're using a nut-lock: turning the inner nut 1/4 turn will change the end play about 0.014 inch (0.355 mm).

If you're using a lockring: turning the inner nut one lockring hole will change the end play about 0.005 inch (0.127 mm). If you take the lockring off and reverse it, then turn the inner nut to the next hole, this will change the end play about 0.0025 inch (0.0635 mm).

Hub Assembly Removal and Installation, Spoke Wheels

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 (0.025 and 0.127 mm), adjust the inner (adjusting) nut, again.

11. Once the end play is correct, bend the nut-lock or lockwasher as applicable to lock the jam nut and/or adjusting nut in place.
12. Rotate the wheel in both directions. It should turn freely with no dragging or binding.
13. If the axle is equipped with grease-packed bearings, pack the hub between the bearing cups with lithium-based wheel bearing grease to the level of the smallest diameter of the cups. See **Fig. 9**.
14. Place the hub cap and a new gasket in position, then install the washers and capscrews. Tighten the capscrews to the torque value in the torque table in **Specifications, 400**.
15. Install the rim and tire assembly. See **Group 40** for instructions.

⚠ WARNING

If the rim nuts cannot be tightened to minimum torque values, the rim studs have lost their locking ability, and the wheel hub flange is probably damaged. In this case, replace it with a new wheel. Failure to replace the wheel when these conditions exist could result in loss of a wheel or loss of vehicle control, and possible personal injury.

16. Lower and remove the jack or wheel-and-tire dolly from under the tires.
17. If the axle is equipped with oil-lubricated bearings, add fresh oil to the wheel hub to the level shown on the hub cap. See **Specifications, 400** for recommended axle lubricants.

⚠ 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. See Fig. 10. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury due to loss of vehicle control.

18. Adjust the front axle brakes. For instructions, refer to **Group 42**.

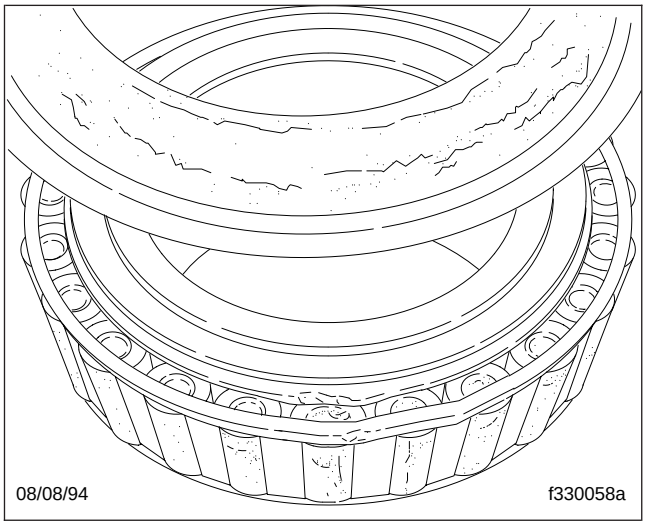


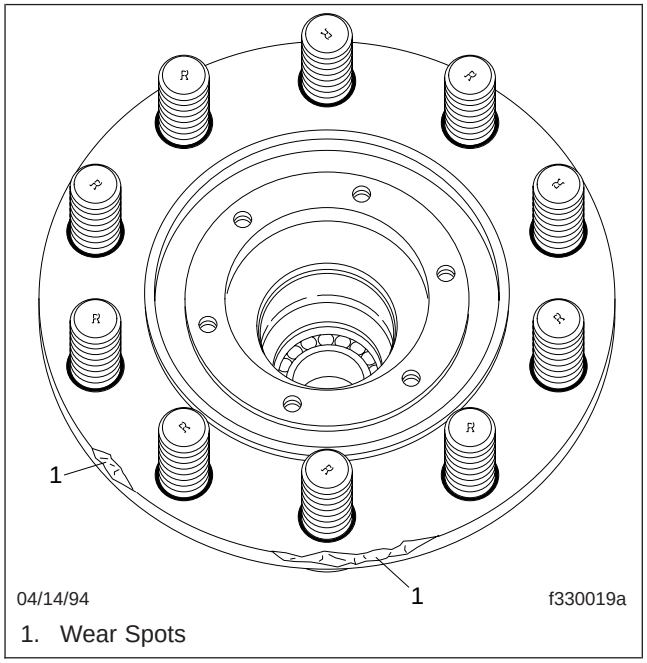
Fig. 10, Bearing Damage Resulting from Inadequate Lubrication

19. Remove the safety stands from under the axle; lower the vehicle.
20. 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.

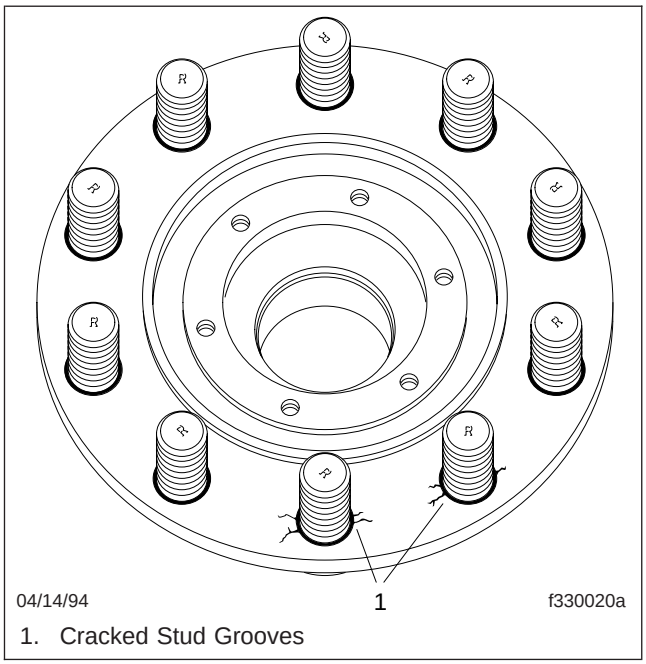
   Inspect the flange surface around the wheel studs. Improperly torqued wheel nuts will cause worn or cracked stud grooves on the hub. See **Fig. 2**. If wear spots or cracks appear anywhere on the hub, or if the hub is otherwise damaged, replace it with a new one.



1. Wear Spots

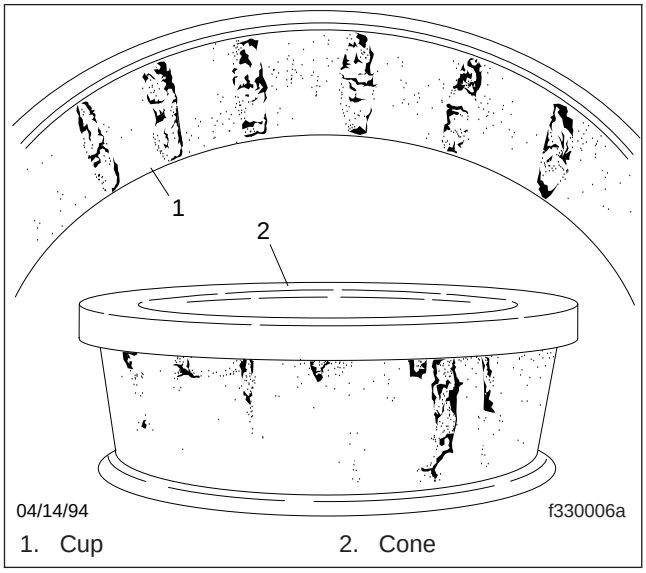
Fig. 1, Damaged Front Axle Wheel Hub

2. Remove all the old oil or grease from the spoke wheel or hub cavity. Inspect the inner surface of the wheel or hub for cracks, dents, wear, or other damage. Replace the wheel or hub if damaged.
3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way. See **Subject 120**.
4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts, usually caused by inadequate tightening, must be replaced with new ones. See **Fig. 4**.



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

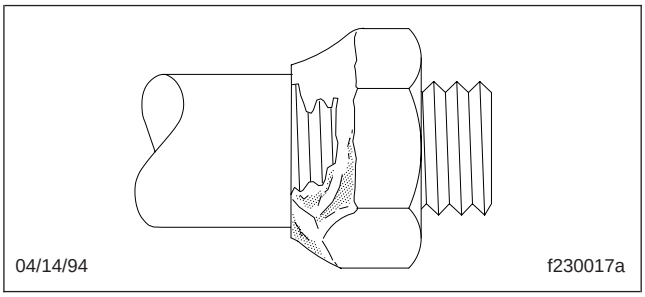


Fig. 4, Damaged Wheel Stud Nut

5. Inspect the wheel studs or rim studs. Replace studs that are stripped, broken, bent, or otherwise damaged. See **Subject 130** or **Subject 140**.

Wheel Bearing Cleaning and Inspection

CLEANING

⚠ WARNING

WARNING: To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, don't expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury if ignited.

⚠ CAUTION

CAUTION: Don't 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.

Wheel bearings should be very closely inspected at the time of disassembly. The best inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush. See **Fig. 5**. Before inspecting, clean the bearings, as described below.

1. Clean all old oil or grease from the bearings and hub cavities, with kerosene or diesel fuel and a stiff brush. See **Fig. 5**. Don't use gasoline or heated solvent.

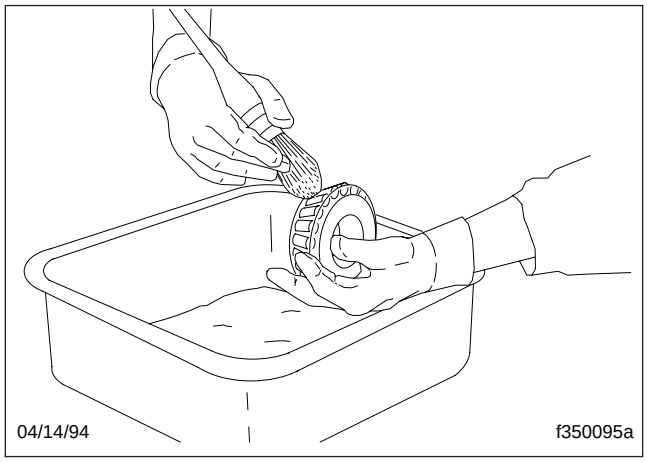


Fig. 5, Wheel Bearing Cleaning

2. 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.

INSPECTION

After the bearings are cleaned, inspect the assemblies, which include the rollers, cones, cups, and cages. If any of the conditions below exist, replace the bearing assemblies.

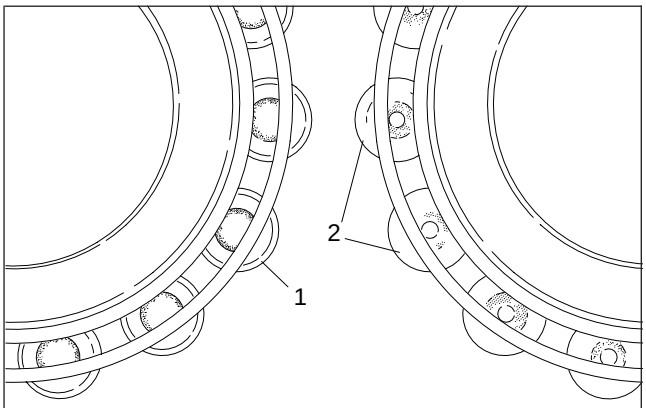
A. The large ends of the rollers are worn flush to the recess; the radii at the large ends of the rollers are worn sharp. These are signs of advanced wear. See **Fig. 6**.

B. Visible step wear, especially at the small end of the roller track, or deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 7**.

C. Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 8**.

D. 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, check the bearing seal sealing surfaces.

E. Etching or pitting on functioning surfaces. See **Fig. 9**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 6, Wheel Bearing Roller Wear

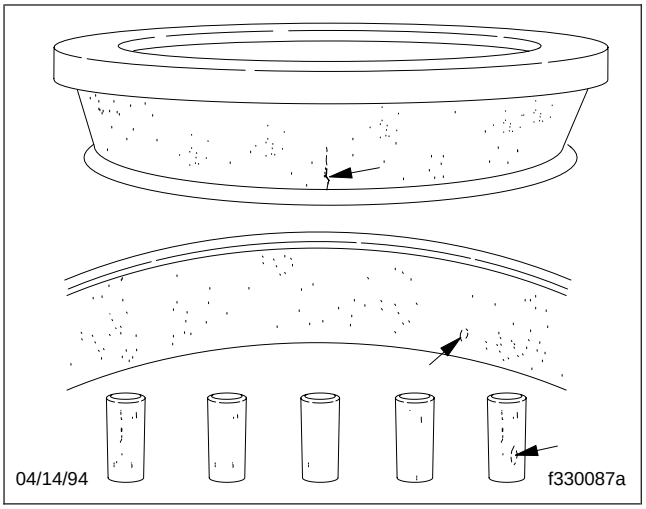


Fig. 7, Indentations, Cracks, or Breaks in Bearing Surfaces

F. Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, pack the bearings with fresh axle lubricant. If a packer is not available, pack the bearing by hand. Starting from the large end of the cone, force lithium-based wheel bearing grease into the cavities between the rollers and the cage. For installation, see **Subject 100** or **Subject 102**.

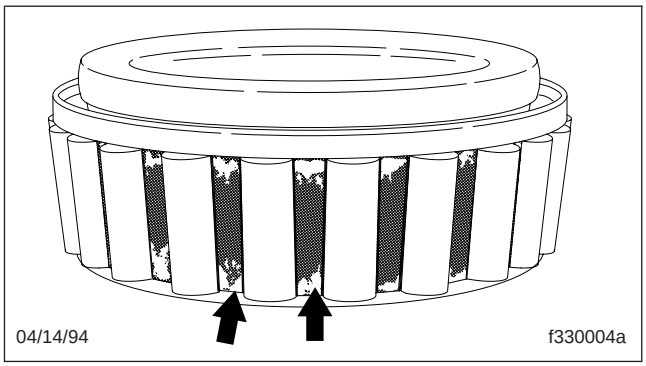


Fig. 8, Rubbing Marks on Bearing Cage

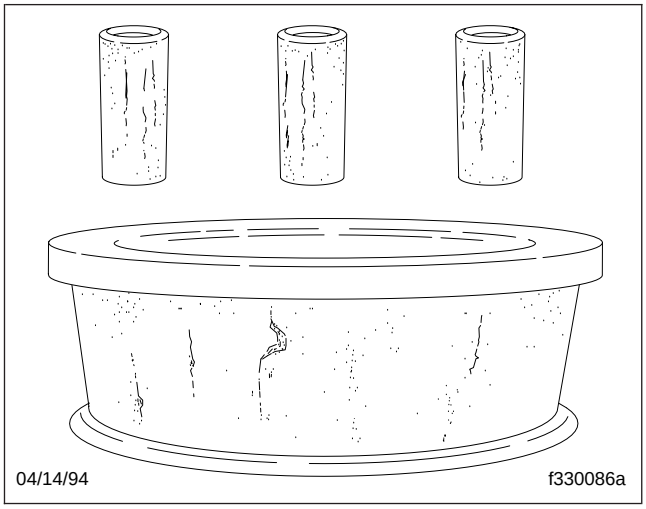


Fig. 9, Etching (Pitting) on Bearing Surfaces

Wheel Bearing Cup Removal and Installation, Ferrous Hubs

Removal

Wheel bearing cups in ferrous hubs are removed by driving them out; there is no need to first heat the hubs.

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

Wheel bearing cups are installed in ferrous hubs by pressing them in; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable driving tool. Cups must seat against the shoulder in the hub.

⚠ WARNING

WARNING: To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, don't expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury if ignited.

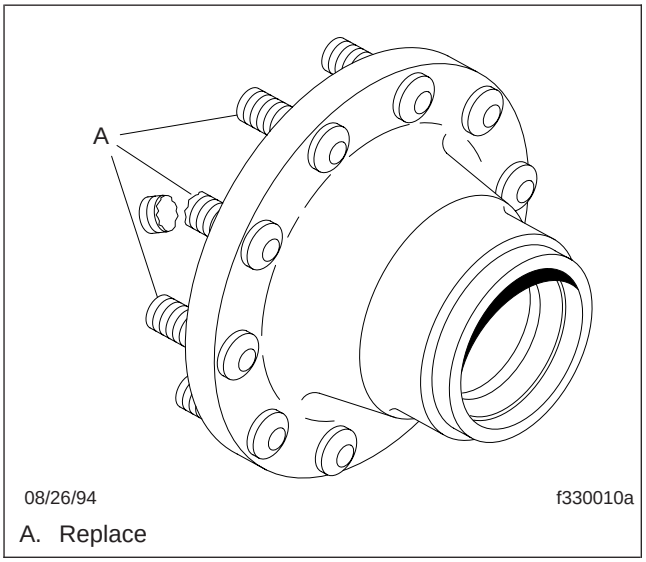
5. Wipe off the accumulation of grease left after the bearing cup has been seated. Then, using a clean lint-free cloth dampened with kerosene or diesel fuel oil, clean the inner surface of the bearing cup. Wipe the surface dry using a clean, absorbent, and lint-free cloth or paper.

Replacement

WARNING

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.

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 evenly supported around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.



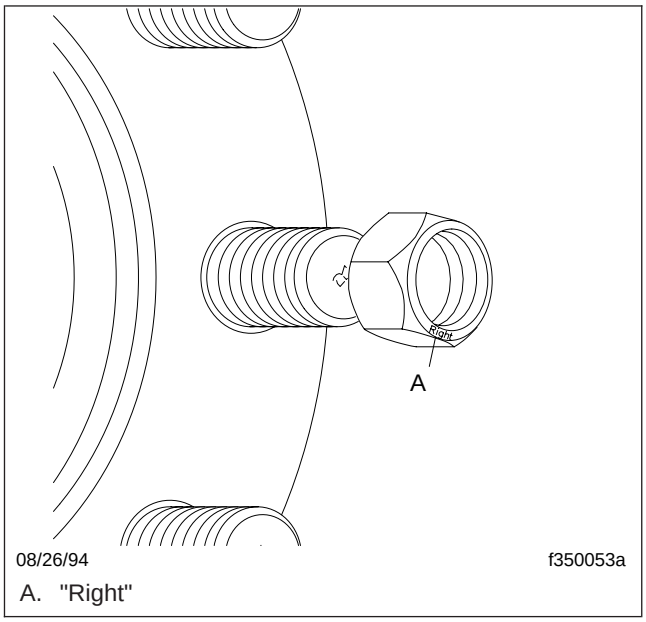
A. Replace

Fig. 1, Studs to Replace

CAUTION

CAUTION: Don't use a drift and hammer or concentrated heat for removing and installing the wheel studs. Constant, smooth movement of the wheel stud is needed 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 coat 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 evenly supported around and next to the stud being installed.
6. Position the stud in its hole.



A. "Right"

Fig. 2, Nut Threads

CAUTION

CAUTION: 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 cannot be achieved, replace the wheel hub assembly.

IMPORTANT: If the driver's side of the vehicle is being serviced, the replacement wheel stud

Wheel Stud Replacement, Disc Wheels

must be stamped with an "L" (left-hand threaded), and the nut's face must be stamped "Left." If the passenger's side of the vehicle is being serviced, the replacement stud must be stamped with an "R" (right-hand threaded), and the nut's face must be stamped "Right". See **Fig. 2**.

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 in the hub. If the head of the stud is embedded in the hub, replace the hub.
9. Wipe off any grease on the wheel studs and hub. Install wheel nuts on dry wheel studs only.
10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Rim Stud Replacement, Spoke Wheels

Replacement

1. Remove the rim and tire assembly from the spoked wheel. For instructions, see **Group 40**.
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, go to the step for tapping out the rim stud hole.

   If the rim stud is broken near the surface of the wheel, 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 centerpunch the surface as starting point for drilling. Remove the stud.

   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 are damaged, replace the wheel.

   2.2 Don't drill more than 1-1/4 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel. Drilling through the bottom of the rim stud could damage the wheel. If the wheel 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 rim stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate tap size, depending on the original rim stud installation size.
4. Be sure the threads of the new stud are clean and dry. Then, coat the insertion end of the rim stud with an anaerobic thread-lock compound.
5. Using double nuts on the fine thread portion of the stud, install the new stud. Seat the rim stud using the torques values in the torque table in **Specifications, 400.**
6. Allow enough time for the thread-lock compound to set, as suggested by the manufacturer.
7. Install the rim and tire assembly. For instructions, see **Group 40**.

Troubleshooting

This subject contains troubleshooting tables for the following problems:

- Noisy Bearings or Excessive Bearing Replacement Intervals
- Broken Wheel or Rim Studs
- Damaged Hub
- Loss of Lubricant from the Wheel Hubs
- Vehicle Doesn't Slow Down Quickly Enough When the Brakes Are Applied

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals

Problem—Noisy Bearings or Excessive Bearing Replacement Intervals	
Possible Cause	**Remedy**
Not enough oil or grease was used on the bearings, or the wrong type of oil or grease was used.	Clean then inspect the bearings for wear. Replace worn seals. Coat the bearing assemblies with fresh oil or grease. For lubricant specification, 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 part 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 100** and **Subject 102**
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—Noisy Bearings or Excessive Bearing Replacement Intervals**

Problem—Broken Wheel or Rim Studs

Problem—Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
The wheel or rim nuts were overtightened.	Replace the wheel or rim studs. See **Group 40** for the wheel or rim nut tightening sequence.
An incorrect nut tightening sequence was used.	
The vehicle is being overloaded.	Don't exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
(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 under **Subject 130**.
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 Doesn't Slow Down Quickly Enough When the Brakes Are Applied

Problem—Vehicle Doesn't Slow Down Quickly Enough When the Brakes Are Applied	
Possible Cause	**Remedy**
The brake drums are worn, heat-checked, or cracked.	Install new brake drums.

Specifications

Application	Size	Torque: lbf·ft (N·m)
Hub Cap Capscrews	5/16-18	15 (20)
Spoke-Wheel Brake Drum Nuts	3/4-10	240 (325)
Spoke-Wheel Rim Studs	3/4-10	240 (325)
Rotor Capscrews	9/16-12	130 (175)

Table 1, Torque Values

Recommended Lubricant Type	Ambient Temperature	Lubricant SAE Viscosity Grade	Rockwell Specification
Hypoid Gear Oil API Service Classification GL–5	+10°F (–12.2°C) and up *	85W–140	0–76–A
	–15°F (–26.1°C) and up *	80W–140	0–76–B
	–15°F (–26.1°C) and up *	80W–90	0–76–D
	–40°F (–40°C) and up *	75W–90	0–76–E
	–40°F (–40°C) to +35°F (+2°C)	75W	0–76–J
	–40°F (–40°C) and up *	75W–140	0–76–L
Synthetic Gear Oil	–40°F (–40°C) and up *	75W–90	0–76–N
	–40°F (–40°C) and up *	75W–140	0–76–M

* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 250°F (121°C).

Table 2, Rockwell Drive Axle Recommended Lubricant

Lubricant Type	Grease Specification
Lithium-Based	Standard: 0-617A or equivalent
Wheel Bearing Grease	Optional: 0-617B or equivalent

Table 3, Approved Lubricants for Rockwell Front Axles With Grease-Lubricated Bearings

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 **Section 42.11** and **Section 42.06**.
10. Remove the brake anchor plates from the axle. For instructions, see **Section 42.09**.
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 **Section 42.09**.
6. Install the brake air chambers and slack adjusters on the axle. For instructions, see **Section 42.11** and **Section 42.06**.
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 **Section 42.06**.
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.

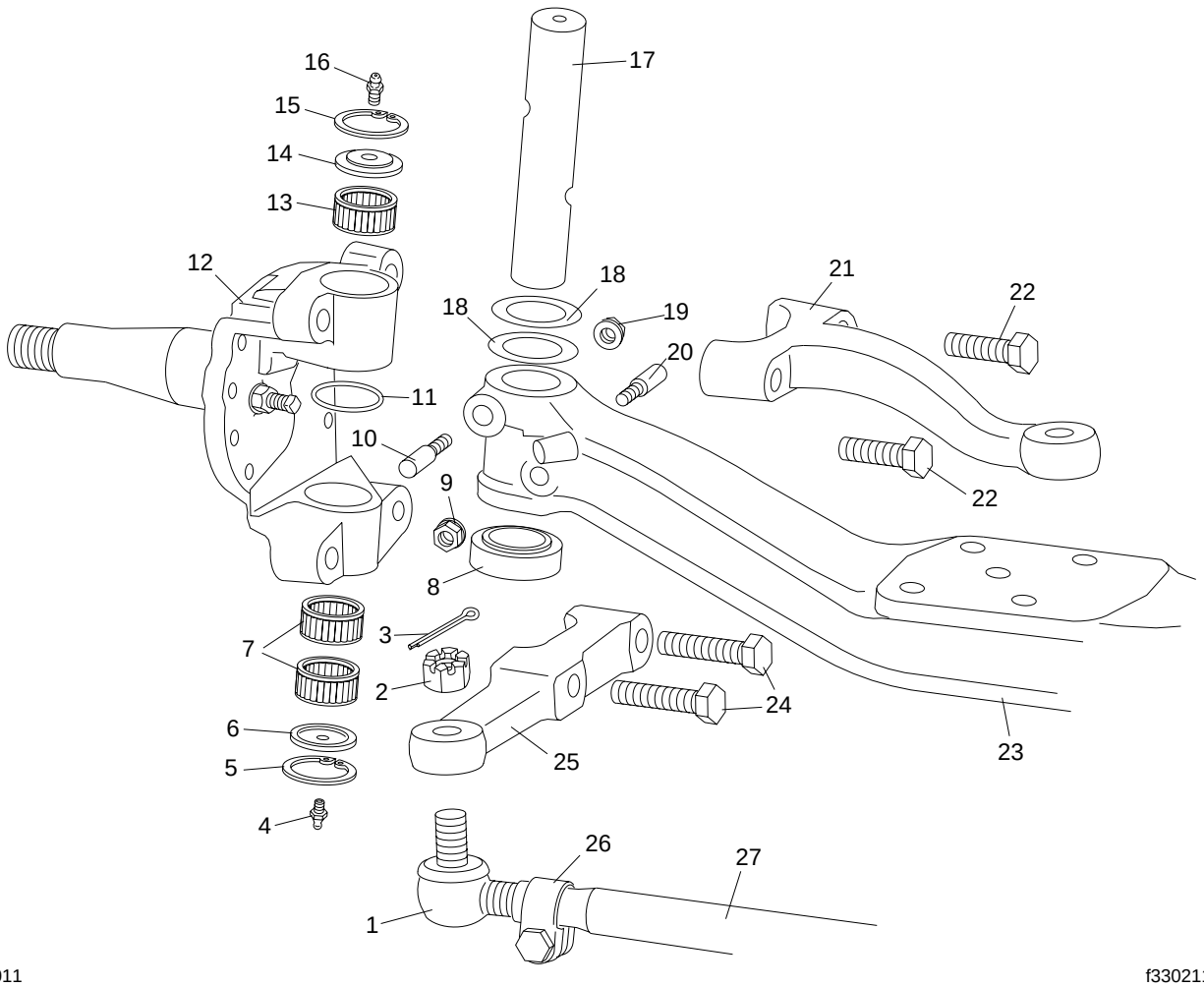
8. Remove the thrust friction bearing (driver side) or the thrust roller bearing (passenger side) from the top of the lower steering knuckle bore.

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



06/08/2011 f330211a

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 *School Bus 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.**

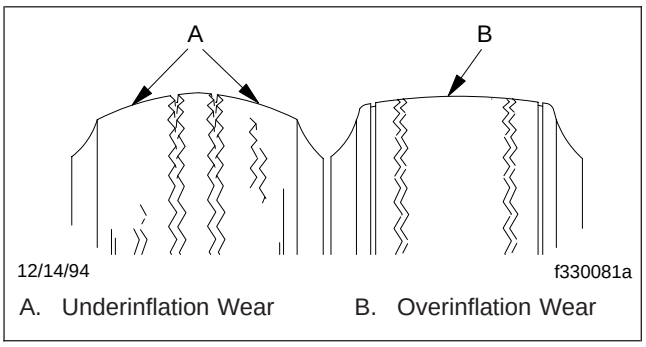


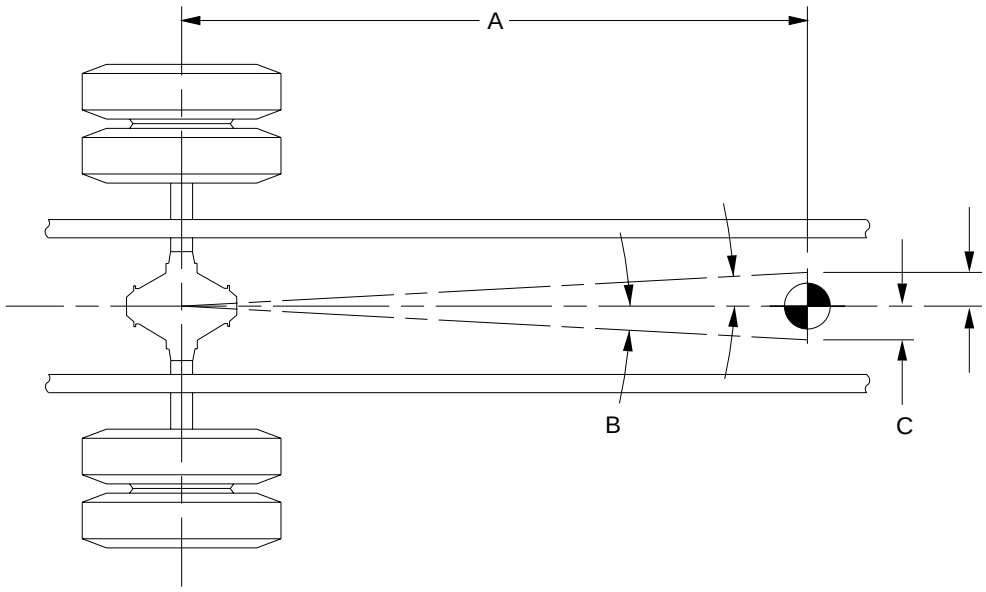
Fig. 1, Tire Damage Due to Underinflated or Overinflated Tires

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

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.

Maximum Tolerance from Perpendicular, Hunter Equipment	
Method	**Maximum Tolerance ± from Perpendicular**
Hunter *	0.18 degree

* To use Hunter alignment equipment, refer to the applicable Hunter service literature.

Table 1, Maximum Tolerance from Perpendicular, Hunter Equipment

Maximum Tolerance from Perpendicular at Target, Bee Line Equipment	
Distance from 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)

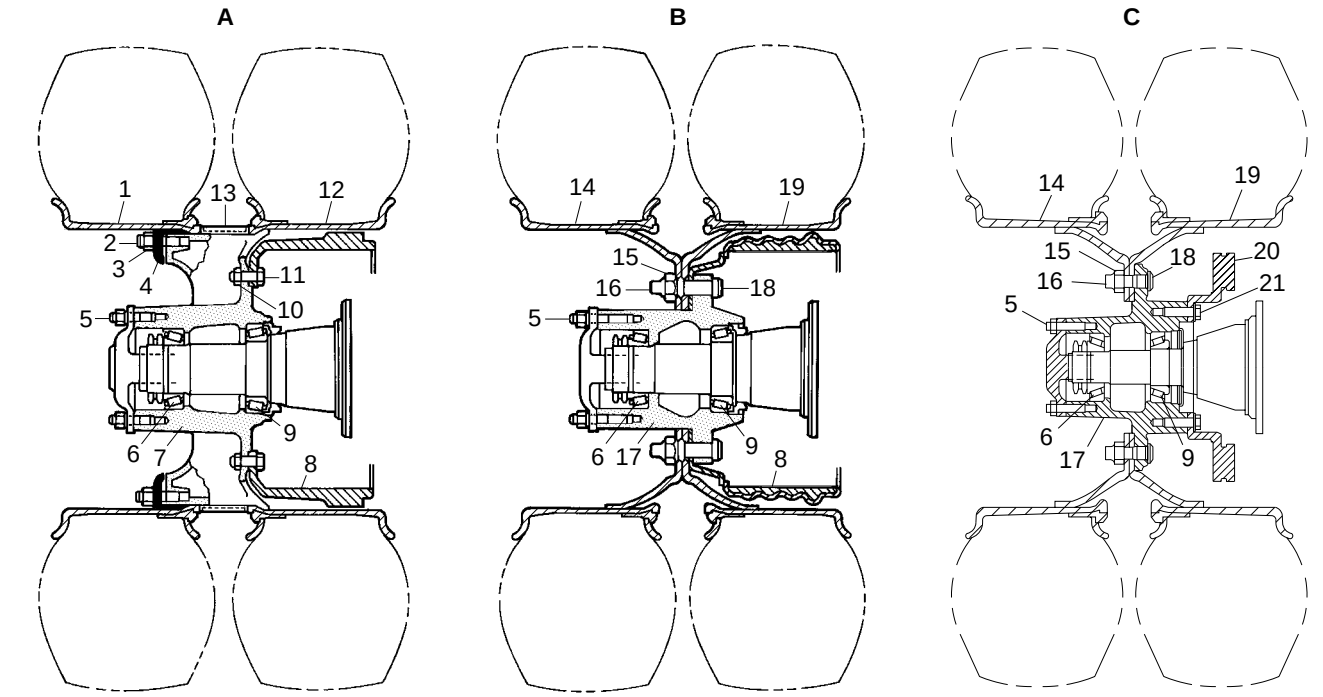
Table 2, Maximum Tolerance from Perpendicular at Target, Bee Line Equipment

General Information

The rear axle full-floating wheel hub assembly is made up of five major components: inner and outer tapered wheel bearings, the drive axle spindle assembly, the wheel hub, the brake drum, and the wheel studs. See **Fig. 1**.

Each hub has a set of inner and outer tapered wheel bearing assemblies. The bearing setting is locked in place on the axle spindle by an adjusting nut, lockring, and jam nut. See **Fig. 3**.

DRIVE AXLE SPINDLE



A. Spoke Wheel and Brake Drum Assembly
B. Disc Wheel, Wheel Hub, and Brake Drum Assembly
C. Disc Wheel, Wheel Hub, and Brake Rotor Assembly

1. Outer Rim
2. Rim Stud
3. Rim Stud Nut
4. Rim Clamp
5. Drive Axle Stud
6. Outer Wheel Bearing
7. Spoke Wheel
8. Brake Drum
9. Inner Wheel Bearing
10. Brake Drum Nut
11. Brake Drum Bolt
12. Inner Rim
13. Rim Spacer
14. Outer Wheel
15. Outer Wheel Nut
16. Inner Wheel Nut
17. Wheel Hub
18. Wheel Stud
19. Inner Wheel
20. Brake Rotor
21. Rotor Bolt

Fig. 1, Wheel and Hub Assemblies

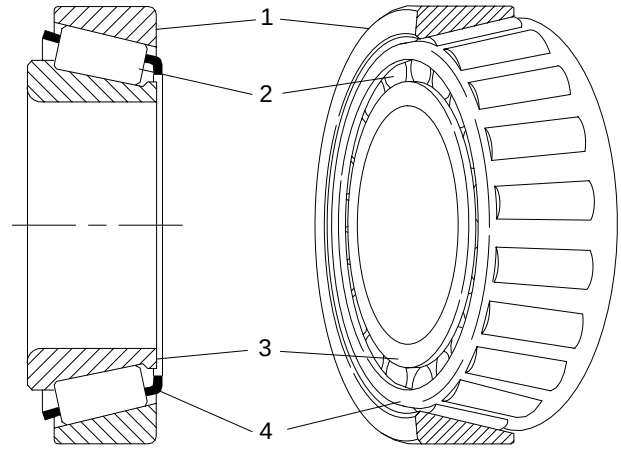
TAPERED WHEEL BEARINGS

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. 2**. All components carry the load, with the exception of the cage, which spaces the rollers around the cone.

ASSEMBLY

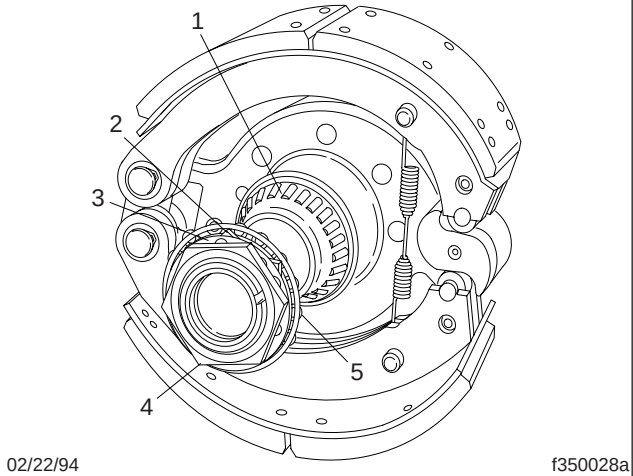
The drive axle spindle assembly is made up of a drive axle flange and shaft, drive axle studs and stud nuts, a flange gasket, an axle spindle, an oil seal, and the nut/lockring assembly described above. See **Fig. 4**.

General Information



1. Cup
2. Tapered Roller
3. Cone
4. Roller Cage

Fig. 2, Tapered Wheel Bearing Assembly



1. Inner Wheel Bearing
2. Wheel Bearing Inner Adjusting Nut
3. Lockring
4. Axle Spindle Jam Nut
5. Outer Wheel Bearing

Fig. 3, Drive Axle Bearings and Spindle 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.

CAUTION

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 inner disc wheel and/or brake drum is mounted on an aluminum or iron wheel hub. See **Fig. 4**. 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.

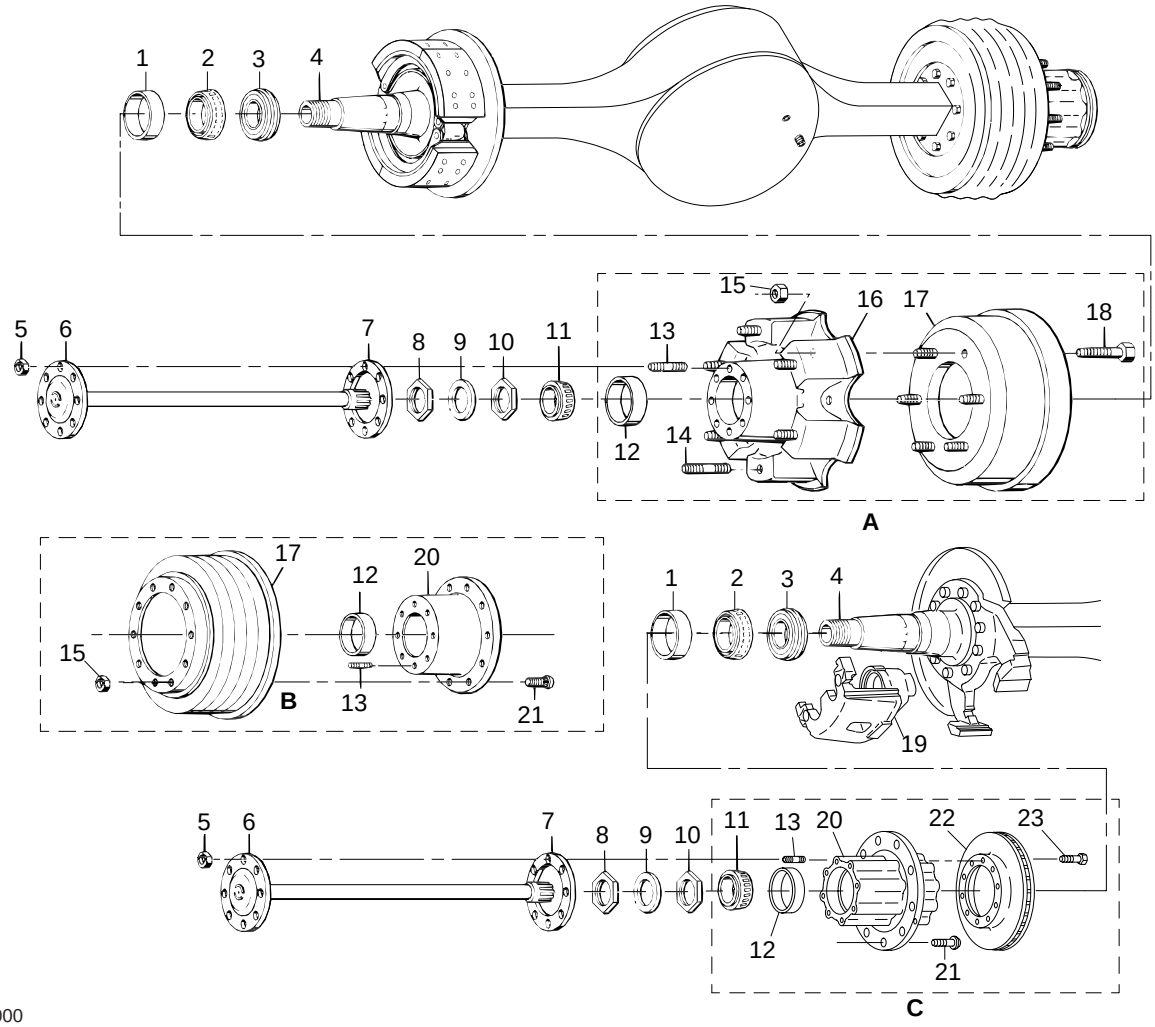
Each spoke wheel combines both wheel and hub into a single unit. See **Fig. 4**.

WHEEL STUDS

A headed wheel stud is used on rear axle disc wheel hub assemblies and has either serrations on the stud body or a flat area on the stud's head to prevent the stud from turning in the wheel hub. See **Fig. 5**.

The end of the stud that faces away from the vehicle is stamped with an "L" or "R," depending on which side of the vehicle the stud is installed. Studs stamped with an "L" are left-hand threaded and are installed on the driver's side of the vehicle. Studs stamped with an "R" are right-hand threaded and are installed on the passenger's side of the vehicle.

Spoke wheels have rim studs. Rim studs are threaded on both ends, with a non-threaded section midway along the shaft of the stud. The studs are coated with an anaerobic locking compound.



A. Spoke Wheel and Drum Assembly
B. Disc Wheel, Hub, and Drum Assembly
C. Disc Wheel, Hub, and Rotor Assembly

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. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Brake Caliper
20. Wheel Hub
21. Wheel Stud
22. Brake Rotor
23. Rotor Bolt

Fig. 4, Typical Drive Axle (exploded view)

General Information

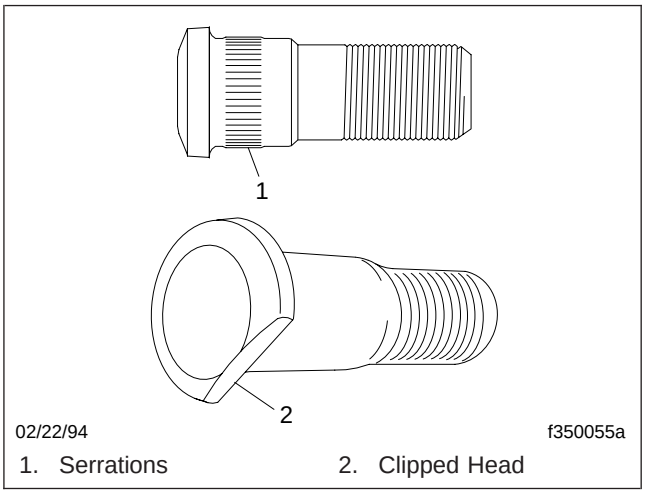
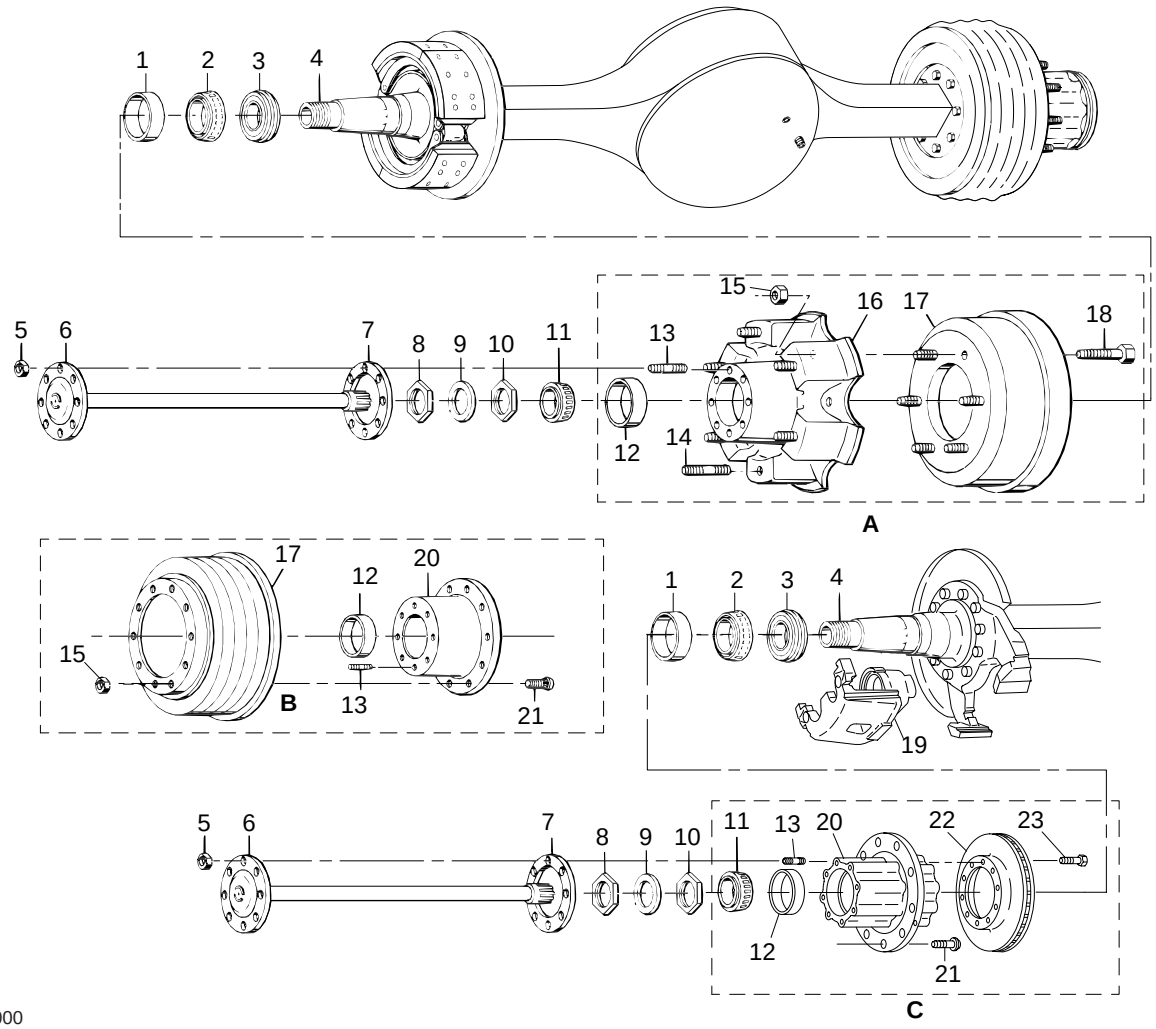


Fig. 5, Typical Headed Wheel Studs

Hub Assembly Removal and Installation, Disc Wheels

Removal



A. Spoke Wheel and Drum Assembly
B. Disc Wheel Hub and Drum Assembly
C. Disc Wheel Hub and Rotor Assembly
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 Adjust Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Brake Caliper
20 Wheel Hub
21. Wheel Stud
22. Brake Rotor
23. Rotor Bolt

Fig. 1, Typical Rear Axle Assembly

Hub Assembly Removal and Installation, Disc Wheels

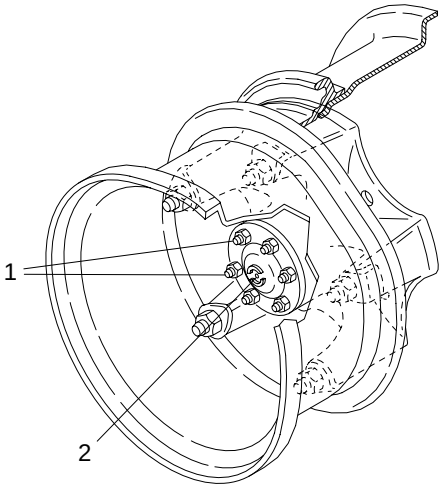
1. Chock the front tires to prevent vehicle movement. Release the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle.
3. If the vehicle is equipped with air brakes, back off the slack adjuster to release the rear axle brake shoes. For instructions, refer to the applicable slack adjuster section in **Group 42**.
4. Remove both wheel and tire assemblies. See **Fig. 1**. For instruction, see **Group 40**.

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.

5. On outboard drums, remove the brake drum. On disc brakes, remove the brake caliper; for instructions, see **Group 42**.

   To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Don't use compressed air or dry brushing to clean the brake assembly.
6. 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, which should later be safely discarded.
7. Remove the drive axle stud nuts and washers. See **Fig. 2**.
8. Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. See **Fig. 2**. The shaft will usually spring slightly outward after the seal has broken. Remove the drive axle shaft.



06/09/94 f400090b

1. Drive Axle Studs and Nuts
2. Center Portion of Drive Axle Flange

Fig. 2, Wheel Assembly and Hub

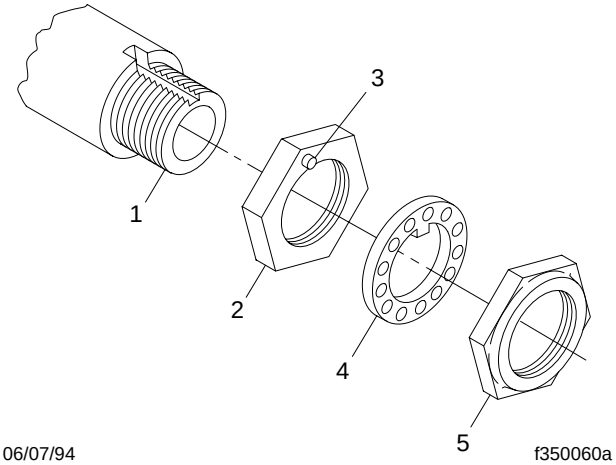
CAUTION

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.

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 spindle. If the seal has not broken, repeat this step.

9. If equipped, remove the tapered dowels and washers from the drive axle flange.
10. Remove and discard the gasket.
11. Remove the axle spindle jam nut and the lockring or nut-lock, as equipped. See **Fig. 3**.
12. Back off the wheel bearing inner adjusting nut about two turns, or enough to allow the weight of the hub to be lifted from the wheel bearings.
13. Lift the hub until all weight is removed from the wheel bearings; remove the wheel bearing inner adjusting nut.

Hub Assembly Removal and Installation, Disc Wheels



1. Axle Spindle
2. Adjusting Nut
3. Pin
4. Pierced Lockring
5. Jam Nut

Fig. 3, Axle Secured With a Lockring

CAUTION

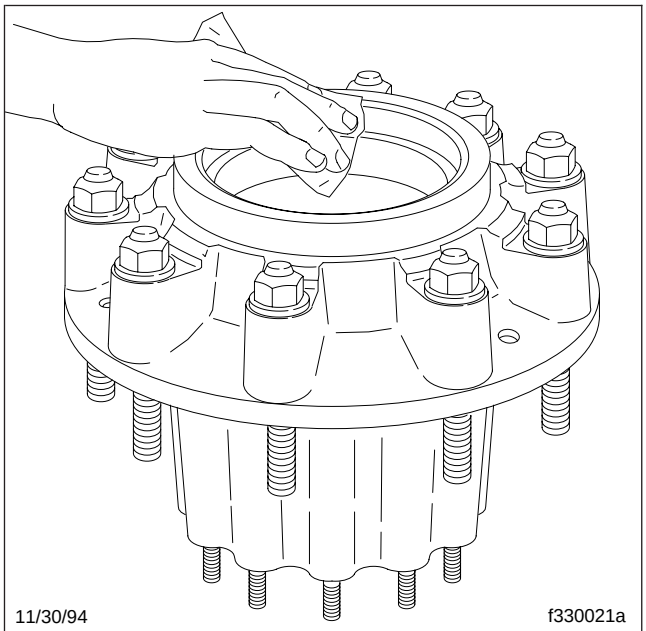
When moving the hub, be careful not to let the outer wheel bearing drop from the axle spindle. If the wheel bearing is dropped, cage warpage or roller damage can occur.

14. 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).
15. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. Wrap them in either clean oil-proof paper or lint-free rags.

CAUTION

Don't spin bearing rollers at any time. Dirt or grit can scratch their surfaces and cause rapid wear of the bearing assembly. Treat used bearings as carefully as new ones.

16. Remove the hub. Be careful not to damage the axle spindle threads as the assembly is removed.
17. Using a seal removal tool, remove the oil seal from the hub, if not already removed.
18. Remove the inner wheel bearing from the hub. If the bearings aren't easily removed, place a protective cushion where it will catch them. Then, use a hardwood drift and a light hammer to gently tap the bearings (and seal, if needed) out of the cup. Handle the bearings with clean, dry hands. Wrap them in either clean oil-proof paper or lint-free rags.
19. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. See **Fig. 4** and **Fig. 5**. Clean any metal filings from the parts.



NOTE: Typical application.

Fig. 4, Clean the Hub Shoulder

IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle. Dirt, metal filings, or other debris can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

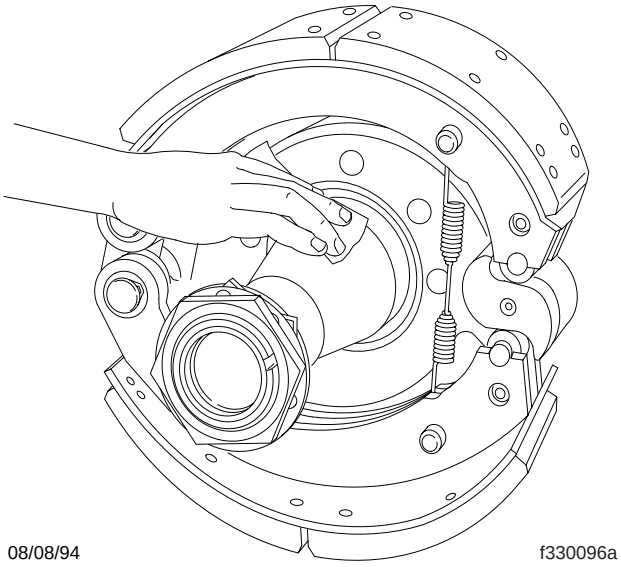
20. For instructions, go to **Subject 110**.

Installation

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure

Hub Assembly Removal and Installation, Disc Wheels



NOTE: Typical application.

Fig. 5, Clean the Spindle

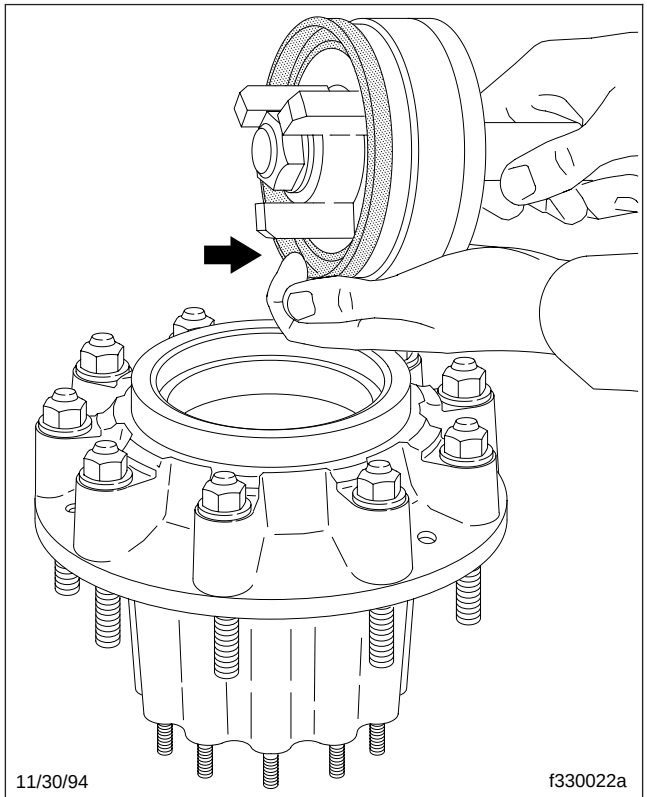
and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, continuing through installation of the wheels.

1. Using clean 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 housing threads.
2. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal. Handle the bearings with clean, dry hands. For lubricant specifications, refer to **Specifications, 400**.

⚠ CAUTION

Use only fresh oil on the bearing assemblies; old oil could be contaminated with dirt or water (both are corrosives) and could cause damage to both wheel bearing assemblies and the wheel hub.

2.1 Seat the small outer diameter of the seal in the recess of the tool adaptor. See **Fig. 6**. The correct adaptor is identified on the box.



NOTE: Typical application.

Fig. 6, Seat the Seal in the Tool

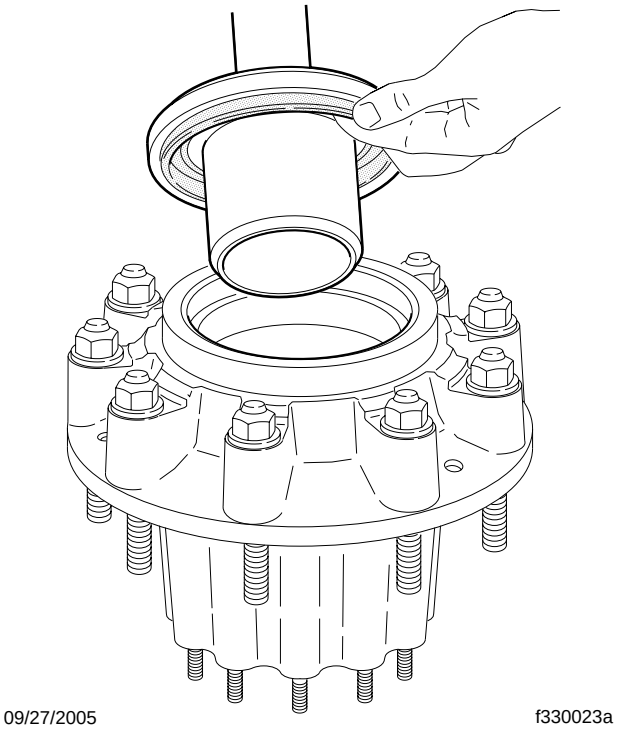
2.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 7**. The plug prevents cocking of the seal in the bore.

2.3 Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms out. See **Fig. 8**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.

2.4 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.

3. Wipe a film of axle oil on the axle spindle to prevent rust from forming behind the inner wheel bearing.
4. Carefully mount the hub and inner wheel bearing assembly on the axle spindle. Be careful not to unseat the inner wheel bearing or seal.

Hub Assembly Removal and Installation, Disc Wheels



NOTE: Typical application.

Fig. 7, Insert the Tool

5. Fill the hub cavity with oil, and 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. Then remove the friction tape from the axle spindle threads.

6. Adjust the wheel bearings as follows. See **Fig. 3**:

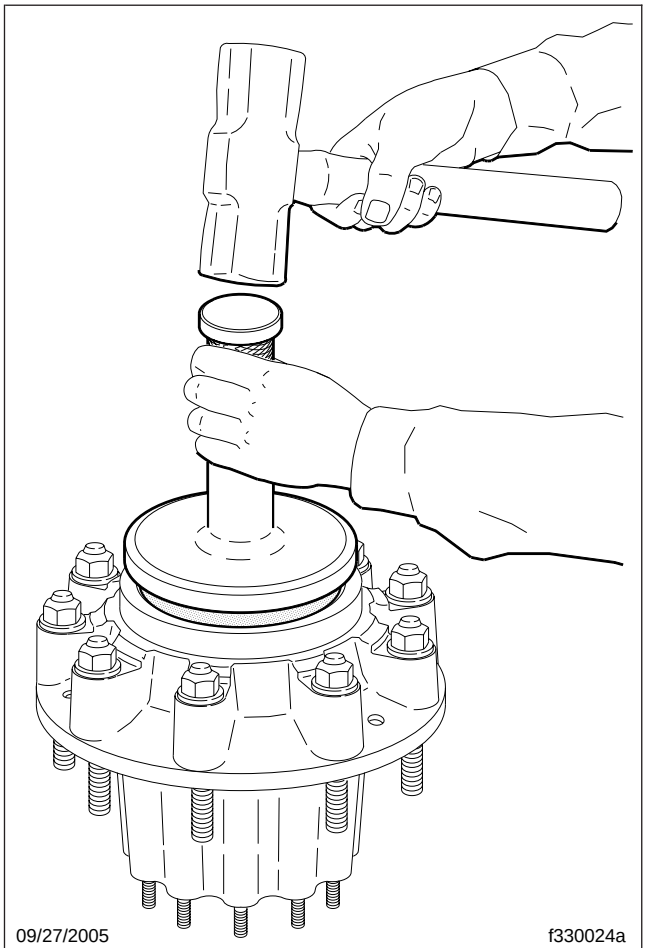
   IMPORTANT: Be sure there is enough clearance between the brake shoes and the brake drum, so brake shoe drag won't interfere with bearing adjustment.

   6.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 200 lbf·ft (271 N·m) while rotating the wheel hub assembly.

   6.2 Back off the inner nut one full turn.

   6.3 Tighten the inner nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.

   6.4 Back off the inner nut one quarter turn.



NOTE: Typical application.

Fig. 8, Strike the Tool

NOTE: If you're securing the wheel bearings with a pierced lockring, and 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.

6.5 Install the locking device:

- Tanged nut-lock
- Lockring
- Lockwasher *and* a lockring
- Nut-lock *and* a lockring

Hub Assembly Removal and Installation, Disc Wheels

Then install the jam nut, and tighten it to the applicable torque in **Table 1**.

Locking Device	Torque: lbf·ft (N·m)	
	1-1/8 to 2-1/2 Inch Jam Nuts	2-5/8 Inch or Larger Jam Nuts
Tanged Nut-Lock	200–300 (271–407)	
Lockring		
Tanged Nut-Lock and Lockring	200–300 (271–407)	250–400 (339–542)
Lockwasher and Lockring		

Table 1, Jam Nut Torques

6.6 With the jam nut installed and tightened, 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.

6.7 Release the brakes if you used them to hold the drum while installing it.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then push the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then pull the hub (and drum, if applicable). Read the dial indicator, and note the end play.

Push the hub back in to confirm that the needle of the dial indicator returns to zero.

The end play must be between 0.001 and 0.005 inch (0.025 and 0.127 mm).

7. If the end play is not within this range, remove the jam nut and locking device, and back off or tighten the inner (adjusting) nut to adjust the end play. Keep the following in mind:

   If you're using a nut-lock: turning the inner nut 1/4 turn will change the end play about 0.020 inch (0.508 mm).

   If you're using a lockring: turning the inner nut one lockring hole will change the end play about 0.005 inch (0.127 mm). If you take the lockring off and reverse it, then turn the inner nut to the next hole, this will change the end play about 0.0025 inch (0.0635 mm).

   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 (0.025 and 0.127 mm), adjust the inner (adjusting) nut, again.

8. Once the end play is correct, bend the nut-lock or lockwasher as applicable to lock the jam nut and/or adjusting nut in place.
9. Rotate the wheel in both directions. It should rotate freely with no dragging or binding.
10. Install a new gasket on the drive axle studs.
11. Install the drive axle shaft. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.
12. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle nuts. Using the sequence shown in **Fig. 9**, tighten the nuts to the torque values in the torque table in **Specifications, 400**.
13. Install the brake drum on the wheel hub.

Hub Assembly Removal and Installation, Disc Wheels

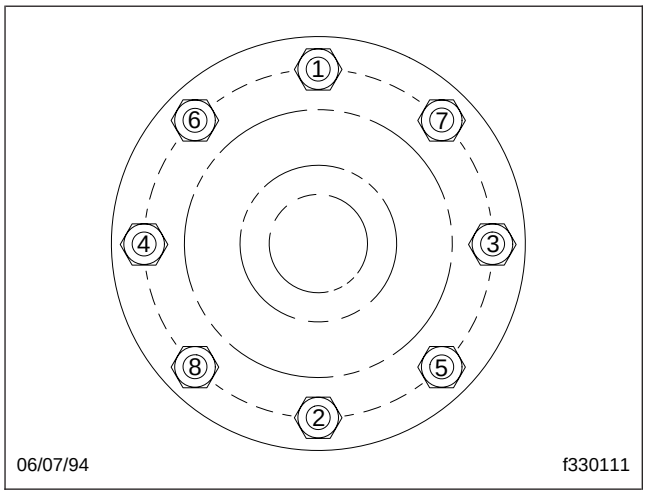


Fig. 9, Axle Shaft Flange Nut-Tightening Sequence

14. Install the inner and outer wheel and tire assemblies. For instructions, see **Group 40**.

⚠ WARNING

If the inner wheel nuts cannot be tightened to minimum torque values, the wheel studs have lost their locking action, 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 loss of a wheel or loss of vehicle control, and possible personal injury.

15. Fill the axle with lubricant.

⚠ WARNING

Failure to add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel hub have been serviced will damage the wheel bearings and cause them to seize during vehicle operation. See Fig. 10. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

15.1 Pour the recommended drive axle lubricant through the axle housing filler hole or until the lubricant is level with the bottom of the hole. See **Fig. 11**, **Fig. 12**, and **Fig. 13**. See **Specifications, 400** for the recommended axle lubricants. Tighten the plug 35 lbf·ft (47 N·m).

15.2 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.

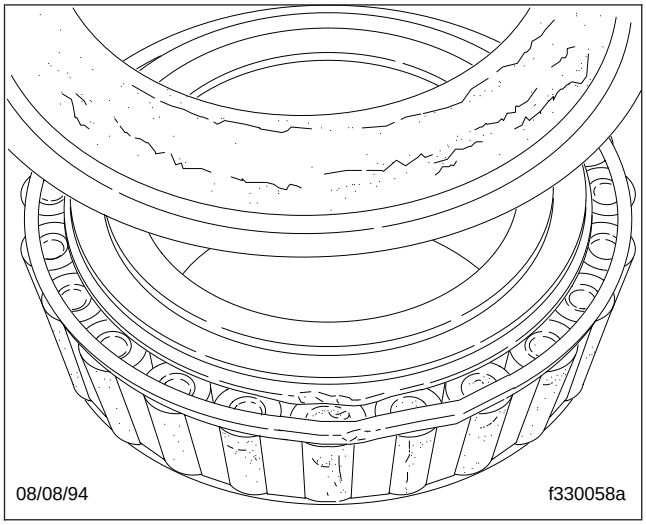


Fig. 10, Bearing Damage Resulting from Inadequate Lubrication

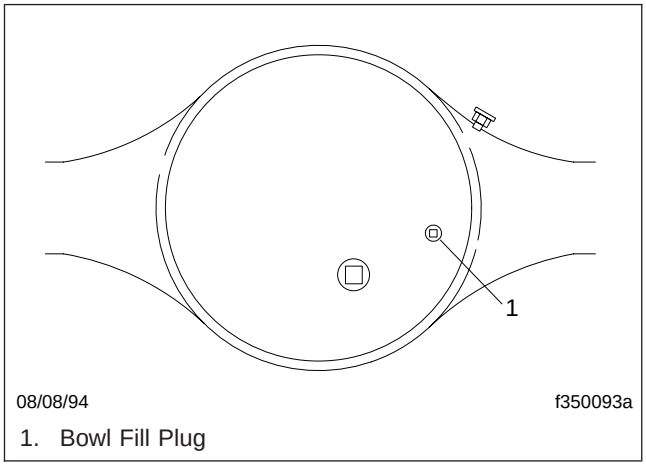
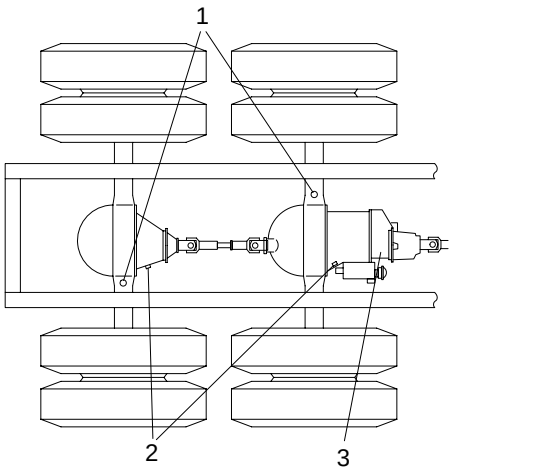


Fig. 11, Filler Hole

15.3 Return the axle to a level position, and add oil through the axle housing fill hole. About two extra pints (one liter) of lubricant will be needed to bring the oil level even with the base of the fill hole.

NOTE: Drive axle wheel bearings are lubricated by oil drawn from the axle housing bowl section. This method ensures good exchange of heat,

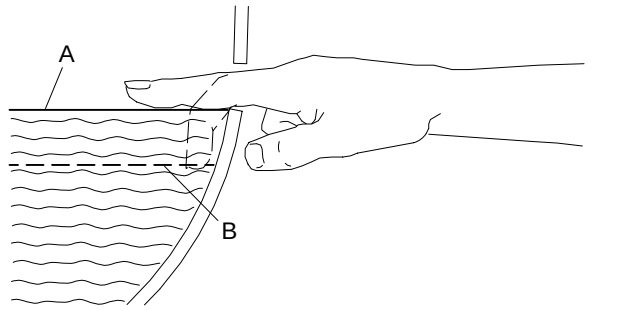
Hub Assembly Removal and Installation, Disc Wheels



06/07/94 f350062a

1. Axle Housing Breathers
2. Carrier Fill Hole Plugs
3. Interaxle Differential

Fig. 12, Axle Filler Holes



06/07/94 f350061a

A. Correct: Lube level at the bottom of the fill hole.
B. Incorrect: Lube level is below the fill hole.

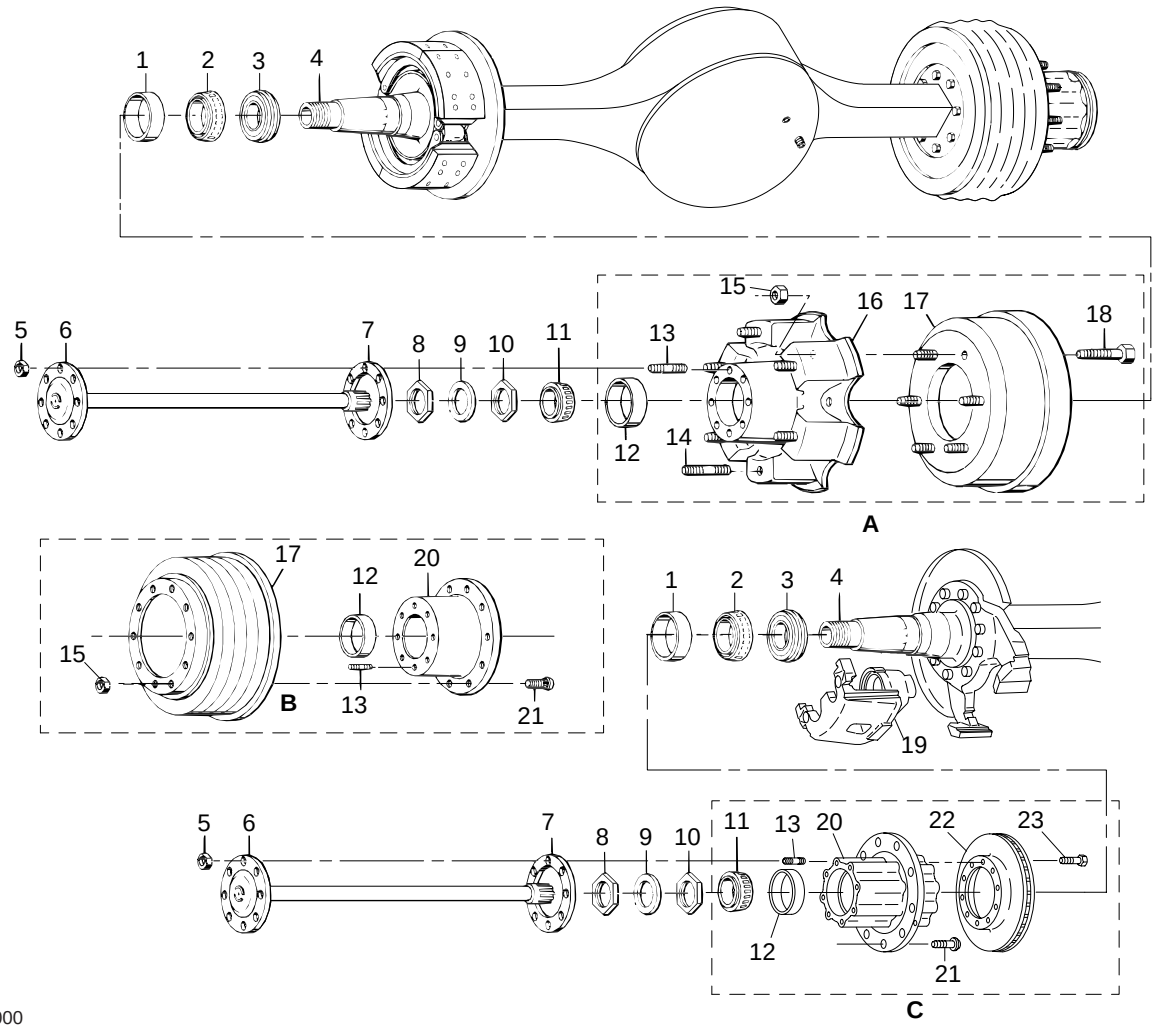
Fig. 13, Checking Lubricant Level

prevents stagnation, and minimizes the maintenance required on bearings and hub assemblies.

16. Turn the wheels, and check the lubricant level.
17. Adjust the rear axle brakes at the slack adjuster. For instructions, refer to the brakes group in the vehicle maintenance manual.
18. Remove the safety stands from under the axle, then lower the vehicle.
19. Apply the parking brakes, then remove the chocks from the front tires.

Hub Assembly Removal and Installation, Spoke Wheels

Removal



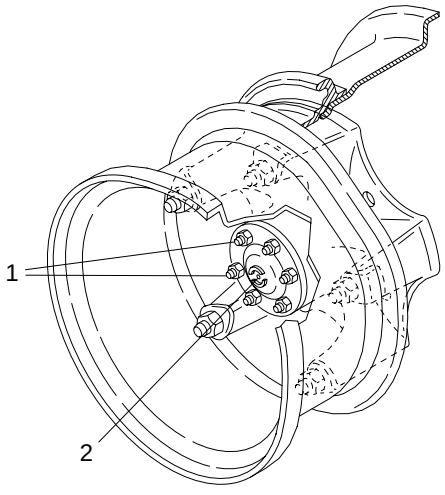
A. Spoke Wheel and Drum Assembly
B. Disc Wheel Hub and Drum Assembly
C. Disc Wheel Hub and Rotor Assembly
1. Inner Wheel Bearing Cup
2. Inner Wheel Bearing
3. Oil Seal
4. Axle Spindle
5. Drive Axle Stud Nut
6. Drive Axle Flange and Shaft
7. Gasket
8. Jam Nut
9. Lockring
10. Wheel Bearing Inner Adjust Nut
11. Outer Wheel Bearing
12. Outer Wheel Bearing Cup
13. Drive Axle Stud
14. Rim Stud
15. Brake Drum Nut
16. Spoke Wheel
17. Brake Drum
18. Brake Drum Bolt
19. Brake Caliper
20 Wheel Hub
21. Wheel Stud
22. Brake Rotor
23. Rotor Bolt

Fig. 1, Typical Rear Axle Assembly

Hub Assembly Removal and Installation, Spoke Wheels

Spoke wheel assemblies with inboard drums don't need to be completely disassembled for brake component maintenance. The tires and rims can remain attached to the wheel, and the wheel to the brake drum. The assembly is then removed from the axle as a single unit to expose brake components. See **Group 42** for brake assembly service information.

1. Chock the front tires to prevent vehicle movement. Release the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Then place safety stands under the axle to be serviced. Position a jack or wheel-and-tire dolly under the tires.
3. Remove both rim and tire assemblies. See **Fig. 1**. For instructions, see **Group 40**.
4. If the vehicle is equipped with air brakes, back off the slack adjuster to release the rear axle brake shoes. For instructions, refer to the applicable slack adjuster section in **Group 42**. If the vehicle is equipped with hydraulic brakes, remove the brake caliper. For instruction, see **Group 42**.
5. Remove the drive axle flange nuts and washers. See **Fig. 2**.



1. Drive Axle Studs and Nuts
2. Center Portion of Drive Axle Flange

Fig. 2, Wheel Assembly and Hub

NOTE: Oil will spill as the drive axle shaft and wheel are removed. Place a suitable container under the wheel to catch any spilled oil. Safely discard the oil.

6. Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. See **Fig. 2**. The shaft will usually spring slightly outward after the seal has broken. Then remove the drive axle shaft.

⚠ 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.

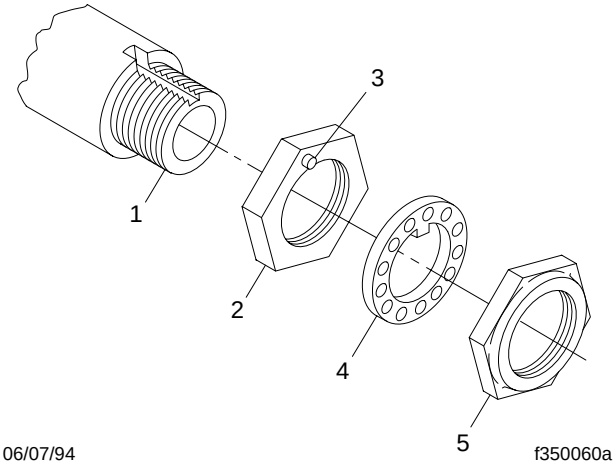
NOTE: Even if the drive axle shaft doesn't spring outward, the seal may have loosened enough to allow the shaft to be pulled from the axle housing. If the seal has not broken, repeat the above step.

7. If so equipped, remove the tapered dowels and washers from the drive axle flange.
8. Remove and discard the gasket.
9. Remove both the axle spindle jam nut and the lockring. See **Fig. 3**. Then, back off the wheel bearing inner adjusting nut about two turns, or enough to allow the weight of the wheel and drum assembly to be lifted from the wheel bearings.
10. Using the wheel dolly or jack, raise the wheel and drum assembly until all weight is removed from the bearings. Then remove the wheel bearing inner adjusting nut.
11. Carefully remove the outer wheel bearing; handle the bearings with clean, dry hands. If the wheel bearings have not loosened from the cup, move the wheel assembly about 1/2 inch (13 mm) to jar loose the outer wheel bearing. Be careful to not drop the bearings. Wrap them in clean oilproof paper or lint-free rags.

⚠ 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 res-

Hub Assembly Removal and Installation, Spoke Wheels



1. Axle Spindle
2. Adjusting Nut
3. Pin
4. Pierced Lockring
5. Jam Nut

Fig. 3, Axle Secured With a Lockring

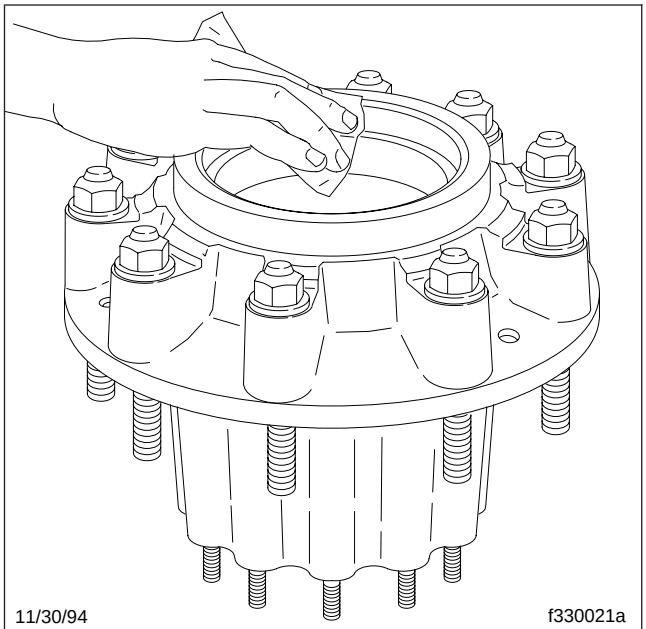
pirator at all times when servicing the brakes, starting with removal of the wheels and continuing through assembly.

CAUTION

Don't 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.

12. Using the wheeled support, pull the wheel assembly away from the vehicle. Be careful not to damage the axle spindle threads as the assembly is removed.
13. Remove the brake drum or rotor nuts and detach the brake drum or rotor from the wheel. See **Fig. 1**. For instructions, see **Group 42**.

    To minimize the possibility of creating airborne brake lining dust, clean the dust from the brake drum, brake backing plate, and brake assembly, using an industrial-type vacuum cleaner equipped with a high-efficiency filter system. Then, using a rag soaked in water and wrung until nearly dry, remove any remaining dust. Don't use compressed air or dry brushing to clean the brake assembly.
14. Remove the oil seal, using an oil seal removal tool.
15. Remove the inner wheel bearing from the hub. If the bearings aren't easily removed, place a protective cushion where it will catch the bearing. Then, use a hardwood drift and a light hammer to gently tap the bearing (and seal, if needed) out of the cup. Handle the bearings with clean, dry hands. Wrap them in clean oil-proof paper or lint-free rags.
16. Remove all burrs from the shoulder and the seal bore with an emery cloth or a file. See **Fig. 4** and **Fig. 5**. Clean any metal filings from the parts.



NOTE: Typical application.

Fig. 4, Clean the Hub Shoulder

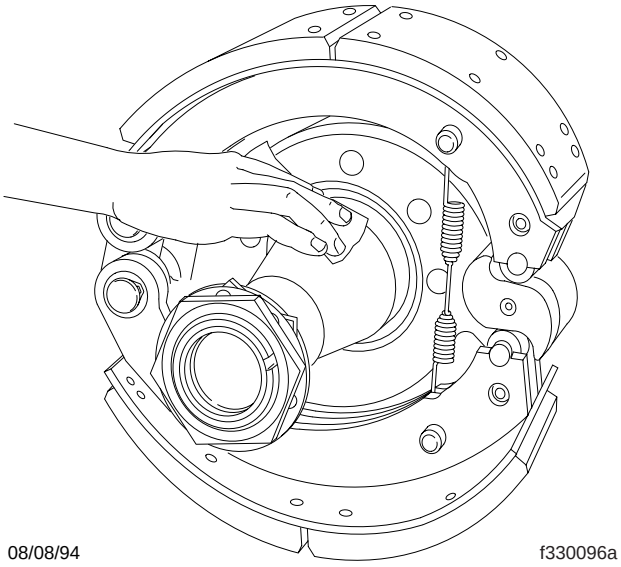
IMPORTANT: Use extreme care in cleaning the wheel hub cavity and axle spindle. Dirt, metal filings, or other contaminants can scratch the bearing roller surfaces, and cause premature wear of the bearing assembly.

Installation

WARNING

Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure

Hub Assembly Removal and Installation, Spoke Wheels

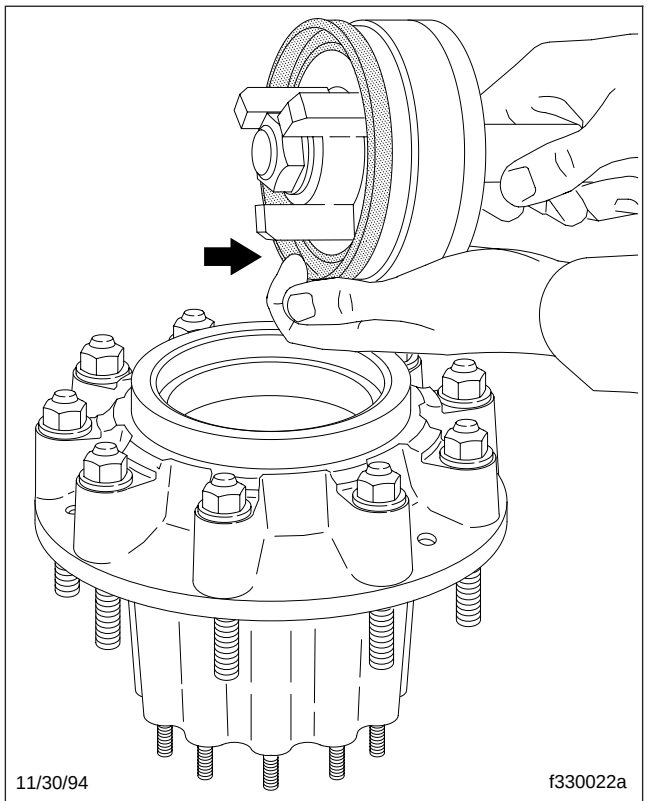


NOTE: Typical application.

Fig. 5, Clean the Spindle

and requires workers to wear an air purifying respirator approved by MSHA or NIOSH. Wear a respirator at all times when servicing the brakes, continuing through installation of the wheels.

1. Using clean solvent, remove the old oil from the axle spindle and also the disassembled parts. See **Fig. 1**. Inspect and clean the wheel hub cavity and the wheel bearings as instructed under **Subject 110**. Allow the parts to dry, or dry them with a clean, absorbent, and lint-free cloth or paper.
2. Wrap a protective layer of friction tape on the axle spindle threads.
3. If it was removed, attach the brake drum or rotor to the wheel. Install the brake drum or rotor bolts and nuts, then tighten the nuts to the torque values in the torque table in **Specifications, 400** See **Group 42** for additional instructions.
4. Coat both bearing assemblies with fresh oil. Install the inner wheel bearing and oil seal. Handle the bearings with clean, dry hands.
   - 4.1 Seat the small outer diameter of the seal in the recess of the tool adaptor. See **Fig. 6**. The correct adaptor is identified on the box.
   - 4.2 Insert the centering plug of the tool in the bore of the inner bearing cone. See **Fig. 7**. The plug prevents cocking of the seal in the bore.

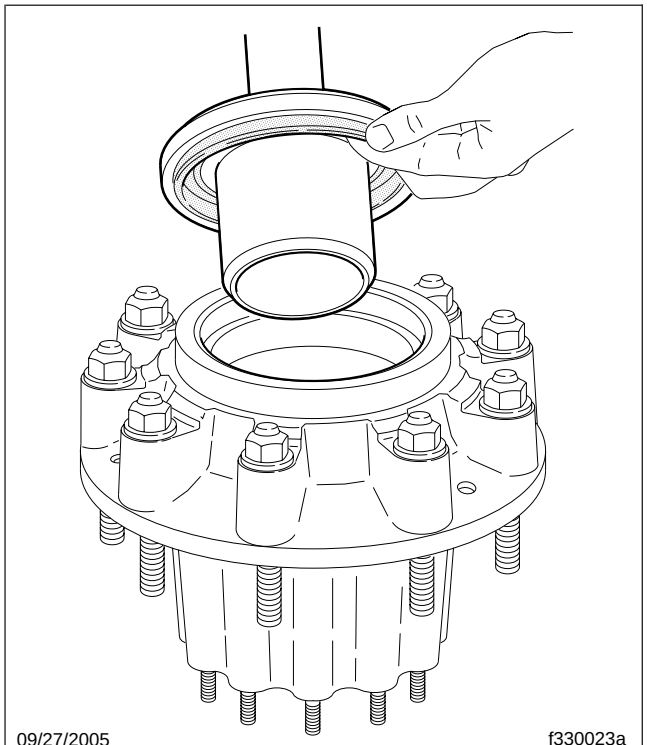


NOTE: Typical application.

Fig. 6, Seat the Seal in the Tool

   - 4.3 Hold the tool handle firmly, and strike it until the sound of the impact changes as the seal bottoms out. See **Fig. 8**. Hold the tool firmly to avoid bounce or unseating of the seal from the adaptor.
   - 4.4 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.
5. 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, Spoke Wheels



NOTE: Typical application.

Fig. 7, Insert the Tool

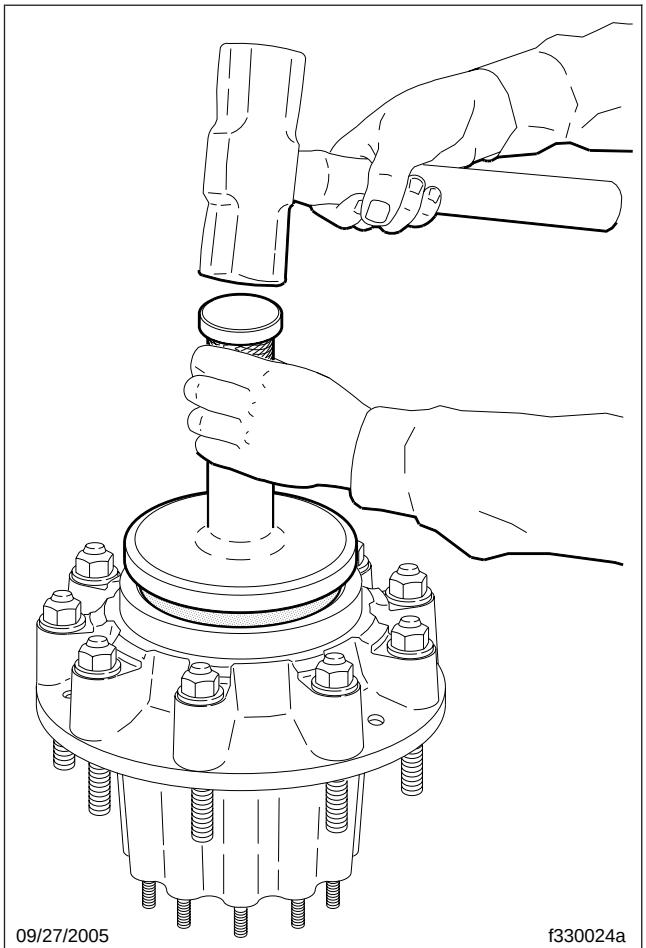
6. Using a wheeled support, mount the wheel and drum assembly on the axle spindle; be careful not to unseat the bearings or seal.
7. Fill the hub cavity with oil, and install the outer wheel bearing; handle the bearings with clean, dry hands. Then remove the friction tape from the axle spindle threads.
8. Adjust the wheel bearings as follows. See **Fig. 3**:

   IMPORTANT: Be sure there is enough clearance between the brake shoes and the brake drum, so brake shoe drag won't interfere with bearing adjustment.

   8.1 After the wheel hub and bearings are assembled on the spindle, tighten the inner (adjusting) nut 200 lbf·ft (271 N·m) while rotating the wheel hub assembly.

   8.2 Back off the inner nut one full turn.

   8.3 Tighten the inner nut 50 lbf·ft (68 N·m) while rotating the wheel hub assembly.



NOTE: Typical application.

Fig. 8, Strike the Tool

8.4 Back off the inner nut one quarter turn.

NOTE: If you're securing the wheel bearings with a pierced lockring, and 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.

8.5 Install the locking device:

- Tanged nut-lock
- Lockring
- Lockwasher *and* a lockring

Hub Assembly Removal and Installation, Spoke Wheels

• Nut-lock *and* a lockring

Then install the jam nut, and tighten it to the applicable torque in **Table 1**.

Locking Device	Torque: lbf·ft (N·m)	
	1-1/8 to 2-1/2 Inch Jam Nuts	2-5/8 Inch or Larger Jam Nuts
Tanged Nut-Lock	200–300 (271–407)	
Lockring		
Tanged Nut-Lock and Lockring	200–300 (271–407)	250–400 (339–542)
Lockwasher and Lockring		

Table 1, Jam Nut Torques

8.6 With the jam nut installed and tightened, 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.

8.7 Release the brakes if you used them to hold the drum while installing it.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then push the hub (and drum, if applicable), to seat the inboard bearing set. Zero the dial indicator.

Grip the sides of the hub at the three o'clock and nine o'clock positions, then pull the hub (and drum, if applicable). Read the dial indicator, and note the end play.

Push the hub back in to confirm that the needle of the dial indicator returns to zero.

The end play must be between 0.001 and 0.005 inch (0.025 and 0.127 mm).

9. If the end play is not within this range, remove the jam nut and locking device, and back off or tighten the inner (adjusting) nut to adjust the end play. Keep the following in mind:

   If you're using a nut-lock: turning the inner nut 1/4 turn will change the end play about 0.020 inch (0.508 mm).

   If you're using a lockring: turning the inner nut one lockring hole will change the end play about 0.005 inch (0.127 mm). If you take the lockring off and reverse it, then turn the inner nut to the next hole, this will change the end play about 0.0025 inch (0.0635 mm).

   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 (0.025 and 0.127 mm), adjust the inner (adjusting) nut, again.

10. Once the end play is correct, bend the nut-lock or lockwasher as applicable to lock the jam nut and/or adjusting nut in place.

11. Rotate the wheel in both directions. It should rotate freely with no dragging or binding.

12. Install a new gasket on the drive axle studs.

13. Install the drive axle shaft. The splined end of the axle shaft must seat before the drive axle flange will fit over the studs.

14. If equipped, install the dowels and washers on the drive axle studs. Install the drive axle nuts. Using the sequence shown in **Fig. 9**, tighten the nuts to the torque values in the torque table in **Specifications, 400**.

Hub Assembly Removal and Installation, Spoke Wheels

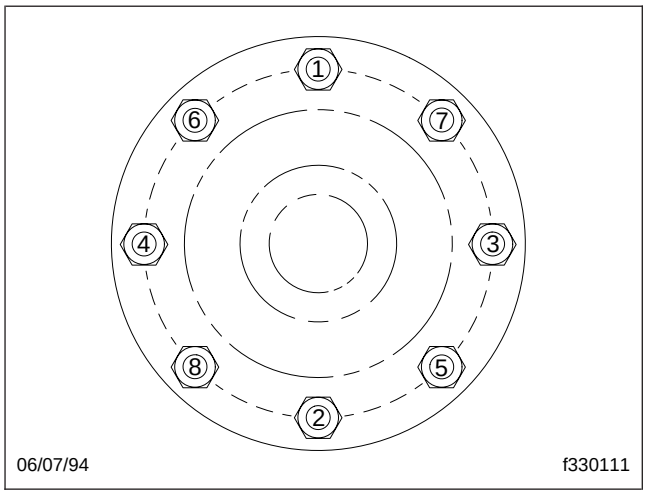


Fig. 9, Axle Shaft Flange Nut-Tightening Sequence

15. Install the brake caliper, if removed. See **Group 42** for instructions.
16. Install the rim and tire assemblies. For instructions, see **Group 40**.

WARNING

If the inner rim nuts cannot be tightened to minimum torque values, the rim studs have lost their locking action, and the wheel is probably damaged. In this case, replace it with a new wheel. Failure to replace the wheel when the conditions described above exist, could result in loss of a wheel or loss of vehicle control, and possible personal injury.

17. Fill the axle with lubricant.

WARNING

Failure to add oil to the axle housing bowl or the wheel hub after the drive axle shaft and wheel have been serviced will damage the wheel bearings and cause them to seize during vehicle operation. See Fig. 10. Seized bearing rollers can cause sudden damage to the tire or axle, possibly resulting in personal injury.

17.1 Pour the recommended drive axle lubricant through the axle housing filler hole until the lubricant is level with the bottom of the hole. See **Fig. 11**, **Fig. 12**, and **Fig. 13**. See **Specifications, 400** for the recommended axle lubricants. Tighten the plug 35 lbf·ft (47 N·m).

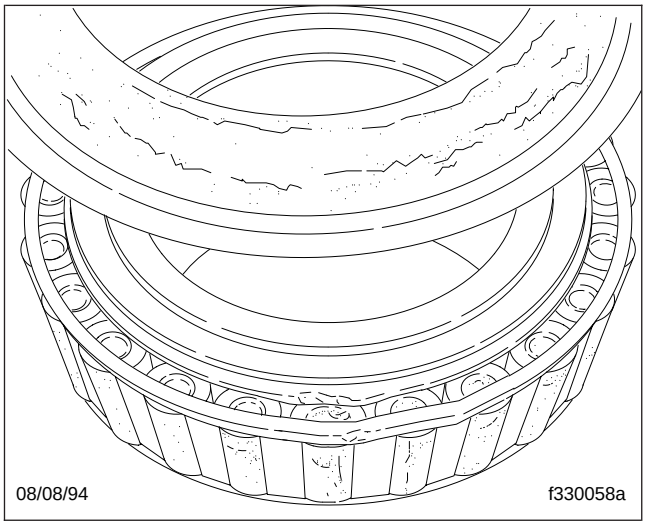


Fig. 10, Bearing Damage Resulting from Inadequate Lubrication

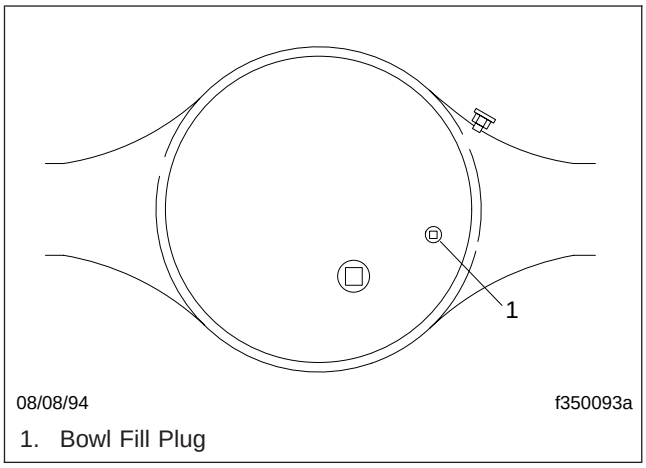
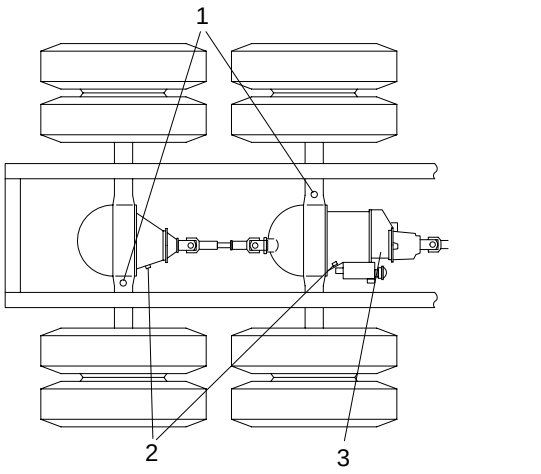


Fig. 11, Filler Hole

17.2 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.

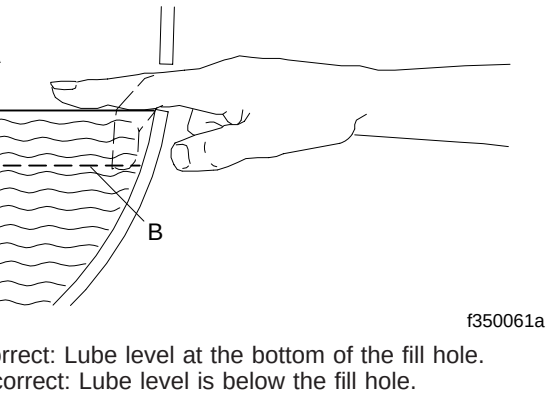
17.3 Return the axle to a level position, and add oil through the axle housing filler hole. About two extra pints (one liter) of lubricant will be needed, to bring the oil level even with the base of the filler hole.

Hub Assembly Removal and Installation, Spoke Wheels



1. Axle Housing Breathers
2. Carrier Fill Hole Plugs
3. Interaxle Differential

Fig. 12, Fill Hole Plug and Axle Housing Breather Locations



A. Correct: Lube level at the bottom of the fill hole.
B. Incorrect: Lube level is below the fill hole.

Fig. 13, Checking the Lubricant Level

NOTE: Drive axle wheel bearings are lubricated by oil drawn from the axle housing bowl section. This method ensures good exchange of heat, prevents stagnation, and minimizes the maintenance required on bearings and hub assemblies.

18. Turn the wheels, and check the lubricant level.
19. If the vehicle is equipped with air brakes, adjust the rear axle brakes at the slack adjusters. For instructions, refer to the brakes group in the vehicle maintenance manual.
20. Remove the safety stands from under the axle, then lower the vehicle.
21. Apply the parking brakes, then remove the chocks from the front tires.

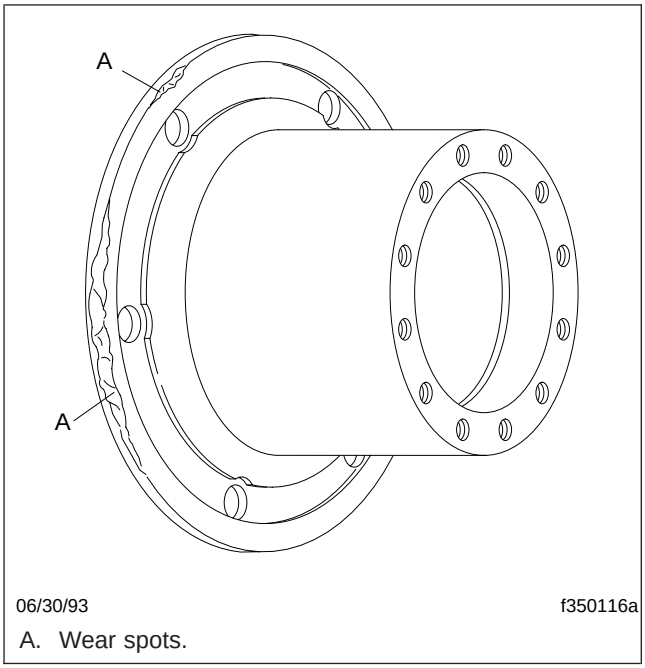
Wheel Hub Assembly and Drive Axle Inspection

1. Inspect the wheel hub 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 the old oil from the spoke wheel or hub cavity. Inspect the inner surface of the wheel or hub for cracks, dents, wear, or other damage. Replace the wheel or hub if damaged.

3. Remove all the old grease or oil from the surfaces of the wheel bearing cups. Inspect the cups for cracks, wear, spalling, or flaking. See **Fig. 3**. Replace the cups if damaged in any way; for instructions, see **Subject 120**.



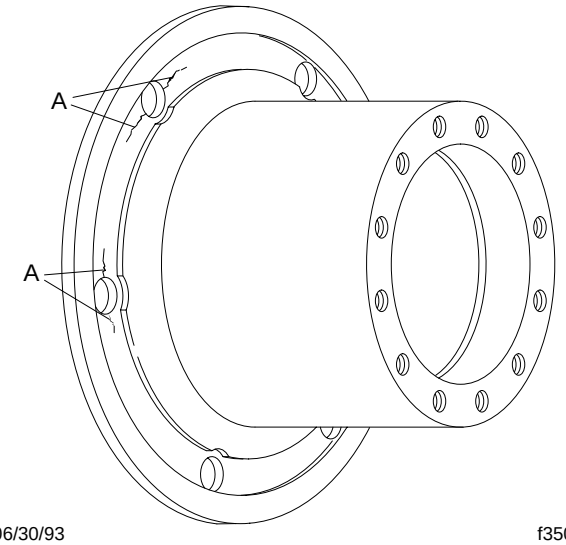
06/30/93 f350116a

A. Wear spots.

Fig. 1, Typical Wheel Hub, Damaged

4. Inspect the wheel nuts on disc wheel installations, or the rim nuts on spoke-wheel installations. Damaged nuts, usually caused by inadequate tightening, must be replaced with new ones. See **Fig. 4**.

   Inspect the wheel studs or rim studs. See **Fig. 5**. Replace studs that are stripped, broken, bent, or otherwise damaged; for instructions, see **Subject 130** or **Subject 140**.



06/30/93 f350031a

A. Cracked stud grooves.

Fig. 2, Typical Wheel Hub, Damaged

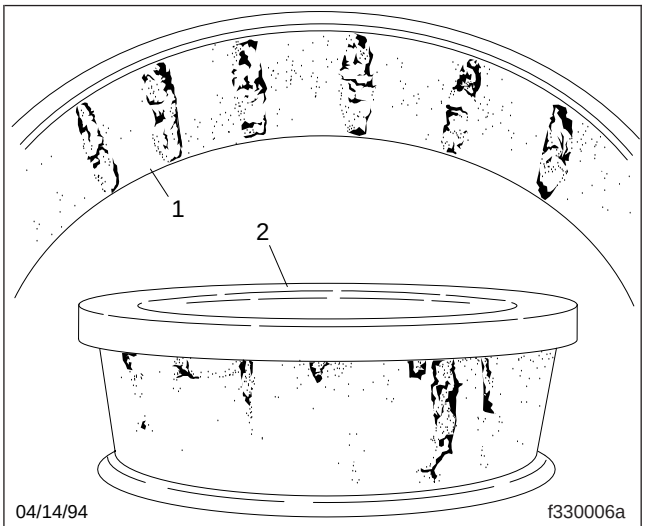
5. Inspect the drive axle studs. Replace the studs that have stripped threads or are broken. Also, replace bent or otherwise damaged studs; for instructions, see **Subject 150**.

6. Inspect the drive axle shaft. If the vehicle has been overloaded, or used under severe or improper operations, the drive axle shaft may be twisted, bent, or otherwise damaged. See **Fig. 6**. Replace the drive axle shaft and flange assembly if damaged.

⚠ CAUTION

CAUTION: If the drive axle shaft and flange assembly is not replaced once the shaft is twisted or otherwise damaged, it will continue to twist until fracture occurs. With complete fracture of the shaft, other axle parts may be damaged which will increase the cost of repairs. Whenever a drive axle assembly is damaged, the drive axle

Axle Components Cleaning and Inspection



1. Cup
2. Cone

Fig. 3, Spalling (Flaking) of Wheel Bearing Assembly

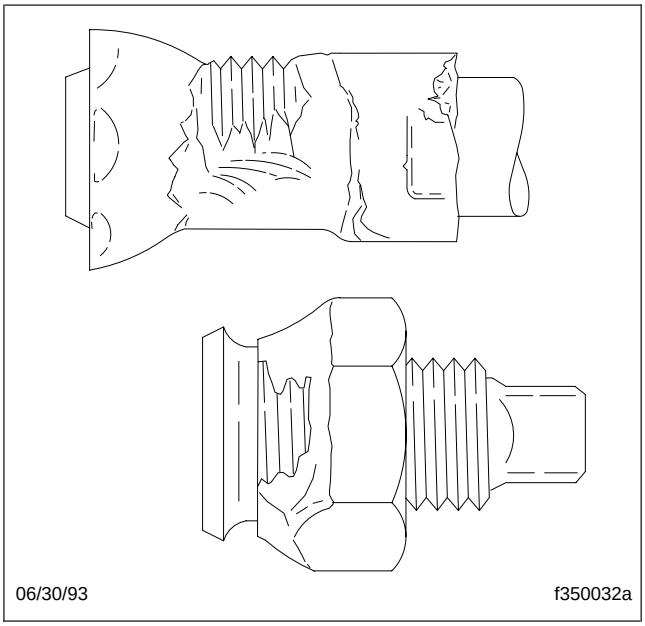


Fig. 4, Damaged Wheel Stud Nuts

shaft and flange on the opposite side of the axle should also be carefully examined, and replaced if damaged.

7. Inspect the drive axle shaft-to-flange surface. Loose wheel bearings can lead to progressive fatigue fractures where the shaft and flange meet. See **Fig. 7**. Replace the drive axle assembly if damaged.

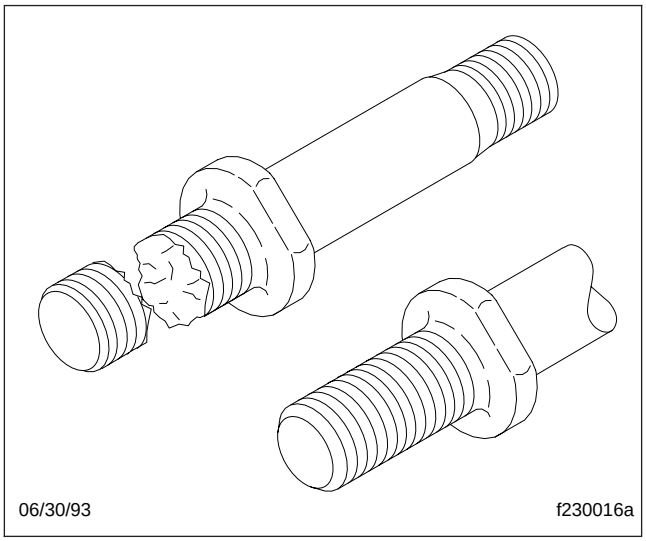
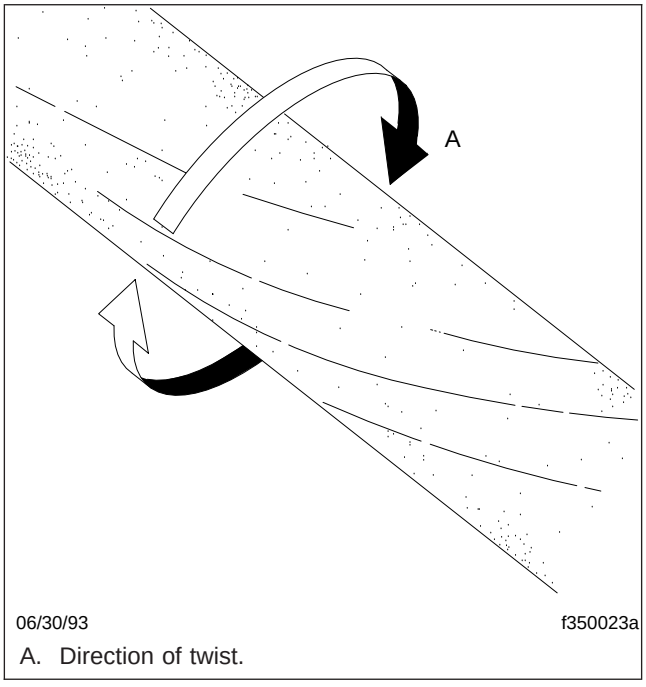


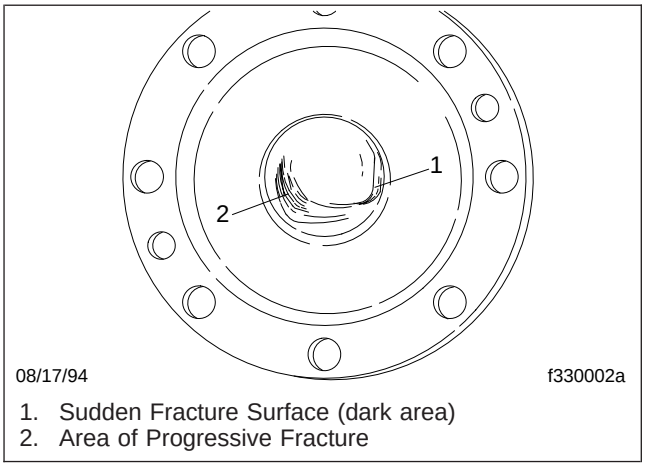
Fig. 5, Damaged Wheel Studs (shouldered type)



A. Direction of twist.

Fig. 6, Overload Damage

8. Inspect the inboard portion of the drive axle flange. Minor burrs or rough spots can adversely affect the sealing action of the oil or grease seals. Remove the burrs or rough spots using



1. Sudden Fracture Surface (dark area)
2. Area of Progressive Fracture

Fig. 7, Fatigue Fracture

fine-grit emery cloth. If they cannot be removed, replace the drive axle shaft.

9. Inspect the drive axle flange around the stud holes. Replace the drive axle shaft and flange assembly if any of the following conditions exist:
   - cracks on the flange surface;
   - metal build-up around the stud holes (a result of wear);
   - out-of-round stud holes.

Wheel Bearing Cleaning and Inspection

CLEANING

⚠ WARNING

WARNING: To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, don't expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury if ignited.

⚠ CAUTION

CAUTION: Don't 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.

Wheel bearings should be very closely inspected at the time of disassembly. The best inspection conditions are possible only after the bearings have been thoroughly cleaned using kerosene or diesel fuel oil, and a stiff brush. See **Fig. 8**. Before inspecting, clean the bearings as follows:

1. Clean all old oil from the bearings and hub cavities, with kerosene or diesel fuel and a stiff brush. See **Fig. 8**. Don't use gasoline or heated solvent.
2. 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.

INSPECTION

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:

1. The large ends of the rollers are worn flush to the recess; the radii at the large ends of the rollers are worn sharp. These are signs of advanced wear. See **Fig. 9**.

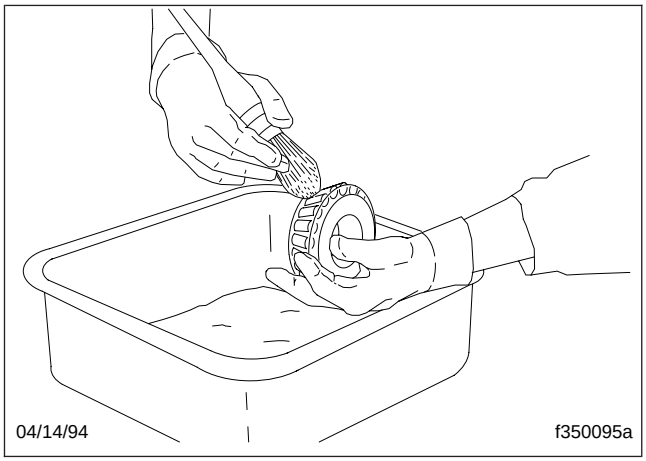


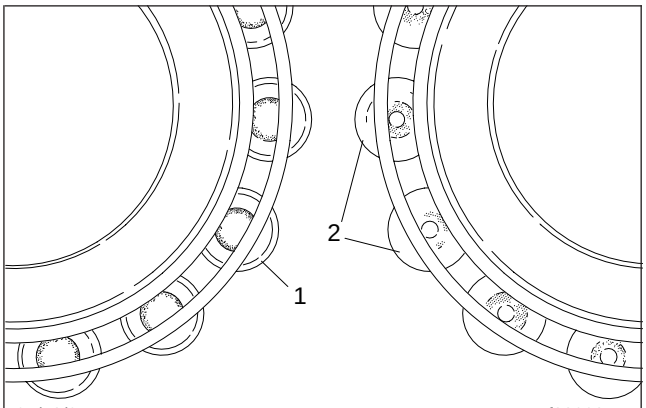
Fig. 8, Cleaning the Bearings

2. Visible step wear, especially at the small end of

Axle Components Cleaning and Inspection

the roller track, or deep indentations, cracks, or breaks in the cone surfaces. See **Fig. 10**.

3. Bright rubbing marks on the dark phosphate surfaces of the bearing cage. See **Fig. 11**.



1. New Bearing
2. Worn Bearing Rollers

Fig. 9, Signs of Wear

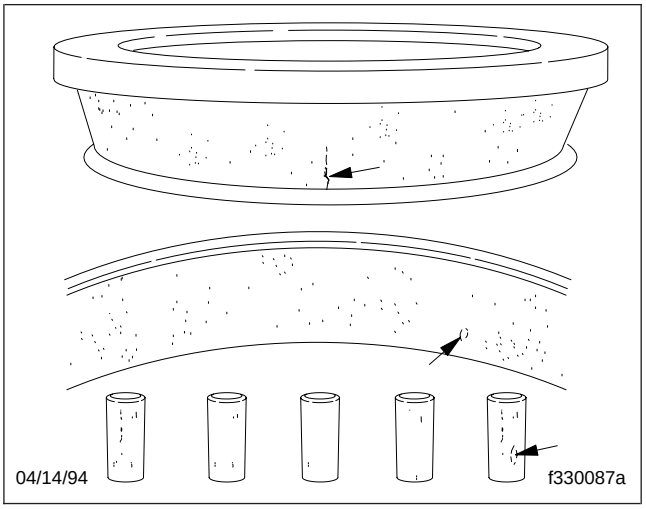


Fig. 10, Indentations, Cracks, or Breaks in Bearing Surfaces

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, check the oil seal sealing surfaces.

5. Etching or pitting on functioning surfaces. See **Fig. 12**.

6. Spalling (flaking) of the bearing cup, roller, or cone surfaces. See **Fig. 3**.

After inspection, brush the bearings with fresh axle lubricant.

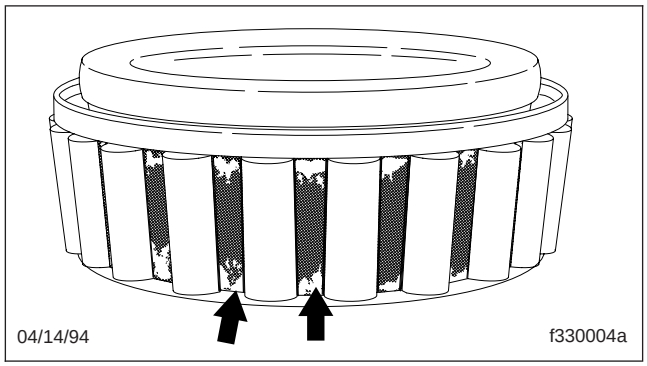


Fig. 11, Rubbing Marks on Bearing Cage

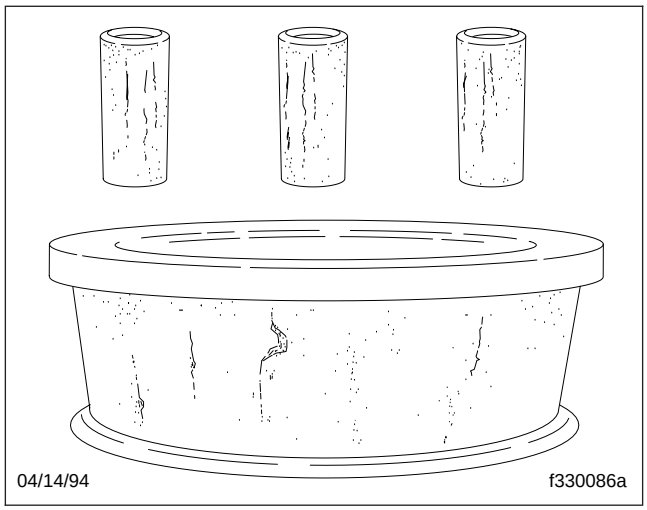


Fig. 12, Etching (Pitting) on Bearing Surfaces

Wheel Bearing Cup Removaland Installation, Ferrous Hubs

Removal

Wheel bearing cups are removed from ferrous hubs by driving them out; there is no need to first heat the hubs.

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

Wheel bearing cups are installed in ferrous hubs by pressing them in; there is no need to first heat the hubs.

1. Using a solvent, completely remove all grease, oil, and other debris from the outer and inner surfaces of the wheel hub assembly, including the bearing cup bores.
2. Inspect the bearing cup bores of the hub for warpage or uneven surfaces. If a bearing cup bore is damaged, replace the wheel hub assembly.
3. Coat the hub-contact surface of the replacement bearing cup with a film of grease.
4. Position the cup in the hub and press it into place, using a suitable tool against the outer edge of the cup. Cups must seat against the shoulder in the hub.

⚠ WARNING

WARNING: To prevent skin irritation, wear chemical resistant gloves when working with diesel fuel or kerosene. Also, don't expose these fluids to flames or heat exceeding 100°F (38°C); both are combustible, and could cause personal injury 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.

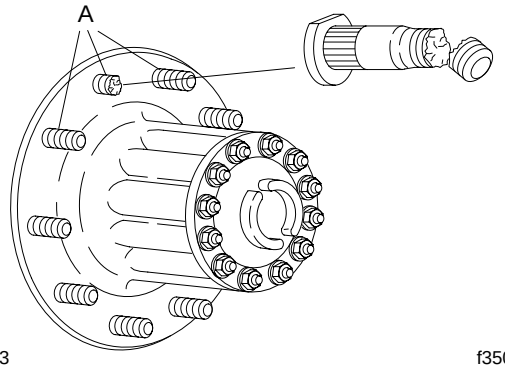
Wheel Stud Replacement, Disc Wheels

Replacement

⚠ WARNING

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.

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 evenly supported around and next to the stud being removed. With steady movement, press the damaged stud out of the hub.



A. Replace all three studs.

Fig. 1, Replacing Damaged Studs

⚠ CAUTION

CAUTION: Don't use a drift and hammer or concentrated heat to remove or install 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 coat 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 evenly supported around and next to the stud being installed.
6. Position the stud in its hole.

⚠ CAUTION

CAUTION: 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.

IMPORTANT: If the driver's side of the vehicle is being serviced, the replacement wheel stud and inner wheel nut must be stamped with an "L" (left-hand threaded), and the nut's face must be stamped "Left." See **Fig. 2**. If the passenger's side of the vehicle is being serviced, the replacement stud and inner wheel nut must be stamped with an "R" (right-hand threaded), and the nut's face must be stamped "Right."

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 in the hub. If the head of the stud is embedded in the hub, replace the hub.

⚠ WARNING

WARNING: 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.

Wheel Stud Replacement, Disc Wheels

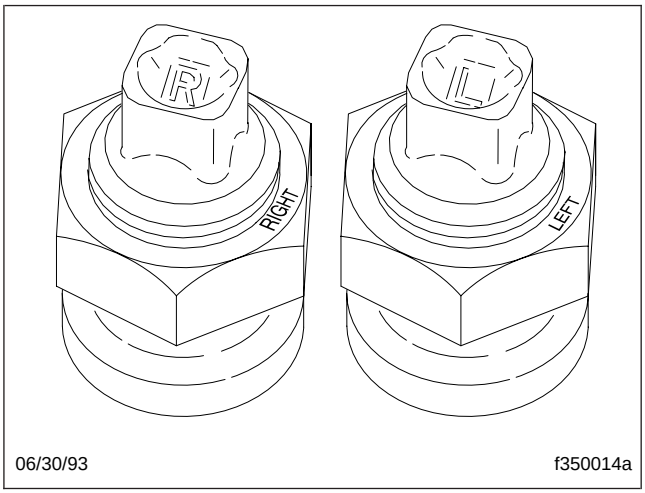


Fig. 2, Wheel Nuts

10. Install the wheel hub on the axle. For instructions, see **Subject 100**.

Rim Stud Replacement, Spoke Wheels

Replacement

1. Remove the rim and tire assemblies from the spoke wheel. For instructions, see **Group 40**.
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, go to the step for tapping out the rim stud hole.

   If the rim stud is broken near the surface of the wheel, 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 centerpunch the surface as a starting point for drilling. Remove the stud.

   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 are damaged, replace the wheel.

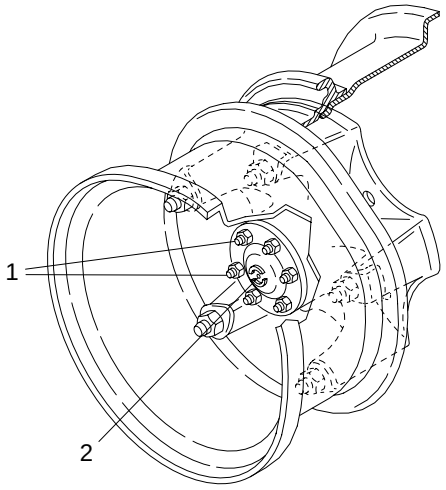
   2.2 Don't drill more than 1-1/4 inches (32 mm) into the broken stud, as measured at the stud's entrance into the wheel. Drilling through the bottom of the rim stud could damage the wheel. If the wheel is drilled into, replace it.

   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 rim stud hole in the wheel to rid the threads of old stud-locking compound. Use an appropriate sized tap, depending on the original rim stud installation size.
4. Be sure the threads of the new stud are clean and dry. Then, coat the insertion end of the rim stud with an anaerobic thread-lock compound.
5. Using double nuts on the fine thread portion of the stud, install the new stud. Seat the rim stud using the torque values in the torque table in **Specifications, 400.**
6. Allow enough time for the thread-lock compound to set, as suggested by the manufacturer.
7. Install the rim and tire assemblies. For instructions, see **Group 40**.

Replacement

NOTE: If the hub has been removed from the axle, go to the step for removing the stud.

1. Apply the parking brakes.
2. Oil will spill as the drive axle shaft is removed. Place a suitable container inside the wheel and under the drive axle flange. Safely discard the lubricant after removal.
3. Remove the drive axle shaft.
   - 3.1 Remove the drive axle stud nuts, and the washers. See **Fig. 1**.



1. Drive Axle Studs and Nuts
2. Center Portion of Drive Axle Flange

Fig. 1, Drive Axle

   - 3.2 Using a hammer and a soft drift, such as one made of brass, sharply tap the center portion of the drive axle flange. See **Fig. 1**. The shaft will usually spring slightly outward after the seal has broken.

CAUTION

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.

   - 3.3 If the drive axle shaft does not spring outward, the seal may have loosened enough to allow the shaft to be manually pulled from the axle housing. Try to manually remove the drive axle shaft from the housing. If the seal has not broken, repeat steps as required.
4. If equipped, remove the tapered dowels and washers from the drive axle flange.
5. Remove and discard the gasket.
6. 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, go to the step for tapping out the drive axle stud hole.

   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 centerpunch the surface as a starting point for drilling.

   - 6.1 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.
   - 6.2 Do not drill more than 1-1/4 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.
   - 6.3 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.
7. 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.
8. 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.

Drive Axle Stud Replacement

9. Using double nuts on the fine-thread portion of the stud, install the new stud. Seat the drive axle stud using the torque values in the torque table in **Specifications, 400.**
10. Allow sufficient time for the thread-lock compound to set, as suggested by the manufacturer.
11. If the hub was removed from the axle, proceed to **Subject 100** or **Subject 102** for installation instructions. If the hub was not removed from the axle, install the drive axle shaft.
    - 11.1 Install a new axle flange gasket over the drive axle studs.
    - 11.2 Install the drive axle shaft in the axle housing. The splined end of the shaft must seat before the drive axle flange will fit over the drive axle studs.
    - 11.3 If equipped, install the dowels and washers on the drive axle studs. Install the drive axle nuts. Using the sequence shown in **Fig. 2**, tighten the nuts to the torque values in the torque table in **Specifications, 400**.

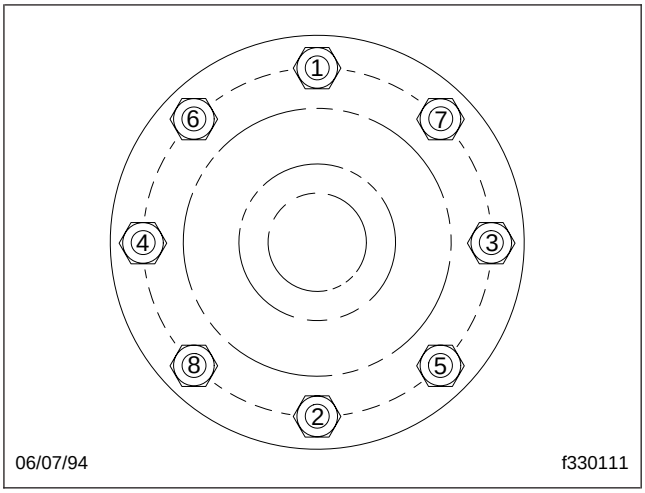


Fig. 2, Axle Shaft Flange Nut-Tightening Sequence

- 11.4 Add fresh oil to the wheel hub. For instructions, see **Subject 100** or **Subject 102**.

WARNING

WARNING: Failure to add oil to the wheel hub after the drive axle shaft has been serviced 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.

Troubleshooting

This subject contains the following troubleshooting tables:

- Noisy Bearings or Excessive Bearing Replacement Intervals
- Broken Wheel or Rim Studs
- Damaged Hub
- Loss of Lubricant From the Wheel Hubs

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 part 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 100** and **Subject 102** 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 the 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 or Rim Studs

Problem—Broken Wheel or Rim Studs	
Possible Cause	**Remedy**
The wheel or rim nuts were overtightened.	Replace the wheel or rim studs. See **Group 40** for the wheel or rim tightening sequence.
The vehicle is being overloaded.	Don't exceed the maximum load-carrying capacity of the vehicle.

Problem—Damaged Hub

Problem—Damaged Hub	
Possible Cause	**Remedy**
(Bent flange) Incorrect installation of the wheel studs, such as using a hammer and drift, or the hub flange wasn't fully supported on the press during wheel stud replacement.	Replace the hub assembly. Replace the wheel studs as instructed under **Subject 130**.
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 drive axle studs are loose.	Tighten the nuts to the torque values in the torque table 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 can't be removed, replace the drive axle shaft.

Specifications

This subject contains the following tables:

- Torque Values
- Rockwell Drive Axle Lubricant Capacities, Single Axles
- Rockwell Drive Axle Recommended Lubricant

Description	Size (grade 8)	Torque lbf·ft (N·m)
Spoke Wheel Brake Drum Nuts	3/4-10	240 (325)
Hub Cap Capscrews	5/16-18	15 (20)
Drive Axle Stud Nuts (with or without dowels)	5/8-18	185-200 (250-270)
Drive Axle Studs (to hub)	1/2-13	70 (95)
	5/8-11	135 (185)
Rotor Capscrews	9/16-12	130 (175)
Spoke Wheel Rim Studs	3/4-10	240 (325)

Table 1, Torque Values

Axle Type	Axle Model	Capacity * pints (liters)	Axle Type	Axle Model	Capacity * pints (liters)
Single †	RS–13–120	16 (7.6)	Single †	RS–19–220	31 (14.7)
"	RS–15–120	16 (7.6)	"	RS–21–145	32 (15.1)
"	RS–15–210	16 (7.6)	"	RS–21–160	39.5 (18.7)
"	RS–17–140	31 (14.7)	"	RS–21–230	39 (18.5)
"	RS–17–145	33.6 (15.9)	"	RS–23–160	42 (19.9)
"	RS–17–220	31 (14.7)	"	RS–23–240	45 (21.3)
"	RS–19–145	34.4 (16.3)			

* Quantities listed are approximate and include 1 pint (0.5 liter) for each wheel end and with the drive pinion at 3 degrees.
† Single drive axles equipped with traction equalizers may require a "friction modifier" to correct a slip-stick condition, as described in the vehicle operator's manual. Rockwell's experience shows that the following additives perform adequately: Add Elco No. 2 Friction Modifier (30 ml [1 ounce] of additive for each 0.5 liter [1 pint] of lube capacity) or Lubrizol No. 797 or 762 (30 mL [one ounce] of additive for each 0.5 liter [1 pint] of lube capacity).

Table 2, Rockwell Drive Axle Lubricant Capacities, Single Axles

Recommended Lubricant Type	Ambient Temperature	Lubricant SAE Viscosity Grade	Rockwell Specification
Hypoid Gear Oil API Service Classification GL–5	+10°F (–12.2°C) and up *	85W–140	0–76–A
	–15°F (–26.1°C) and up *	80W–140	0–76–B
	–15°F (–26.1°C) and up *	80W–90	0–76–D
	–40°F (–40°C) and up *	75W–90	0–76–E
	–40°F (–40°C) to +35°F (+2°C)	75W	0–76–J
	–40°F (–40°C) and up *	75W–140	0–76–L

Specifications

Recommended Lubricant Type	Ambient Temperature	Lubricant SAE Viscosity Grade	Rockwell Specification
Synthetic Gear Oil	–40°F (–40°C) and up *	75W–90	0–76–N
	–40°F (–40°C) and up *	75W–140	0–76–M

* There is no upper limit on these ambient temperatures, but axle sump temperature must never exceed 250°F (121°C).

Table 3, Rockwell Drive Axle Recommended Lubricant

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

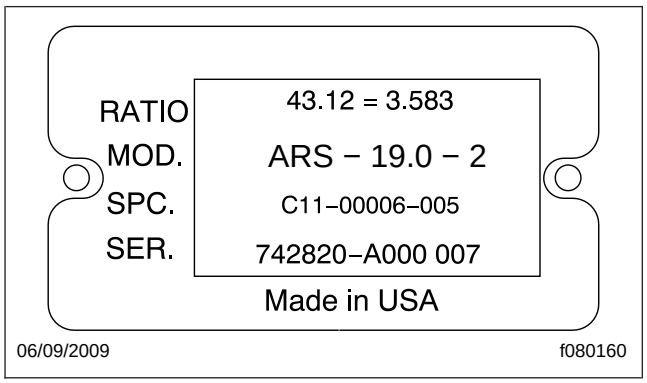


Fig. 1, Rear Axle ID Tag

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 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
9. Release the parking brakes.
10. Cage the parking brake springs to prevent the parking brakes from engaging. For instructions, see **Group 42**.
11. Place a basin under the axle shaft flanges to catch any oil, then remove the axle shafts. For instructions, see **Subject 120**.
12. Drain the air system, if installed.
13. If necessary, back off the slack adjusters. Remove the brake drums.
14. Remove the hubs from the axle spindles. For instructions, see **Section 35.01**.
15. Remove the brake shoes. For instructions, see the applicable service brake section in **Group 42**.
16. If applicable, disconnect the leveling valve rod(s) from the suspension.
17. 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**.
18. Remove the brake spiders from the axle flanges.
    - 18.1 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.
    - 18.2 Remove the ABS sensors and wiring.
    - 18.3 Remove the fasteners that hold the brake spiders to the axle flanges. Remove the spiders from the axle.
19. Using a suitable jack, support the axle housing.
20. If applicable, remove the hexnuts that hold the bottom of each suspension air bag to its suspension bracket.
21. 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.
22. Lower the axle enough to clear the suspension components.
23. Remove the axle from the vehicle.
24. If you are going to replace the differential carrier, place the axle on a secure axle stand.

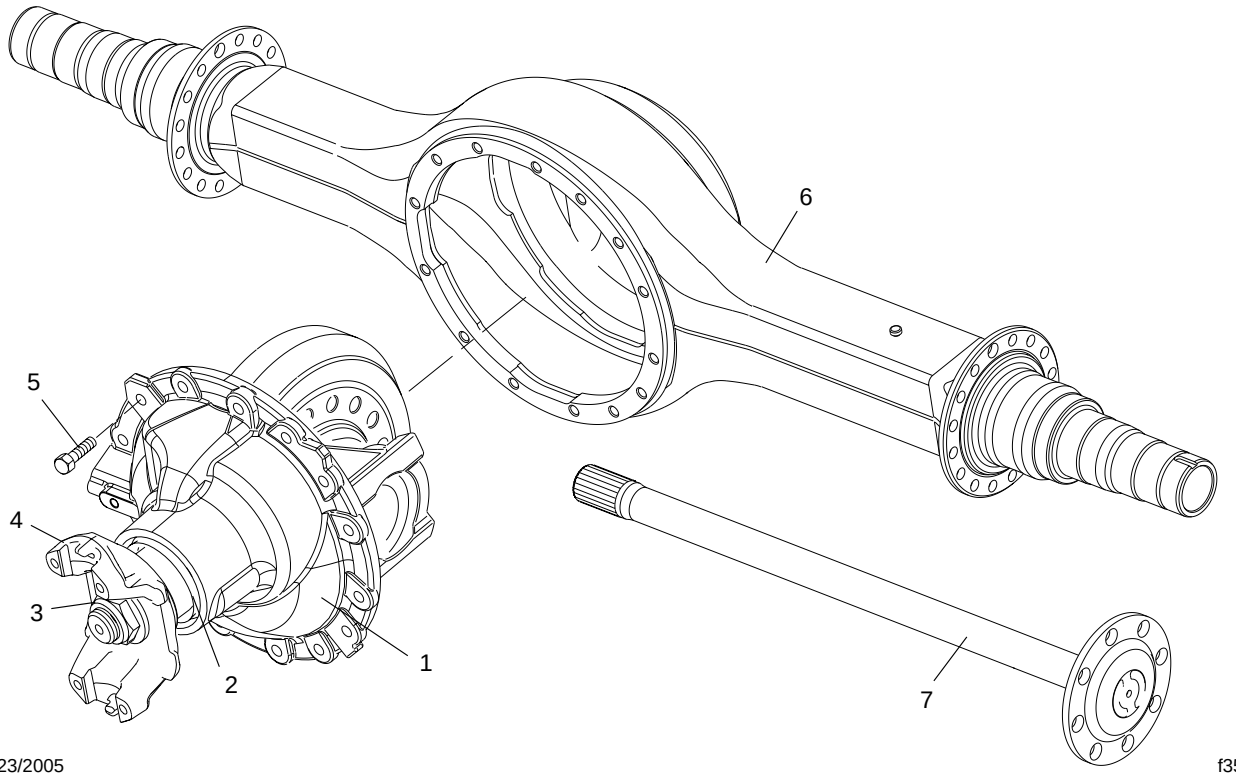
Installation

1. Position the axle underneath the vehicle.
2. Install the suspension components that attach the axle to the vehicle, as follows.

   NOTE: U-bolts and U-bolt nuts cannot be reused.

   - 2.1 On vehicles with conventional suspensions, install the upper U-bolt brackets, new U-bolts, lower U-bolt brackets, and new U-bolt nuts.

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

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 120**.
4. Install the brake spiders on the axle flanges. For instructions, see the applicable service brake section in **Group 42**.
5. Install the ABS sensors and connect the wiring at the frame rail. Secure the wiring with tie straps as needed.
6. Install the brake air chambers (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. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
11. Install the brake drums on the hubs.
12. Install the tire and wheel assemblies. For instructions, see **Group 40**.
13. Adjust the brakes. For instructions, see the applicable service brake section in **Group 42**.
14. Uncage the parking brake springs.
15. 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

16. 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.

17. Turn the wheels, wait one minute, and check the lubricant level.
18. Raise the vehicle, remove the safety stands, then lower the vehicle.
19. 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**.
20. 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.
21. Set the parking brake, then remove the chocks from the front tires.

Single Axle Differential Carrier Removal and Installation

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. Disconnect the driveshaft from the carrier input yoke. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
7. Place a basin under the axle shaft flanges, then remove the axle shafts. For instructions, see **Subject 120**.
8. 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. Remove the carrier capscrews that hold the differential carrier to the axle housing. See **Fig. 1**.
3. 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).

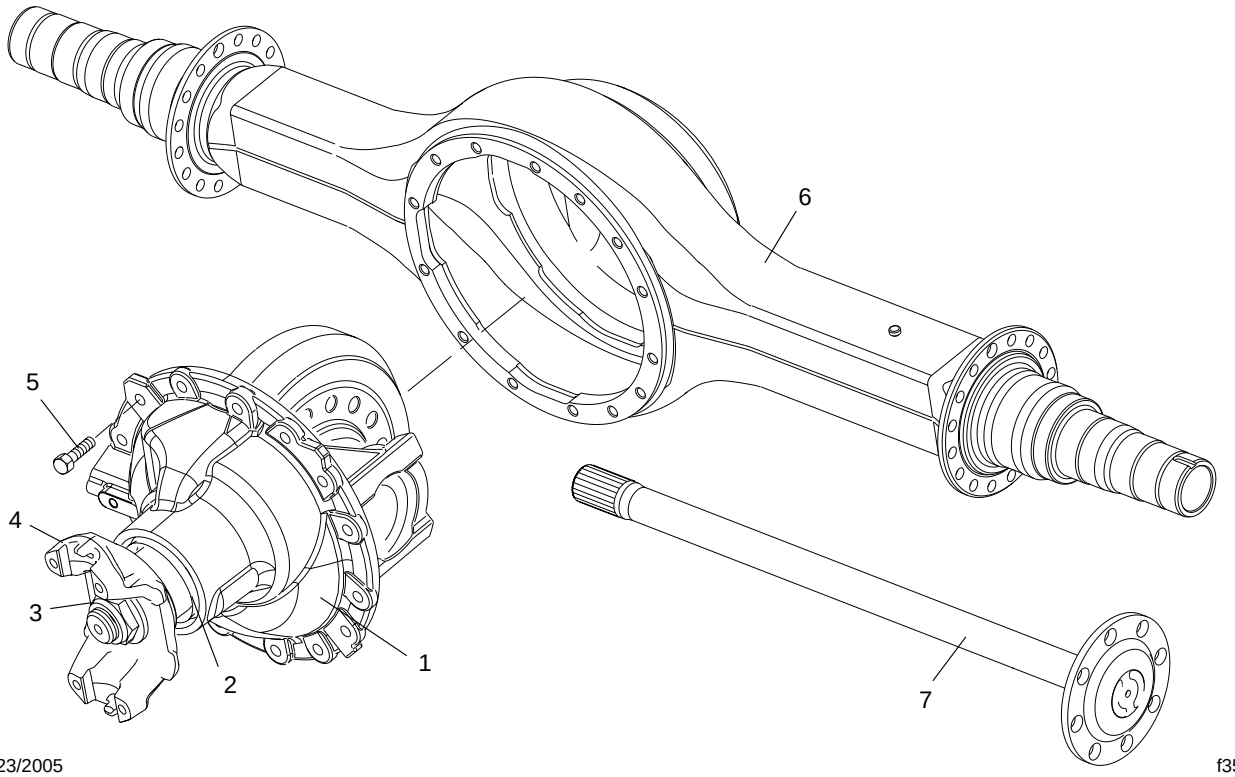
4. Install alignment dowels 180 degrees apart at the 3 o'clock and 9 o'clock positions on the axle housing flange.

NOTICE

Make sure the differential carrier is centered and straight on the axle housing before you install the mounting capscrews. Attempting to install the carrier when it is not centered or straight may cause damage to the carrier.

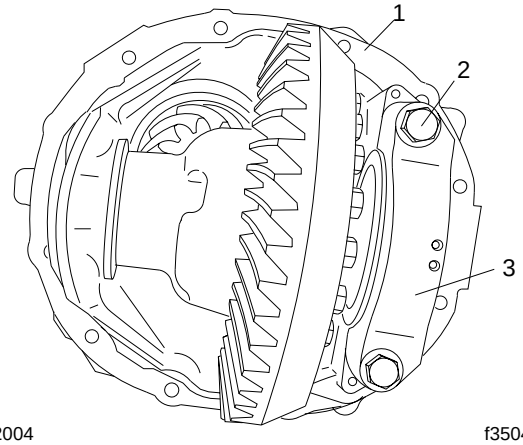
5. Using a hoist (if the axle is removed from the vehicle) or a suitable transmission jack, install the differential carrier into the axle housing. Use the alignment dowels to center the carrier on the axle housing.
6. Install the end caps at the sides of the carrier into the corresponding slots in the axle housing. See **Fig. 2**.
   - 6.1 For the last 3/4 inch (19 mm) or so of travel, walk the carrier slowly into the housing.

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



1. Differential Carrier
2. End Cap Bolt
3. End Cap

Fig. 2, Carrier End Caps

IMPORTANT: The end caps fit tightly into the axle housing. Be very careful not to cock the carrier.

6.2 Install the carrier capscrews finger-tight. Make sure the carrier capscrews turn easily in the axle housing.

6.3 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 (271 N·m)

7. 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.

8. Connect the driveshaft to the carrier input yoke. For instructions, see **Section 41.00, Subject 120**.
9. Using new gaskets, install the axle shafts. For instructions, see **Subject 120**.
10. Install the tire and wheel assemblies. For instructions, see **Group 40**.
11. 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

12. 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.

13. Turn the wheels, wait one minute, and check the lubricant level.
14. Raise the vehicle, remove the safety stands, then lower the vehicle.
15. 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.
16. 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.
17. Remove the chocks from the front tires.

Removal

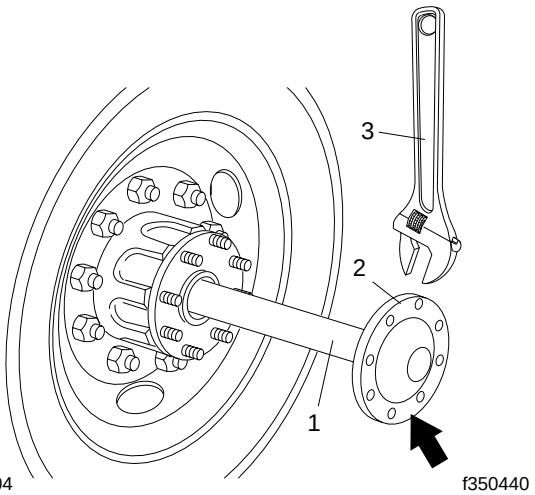
1. Chock the front tires.
2. Raise the rear of the vehicle with a suitable jack high enough to clear the axle. Support the axle with jack stands.
3. Place a basin under the axle shaft flanges to catch any oil. Dispose of used oil properly.
4. If necessary, remove the rear wheels and tires. For procedures, see **Group 40**.

NOTE: This procedure can be done with the wheels and tires installed or with the wheels and tires removed.

5. Remove the drive axle stud nuts that attach the axle shaft to the wheel hub.
6. 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. Install the axle shaft, as follows. See **Fig. 1**.



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

2.1 Carefully raise the axle with the floor jack, and support the axle with jack stands. Slide the axle shaft into the axle.

2.2 Apply light pressure with the hand or knee to the axle flange.

2.3 Use an adjustable wrench to center the shaft. Turn the shaft with a slight rotating motion.

2.4 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)

3. If removed, install the rear wheels and tires. Tighten the wheel nuts according to the procedures in **Group 40**.
4. Remove the supports and lower the vehicle.
5. As needed, replace any oil that was drained from the hub when the axle shaft was removed.
6. 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.

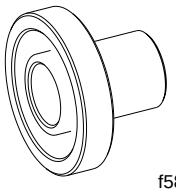
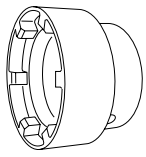
Replacement

1. Disconnect the driveshaft from the differential carrier. For instructions, see **Section 41.00, Subject 120**. Using suitable straps, support the end of the driveshaft by attaching it to the frame rail.
2. Remove the yoke nut from the center of the carrier yoke. If the yoke nut is round and slotted, use the yoke nut socket shown in **Table 1**. See **Fig. 1**. Be careful not to damage the seal bore.
3. Remove the carrier yoke from the input shaft.
4. Pry up the seal, using a prybar or large screwdriver. Clean any old sealant from the axle housing. Do not allow dirt or grease to contaminate the seal bore or shaft bearings. See **Fig. 2**.
5. Install the rear pinion seal on the rear input shaft, as follows. See **Fig. 3**.
   - 5.1 Inspect the area around the seal for damage. Use emery paper to remove scratches, nicks, or burrs on the seal bore.
   - 5.2 Assemble the rear pinion seal installer onto the threaded end of the universal handle. See **Table 1**.

   IMPORTANT: Be careful not to cock the seal during installation.

   - 5.3 Using the rear pinion seal installer assembly, press the seal into the bore until the seal surface is flush with the bottom surface of the counterbore.
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

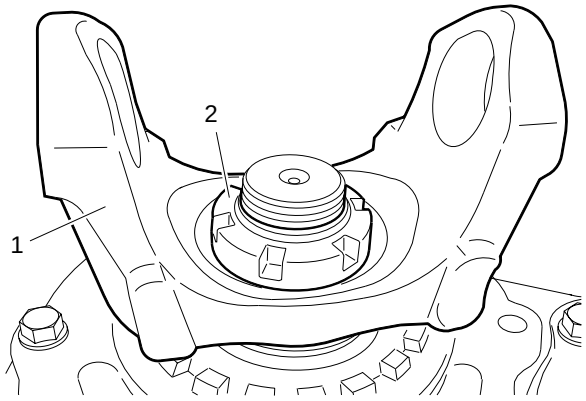
Single Axle Yoke and Seal Replacement, Model 4 Axles

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 120**.

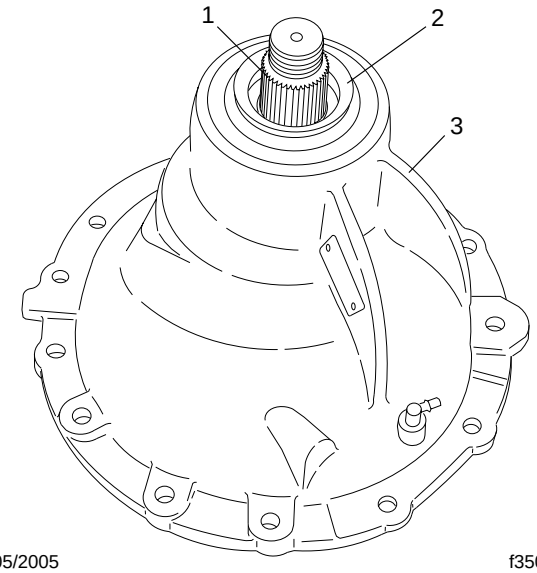


04/01/2008 f350496

NOTE: The yoke nut may be a hexnut rather than the round, slotted nut shown here.

1. Yoke
2. Yoke Nut

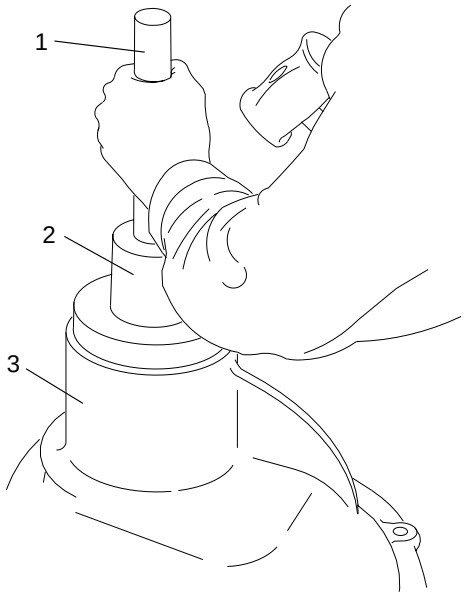
Fig. 1, Yoke Nut on the Carrier



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

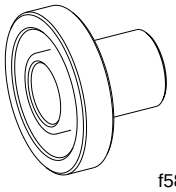
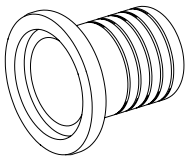
Fig. 3, Installing the Rear Pinion Seal

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)

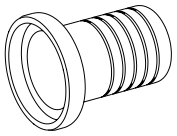
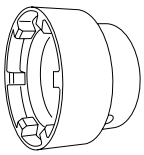
Table 1, Torque Values

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

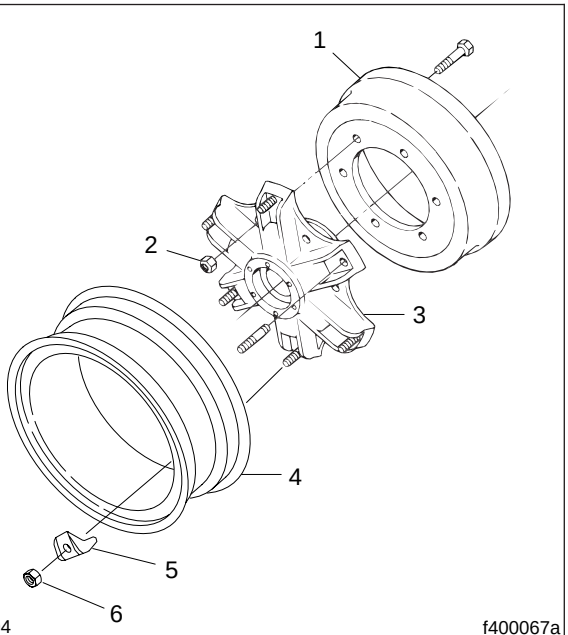
General Information

Wheels and Tires

The tires support the weight of the vehicle, and are integral parts of the drivetrain and braking systems. The wheels serve as load carrying members between the tires and the axle.

There are two types of wheels: spoke and disc.

Spoke wheels consist of a wheel and brake drum assembly installed on the axle, and a tire and rim assembly that mounts on the wheel. See **Fig. 1**. Rim clamps and rim nuts hold the tire and rim assembly in place.

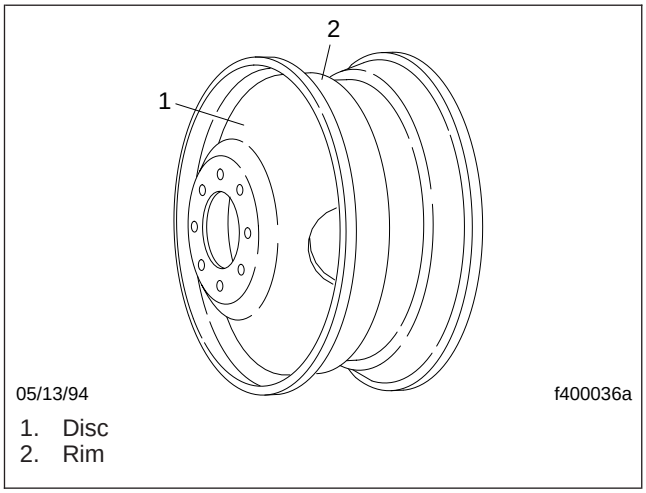


1. Brake Drum
2. Spoke Wheel
3. Brake Drum Nut
4. Rim Base
5. Rim Clamp
6. Rim Nut

Fig. 1, Spoke Wheel and Brake Drum Assembly

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. 2**. After the tire is mounted on the wheel, the assembly is held in place on the hub with wheel studs and nuts.

Standard ten-hole dual disc wheels are held in place on the hub by self-centering inner and outer wheel nuts. Eight-hole and optional ten-hole (single and



1. Disc
2. Rim

Fig. 2, Disc Wheel

dual) disc wheels are centered by pilot pads and are held in place on the hub with two-piece flange nuts.

Tires are constructed of either radial or bias plies:

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. 3**. The belt plies constrict the radial ply cords and give rigidity to the tread.

Bias ply tires have body ply cords that run diagonally from bead to bead. See **Fig. 4**. The tires may also have narrow plies under the tread, called breakers, with cords that lie in about the same direction as the body ply cords.

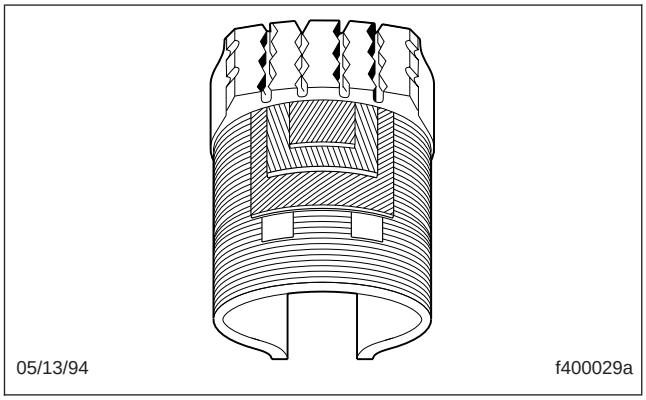


Fig. 3, Radial Ply Tire Construction

Tire body plies, breakers, and belts are made of polyester, rayon, nylon, fiberglass, steel, or aramids (fibrous reinforcements). In radial ply tires, these materials are used in various combinations, including

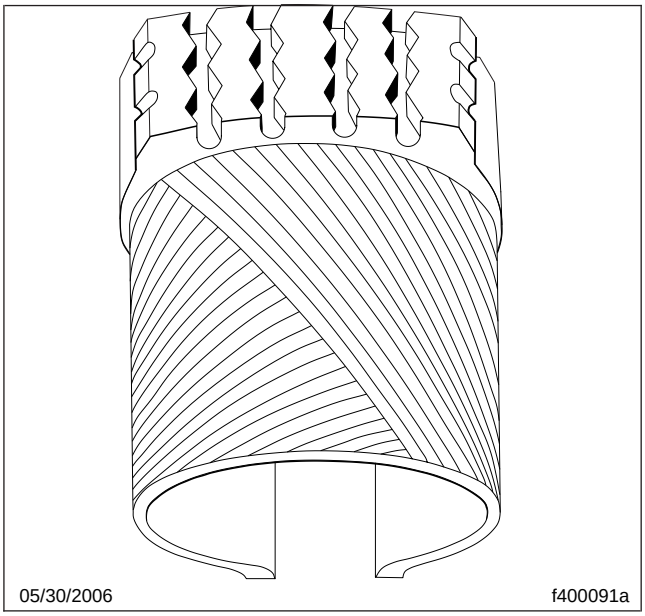


Fig. 4, Bias Ply Tire Construction

steel body/steel belt, polyester body/fiberglass belt, or nylon body/steel belt.

Wheels and tires operate either with or without tubes. Tube-type tires require a tube and flap for correct assembly on a two-or three-piece rim. See **Fig. 1**. Tubeless tires require only the tire, and a one-piece drop-center wheel or rim. See **Fig. 2**.

Tire Matching and Mixing

IMPORTANT: Review and follow these requirements for matching and mixing tires, before installing any tire and wheel or rim assembly on a vehicle.

Before changing wheels and tires, consider the effect that the change may have on the Gross Vehicle Weight Rating (GVWR) of the vehicle. At the time of vehicle certification, the GVWR is calculated by adding the vehicle'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 by the body builder.

Tire and rim labels certify the minimum tire and rim combinations that can be installed on the vehicle for the given GAWRs. 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 separation, tire body breaks, and blowouts can occur from mismatched duals.

With an endless pi tape or square, measure the diameter of the tires 24 hours after inflation. See **Fig. 5** and **Fig. 6**. A matching stick, string gauge, or tire straight edge can also be used to determine the difference in tire radius, which is then doubled to calculate the diameter difference. See **Fig. 7**, **Fig. 8**, and **Fig. 9**.

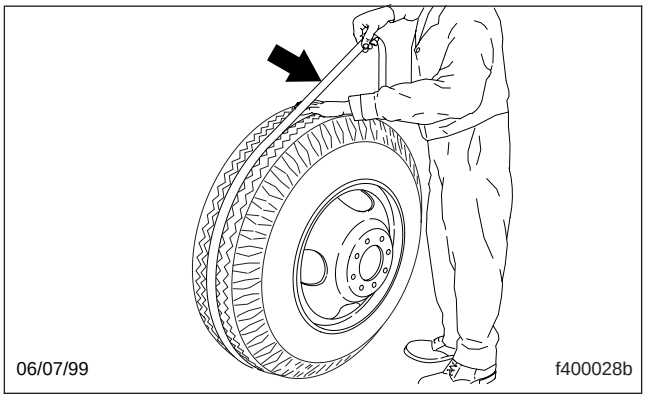


Fig. 5, Endless Pi Tape

When pairing tires of unequal diameters (but within the above limits), mount the larger tire on the outside.

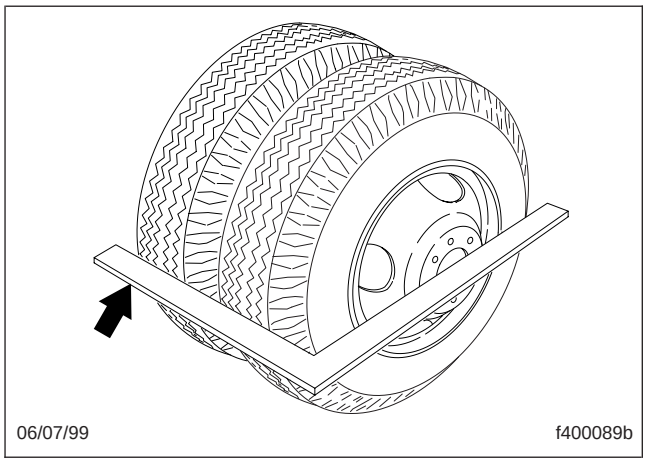


Fig. 6, Square

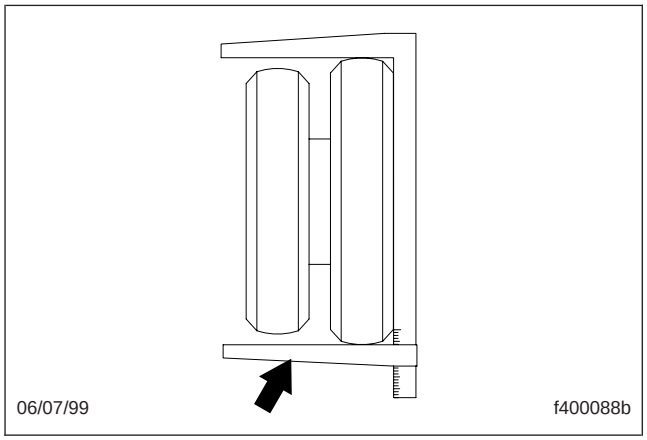


Fig. 7, Matching Stick

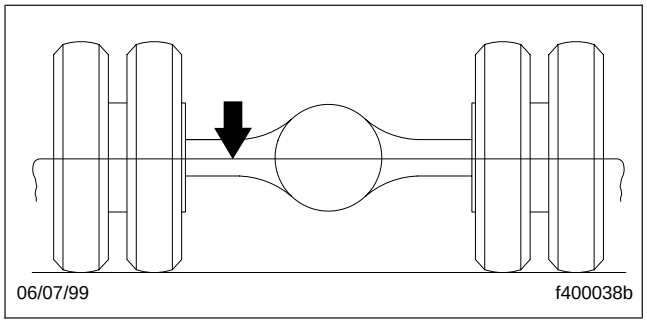


Fig. 8, String Gauge

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.

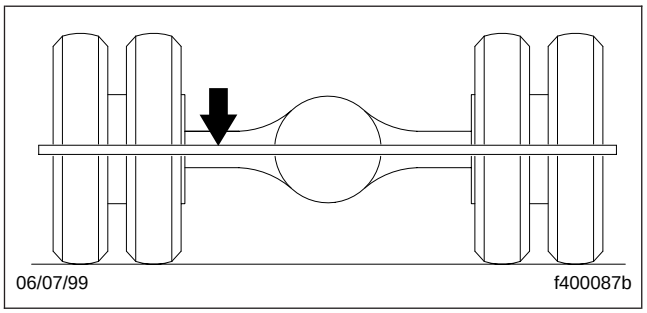


Fig. 9, Tire Straight Edge

Inflate all tires on an axle to within 5 psi (35 kPa) of one another. For tire inflation specifications, see the applicable tables in **Specifications, 400**.

There must be sufficient space between dual tires for air to flow and cool the tires, and to prevent them from rubbing against one another. 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, see the tire manufacturer's catalog to determine the minimum dual spacing. See 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.

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.

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.

General Information

If installing radial tires on a vehicle formerly equipped with bias ply tires, see the applicable tables in **Specifications, 400** concerning the inflation needs and load limits of the bias ply tires being removed, and of the radial ply tires being installed. Radial ply tires permit greater loads per tire, but also require higher inflation. They can also cause higher stresses on rims and wheels than bias ply tires. Contact the rim or wheel manufacturer about the compatibility of the rim or wheel with radial ply tires.

8-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock all tires that will not be serviced, to prevent vehicle movement.
2. Raise the end of the vehicle being serviced until the tires clear the floor. Place safety stands under the axle being serviced.
3. If the tire or wheel is damaged (or if there is suspected damage), deflate the tire being serviced by removing the valve core. On rear axles deflate both tires of the dual assembly.
4. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced. Turn the wheel until one hub-pilot pad is in the top-center position.
5. Leaving the top nut until last, remove all eight two-piece flange 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 threads.

6. 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 160**. Also, follow the tire matching and mixing requirements in **Subject 050**.

1. Clean the hub and wheel mounting surfaces, and between the rims of dual wheels. Make sure the tire is correctly inflated. For instructions, see **Subject 180**.
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. Wipe off any excess oil.

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 adjust 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 of rear axles) on the hub. Make sure the wheel is square to the hub and that the threads or pilot pads are not damaged by contact with the wheel during installation. On rear axles, mount the outer wheel against the inner wheel using the same procedure.
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 on rear wheel assemblies to be in the same wheel hole, mount the outer wheel so that the outer wheel balance weight(s) are on the same side as the brake drum balance weight(s).

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 two-piece flange nuts 50 to 100 lbf·ft (68 to 135 N·m) following the sequence in **Fig. 1**.
7. Check that the wheel is correctly seated against the hub and on the hub-pilot pads.

8-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

8. Following the sequence in **Fig. 1**, tighten the two-piece flange nuts 450 to 500 lbf·ft (610 to 678 N·m).

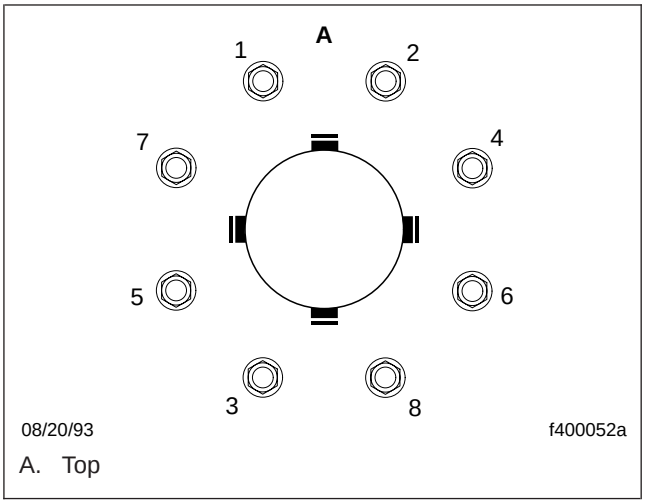


Fig. 1, 8-Stud Disc Wheel Tightening Sequence

WARNING

If the wheel nuts cannot be tightened to minimum torque values, check for loose studs and stripped threads. Replace damaged parts. If a stud is turning in the hub flange, replace the wheel hub assembly. Failure to replace damaged parts could result in the loss of a wheel, loss of vehicle control, and resulting personal injury and property damage.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35**.

NOTE: Nuts on double-threaded wheel studs should be tightened 390 to 450 lbf·ft (529 to 610 N·m).

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 nuts 450 to 500 lbf·ft (610 to 678 N·m). Follow the sequence in **Fig. 1**.

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. 1.

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 50,000 miles (80 000 km) thereafter.

10-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

Removal

1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock all tires that will not be serviced to prevent vehicle movement.
2. Raise the end of the vehicle being serviced until the tires clear the floor. Place safety stands under the axle being serviced.
3. If the tire or wheel is damaged or if there is suspected damage, deflate the tire (or tires, on a dual assembly) being serviced by removing the valve core.
4. Turn the wheel until one hub-pilot pad is in the top-center position.
5. Leaving the top and bottom nuts until last, remove the other eight two-piece flange nuts.
6. 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.

7. 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 160**. Also 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 180**.
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. Wipe off any excess oil.

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 adjust 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 of rear axles) 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 rear axles, mount the outer wheel against the inner wheel using the same procedure.
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. 1**.

10-Hole Disc Wheel With Two-Piece Flange Nuts Removal and Installation

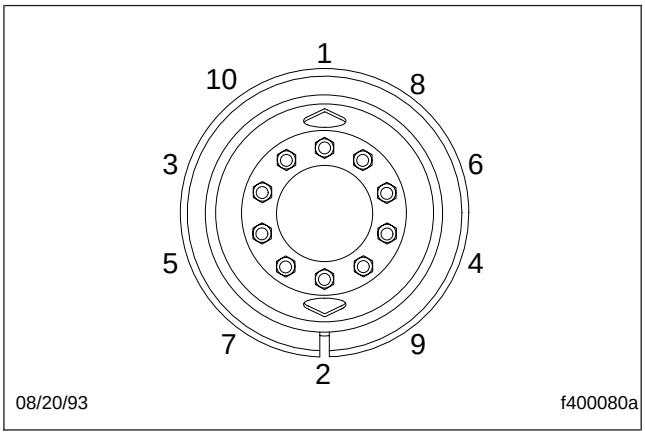


Fig. 1, 10-Stud Disc Wheel Tightening Sequence

7. Check that the wheel is correctly seated against the hub and on the hub-pilot pads.
8. Following the sequence in **Fig. 1**, tighten the two-piece flange nuts 450 to 500 lbf·ft (610 to 678 N·m).

⚠ WARNING

If the wheel nuts cannot be tightened to minimum torque values, check for loose studs and stripped threads. Replace damaged parts. If a stud is turning in the hub flange, replace the wheel hub assembly. Failure to replace damaged parts could result in the loss of a wheel, loss of vehicle control, and resulting personal injury and property damage.

IMPORTANT: Replace damaged parts following the instructions in **Group 33** or **Group 35** in this manual.

NOTE: Nuts on double-threaded wheel studs should be tightened 390 to 450 lbf·ft (529 to 610 N·m).

9. Remove the safety stands, lower the vehicle, and remove the chocks.
10. After operating the vehicle for 80 to 160 km (50 to 100 miles), retighten the wheel nut 450 to 500 lbf·ft (610 to 678 N·m). Follow the sequence in **Fig. 1**.

⚠ 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. 1.

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) thereafter.

10-Hole Disc Wheel With Inner and Outer Nuts; Removal and Installation

Removal

1. Apply the parking brake. Chock all tires that will not be serviced, to prevent vehicle movement.
2. Raise the end of the vehicle being serviced until the tires clear the floor. Place safety stands under the axle being serviced.
3. If the tire or wheel is damaged (or if there is suspected damage), deflate the tire being serviced by removing the valve core. On rear axles deflate both tires of the dual assembly.
4. Place a jack or wheel-and-tire dolly under the wheel assembly being serviced. Remove the wheel nuts, then raise and remove the wheel assembly. Be careful not to damage the threads of the wheel studs as the wheel is pulled away. On rear wheel assemblies, remove the outer wheel first, being careful not to damage the threads of the inner wheel nuts.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions under **Subject 160**. Also, follow the tire matching and mixing requirements under **Subject 050**.

1. Clean the hub and wheel mounting surfaces, and between the rims of dual wheels. Make sure the tire is inflated using the procedures under **Subject 180**.
2. Use a jack or wheel-and-tire dolly to mount the wheel assembly (inner dual wheel of rear wheel assemblies) on the wheel studs. Be careful not to damage the threads of the wheel studs when installing the wheel assembly.

IMPORTANT: Mount the wheel assembly so that the balance weight(s) on the wheels are 180 degrees opposite the balance weight(s) on the brake drum. See **Fig. 1**.

If, on two-handhole wheels, this causes the valve stems of rear wheel assemblies to be in the same wheel hole, mount the outer wheel so that the outer wheel balance weight(s) are on the same side of the assembly as the brake drum balance weight(s). See **Fig. 2**.

If, on five-handhole or aluminum wheels, the valve stems of rear wheel assemblies are in the same handhole, separate the valve stems by one hole. Install the wheel weights evenly and as close to 180 degrees opposite the brake drum balance weight(s) as possible. **See Fig. 3**.

3. Install a wheel nut (inner wheel nut of rear wheel assemblies) on each wheel stud, and run them up until each nut is flush with the face or the chamfer of the wheel. Rotate the wheel a half turn to seat the parts.
4. Tighten the wheel nuts 50 lbf·ft (68 N·m), following the sequence in **Fig. 4**.
5. Following the same sequence, tighten the wheel nuts again. Refer to the applicable table in **Specifications, 400**.

WARNING

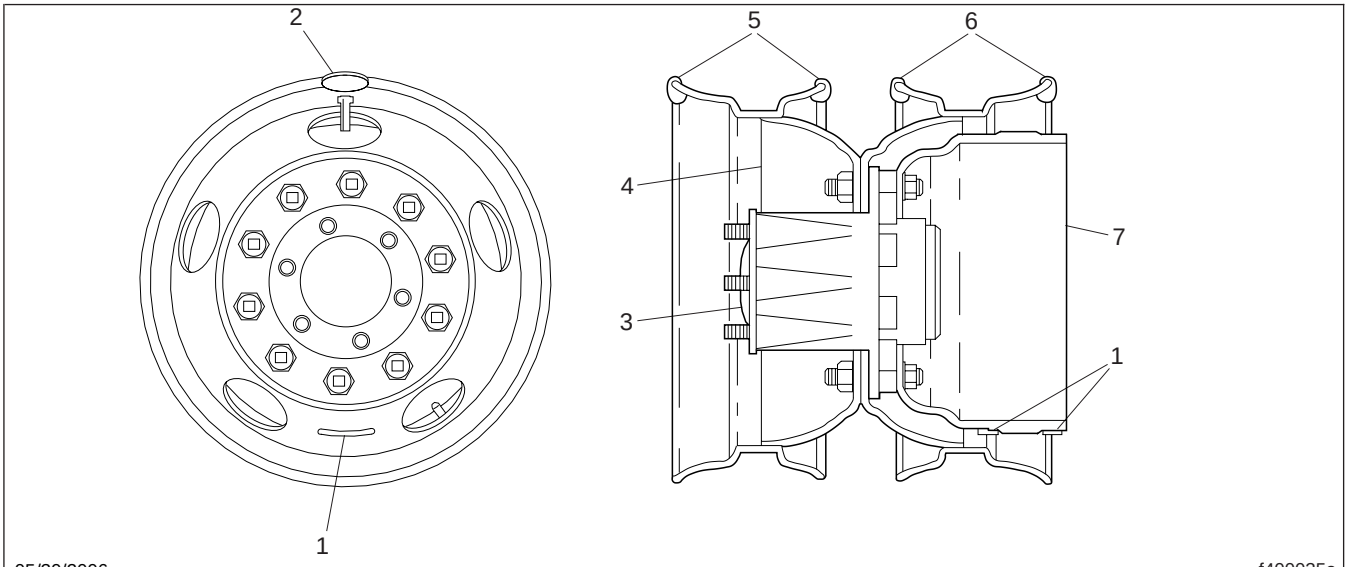
WARNING: If the wheel nuts cannot be tightened to minimum torque values, check for loose studs and stripped threads. Replace damaged parts. If a stud is turning in the hub flange, replace the wheel hub assembly. Failure to replace damaged parts could result in the loss of a wheel, loss of vehicle control, and resulting personal injury and property damage.

6. For front wheel assemblies, go to the next step. For rear wheel assemblies, use a jack or wheel-and-tire dolly to mount the outer dual wheel on the inner wheel nuts. Be careful not to damage the threads of the inner wheel nuts when installing the wheel assembly. Install the outer wheel nuts following the procedures above.
7. Remove the safety stands, lower the vehicle, and remove the chocks.
8. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the wheel nuts to the torque in the applicable table in **Specifications, 400**. Follow the sequence in **Fig. 4**.

CAUTION

CAUTION:Locknuts seat during vehicle operation. It is necessary to periodically tighten the wheel nuts to the specified torque. 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

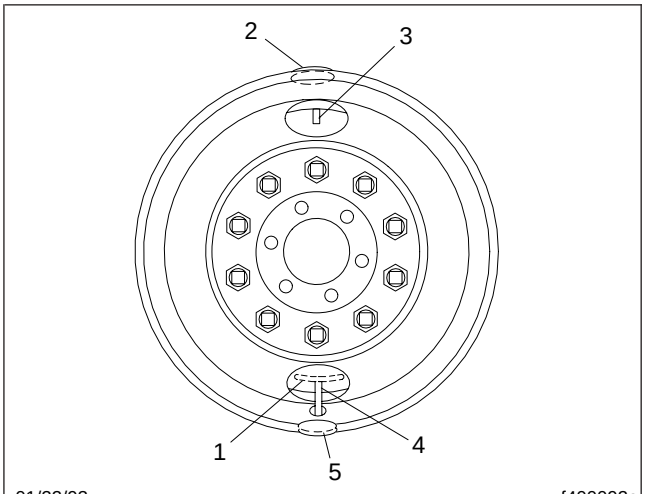
10-Hole Disc Wheel With Inner and Outer Nuts; Removal and Installation



05/30/2006 f400035a

1. Brake Drum Balance Weight(s)
2. Inner and Outer Wheel Balance Weight(s)
3. Hub
4. Disc Wheel
5. Outer Wheel Balance Weight(s)
6. Inner Wheel Balance Weight(s)
7. Brake Drum

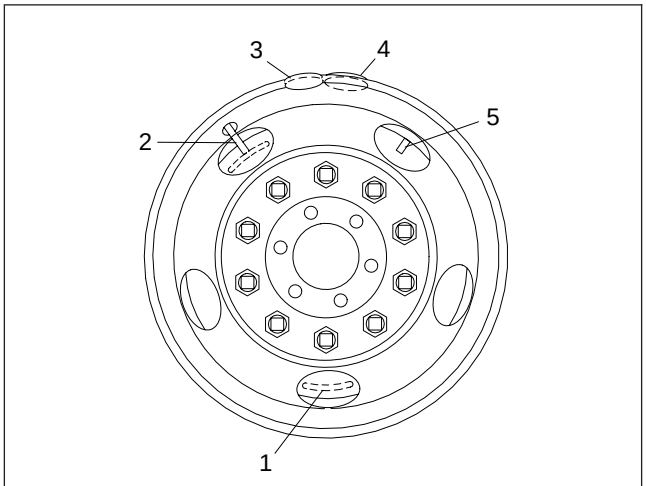
Fig. 1, Recommended Location of Wheel and Brake Drum Balance Weights



01/22/93 f400092a

1. Brake Drum Balance Weight(s)
2. Inner Wheel Balance Weight(s)
3. Inner Wheel Valve Stem
4. Outer Wheel Valve Stem
5. Outer Wheel Balance Weight(s)

Fig. 2, Alternate Location of Wheel and Brake Drum Balance Weights, Two-Handhole Wheels



08/24/93 f400093a

1. Brake Drum Balance Weight(s)
2. Outer Wheel Valve Stem
3. Outer Wheel Balance Weight(s)
4. Inner Wheel Balance Weight(s)
5. Inner Wheel Valve Stem

Fig. 3, Alternate Location of Wheel and Brake Drum Balance Weights, Five-Handhole or Aluminum Wheels

10-Hole Disc Wheel With Inner and Outer Nuts; Removal and Installation

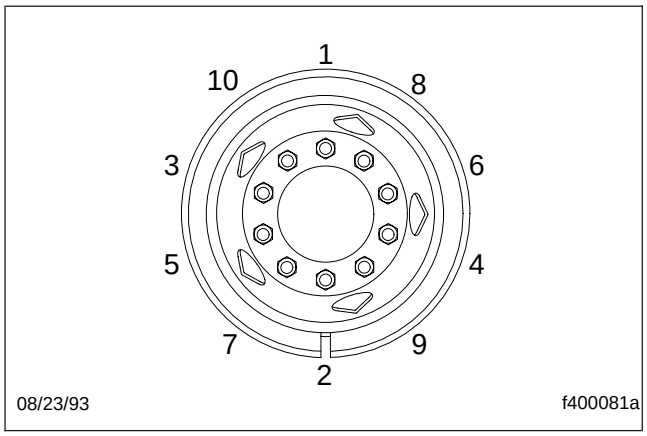


Fig. 4, 10-Stud Disc Wheel Tightening Sequence

threads, and crack discs in the stud hole area. Use the specified torque values, and follow the tightening sequence in Fig. 4.

NOTE: When retightening the inner wheel nuts, loosen the outer wheel nuts several turns, re-tighten the inner wheel nuts, then the outer wheel nuts.

Spoke Wheel, Tire and Rim Assembly; Removal and Installation

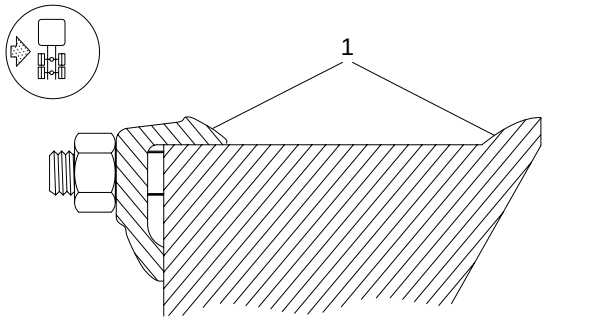
Removal

1. Chock all tires that will not be serviced, to prevent vehicle movement. If removing tire and rim assemblies from the front axle, apply the parking brake.
2. Raise the end of the vehicle being serviced until the tires clear the floor. Place safety stands under the axle being serviced.
3. Deflate the tire(s) being serviced by removing the valve core(s).
4. Place a jack or wheel-and-tire dolly under the tire and rim assembly being serviced (outer tire and rim assembly on rear axle). Remove the rim nuts and clamps; then, slide the tire and rim (outer tire and rim on rear axle) off the wheel.
5. On rear axles only, remove the rim spacer. Place a jack or wheel-and-tire dolly under the inner tire and rim assembly, and slide it off.

Installation

NOTE: Before installing a wheel and tire assembly, inspect it using the instructions under **Subject 160**. Also, follow the tire matching and mixing requirements under **Subject 050**.

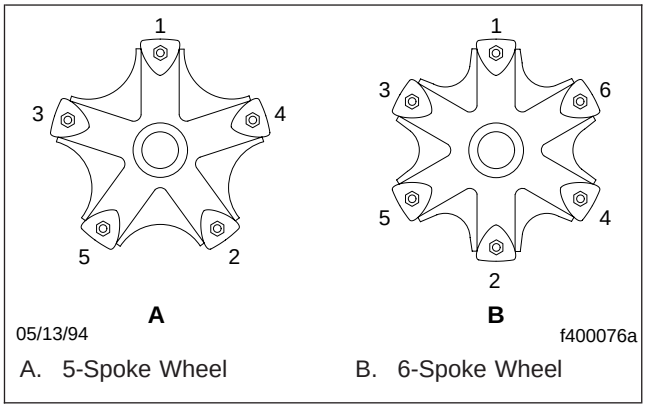
1. Clean the wheel, rim spacer, and rim mounting surfaces. The mounting surface of the wheel is the 28-degree taper on the inboard side of each spoke. See **Fig. 1**.



1. 28-Degree Tapered Rim Mounting Surfaces

Fig. 1, Spoke Wheel Tapered Mounting Surface

2. Make sure the tire and rim assembly is inflated using the procedures under **Subject 180**.
3. Slide the assembly over the wheel and push it into place against the tapered mounting surface. It should fit snugly against all the tapers. Be sure that the valve stem faces out and is centered between two spokes.
4. Install the rim clamps and nuts. Run the nuts up until the end of each wheel stud is flush with the face of its nut. Rotate the wheel a half turn to seat the parts.
5. Tighten the rim nuts a quarter turn at a time, following the star pattern shown in **Fig. 2**. Continue until all the rim nuts are tightened to the required torque value. Refer to the applicable torque table in **Specifications, 400**.



A. 5-Spoke Wheel B. 6-Spoke Wheel

Fig. 2, Spoke Wheel Tightening Sequence

WARNING

WARNING: If the wheel nuts cannot be tightened to minimum torque values, check for loose studs and stripped threads. Replace damaged parts. If a stud is turning in the hub flange, replace the wheel hub assembly. Failure to replace damaged parts could result in the loss of a wheel, loss of vehicle control, and resulting personal injury and property damage.

CAUTION

CAUTION: Failure to tighten the nuts in the sequence shown, and to the correct torque, could cause misalignment of the tire and chording of the rim (Fig. 3). This would result in excessive

Spoke Wheel, Tire and Rim Assembly; Removal and Installation

vehicle vibration and permanent damage to the rim and wheel.

IMPORTANT: On rear tire and rim assemblies, the clamps must not bottom out until at least 80 percent of the recommended torque is reached. If the clamps do bottom out, make sure the correct clamps and rim spacers are being used. Make sure the rim edges contact the spacer edges.

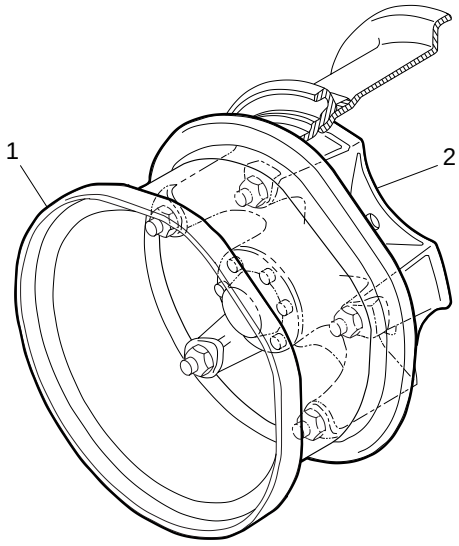
NOTE: When replacing a spoke wheel, contact the wheel manufacturer for the correct torque value for the brake drum nuts attaching the spoke wheel to the brake drum.

6. Check the wheel alignment by placing a block of wood or any other point of reference on the floor next to the tire. Rotate the tire and note any variations in the space between the tire and the block. If the variation exceeds 1/16 inch (1.5 mm) for front rims, or 1/8 inch (3 mm) for rear duals, the rim is not correctly mounted.

   To correct any misalignment, loosen the rim nuts where the largest gap occurs, and tighten the nuts on the opposite side. Recheck and correct until the variation is corrected. Make sure the rim nuts are tightened to the correct. Refer to the applicable torque table in **Specifications, 400**.

7. Remove the safety stands, lower the vehicle, and remove the chocks.

8. After operating the vehicle for 50 to 100 miles (80 to 160 km), retighten the rim nuts to the torque specified in the applicable table in **Specifications, 400**. Follow the sequence shown in **Fig. 2**.



1. Rim
2. Spoke Wheel

Fig. 3, Out-of-Round Rim (Rim Chording)

Tire Demounting and Mounting Safety Precautions

Safety Precautions

WARNING

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 under the headings **Subject 160** and **Subject 170**. Replace damaged, rusted, or worn parts.
- Since wheels and rims are under stress, and are dangerous if improperly assembled, be sure all parts of an assembly match in size, manufacturer, and classification within a manufacturer's line. Before assembling the wheel or rim, check the catalog issued by the wheel or rim manufacturer for the correct part numbers and sizes of approved parts. Never use a part that does not bear clear, legible, and correct numbers and manufacturer's identification, even if that part appears to fit.
- 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 and rims on a wooden floor or rubber mat to prevent nicking or gouging the wheel or rim.
- Do not use a duck-bill hammer, or any steel hammer on wheel or rim parts. Use rubber, leather-faced, or plastic mallets to tap parts together, if necessary.
- Lubricate the tire with an approved tire-mounting lubricant. Never use antifreeze, silicones, petroleum-based lubricants, or any flammable material (ether/starting fluid).
- 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.
- Balance the tire and wheel or rim assembly before installing the assembly on a vehicle.
- Don't reinflate a tire that has been run flat or has been run at 80 percent 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, including the side or lockrings.
- The air pressure contained in a tire is dangerous. When servicing a tire, stay out of any potential path or route that a rim wheel component may travel during an explosive separation.

Demounting and Mounting Tubeless Tires on One-Piece Drop Center Wheels or Rims

Fifteen Degree Tapered Drop Center

⚠ WARNING

WARNING: Read the information under 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 equipment damage and personal injury.

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.

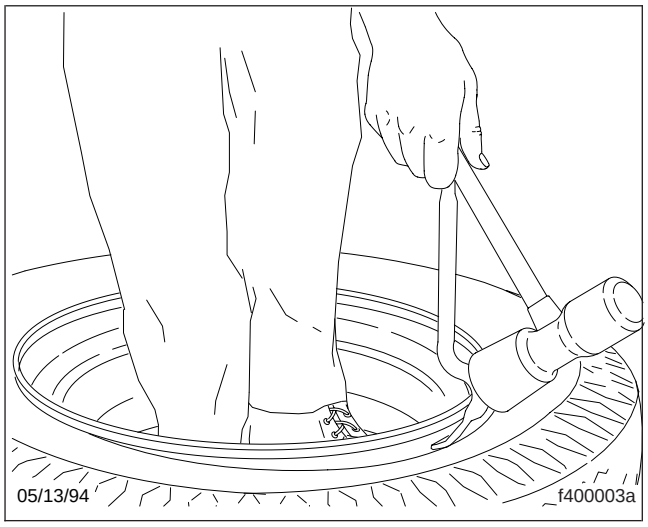


Fig. 1, Loosening the Beads

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.

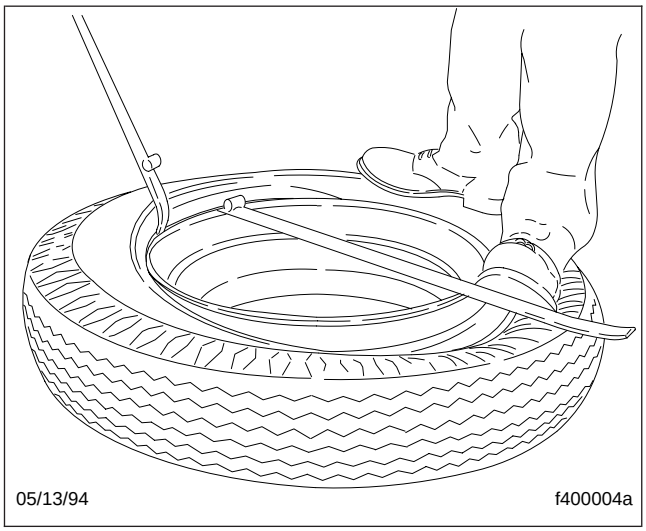


Fig. 2, Forcing Bead into the Rim Well

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. Refer to **Subject 160** and **Subject 170** for procedures.

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 collar or nut are centered and fit snugly in the valve hole. See **Fig. 4**. Tighten the nut securely.
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

Demounting and Mounting Tubeless Tires on One-Piece Drop Center Wheels or Rims

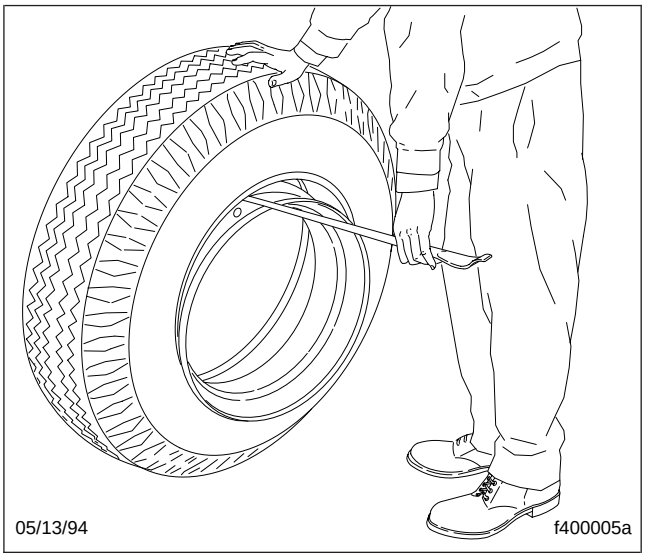


Fig. 3, Prying the Rim Out of the Tire

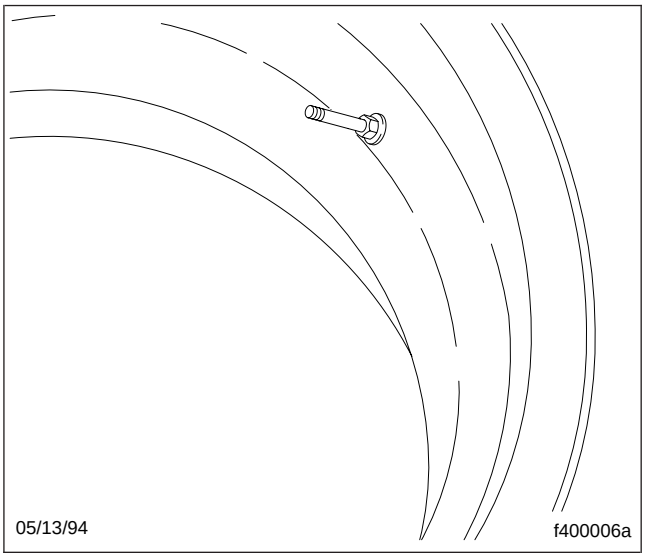


Fig. 4, Valve Stem Installation

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**.

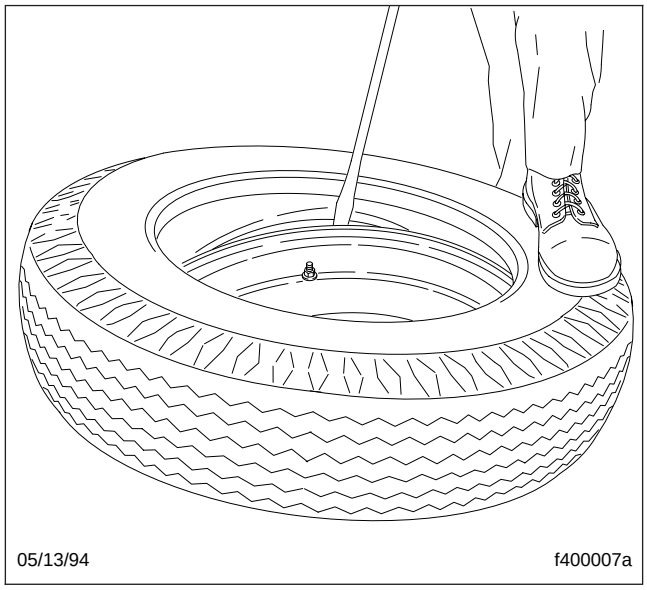


Fig. 5, Working the Lower Bead into the Rim

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 20 cm (8 inches) of bead.
5. Inflate the tire. Refer to **Subject 180** for procedures.

Demounting and Mounting Tubeless Tires on One-Piece Drop Center Wheels or Rims

Fig. 6, Working the Upper Bead into the Rim

Inspection

WARNING

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 equipment damage and personal injury.

Examine the wheel or rim, 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. Rust or other foreign matter can prevent the correct fitting of side rings. Replace corroded parts. Paint the rim to prevent corrosion.

NOTE: Don't paint Alcoa aluminum disc wheels. If the wheels are corroded, contact the manufacturer for instructions.

A cracked wheel, brake drum, or rim, damaged inner or outer wheel nuts, or an out-of-round wheel or rim makes the replacement of the damaged part. See **Fig. 1** and **Fig. 2**. Replace the wheel if it has out-of-round stud holes.

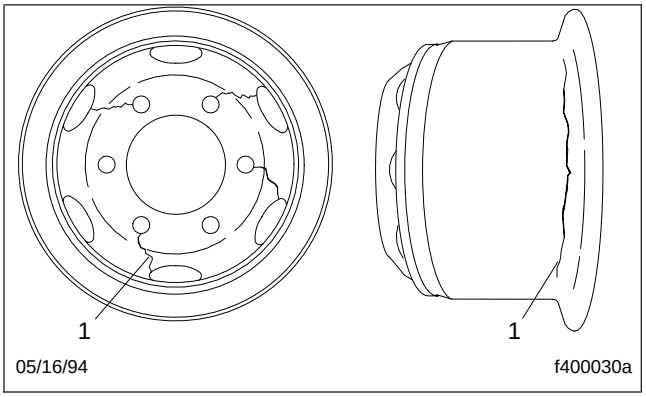


Fig. 1, Cracked Wheel and Rim

NOTE: Refer to **Group 33** or **Group 35** for inspection and service procedures for the hub, wheel studs, wheel, and brake drum or disc rotor assemblies. When replacing the spoke wheel or the brake drum, contact the wheel manufacturer for the correct torque value for the brake drum nut that attaches the spoke wheel to the brake drum.

Inspect valve cores for cracks, bends, and air retention. Replace damaged or leaky cores.

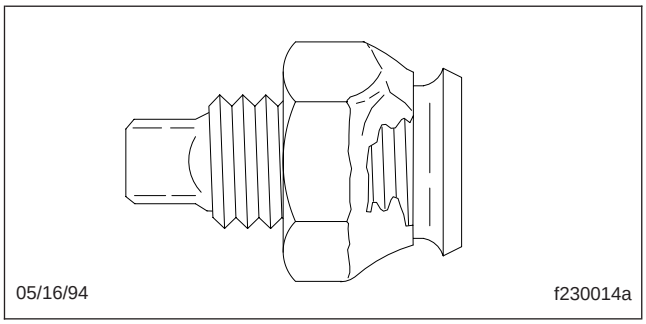


Fig. 2, Damaged Outer Wheel Nut

The most critical area of a spoke wheel is the 28-degree tapered rim mounting surface. See **Fig. 3**. Clean the surface and examine it for damage or excessive wear. Replace the wheel if the mounting surface is damaged or worn below the 28-degree taper.

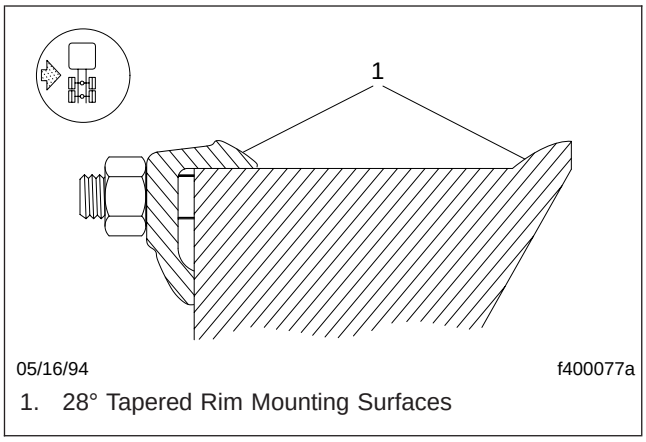


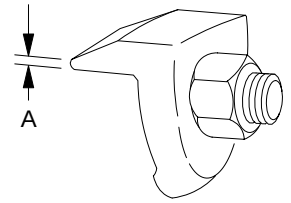
Fig. 3, Spoke Wheel Tapered Mounting Surface

Check the clamps, rim spacer, rim studs, and spoke-wheel nuts for damage or wear. The clamps must not be excessively worn. The end of the wedge portion must be at least 1/16-inch (1.5-mm) thick. See **Fig. 4**. The rim spacer must not be bent, distorted, or crushed. Replace all damaged or broken parts.

Do not attempt to rework, weld, heat, or braze any rim or 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.

Wheel and Components Inspection



05/16/94 f400078a

A. End of wedge must be at least 1/16" (1.5 mm) thick.

Fig. 4, Rim Clamp

Inspection

WARNING

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 equipment damage and personal injury.

Inspect the inside and outside of the tire for out-of-roundness, loose cords, cuts, foreign objects, and other damage. Repair as needed. Contact the tire manufacturer for repair procedures.

Do not repair tires with the following problems:

- Cuts in the tread that are wire or breaker fiber deep.
- Tread worn to the wire or breaker fibers.
- Tread that is scalloped or otherwise worn unevenly.
- Visible, broken, deformed, or otherwise damaged bead wires.
- Deteriorated rubber.
- Rubber cracked to the wire or cord.
- Separations in the casing.
- Exposed cord (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. Refer to the vehicle 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 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

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 rings or other parts by hammering on an inflated or partially inflated tire.

IMPORTANT: Due to the different flex characteristics of radial sidewalls, it may be necessary to use an inflation aid 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.

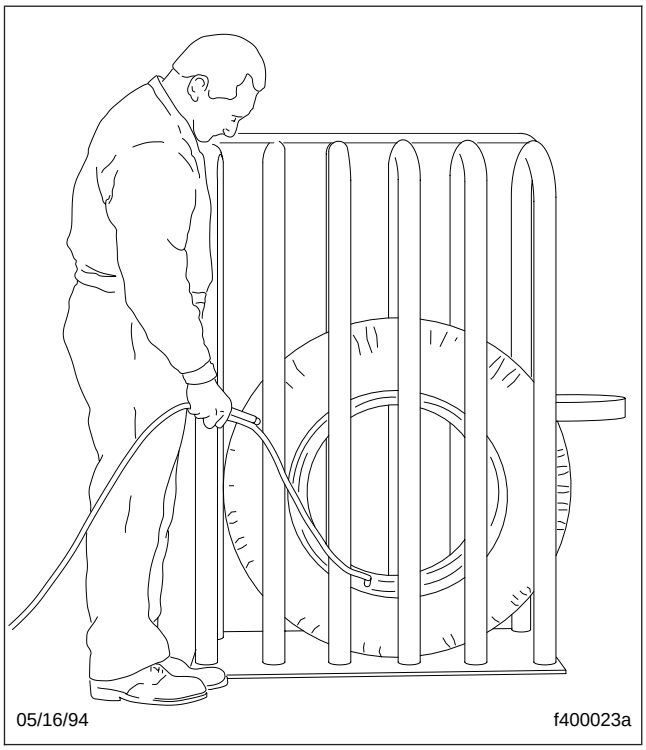


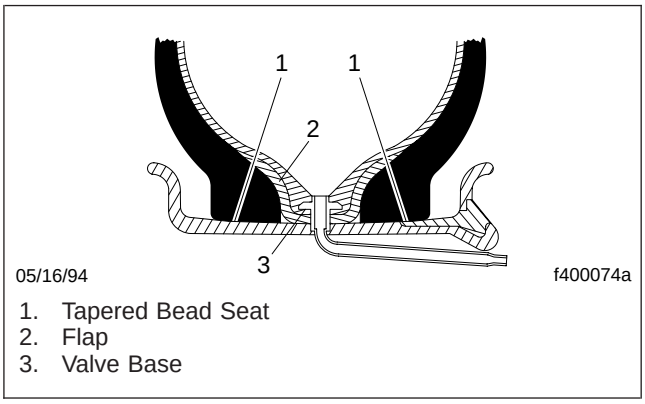
Fig. 1, Safety Cage

3. If there are no problems with the assembly at 10 psi (69 kPa), continue to inflate the tire to the recommended pressure. Refer to **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**.

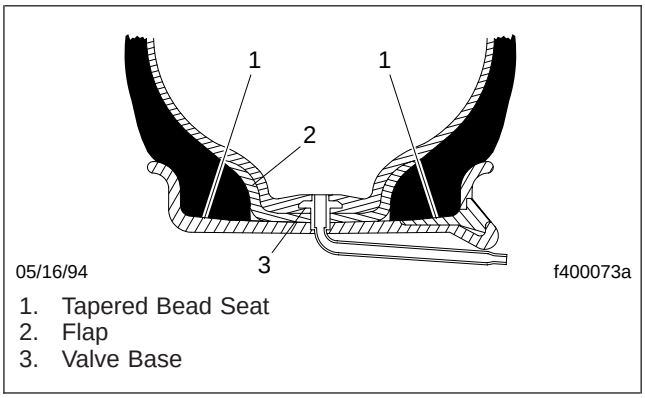
4. After the initial inflation, completely deflate the tire by removing the valve core. This ensures correct bead seating, and prevents buckling or overstretching the tube in tube-type tires. Then inflate the tire to the recommended cold inflation pressure listed in **Specifications, 400**. Install valve 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

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

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.

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".

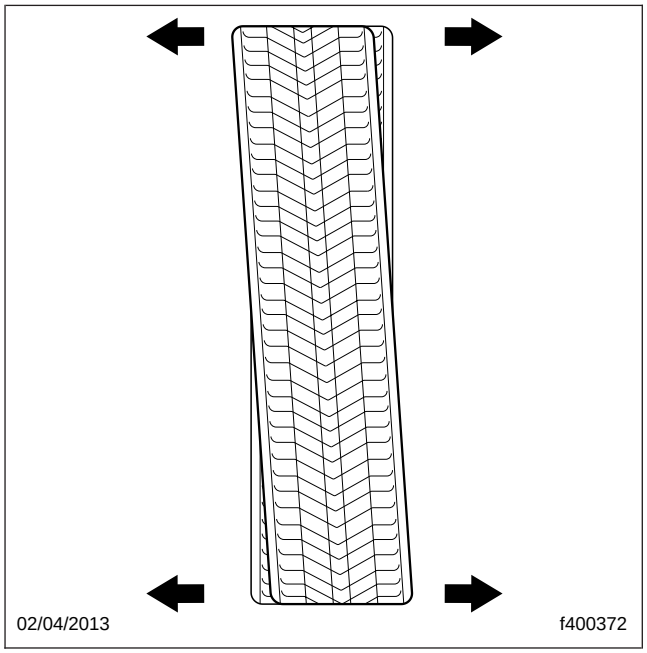


Fig. 1, Lateral Runout

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:

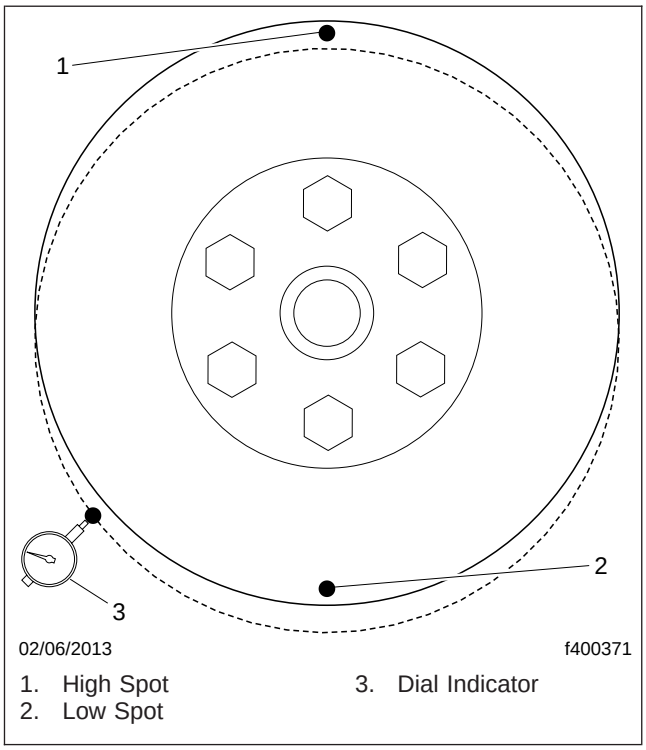


Fig. 2, Radial Runout

- 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)

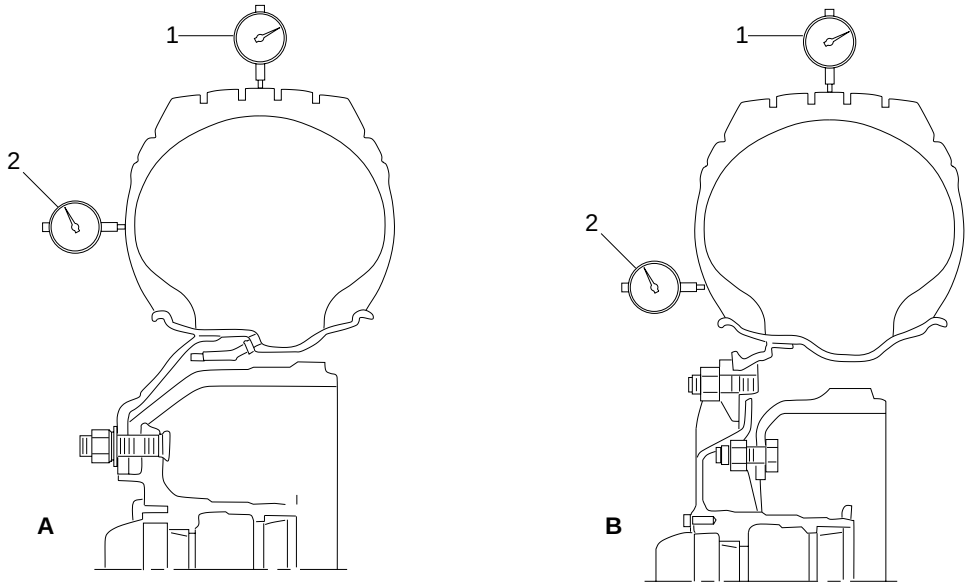
Wheel and Tire Runout Measurements

- 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

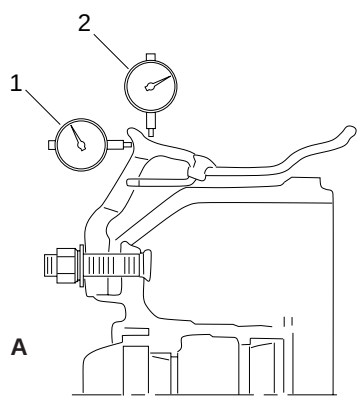


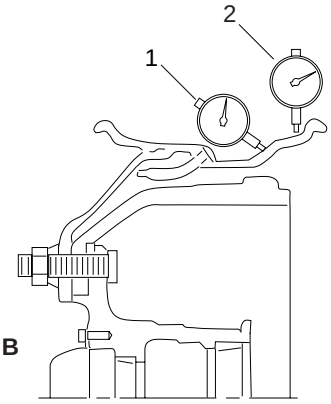
02/04/2013 f400373

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





02/04/2013 f400374

A. Tubeless Aluminum Disc Wheel
B. Tubeless Steel Disc Wheel
1. Lateral Runout
2. Radial Runout

Fig. 4, Runout Check for Wheels

Troubleshooting Chart

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, wheels, and rims for the load to be carried. Refer to **Specifications, 400.**
Inflation pressures in a dual assembly are unequal.	Inflate all tires to a uniform pressure, within 5 psi (35 kPa). Refer to **Specifications, 400** for the proper cold inflation pressures.
Dual tires are mismatched.	Examine all tires and make sure they all match.
Vehicle is vibrating severely.	Follow the recommendations under "Vehicle Vibration" in this chart.
Brakes are grabbing.	Examine and adjust the brakes according to the instructions in **Group 42** in this manual.
Axles are improperly aligned.	Align the axles. Refer to **Group 33** and **Group 35** in this manual for instructions.
Wheel bearings are loose or damaged, or bushings are excessively worn.	Examine, and repair or replace according to the instructions in **Group 33** and **Group 35** in this manual.
Wear is uneven among tire sets.	Rotate the tires according to the instructions in the vehicle maintenance manual.
Driver is abusing equipment.	Caution the driver.

Problem—Vehicle Vibration

Problem—Vehicle Vibration	
Possible Cause	**Remedy**
Axles are improperly aligned.	Align the axles. Refer to **Group 33** and **Group 35** in this manual for instructions.
Wheels, rims, or tires are out-of-round, bent, or distorted.	Replace damaged components.
Tires, wheels, rims, 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.
Tire and rim assembly is improperly installed on a spoke wheel.	Remove the tire and rim assembly and inspect it for out-of-round or rim chording. Replace the rim if it is damaged. Follow closely the tightening sequence and torque values listed.
Rim spacers are worn or distorted.	Replace the rim spacers.
Driveline, suspensions, or steering components are loose or worn.	Determine the location of the vibration, then repair or replace the loose or worn components.

Troubleshooting

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, wheels, and rims for the load to be carried. Refer to **Specifications, 400**.
Dual tires are mismatched.	Examine all tires and make sure they match.
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.
Tires are contaminated with oil.	Clean the tires and inspect the engine seals, transmission seals, axle-end and drive axle seals, oil filters and oil lines for leakage. Make sure the lubricant used in mounting does not contain a petroleum derivative.
Vehicle is vibrating severely.	Follow the recommendations under "Vehicle Vibration" in this chart.
Wheel or rim components are mismatched.	Check the catalog issued by the applicable wheel or rim manufacturer for the proper part numbers and sizes of approved components. Make sure that all parts of an assembly match in size, manufacturer, and classifications within a manufacturer's line. Never use a component which does not bear clear, legible, and proper numbers and manufacturer's identification, even if it appears to fit.
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 rim or wheel manufacturer's recommendations, even though the tire may be approved for a higher load or inflation. Some rims and wheels are stamped with a maximum load and maximum cold inflation rating. Consult the rim or wheel manufacturer if they are not stamped. If the load exceeds the maximum rim or 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.

Disc-Type Wheel Fastener Torques			
Description	**Nut Size**	**Wheel Manufacturer**	**Torque (dry threads): lbf·ft (N·m)**
8-Hole Disc Wheel With Two-Piece Flange Nuts			
Front and Rear Wheel Nut	M22 x 1.5	All	450–500 (610–678)*
10-Hole Disc Wheel With Two-Piece Flange Nuts			
Front and Rear Wheel Nut	M22 x 1.5	All	450–500 (610–678)*
10-Hole Disc Wheel With Inner and Outer Nuts			
Front Wheel Nut	1-1/8–16	Alcoa	400–500 (540–678)†
		Budd	450–500 (610–678)‡
		Firestone and Motor Wheel	450–500 (610–678)
Rear Wheel Inner Nut	3/4–16	Alcoa	400–500 (540–678)†
		Budd, Firestone, and Motor Wheel	450–500 (610–678)
Rear Wheel Outer Nut	1-1/8–16	Alcoa	450–500 (610–678)†
		Budd, Firestone, and Motor Wheel	450–500 (610–678)
Wheel Stud Retainer Nut	3/4–16	All	175–200 (235–270)

* Torque values are given for lubricated threads.

† Lubricated threads should be tightened 300 to 375 lbf·ft (405 to 510 N·m). Lubricate threads with a mixture of 25 percent colloidal graphite in cup grease or equivalent. Do not apply thread lubricant to ball seats of the nuts and wheels. Wipe it off if it is applied accidentally.

‡ On 1–1/8-16 size wheel studs with a head, tighten the wheel nuts 650 to 750 lbf·ft (990 to 1020 N·m). See **Fig. 1.**

Table 1, Disc-Type Wheel Fastener Torques

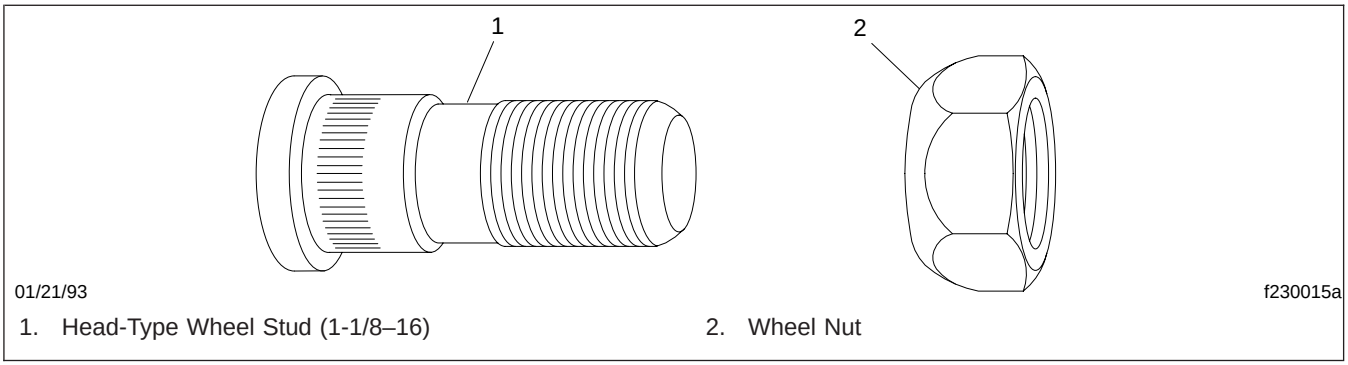
Specifications

Spoke-Type Wheel Mounting Torque			
Description	**Nut Size**	**Manufacturer**	**Dry Threads: lbf·ft (N·m)**
Front Wheel Nut, 5 and 6 Spoke	5/8–11	Dayton and Gunite	160–175 (215–235)
		Webb	150–175 (205–235)
	3/4–10	Dayton	240–260 (325–355)
		Gunite	200–225 (270–305)*
		Webb	200–250 (270–340)
Rear Wheel Nut, 5 and 6 Spoke	5/8–11	Dayton and Gunite	160–175 (215–235)
		Webb	150–175 (205–235)
	3/4–10	Dayton	190–210 (260–285)†
		Gunite	200–225 (270–305)
		Webb	200–250 (270–340)

* On front axles with over 12,000 lb (5448 kg) capacity, tighten nuts 240 to 265 lbf·ft (325 to 360 N·m). Gunite part number W-854 nut, with a phosphate and oil coating, must be used.

† 190 to 210 lbf·ft (260 to 285 N·m) recommended when using channel spacers. See **Fig. 2**. 240 to 260 lbf·ft (325 to 355 N·m) permitted when using corrugated or corrugated-channel spacers. See **Fig. 3**.

Table 2, Spoke-Type Wheel Mounting Torque



1. Head-Type Wheel Stud (1-1/8–16)
2. Wheel Nut

Fig. 1, Head-Type Wheel Stud

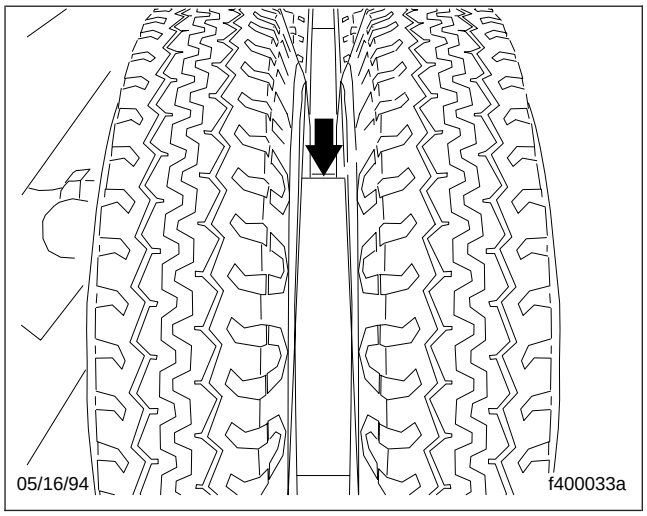


Fig. 2, Channel Spacer

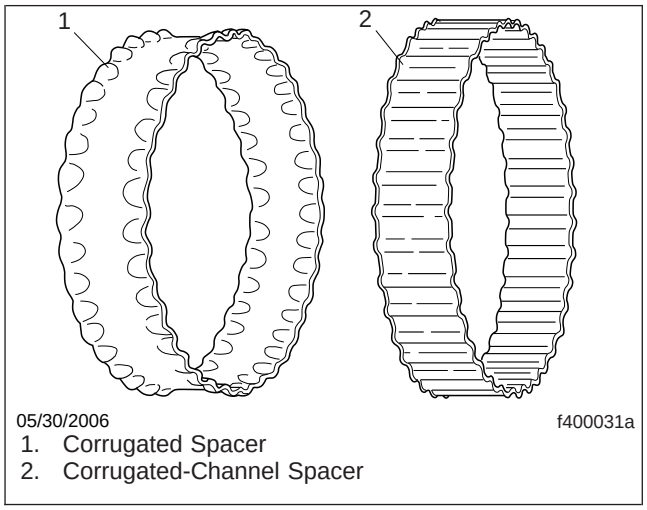


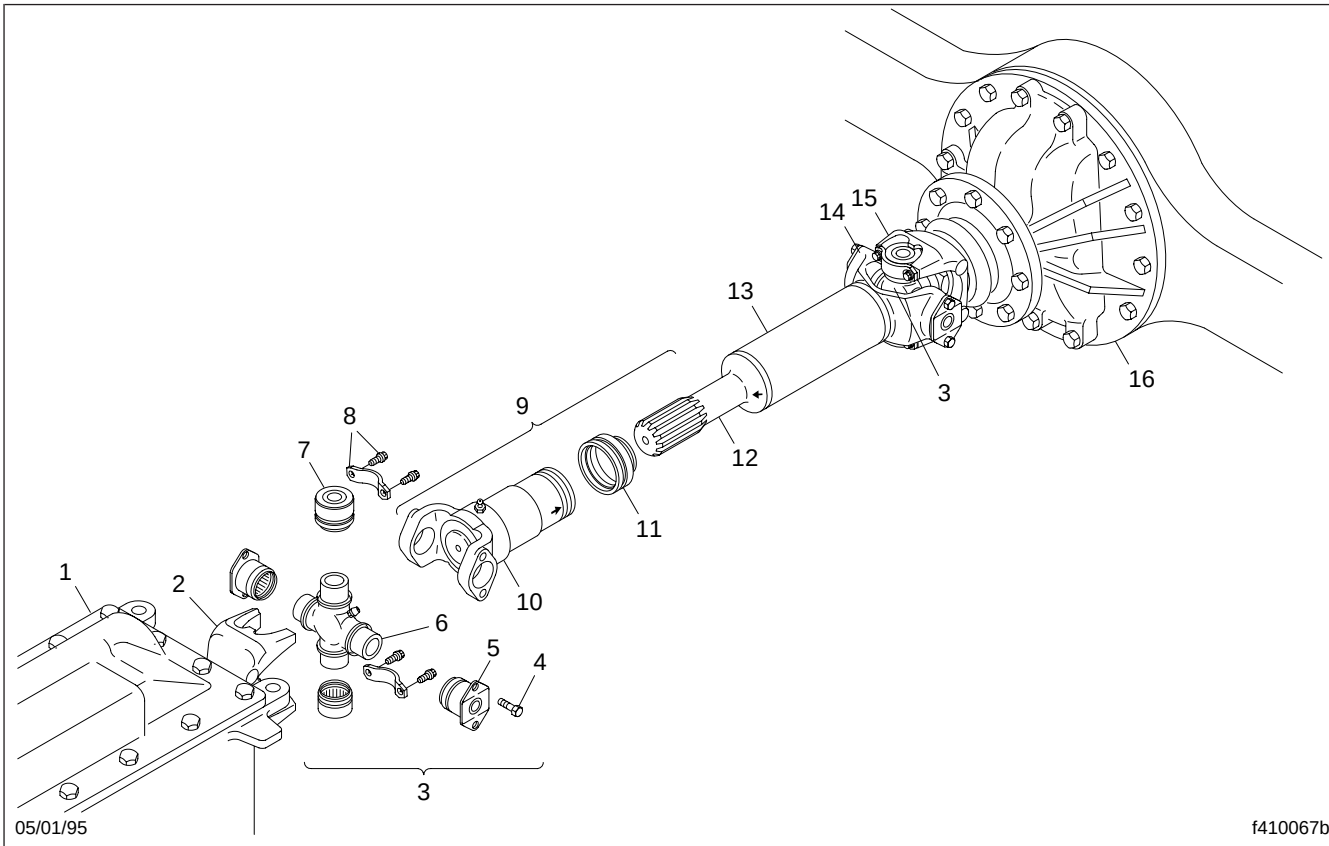
Fig. 3, Corrugated and Corrugated-Channel Spacers

General Information

The simplest driveline consists of a transmission output-shaft end-yoke, an axle input-shaft end-yoke, and a single slip-jointed driveshaft connecting the two end-yokes. See **Fig. 1**. The driveshaft is made up of a universal joint (U-joint), a sleeve-yoke, a splined stub shaft, a driveshaft tube, a tube-yoke, and a second U-joint.

DRIVELINE CONFIGURATIONS

The specific type and number of drivelines used on each vehicle depends on its number of transmissions, its 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



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

Fig. 2, examples *A*, *B*, and *C*.

A long driveshaft, supported only at its ends, will sag in the middle from its own weight. When turning at

General Information

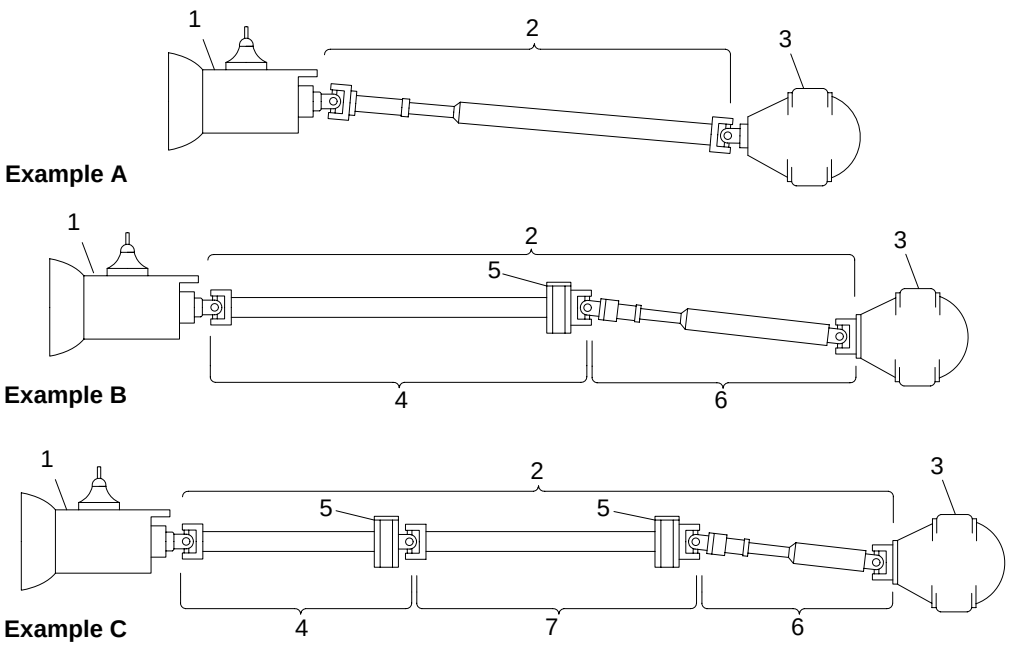
high rpm, it will flex, causing an out-of-balance vibration. Therefore, vehicles having a long wheelbase use a midship bearing, mounted on a frame crossmember, for additional support. See **Fig. 2**, example *B*. This allows the no. 2 driveline to be separated into two, shorter shafts (a coupling shaft 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.

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. Coupling shafts do not require a slip-joint.

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 (or coupling shaft) to the driveshaft, and from the driveshaft to an input shaft, even though the angles between the shafts may be constantly changing.

Each U-joint consists of a cross with a close-tolerance ground cylindrical surface (trunnion) at the



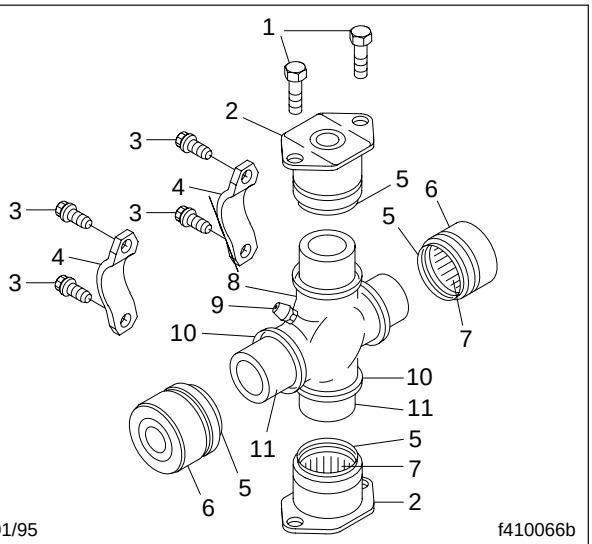
1. Main Transmission
2. No. 2 Driveline
3. Rear Axle
4. Primary Coupling Shaft
5. Midship Bearing
6. No. 2 Driveshaft
7. Intermediate Coupling Shaft

Fig. 2, Driveline Configurations

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

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 no. 2 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. See **Fig. 4**, Refs. 4 and 9.

An end-yoke is an internally splined yoke, held on an externally splined shaft by a locknut. As standard equipment, all no. 2 driveline end-yokes are half-round, with full-round optional. End-yokes are installed on the transmission output shaft, on each axle input and output shaft, and behind the midship bearing of most coupling shafts. See **Fig. 4**, Refs. 2, 7, 12, and 14.

Rockwell 17T and 18T U-joints are coupled to half-round end-yokes by capscrews inserted through semicircular bearing straps that hold the bearing cups in place under tabs in the yoke cross-holes. See **Fig. 5**.

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 outsides of the yoke and over the ends of the trunnions. Self-locking capscrews, inserted through a bearing plate at the back of each cup, thread into the yoke to secure the cups. See **Fig. 6**.

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 (or other driveshaft) to which the U-joint connects. See **Fig. 7**. 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 which bisects the shaft lengthwise) the U-joints will be in phase. See **Fig. 8**.

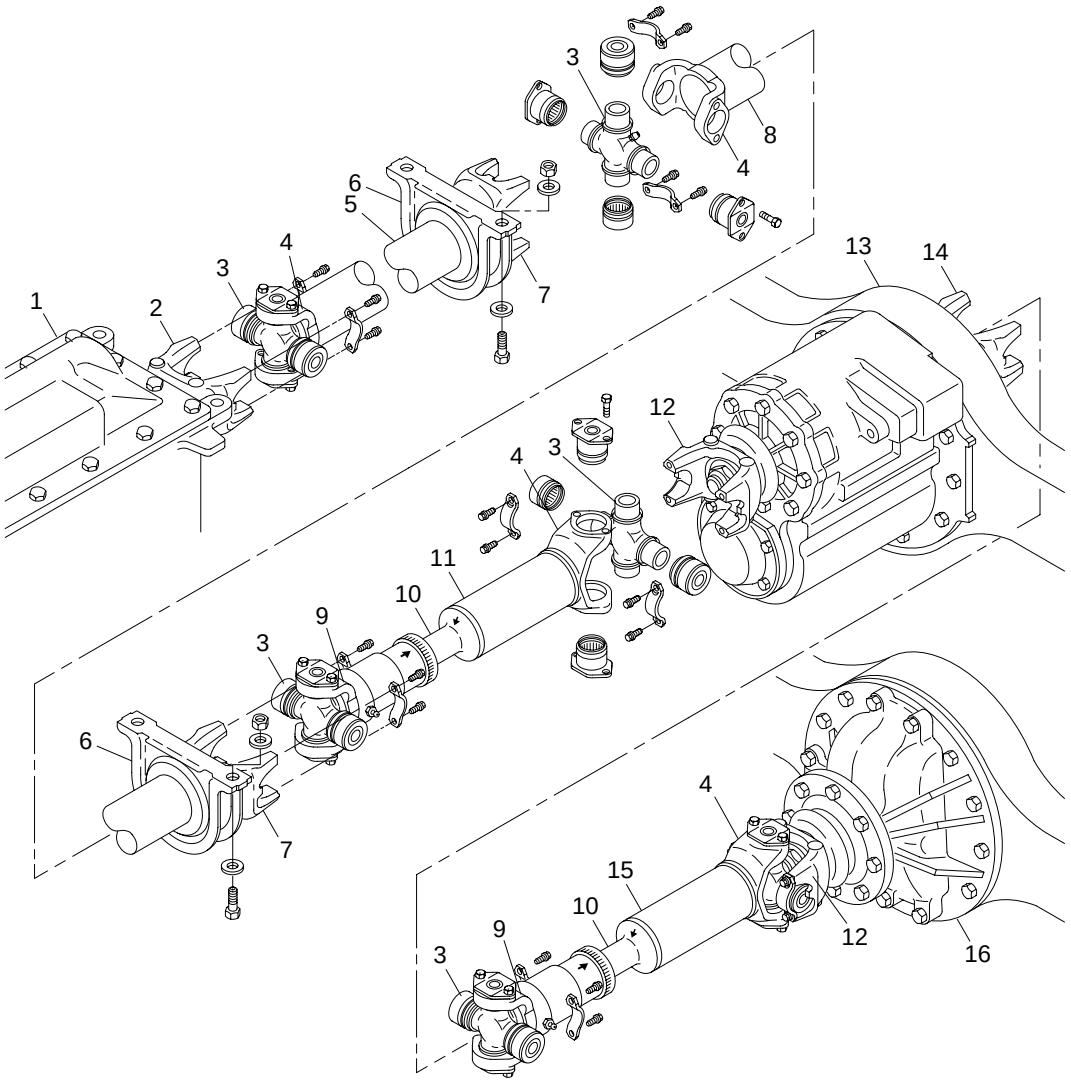
After manufacture, each driveline yoke is statically balanced. After assembly, each driveshaft and coupling shaft is checked for out-of-roundness, straightened as necessary, then dynamically balanced.

AVOIDING DRIVELINE PROBLEMS

To ensure that U-joints turn in phase, sleeve-yokes, splined shafts, coupling shaft end-yokes, and coupling shafts, should be marked for assembly reference before disassembly. A misaligned slip-joint will seriously affect driveline balance (and U-joint phasing). Even if a slip-joint is assembled 180 degrees from its original position (which will keep the U-joints in phase), the dynamic balance of the driveshaft will be negatively affected.

A driveline can become unbalanced or greatly weakened if a driveshaft has been dented, bent, twisted, or otherwise damaged. Operating a vehicle at speeds which exceed the speed of the driveshaft's

General Information



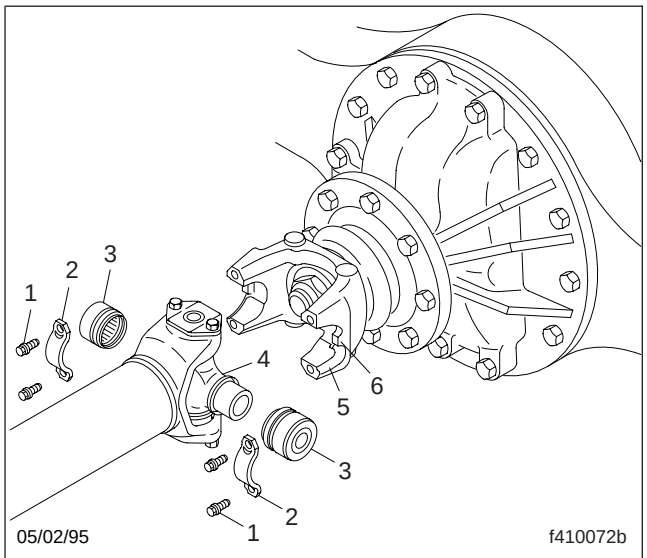
05/01/95 f410068b

NOTE: Not all fasteners are shown.

1. Transmission
2. Transmission Output-Shaft End-Yoke (half-round)
3. U-Joint Assembly
4. Full-Round Tube-Yoke
5. Primary Coupling Shaft Tube
6. Midship Bearing Assembly
7. Coupling Shaft End-Yoke (half-round)
8. Intermediate Coupling Shaft Tube
9. Sleeve-Yoke (full-round)
10. Slip-Joint Assembly
11. No. 2 Driveshaft Tube
12. Axle Input-Shaft End-Yoke (half-round)
13. Forward-Rear Axle
14. Axle Output-Shaft End-Yoke (half-round)
15. No. 3 Driveshaft Tube
16. Rearmost Axle

Fig. 4, Dual-Drive Installation With Primary and Intermediate Coupling Shafts

design specifications will cause an out-of-balance vibration. Any condition which allows excessive movement of a driveshaft will cause driveline imbalance: loose end-yoke nuts, loose midship bearing



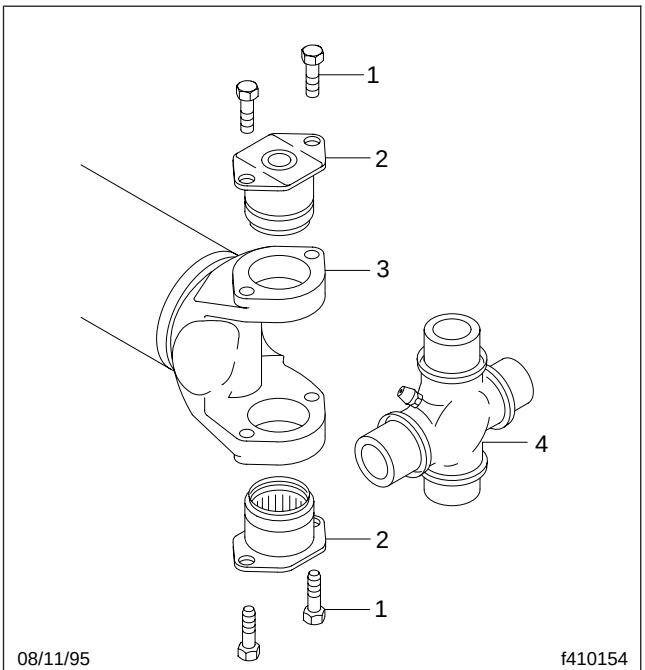
1. Bearing-Strap Capscrew
2. Bearing Strap
3. Bearing Cup
4. U-Joint Cross
5. Half-Round Yoke
6. Yoke Cross-Hole Tab

Fig. 5, Coupling of a U-Joint With a Half-Round End-Yoke

mounts, loose U-joint bearing cup retaining capscrews, worn U-joint trunnions and bearings, and worn slip-joint splines.

Among the most common causes of U-joint and slip-joint damage is lack of lubrication.

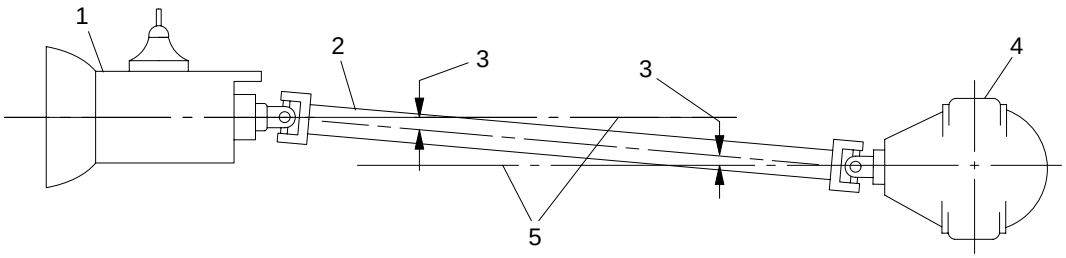
To keep a vehicle operating smoothly and economically, the driveline must be carefully checked and lubricated at regular intervals. For inspection and lubrication intervals and procedures, see Group 41 of the *School Bus Chassis Maintenance Manual*.



1. Bearing-Plate Self-Locking Capscrew
2. Bearing Cup (bearing-plate-type)
3. Full-Round Yoke
4. U-Joint Cross

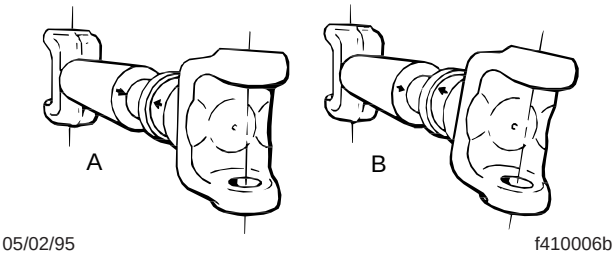
Fig. 6, Installation of a U-Joint in a Full-Round Yoke

General Information



1. Transmission
2. No. 2 Driveshaft
3. U-Joint Working Angles
4. Rear Axle
5. Extended Centerlines

Fig. 7, U-Joint Working Angles



A. In Phase
B. Out of Phase

Fig. 8, 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 or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or a balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke. To remove the driveshaft, see **Subject 120**.

Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft.

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**, details *A* and *B*.
2. Apply the parking brakes, and chock the tires.
3. If the half-round bearing cups do not already have a retaining wire installed, install a bearing-cup retaining wire. See **Fig. 1**, detail *C*. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
4. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s). See **Fig. 1**.
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.

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.

U-Joint Coupling

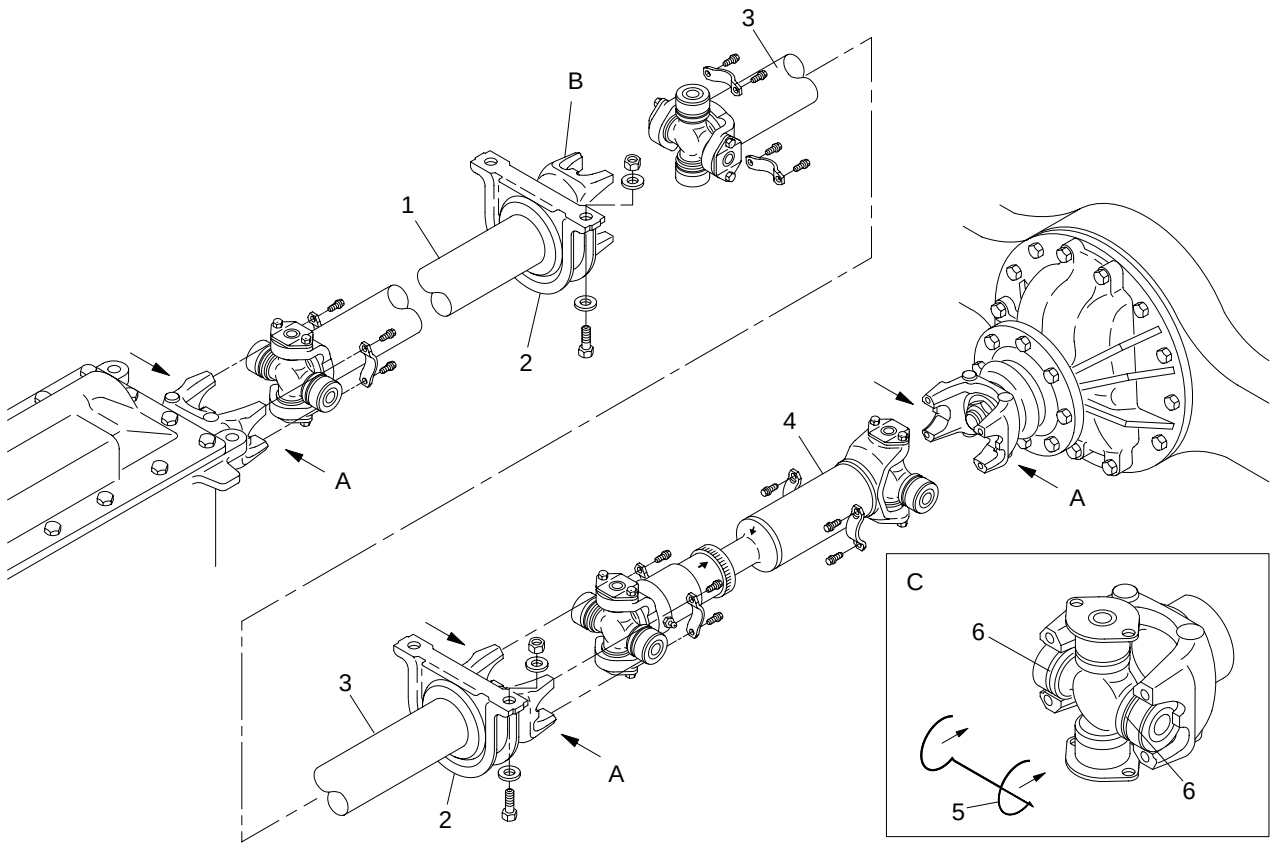
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut; see **Specifications, 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a half-round file, remove burrs or raised metal. See **Fig. 2**.
   - 1.3 Using fine emery cloth, smooth and clean the 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.
   - 2.1 Remove the bearing-cup retaining wire or safety wire. See **Fig. 1**, detail *C*.

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**, detail *C*. Or, install safety wire from the retaining-wire groove of one half-round bearing cup to the other.
3. Extend the slip-joint, while pressing the cross and bearing cups into place in the yoke cross-

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



08/11/95 f410074b

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

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.

⚠ 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. Drive-

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke

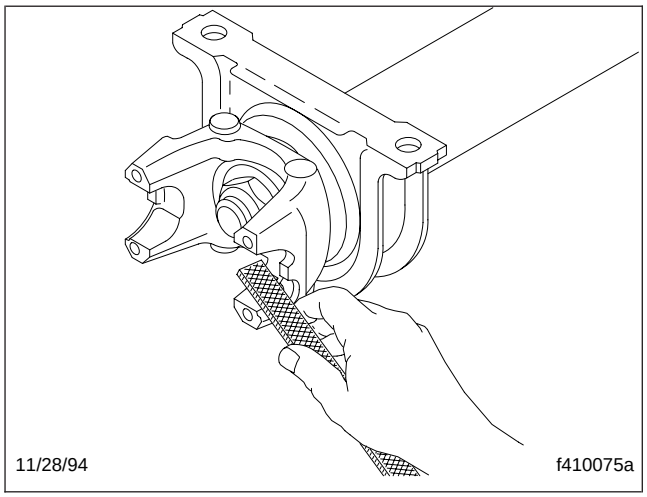
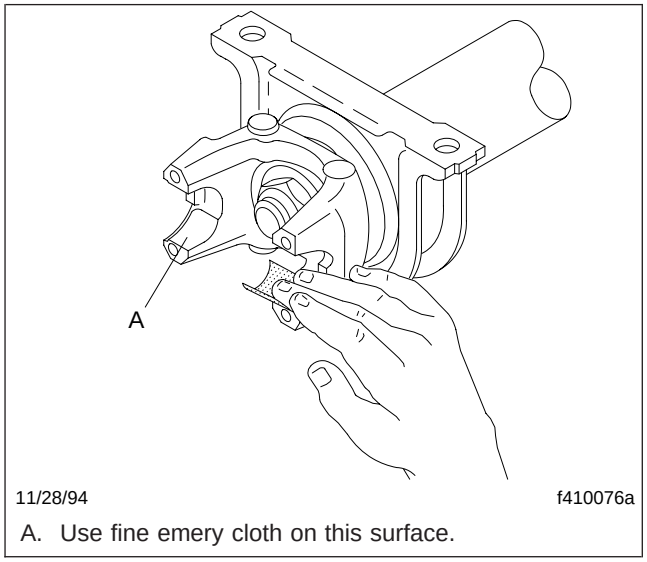


Fig. 2, Removing Burrs From a Half-Round End-Yoke Cross-Hole



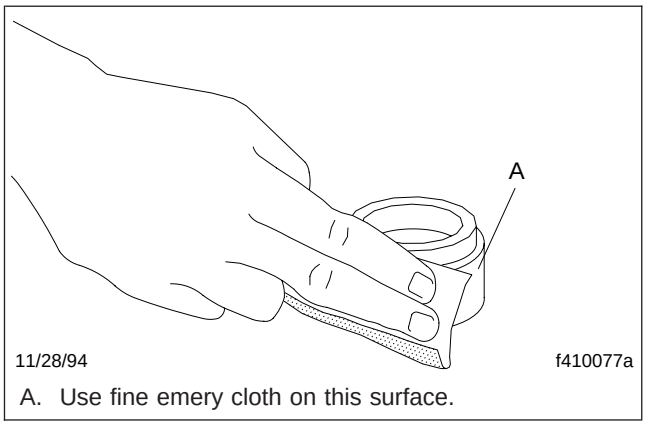
A. Use fine emery cloth on this surface.

Fig. 3, Smoothing a Half-Round End-Yoke Cross-Hole

line separation can cause loss of vehicle control that could result in serious personal injury or death.

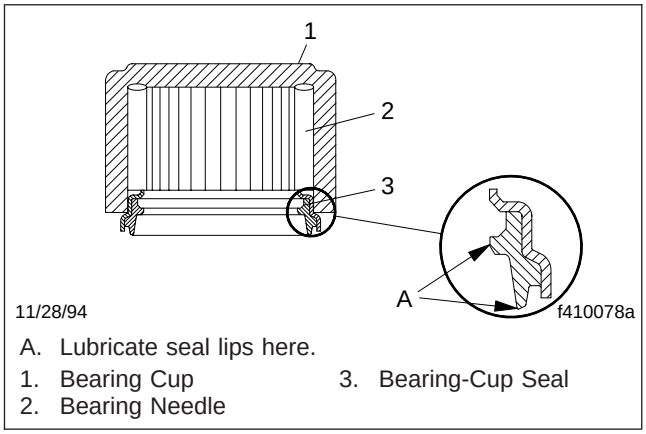
Separation of the driveline can also cause damage to the driveline, driveline components, or other areas of the vehicle.

5. Alternately tighten the bearing-strap capscrews in increments of 20 lbf·ft (27 N·m) to the applicable torque value in **Specifications, 400**.



A. Use fine emery cloth on this surface.

Fig. 4, Smoothing a Half-Round End-Yoke U-Joint Bearing Cup

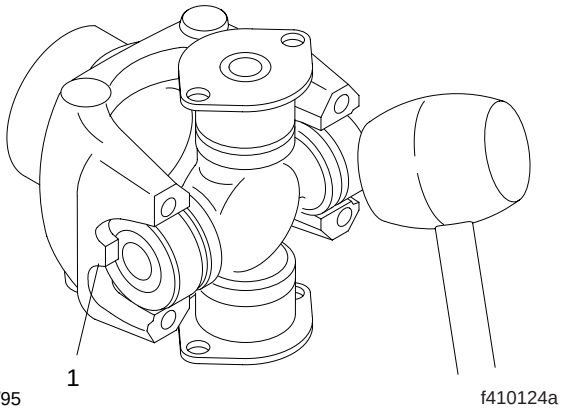


A. Lubricate seal lips here.
1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

Fig. 5, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup

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 *School Bus Chassis Maintenance Manual*.
8. Remove the nylon support straps, then remove the chocks.

U-Joint Uncoupling and Coupling With a Half-Round End-Yoke



1. Retaining Tab

Fig. 6, Seating a U-Joint in a Half-Round End-Yoke

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

NOTE: It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or 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 appropriate driveshaft.

U-Joint Uncoupling

1. Roll the vehicle forward or backward as needed to turn the rearmost end-yoke (of the driveline that is being uncoupled) until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Apply the parking brakes, and chock the tires.
3. Support the driveshaft with a nylon support strap.

   When uncoupling a coupling shaft, install two or three support straps, as needed. Remove the fasteners that attach the midship bearing(s) to its bracket(s).
4. Remove and discard all four bearing-cup-plate self-locking capscrews.
5. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing assemblies from the end-yoke cross-holes. See **Fig. 2**.
6. Compress the slip-joint and pivot the end of the U-joint cross to remove it from the yoke. Install the bearing cups, then use tape to secure them to the U-joint cross.

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.

U-Joint Coupling

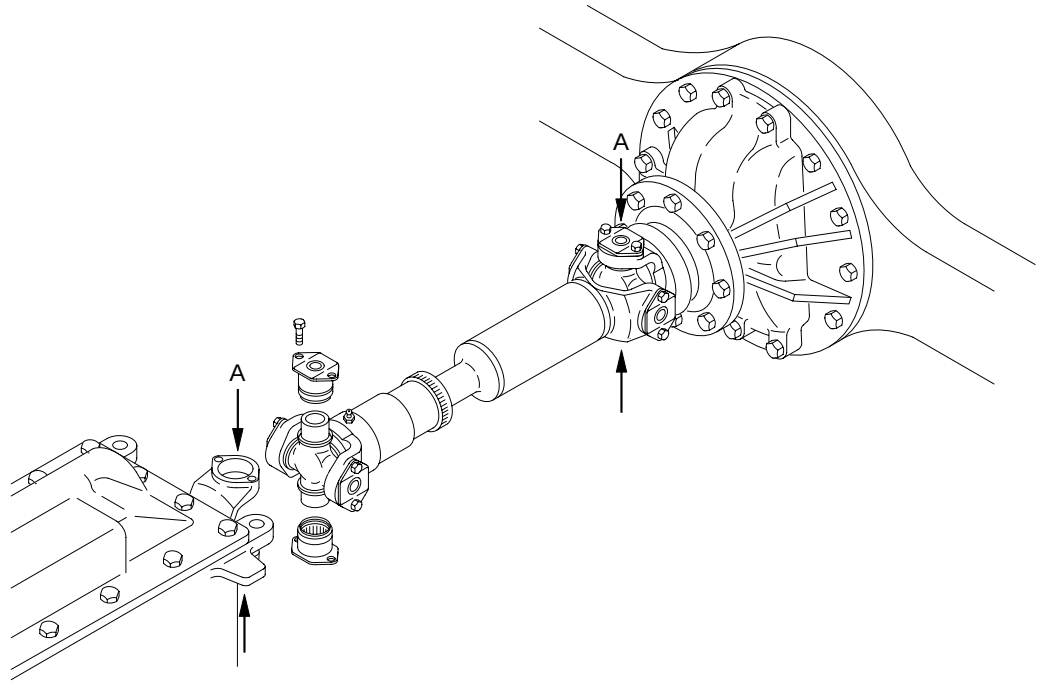
1. Check and clean the end-yoke.
   - 1.1 Check the torque on the end-yoke nut; see **Specifications, 400**.
   - 1.2 Check the end-yoke cross-holes for burrs or raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.
   - 1.3 Using a mill file, and holding it flat against the machined surface of the yoke lug, remove any burrs or raised metal. See **Fig. 4**.
   - 1.4 Using fine emery cloth, smooth and clean the entire surface of the yoke cross-holes. See **Fig. 5**.
   - 1.5 Turn the end-yoke until the centerline through its cross-holes is vertical. See **Fig. 1**.
2. Check, clean, and lubricate the U-joint.
   - 2.1 Using fine emery cloth, smooth and clean the outside surfaces of both bearing cups. See **Fig. 6**.
   - 2.2 Check the U-joint trunnions and bearing cups for minute particles of dirt or grit. Clean if necessary; see **Subject 140**.

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.

   - 2.3 Using NLGI grade 2 grease with EP additives, wipe a small amount of grease on the needles in the bearing cups.
   - 2.4 Using a light-weight oil, lubricate the lips of the bearing-cup seals. See **Fig. 7**.
3. Couple the U-joint cross to the end-yoke.
   - 3.1 Extend the slip-joint, while pivoting the U-joint cross into place in the yoke cross-holes.
   - 3.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



NOTE: Not all fasteners are shown.
A. End-yoke cross-hole centerline is vertical.

Fig. 1, U-Joint Uncoupling/Coupling of a Driveline With Full-Round End-Yokes

Using a Spicer trunnion (journal) locator, hold the trunnions in alignment with the cross-holes, while placing a bearing assembly over the projected trunnion, and aligning it with the cross-hole. See **Fig. 8**. See **Specifications 400**.

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

3.3 By hand, press the bearing assembly flush with the face of the yoke. If the bearing assembly binds in the cross-hole, tap the *center* of the bearing plate with a rubber or rawhide mallet; do not tap the outer edges of the bearing plate. See **Fig. 9**.

3.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 10**. Tighten the capscrews until all the parts are drawn down tight, with no gaps; do not yet tighten the capscrews to their final torque value.

WARNING

Self-locking bearing-cup-plate capscrews must not be reused; replace the capscrews with new ones. Also, do not undertighten or overtighten any bearing-cup-plate capscrews. A loose or broken fastener at any point in the driveline weakens the driveline connection, which could cause serious vehicle damage, or could result in a driveshaft separating from the vehicle, possibly causing loss of vehicle control that could result in serious personal injury or death.

3.5 Move the cross until it projects beyond the machined surface of the opposite yoke lug. Repeat applicable substeps to install the opposite bearing.

3.6 Alternately tighten the bearing-cup-plate capscrews in increments of 5 lbf·ft (7 N·m), to the torque value in **Specifications, 400**.

U-Joint Uncoupling and Coupling With a Full-Round End-Yoke

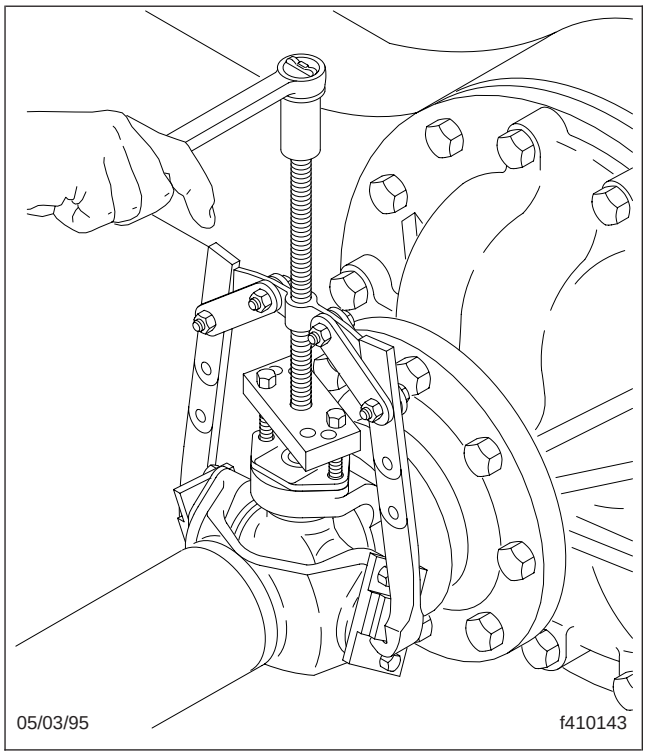


Fig. 2, Removing a Bearing Cup From a Full-Round End-Yoke

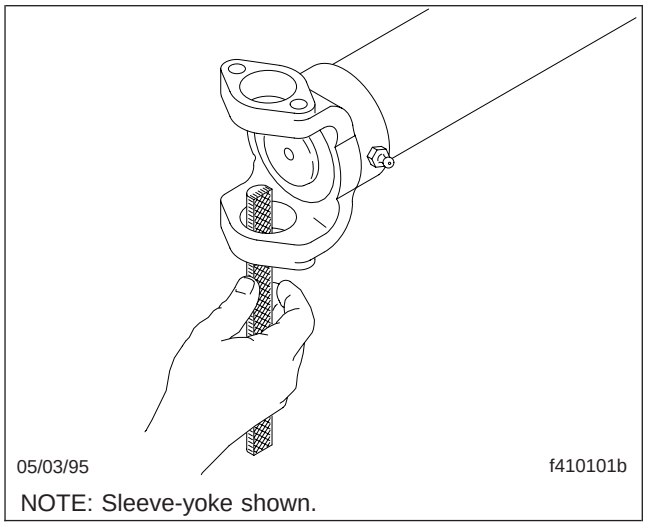


Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

4. If they were removed, install the fasteners that attach each midship bearing to its bracket; tighten the flanged locknuts 91 lbf·ft (123 N·m).

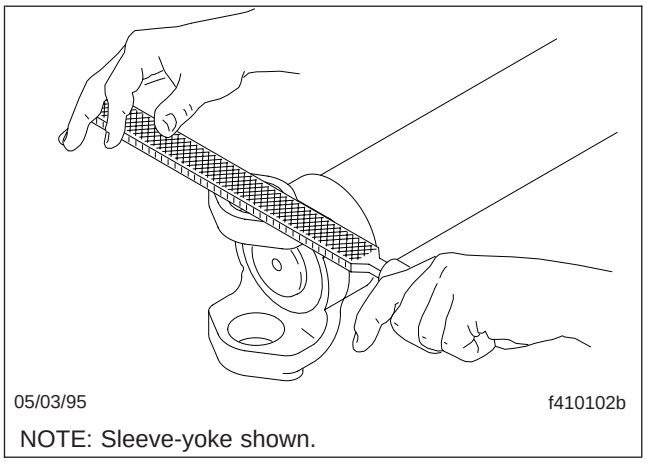


Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug

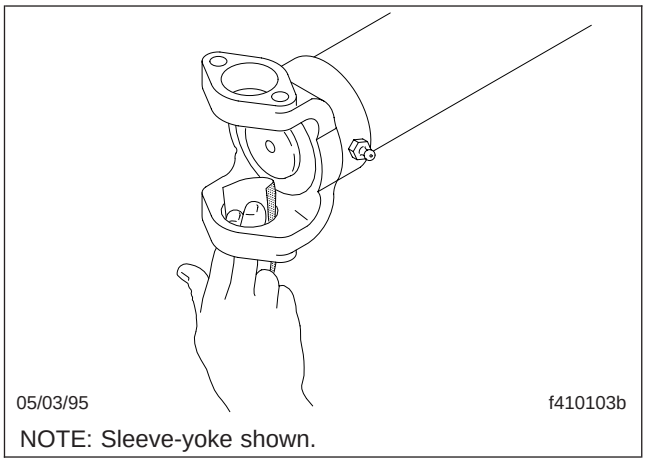


Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

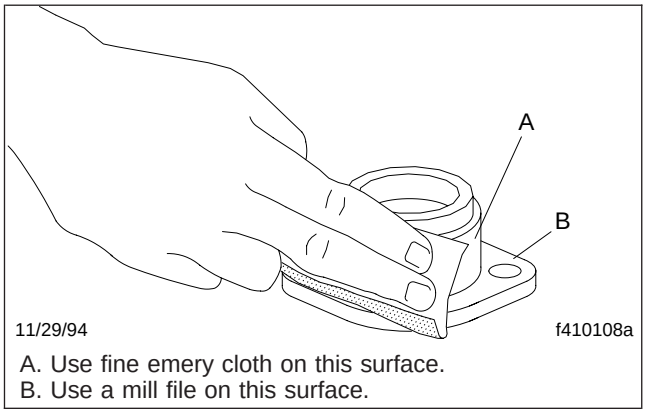
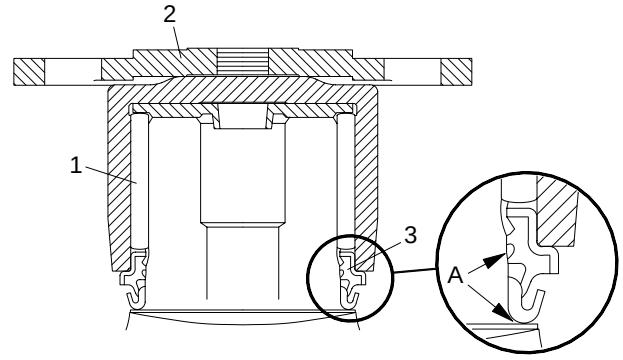


Fig. 6, Smoothing a Full-Round Yoke U-Joint Bearing Cup

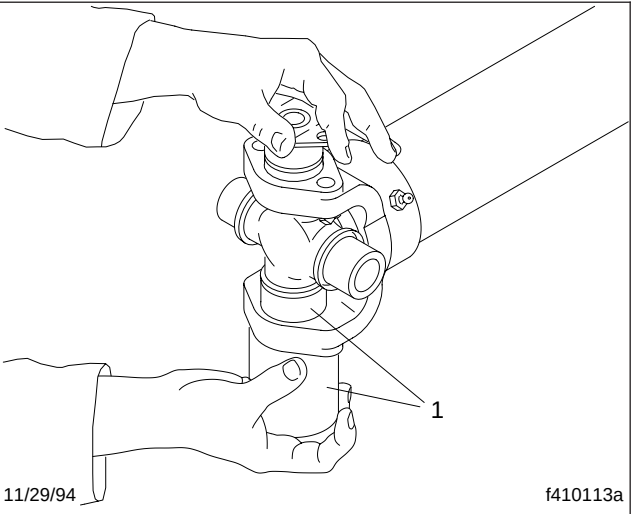
U-Joint Uncoupling and Coupling With a Full-Round End-Yoke



08/02/96 f410145a

A. Lubricate seal lips here.
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing-Cup Seal

Fig. 7, Sectional View of a Full-Round Yoke U-Joint Bearing Cup

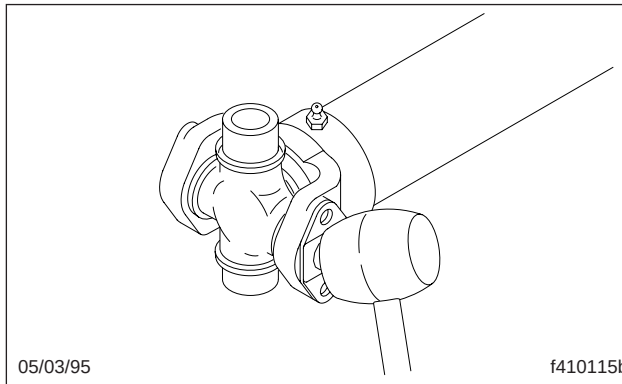


11/29/94 f410113a

NOTE: Sleeve-yoke shown.
1. Trunnion Locator

Fig. 8, Using a U-Joint Trunnion Locator

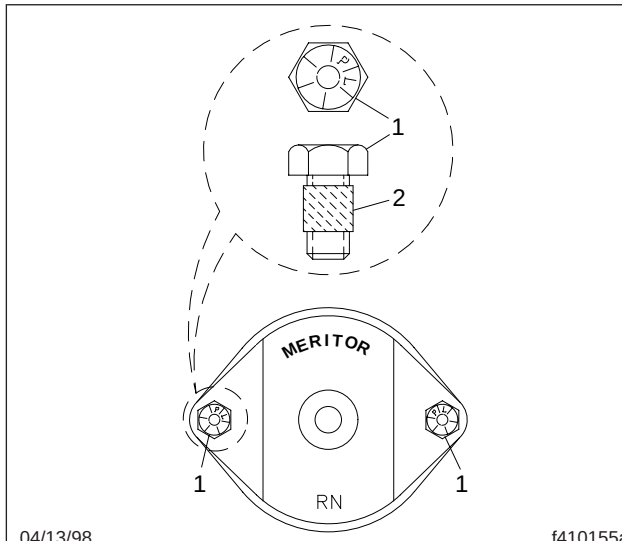
5. Lubricate the U-joint, following the procedure in Group 41 of the *School Bus Chassis Maintenance Manual*.
6. Remove the nylon support straps, then remove the chocks.



05/03/95 f410115b

NOTE: Sleeve-yoke shown.

Fig. 9, Seating a U-Joint Bearing Cup in a Full-Round Yoke



04/13/98 f410155a

1. Self-Locking Capscrew
2. Adhesive Band

Fig. 10, Rockwell U-Joint Fasteners for Full-Round Yokes

Driveshaft Removal and Installation

NOTE: Many service operations do not require driveshaft removal from the vehicle: end-yoke nut tightening; drive component shaft seal or end-yoke replacement; changing U-joint phasing at the slip-yoke; and transmission or axle removal (for overhaul, repair, or replacement). To perform these operations, uncouple the U-joint at the applicable end of the appropriate driveshaft; see **Subject 100** for uncoupling from a *half-round* end-yoke, or see **Subject 110** for uncoupling from a *full-round* end-yoke.

It is easier to check driveline parts, and to replace a U-joint or midship bearing assembly if the driveshaft is removed from the vehicle. If a driveshaft requires straightening or balancing, it must be removed, and installed on a lathe or balance machine. Removal is required for replacement of slip-joint parts, a driveshaft tube, or a tube-yoke.

No. 2 Driveshaft Removal

1. Uncouple the no. 2 driveshaft from the single or forward-rear axle. See **Fig. 1**. If the no. 2 driveshaft is coupled to *half-round* end-yokes, follow the uncoupling procedure in **Subject 100**. If the no. 2 driveshaft is coupled to *full-round* end-yokes, follow the uncoupling procedure in **Subject 110**.
2. Uncouple the no. 2 driveshaft from the transmission or coupling shaft. If the no. 2 driveshaft is coupled to half-round end-yokes, follow the uncoupling procedure in **Subject 100**. If the no. 2 driveshaft is coupled to full-round end-yokes, follow the uncoupling procedure in **Subject 110**.
3. Lift the no. 2 driveshaft out of the chassis.

Intermediate Coupling Shaft Removal

1. If the no. 2 driveshaft is also being removed, remove it first. See **Fig. 2**.

   If the no. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.
2. Uncouple the intermediate coupling shaft from the no. 2 driveshaft. If the intermediate coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the intermediate coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Uncouple the intermediate coupling shaft from the primary coupling shaft. See **Fig. 3**. If the primary coupling shaft has a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.
4. Lift the intermediate coupling shaft out of the chassis.

Primary Coupling Shaft Removal

1. *For a vehicle with one coupling shaft:*

   If the no. 2 driveshaft is also being removed, remove it first. See **Fig. 3**.

   If the no. 2 driveshaft is not being removed, use a nylon support strap to support its forward end.

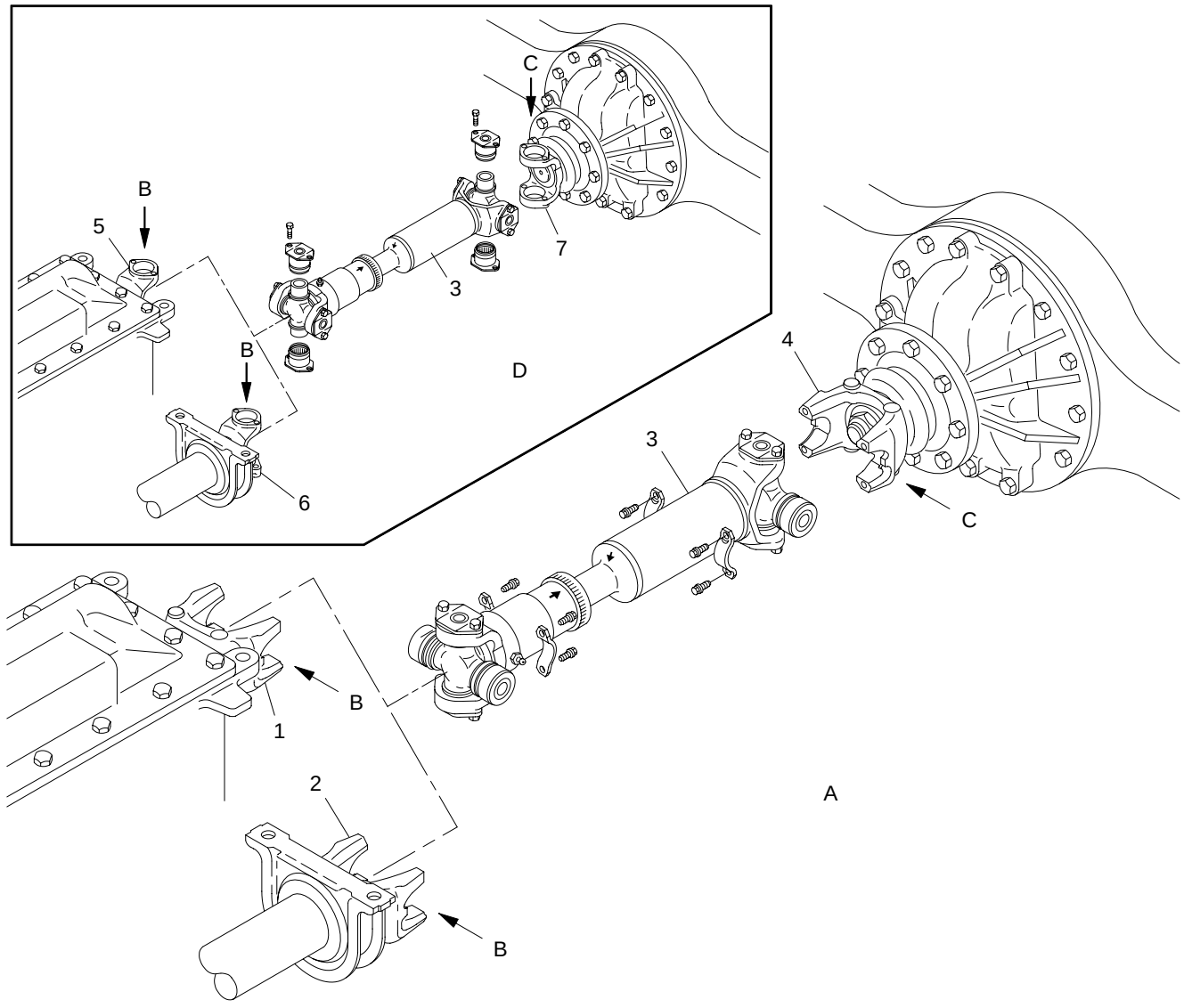
   For a vehicle with two coupling shafts:

   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. If the primary coupling shaft has a *half-round* end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft has a *full-round* end-yoke, follow the uncoupling procedure in **Subject 110**.
3. Using two nylon support straps, support the primary coupling shaft. Then remove the fasteners

Driveshaft Removal and Installation

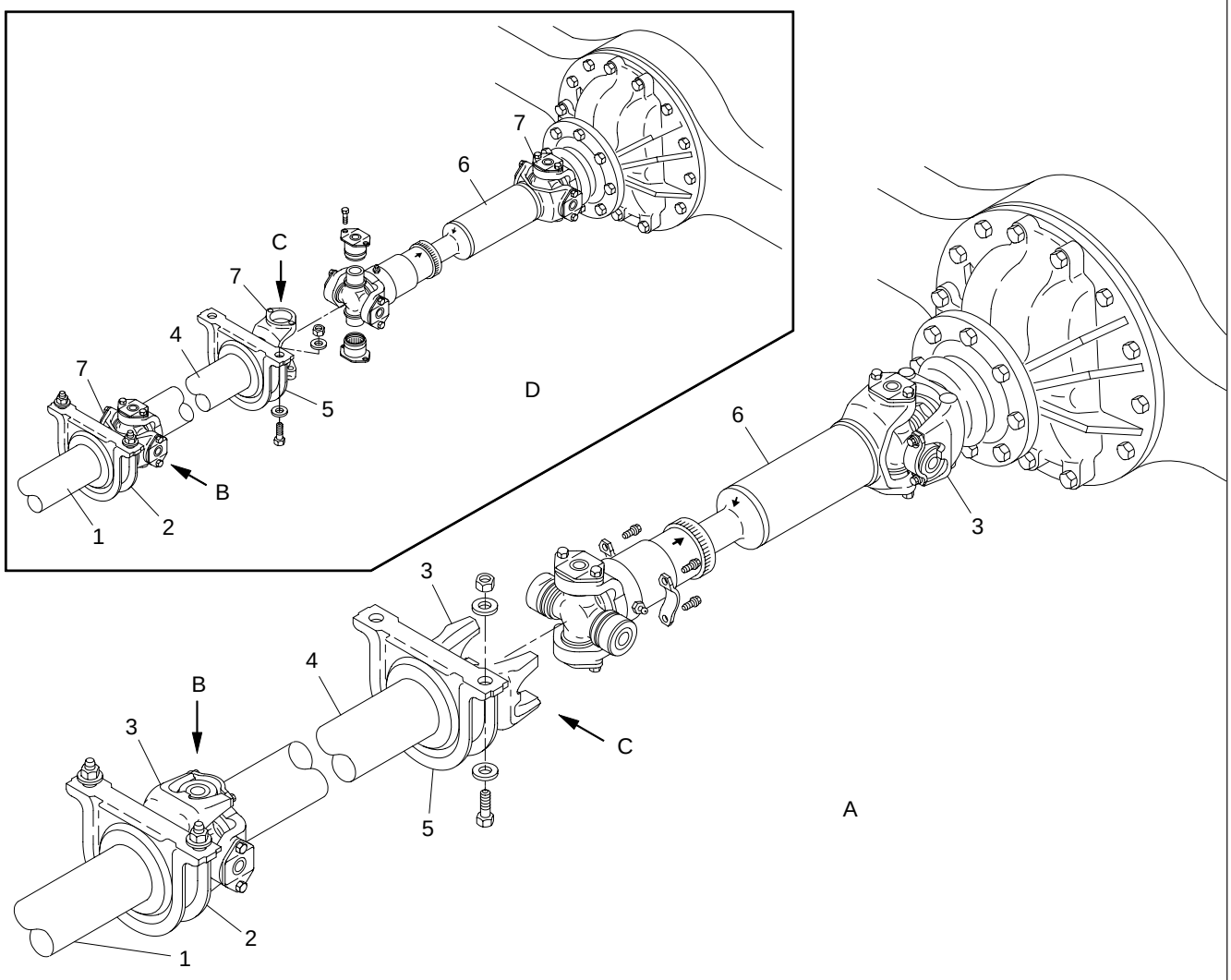


05/05/95 f410080b

NOTE: Not all fasteners are shown.

A. No. 2 Driveshaft Coupled to Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveshaft Coupled to Full-Round End-Yokes
1. Transmission Output-Shaft Half-Round End-Yoke
2. Coupling Shaft Half-Round End-Yoke
3. No. 2 Driveshaft
4. Single Axle or Forward-Rear Axle Input-Shaft Half-Round End-Yoke
5. Transmission Output-Shaft Full-Round End-Yoke
6. Coupling Shaft Full-Round End-Yoke
7. Single Axle or Forward-Rear Axle Input-Shaft Full-Round End-Yoke

Fig. 1, Removal/Installation of a No. 2 Driveshaft



05/04/95 f410084b

NOTE: Not all fasteners are shown.

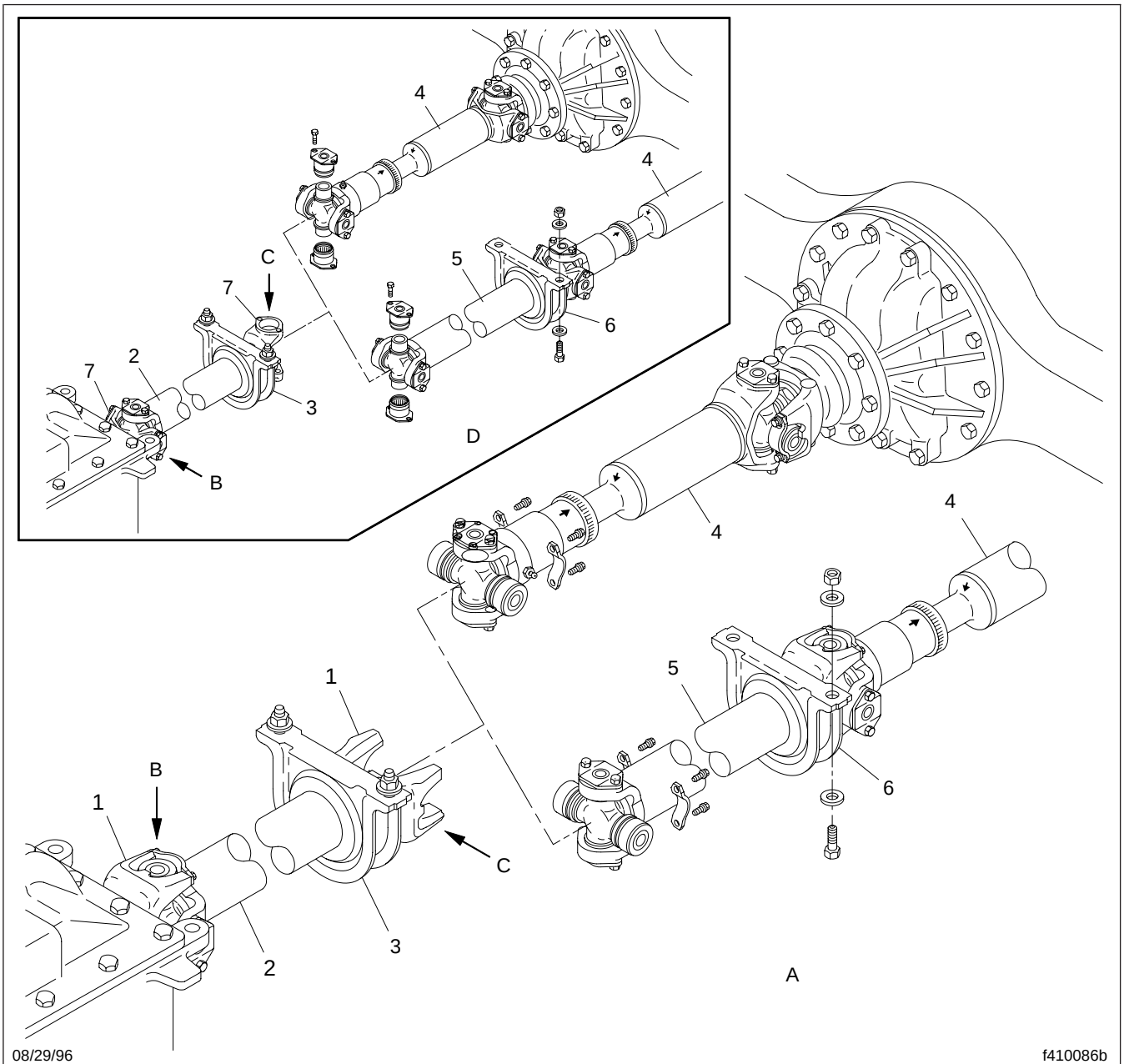
A. No. 2 Driveline With Half-Round End-Yokes
B. Uncouple this end last; couple this end first.
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes
1. Primary Coupling Shaft
2. Primary Coupling Shaft Midship Bearing
3. Half-Round End-Yoke
4. Intermediate Coupling Shaft
5. Intermediate Coupling Shaft Midship Bearing
6. No. 2 Driveshaft
7. Full-Round End-Yoke

Fig. 2, Removal/Installation of an Intermediate Coupling Shaft

that attach the primary coupling shaft midship bearing to its bracket. See **Fig. 3**.

4. Uncouple the primary coupling shaft from the transmission. If the primary coupling shaft is

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.
1. Half-Round End-Yoke
2. Primary Coupling Shaft
3. Primary Coupling Shaft Midship Bearing
4. No. 2 Driveshaft
C. Uncouple this end first; couple this end last.
D. No. 2 Driveline With Full-Round End-Yokes
5. Intermediate Coupling Shaft
6. Intermediate Coupling Shaft Midship Bearing
7. Full-Round End-Yoke

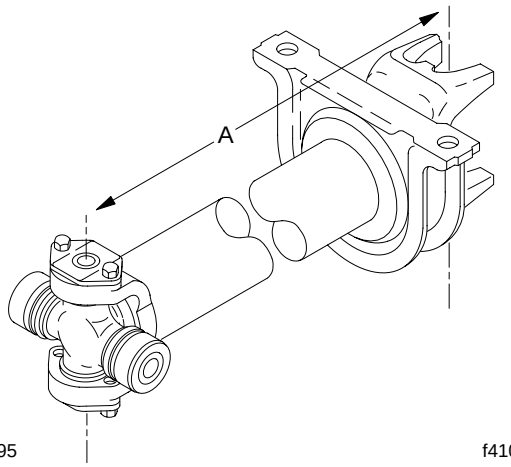
Fig. 3, Removal/Installation of a Primary Coupling Shaft

coupled to a half-round end-yoke, follow the uncoupling procedure in **Subject 100**. If the primary coupling shaft is coupled to a full-round end-yoke, follow the uncoupling procedure in **Subject 110**.

5. Lift the primary coupling shaft out of the chassis.

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**.



A. Cross-hole centerlines of both yokes must be in alignment.

Fig. 4, U-Joint Phasing of a Coupling Shaft

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. See **Fig. 3**.
2. Couple the shaft to the transmission end-yoke. If the primary coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
3. *For a vehicle with one coupling shaft:*

   If the no. 2 driveshaft was also removed, install it, as instructed in this subject.

   If the no. 2 driveshaft was not removed, couple it to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

   For a vehicle with two coupling shafts:

   If the intermediate coupling shaft was also removed, install it, as instructed in this subject.

   If only the primary coupling shaft was removed, couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the primary coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the primary coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

Intermediate Coupling Shaft Installation

IMPORTANT: Before installing a coupling shaft, make sure the yokes are aligned to keep the U-joints in phase; see **Fig. 4**.

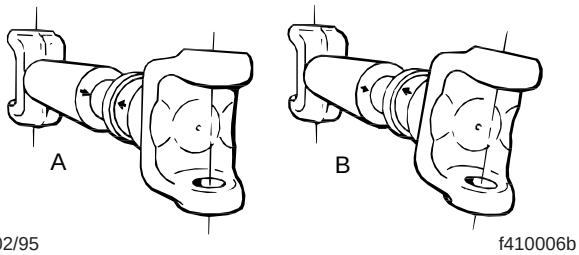
1. If the primary coupling shaft was also removed, install it first, as instructed in this subject.
2. Place the intermediate coupling shaft under the vehicle and support it with nylon support straps so it can be coupled to the primary coupling shaft end-yoke. See **Fig. 2**.
3. Couple the intermediate coupling shaft to the primary coupling shaft end-yoke. If the intermediate coupling shaft was coupled to a *half-round* end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft was coupled to a *full-round* end-yoke, follow the coupling procedure in **Subject 110**.
4. If the no. 2 driveshaft was also removed, install it, as instructed in this subject.

   If the no. 2 driveshaft was not removed, couple it to the intermediate coupling shaft end-yoke. If the intermediate coupling shaft has a half-round end-yoke, follow the coupling procedure in **Subject 100**. If the intermediate coupling shaft has a full-round end-yoke, follow the coupling procedure in **Subject 110**.

Driveshaft Removal and Installation

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. 5**.



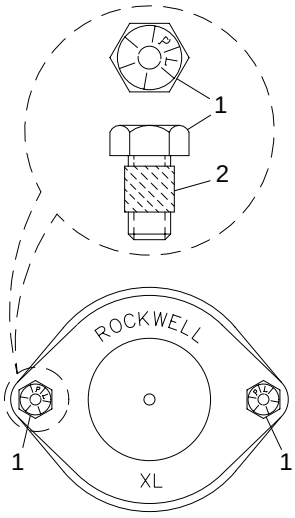
A. In Phase B. Out of Phase

Fig. 5, U-Joint Phasing

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. See **Fig. 1**.
3. Place the no. 2 driveshaft under the vehicle with its sleeve-yoke at the forward end, and support its rear end with a nylon support strap.
4. Couple the sleeve-yoke to the coupling shaft end-yoke or transmission output-shaft end-yoke, as applicable. If the no. 2 driveshaft was coupled to *half-round* end-yokes, follow the coupling procedure in **Subject 100**. If the no. 2 driveshaft was coupled to *full-round* end-yokes, follow the coupling procedure in **Subject 110**.
5. Couple the no. 2 driveshaft to the axle input-shaft end-yoke. If the no. 2 driveshaft was coupled to half-round end-yokes, follow the coupling procedure in **Subject 100**. If the no. 2 driveshaft was coupled to full-round end-yokes, follow the coupling procedure in **Subject 110**.

U-Joint Removal

1. Remove the driveshaft from the vehicle; see **Subject 120**.
2. Place the driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove and discard all four bearing-plate self-locking capscrews. See **Fig. 1**.



08/11/95 f410155

1. Self-Locking Capscrew
2. Adhesive Band

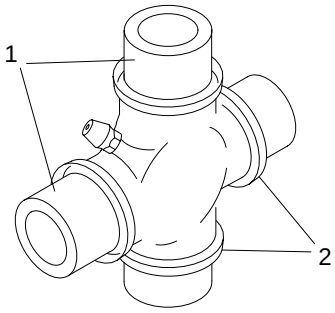
Fig. 1, Rockwell U-Joint Fasteners for Full-Round Yokes

IMPORTANT: If the U-joint will be reinstalled, use care not to nick the cross trunnions or damage the slingers. See **Fig. 2**.

4. Using one of the U-joint pullers listed in **Specifications, 400**, remove both bearing cups from the yoke cross-holes. See **Fig. 3**. Remove the cross from the yoke.

Slip-Joint Disassembly

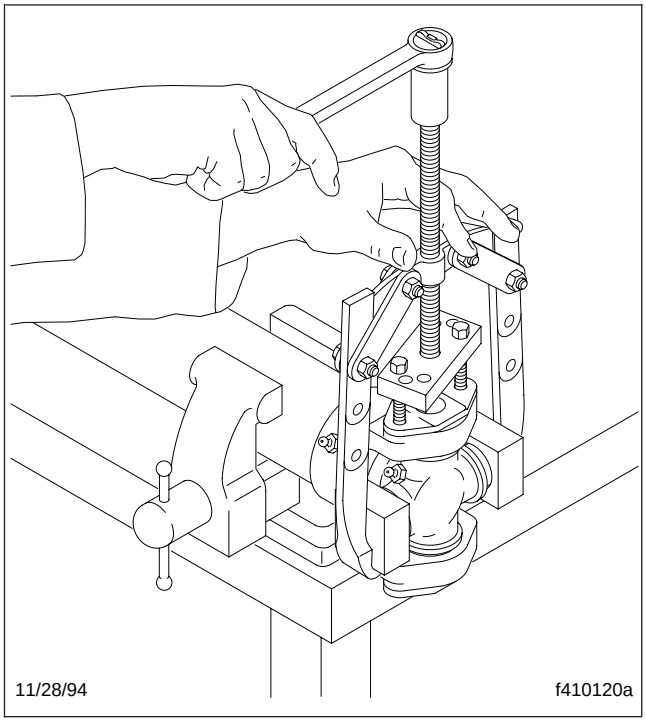
1. Check that the driveshaft yokes are aligned to hold the U-joints at either end in phase, as shown in **Fig. 4**. Using a marking stick or paint, mark the sleeve-yoke and splined shaft with alignment marks, as shown in **Fig. 5**. This will ensure proper alignment of the slip-joint components when the driveshaft is assembled.



11/28/94 f410088a

1. Trunnions 2. Slingers

Fig. 2, U-Joint Cross



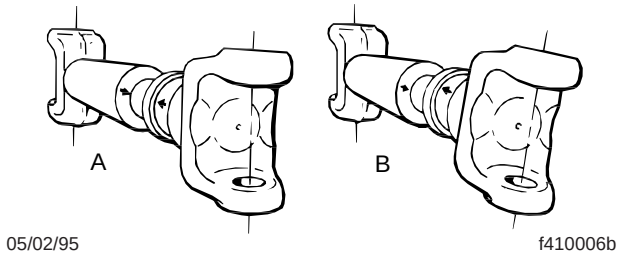
11/28/94 f410120a

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.

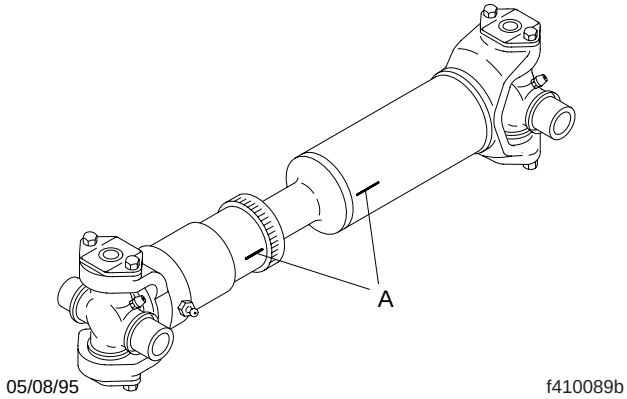
2. With the driveshaft uncoupled at one end, *or* removed from the vehicle, use a strap wrench to unscrew the slip-joint dust cap from the sleeve-

Driveline Component Removal/Disassembly



1. In Phase
2. Out of Phase

Fig. 4, U-Joint Phasing



A. Use a marking stick or paint to add alignment marks.

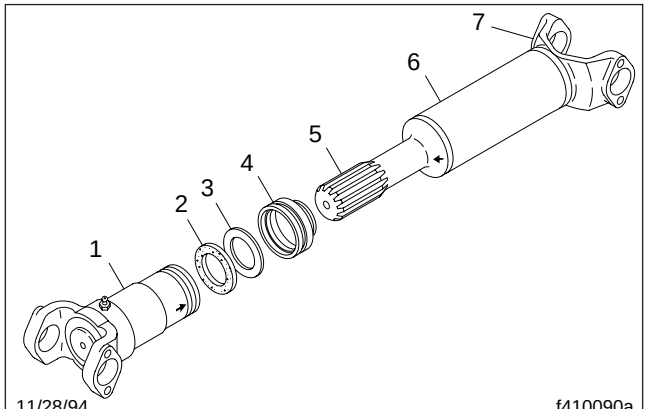
Fig. 5, Slip-Joint Alignment Marks

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**.

Transmission/Axle End-Yoke Removal

IMPORTANT: Before removing a transmission output-shaft end-yoke or an axle shaft end-yoke, do the steps under "End-Yoke Cleaning and Inspection," in **Subject 140**.

1. Uncouple the driveshaft from the end-yoke. See **Subject 100** for a half-round yoke or **Subject 110** for a full-round yoke. To remove the driveshaft from the vehicle, see **Subject 120**.
2. Remove the end-yoke locknut. See **Fig. 7** .



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

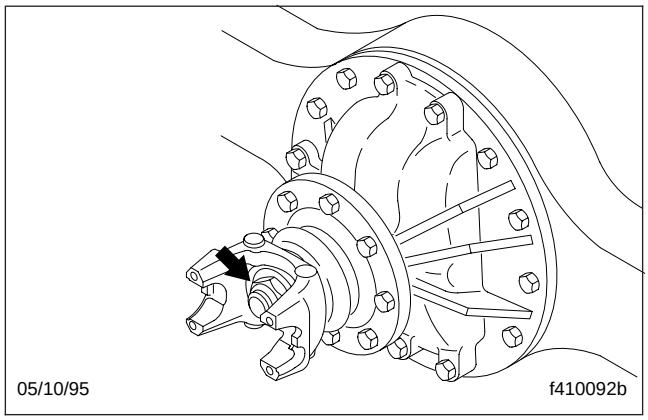
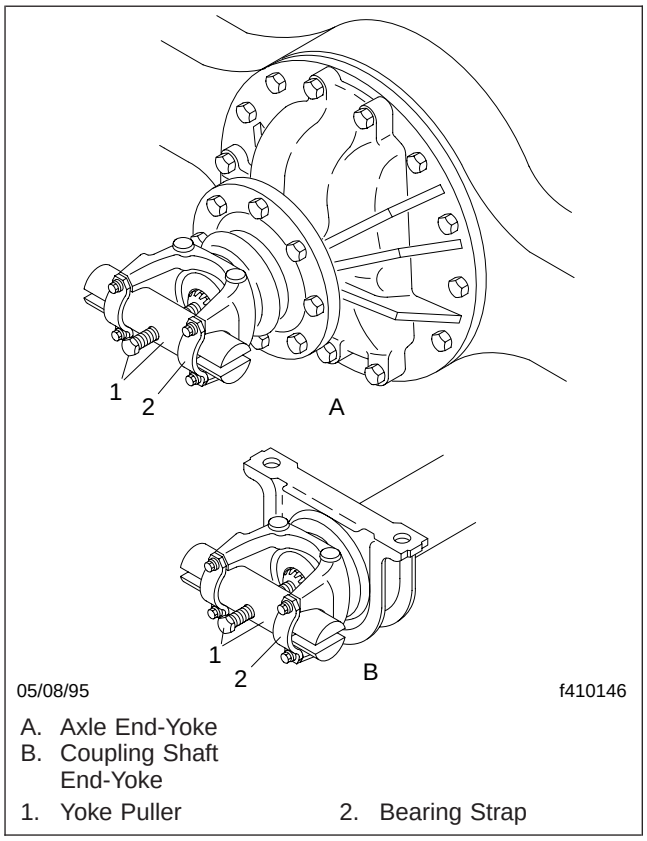


Fig. 7, Axle End-Yoke Locknut

3. Using a yoke puller, remove the end-yoke. See **Fig. 8** for a half-round end-yoke, or see **Fig. 9** for a full-round end-yoke.

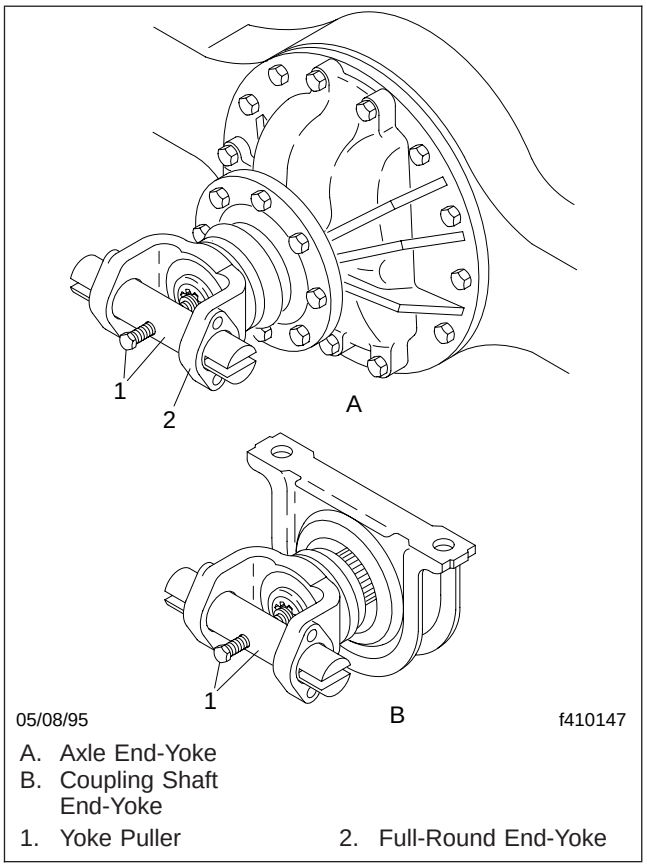
Coupling Shaft End-Yoke and Midship Bearing Removal

1. Remove the coupling shaft from the vehicle; see **Subject 120**.
2. Clamp the coupling shaft in a soft-jawed vise; do not distort the tube with excessive grip.
3. Remove the end-yoke; see **Fig. 8** for a half-round end-yoke, or see **Fig. 9** for a full-round



A. Axle End-Yoke
B. Coupling Shaft End-Yoke
1. Yoke Puller
2. Bearing Strap

Fig. 8, Removing a Half-Round End-Yoke



A. Axle End-Yoke
B. Coupling Shaft End-Yoke
1. Yoke Puller
2. Full-Round End-Yoke

Fig. 9, Removing a Full-Round End-Yoke

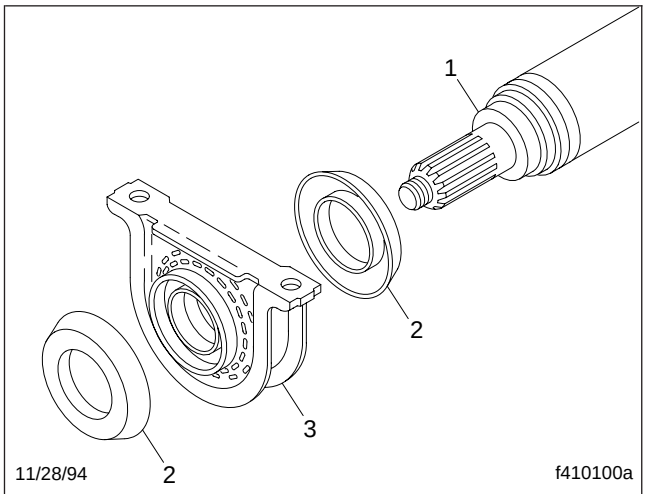
end-yoke. Then, remove the midship bearing and slingers; see **Fig. 10**.

3.1 Use a marking stick or paint to mark the end-yoke and coupling shaft with alignment marks. See **Fig. 11**.

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, or see **Fig. 9** for a full-round end-yoke.

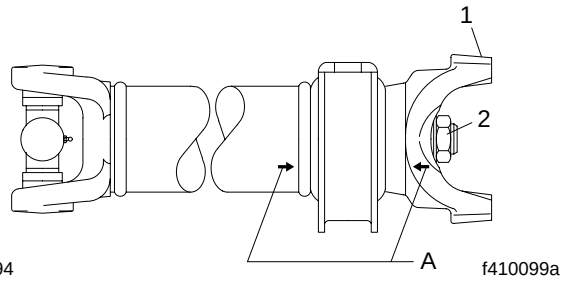
3.4 Use a hammer and a brass drift to remove the midship bearing and slingers. See **Fig. 10**.



1. Midship Bearing Shaft
2. Slinger
3. Midship Bearing

Fig. 10, Midship Bearing and Slingers

Driveline Component Removal/Disassembly



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. 11, Alignment Marks on a Coupling Shaft With an End-Yoke

Driveshaft Tube, Slip-Joint, Sleeve-Yoke, and Tube-Yoke Cleaning and Inspection

1. With the driveshaft removed, scrape or soak away any foreign material.
2. Examine the driveshaft tube for dents, bends, twists, splitting weld-seams, and signs of missing balance weights.

   Replace the driveshaft tube if damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. If balance weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
3. Clean the slip-joint (male and female) splines, then check them for twisting and galling. See **Fig. 1**. Replace both the sleeve-yoke and the splined shaft if the slip-joint is damaged; see "Driveshaft Tube, Stub Shaft (Slip-Joint), or Tube-Yoke Replacement," in **Subject 150**. Remove any burrs or rough spots using fine emery cloth.

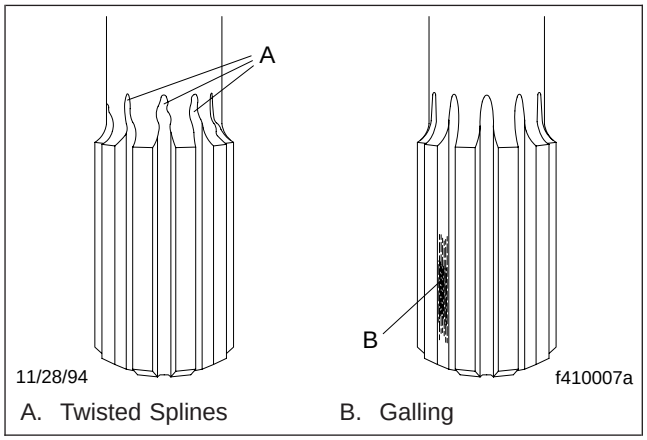


Fig. 1, Damaged Slip-Joint Splines

4. Check for a loose or missing sleeve-yoke plug. See **Fig. 2**. Repair or replace the plug as needed.
5. With the U-joint assemblies removed, check all driveshaft yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3**.

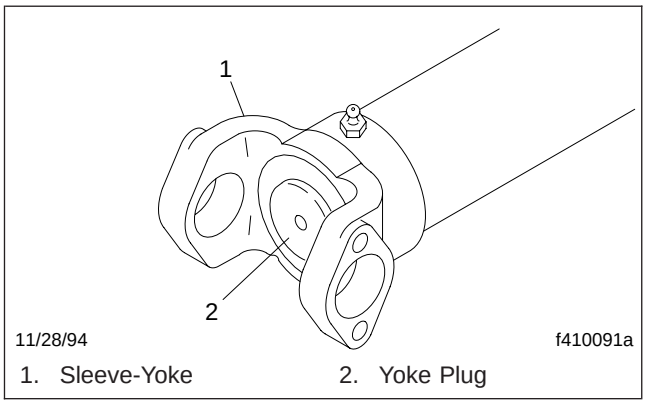


Fig. 2, Sleeve-Yoke Plug

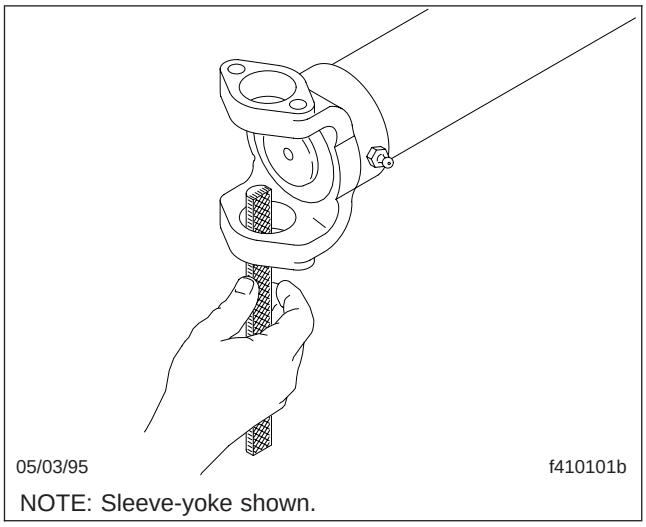


Fig. 3, Removing Burrs From a Full-Round Yoke Cross-Hole

6. Using a mill file, and holding it flat against the machined surface of the driveshaft yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**
7. Using fine emery cloth, smooth and clean the entire surface of all driveshaft yoke cross-holes. See **Fig. 5**.

Midship Bearing Cleaning and Inspection

1. With the midship bearing removed from the coupling shaft, use clean rags or paper towels to

Driveline Component Cleaning and Inspection

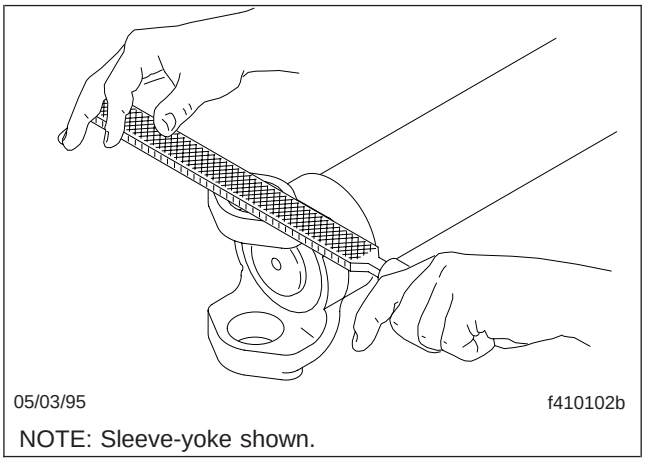


Fig. 4, Removing Burrs From the Machined Surface of a Full-Round Yoke Lug

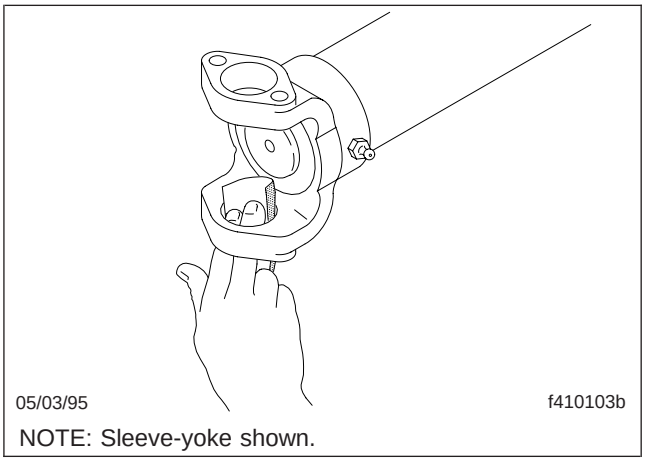


Fig. 5, Smoothing a Full-Round Yoke Cross-Hole

wipe off the outside of the midship bearing, rubber cushion, and slingers.

IMPORTANT: Do not immerse the midship bearing in cleaning solvent. The solvent will wash out the lubricant, requiring bearing-assembly replacement.

2. Check the midship bearing for roughness or rattles by holding the outside of the bearing while manually turning the inner bearing race. Replace the bearing assembly if there are any rough spots or rattles.
3. Check the rubber cushion for deterioration or oil-soaking, and replace the midship bearing assembly if needed.

End-Yoke Cleaning and Inspection

1. With the transmission output-shaft and axle shaft end-yokes installed, check them for cracks and looseness.

   Replace cracked yokes. If the end-yoke can be moved in or out on its shaft, or can be rocked on its shaft, uncouple the driveshaft from the end-yoke. Check the drive component's shaft seal for leakage or other visible damage that may have been caused by the loose yoke. Replace the shaft seal if needed. Tighten the end-yoke nut to the torque value given in **Specifications, 400**. If the end-yoke is still loose after tightening the yoke nut, install a new yoke and yoke nut.

NOTE: If the end-yoke locknut is removed for any reason, install a new one.

2. With the U-joints uncoupled from the end-yokes, check all driveshaft and input/output shaft end-yoke cross-holes for raised metal. Using a rat-tail or half-round file, remove burrs or raised metal. See **Fig. 3** for full-round yokes, or see **Fig. 6** for half-round yokes.

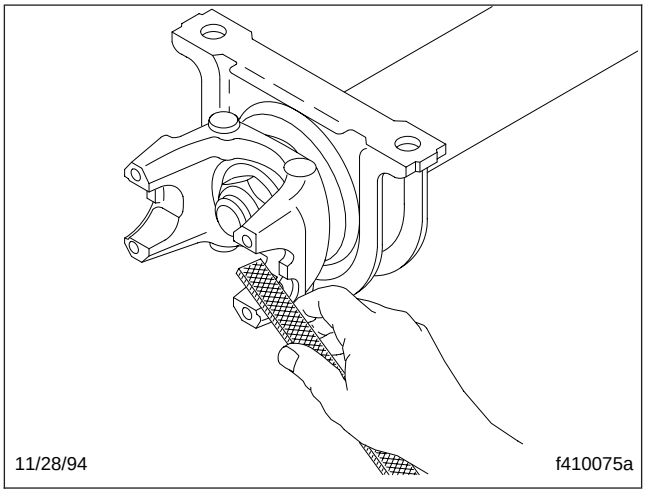
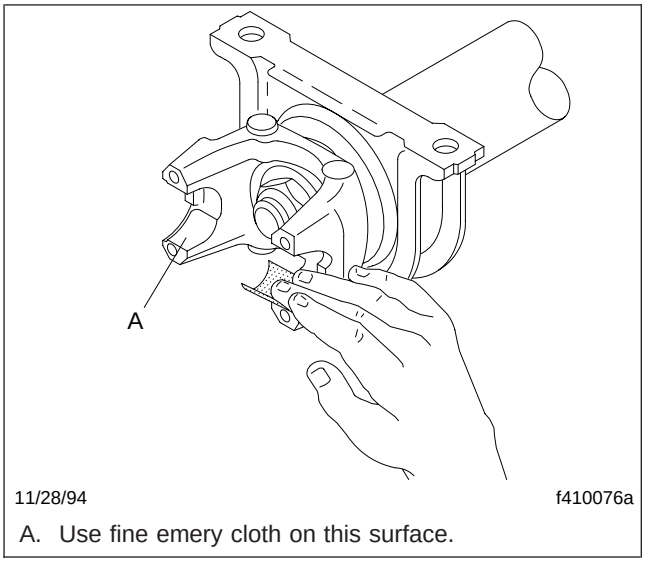


Fig. 6, Removing Burrs From a Half-Round End-Yoke Cross-Hole

3. Using a mill file, and holding it flat against the machined surface of the *full-round* end-yoke lug, file each yoke lug, to remove any burrs or raised metal. See **Fig. 4**.

4. Smooth and clean the entire surface of all end-yoke cross-holes, using fine emery cloth. See **Fig. 5** for full-round yokes, or see **Fig. 7** for half-round yokes.



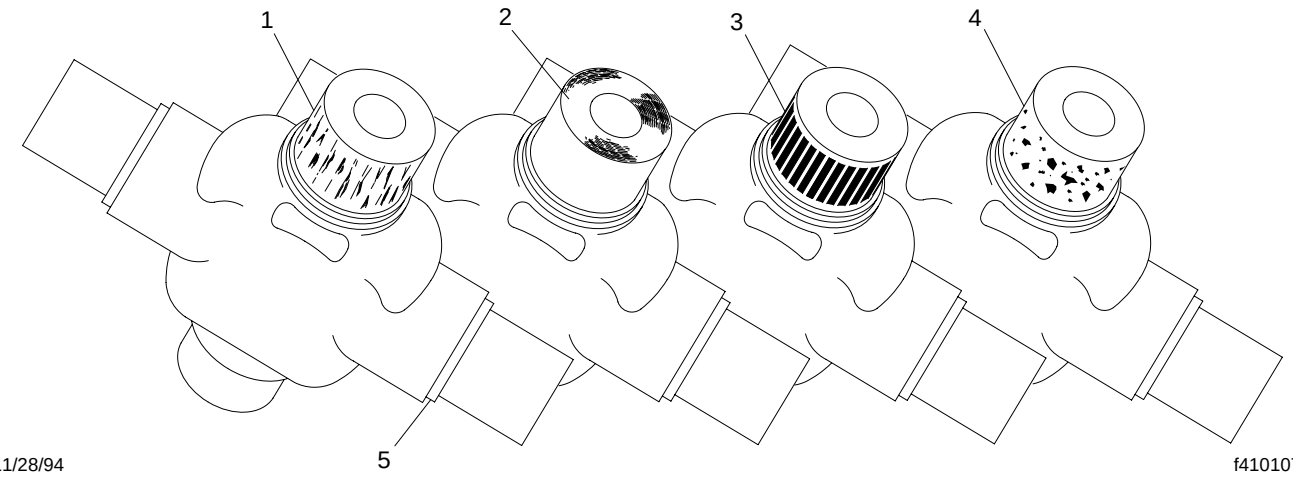
A. Use fine emery cloth on this surface.

Fig. 7, Smoothing a Half-Round End-Yoke Cross-Hole

U-Joint Cleaning and Inspection

1. With the U-joints removed from the yokes, and the bearing cups removed from the crosses, inspect the U-joint cross slingers for damage, then inspect the U-joint trunnions for spalling (flaking metal), end galling (displacement of metal), brinelling (grooves caused by bearing needles), and pitting (small craters caused by corrosion). See **Fig. 8**. If damaged, replace the U-joint assembly.
2. Using a hand-type grease gun, apply multipurpose chassis grease to the fitting on each U-joint cross until all old lubricant is forced out. See **Fig. 9**. Examine the old lubricant. If it appears rusty, gritty, or burnt, replace the U-joint assembly.
3. Soak the bearing cups in a non-flammable cleaner until particles of grease and foreign matter are loosened or dissolved. Do not disassemble the bearing cups; clean the bearing needles with a short, stiff brush, then blow them dry with compressed air. Check for minute particles of dirt or grit, and clean again if necessary.
4. Check each bearing cup for missing bearing needles. Check the bearing-cup seals for nicks. See **Fig. 10** for a half-round-yoke U-joint bearing cup, or see **Fig. 11** for a full-round-yoke U-joint bearing cup. Replace the U-joint assembly if any bearing needles are missing or any seals are damaged.
5. Apply a small quantity of multipurpose chassis grease to the bearing needles in each cup, then apply a small amount of light-weight oil to the lips of the bearing-cup seals. Rotate each bearing cup on the cross to check for wear. Replace the U-joint assembly if any bearing surfaces are worn.
6. Check the underside of each bearing-cup plate for burrs or raised metal. Use a mill file to remove any burrs or raised metal. See **Fig. 12**.
7. Using fine emery cloth, smooth and clean the outside surfaces of all bearing cups. See **Fig. 12** and **Fig. 13** .

Driveline Component Cleaning and Inspection



1. Spalling
2. End Galling
3. Brinelling
4. Pitting
5. Slinger

Fig. 8, Damaged U-Joint Crosses

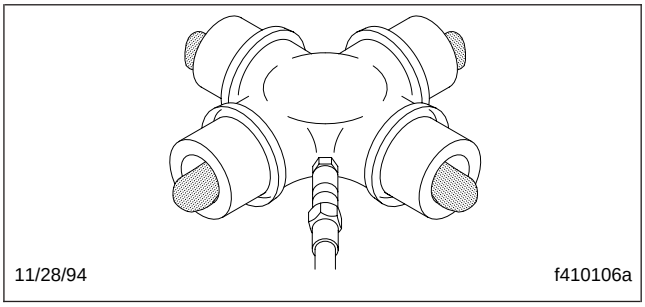
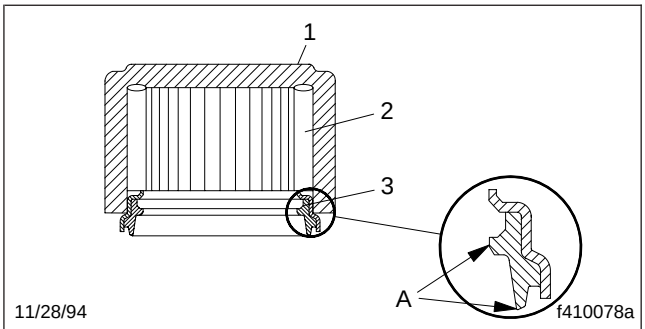


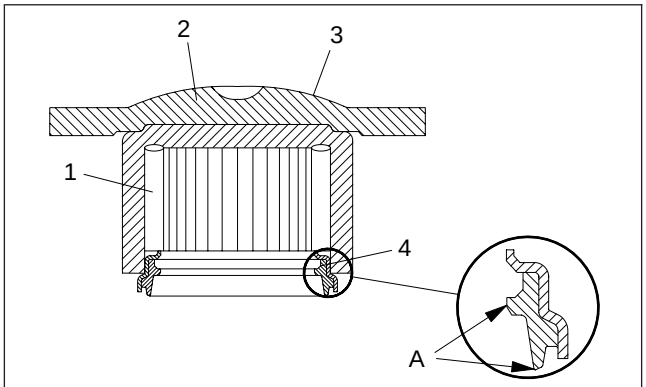
Fig. 9, Forcing Out Old Lubricant From a U-Joint Cross



A. Lubricate seal lips here.

1. Bearing Cup
2. Bearing Needle
3. Bearing-Cup Seal

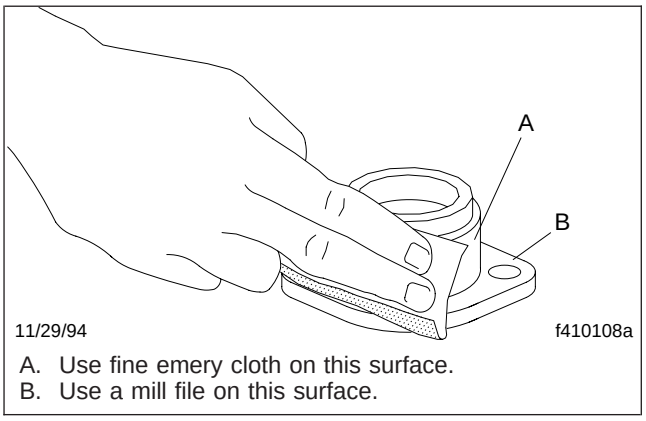
Fig. 10, Sectional View of a Half-Round End-Yoke U-Joint Bearing Cup



A. Lubricate seal lips here.

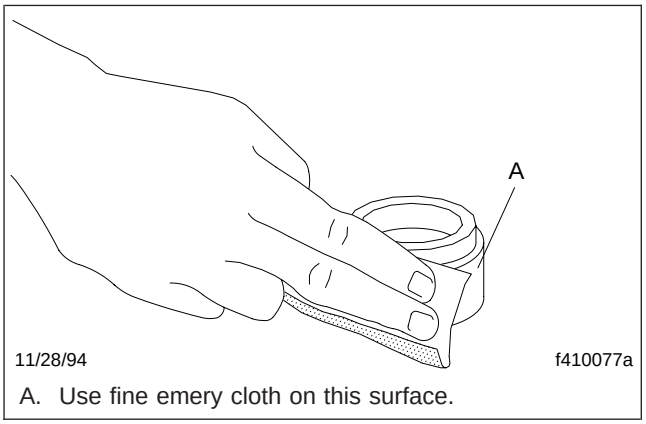
1. Bearing Needle
2. Bearing-Cup Plate
3. Bearing Cup
4. Bearing-Cup Seal

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



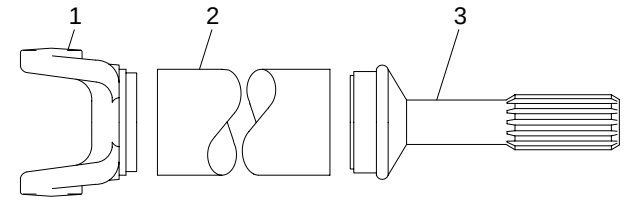
A. Use fine emery cloth on this surface.

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**. Runout limits for a new (rebuilt) driveshaft are:

0.005 in (0.127 mm) T.I.R. (Total Indicator Reading) on the smooth portion of the stub shaft neck;

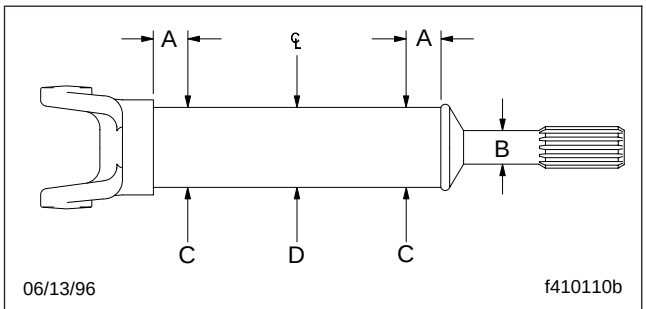
0.010 in (0.254 mm) T.I.R. on the tube 3 in (76 mm) from the front and rear welds;

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

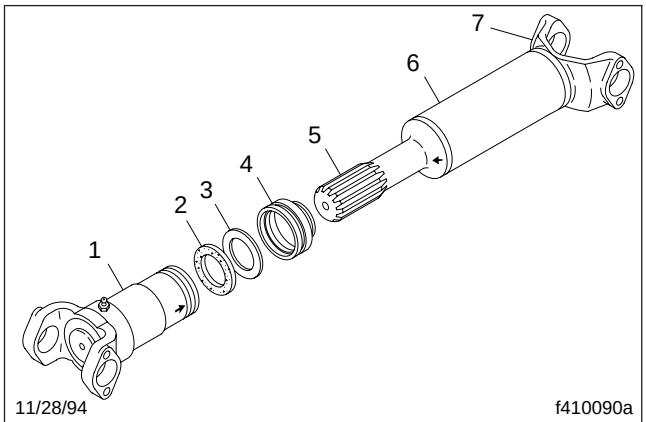


A. Measurement: 3" (76 mm)
B. Measurement: 0.005" (0.127 mm)
C. Measurement: 0.010" (0.254 mm)
D. Measurement: 0.015" (0.381 mm)

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**.

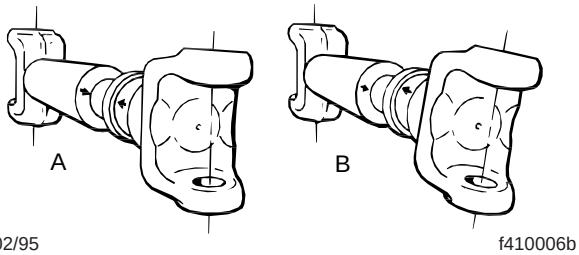


1. Sleeve-Yoke
2. Cork Washer
3. Steel Washer
4. Dust Cap
5. Splined Stub Shaft
6. Tube
7. Tube-Yoke

Fig. 3, Slip-Joint Components

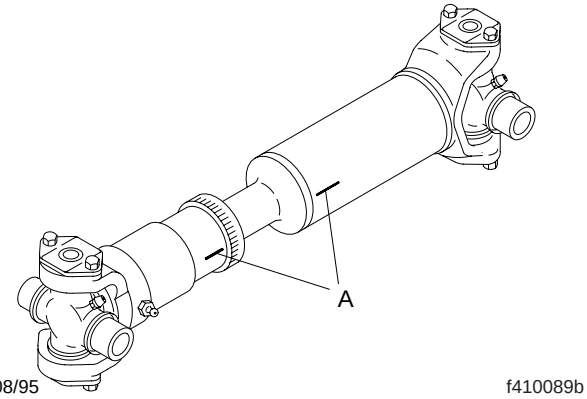
2. Coat the splines of the shaft with multipurpose chassis grease.
3. Insert the splined shaft in the sleeve-yoke, so that the alignment marks are aligned, and the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

Driveline Component Replacement or Installation/ Assembly



1. In Phase
2. Out of Phase

Fig. 4, U-Joint Phasing



A. Use a marking stick or paint to add alignment marks.

Fig. 5, Slip-Joint Alignment Marks

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.

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.
2. Fill the entire cavity around the midship bearing with a waterproof grease, to shield the bearing from water and contaminants. Use enough grease to fill the cavities to the extreme edge of the slingers that surround the front and rear of the bearing. See **Fig. 6**.

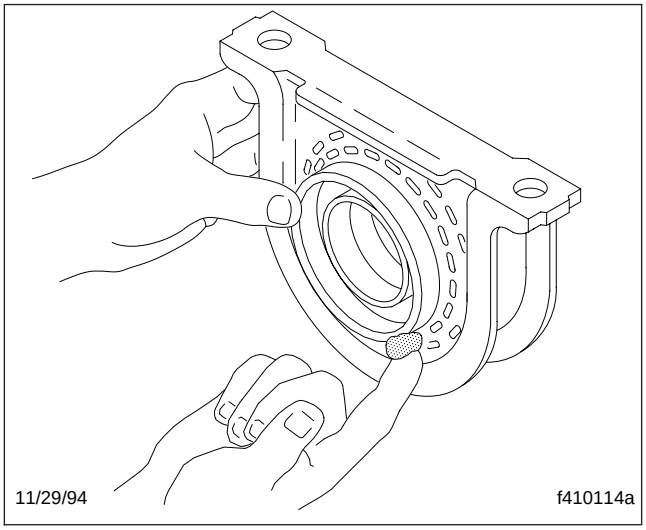


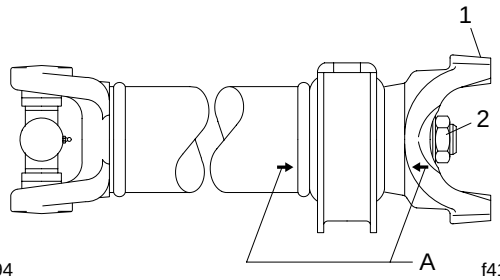
Fig. 6, Greasing a Midship Bearing

NOTE: Midship bearings are permanently lubricated when manufactured; it is not necessary to pack the bearing with grease.

3. Install one of the slingers, the midship bearing, then the other slinger on the coupling shaft. Press the bearing and slingers on by hand, as far as they will go.
4. Install the end-yoke. See **Fig. 7**.

4.1 Apply Loctite® 242 to the shaft threads where the end-yoke locknut will be installed.

4.2 Align the marks added to the coupling shaft and end-yoke during removal, then place the end-yoke on the shaft so the yoke bores are aligned at both ends of the shaft. See **Fig. 7**.



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. 7, Alignment Marks on a Coupling Shaft With an End-Yoke

4.3 Install the end-yoke nut, and tighten it 475 to 525 lbf·ft (645 to 710 N·m). Then back the nut off slightly, and tighten it to the same torque.

U-Joint Replacement or Installation

IMPORTANT: Parts for different series drivelines must not be intermixed. Also, components of the various makes of U-joints may not be interchangeable, and must be assembled only with compatible products. Incorrectly assembled or worn components can affect the entire driveline, resulting in too much vibration or driveline damage.

Worn bearing assemblies used with a new cross, or new bearing assemblies used with a worn cross will wear rapidly, making another replacement necessary in a short time. Always replace the cross and all four bearing assemblies at the same time.

If the slip-joint of a no. 2 or no. 3 driveshaft has been disassembled, assemble the slip-joint before installing the U-joints.

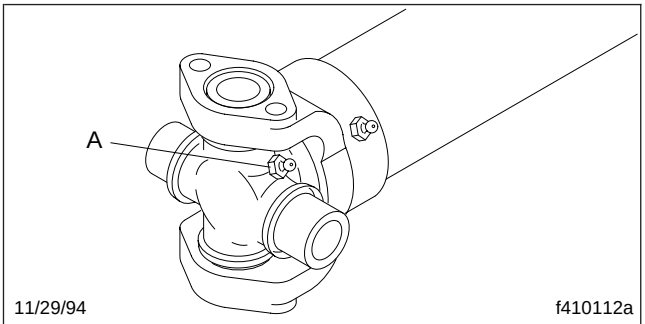
1. Place the assembled driveshaft in V-blocks or a soft-jawed vise; do not distort the tube with excessive grip.
2. For a no. 2 or no. 3 driveshaft, check that the slip-joint alignment marks are aligned, so that the U-joints at each end of the driveshaft will be in phase. See **Fig. 4** and **Fig. 5**.

   For a coupling shaft, check that the end-yoke and tube-yoke are aligned, so that the U-joints at each end of the coupling shaft will be in phase. See **Fig. 7**.

IMPORTANT: Misaligned driveshaft yokes will cause the U-joints to be out of phase, which will cause vibration in the driveline.

3. Inspect and lubricate the U-joint; see **Subject 140**.
4. Install the U-joint cross and bearing assemblies in the yoke.

   4.1 Position the U-joint cross in the driveshaft yoke so one grease fitting points toward the driveshaft, and aligns with the grease fitting on the sleeve-yoke (if so equipped). See **Fig. 8.**



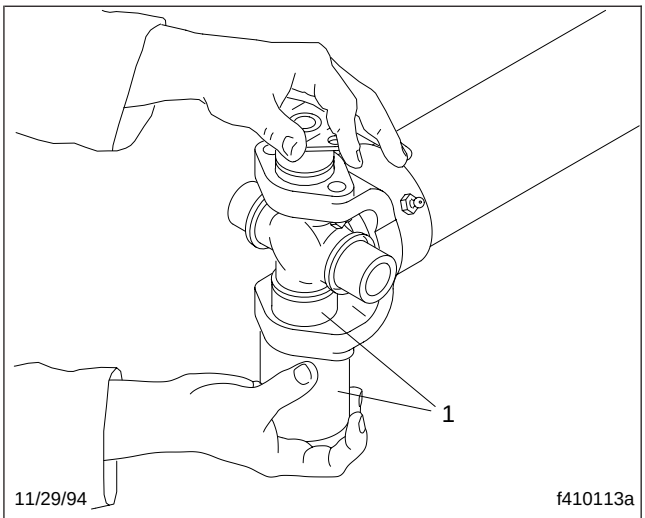
A. Install cross with grease fitting pointing toward driveshaft, and aligned with sleeve-yoke grease fitting.

Fig. 8, U-Joint Grease Fitting Positioning

4.2 Move one end of the cross until a trunnion projects through the cross-hole, beyond the outer machined face of the yoke lug. Using a Spicer trunnion (journal) locator, hold the trunnions in alignment with the

Driveline Component Replacement or Installation/ Assembly

cross-holes, while placing a bearing cup (plate-type) over the projected trunnion, and aligning it with the cross-hole. See **Specifications 400**. See **Fig. 9**.



NOTE: Sleeve-yoke shown.
1. Trunnion Locator

Fig. 9, Using a U-Joint Trunnion Locator

IMPORTANT: A Spicer trunnion (journal) locator should be used, to prevent damage to the U-joint trunnions and slingers.

4.3 By hand, press the bearing-cup-plate flush with the face of the yoke. If the bearing cup binds in the cross-hole, tap the *center*of the bearing-cup plate with a leather or rubber mallet; do not tap the outer edges of the plate. See **Fig. 10**.

4.4 Install *new* bearing-cup-plate self-locking capscrews. See **Fig. 11**. 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.

⚠ 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 drive-

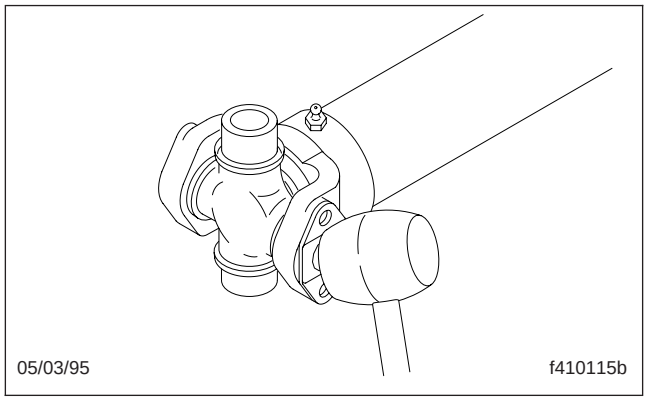
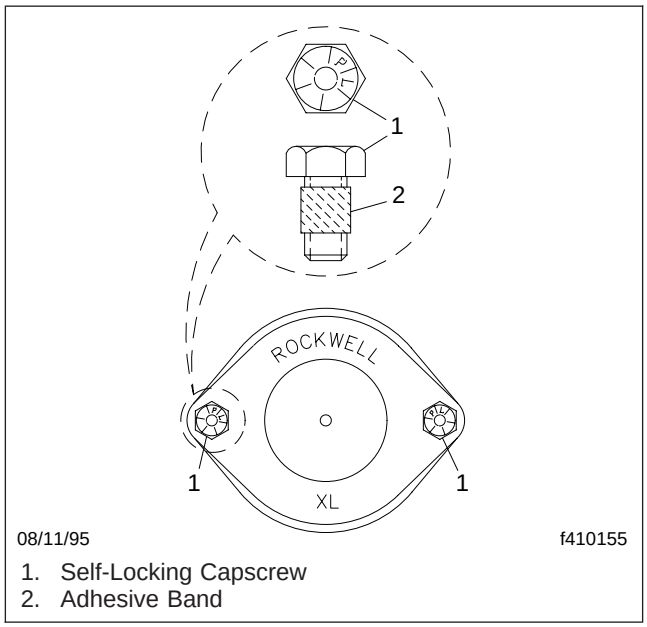


Fig. 10, Seating a U-Joint Bearing Cup In a Full-Round Yoke



1. Self-Locking Capscrew
2. Adhesive Band

Fig. 11, Rockwell U-Joint Fasteners for Full-Round Yokes

shaft 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. 12.**

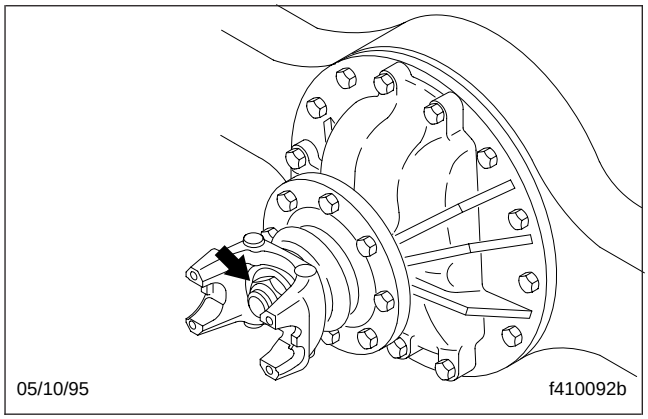


Fig. 12, Axle End-Yoke Locknut

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**.

Driveline Angularity and Balance

Driveline angularity is dependant on the type of axle and suspension the vehicle has. Contact customer support at Freightliner Custom Chassis Corporation for specifications and procedures covering driveline angularity and driveline balance.

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.

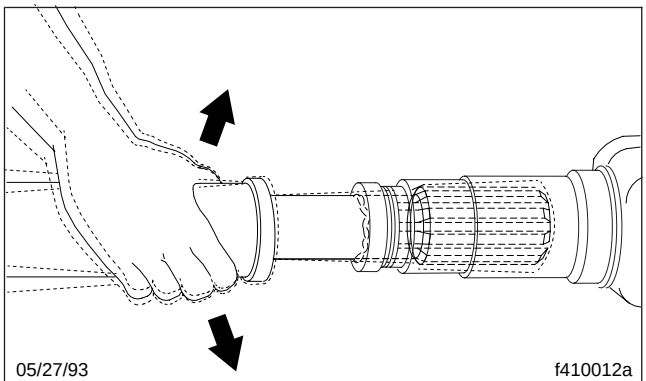
1. Check all tires for uneven wear and for out-of-roundness. Check for mismatched tires. Look for wheels and rims that are out of alignment. For instructions, see **Group 40**.
2. Check the rear suspension for loose or broken U-bolts; broken, shifted, or mismatched rear springs; or broken spring seats. 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's midship bearing mounts. Replace mountings that are deteriorated or oil-soaked; tighten loose mounting bolts. Oil-soaked or deteriorated mountings, or loose mounting bolts, can cause driveline angular misalignment.
5. Check for loose U-joint bearing-cup-plate and bearing-strap capscrews. Tighten any loose fastener to the applicable torque value in **Specifications, 400**.

CAUTION

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, slip-joint splines, and midship bearings for wear.
   - 6.1 Try to move each driveshaft up and down, and from side to side. If movement is greater than 0.006 in (0.15 mm) of a U-joint cross in its bearings, replace the U-joint assembly.
   - 6.2 If the midship bearing rattles or is loose on its shaft, replace it.
   - 6.3 Try to bend the sleeve-yoke and splined shaft up and down, and from side to side. See **Fig. 1**. If looseness is greater than 0.007 in (0.18 mm), replace the sleeve-yoke and splined shaft.

     If driveline components must be replaced, see **Subject 150**.



Try to bend the sleeve-yoke and splined shaft up and down, and from side to side.

Fig. 1, Checking for Slip-Joint Spline Wear

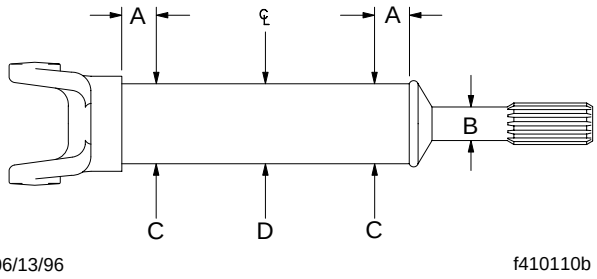
7. Check each driveshaft for an indication of missing balance weights. If any weights appear to be missing, have the driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.
8. Check each driveshaft for dents, bends, twists, or other damage.

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 150** for runout specifications for a *new* (or rebuilt) driveshaft.

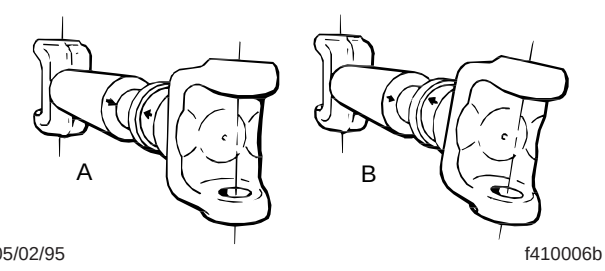


A. Measurement: 3" (76 mm)
B. Measurement: 0.015" (0.38 mm)
C. Measurement: 0.020" (0.51 mm)
D. Measurement: 0.025" (0.635 mm)

Fig. 2, Runout Specifications for a Used Driveshaft

9. Check each driveline for proper U-joint phasing. 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.



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.

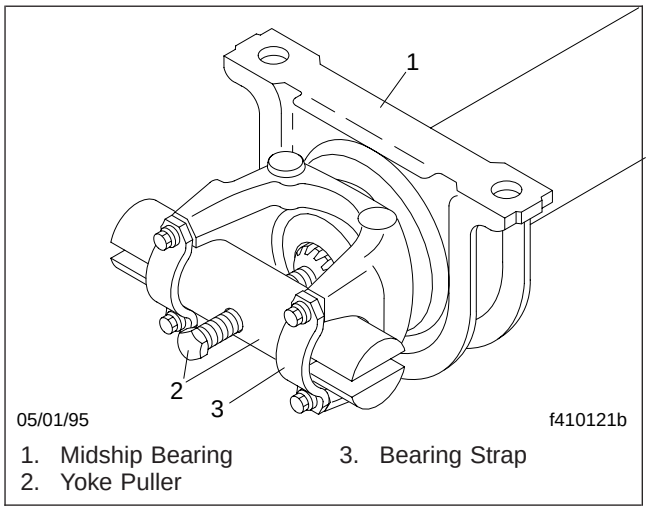
10. Check the torque on all of the end-yoke nuts in the drivetrain; see the applicable torque values in **Specifications, 400**.

    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 150**.

    If the yoke is not worn, tighten the yoke nut to its torque value.

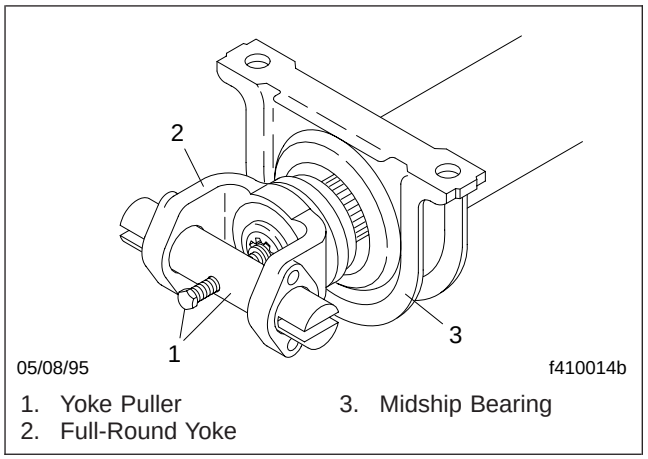
11. Have the no. 2 driveshaft balanced to a maximum tolerance of one inch-ounce per ten pounds weight per end, at 3000 rpm.

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

Specifications

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 (Coupling Shaft)	Spicer	SPL90, 1610, 1710	1-1/4–18	475–525 (645–710)
Companion-Flange Nut				
Transmission Output Shaft	Fuller	FS 4205A, 4205B, 5205A/B, 6305A/B (all five-speeds); FS 5306A, 6306A (all six-speeds)	1-1/4–18	300–350 (405–475)
U-Joint Capscrew				
Bearing Strap (for half-round end-yoke)	Spicer	SPL90, 1610	3/8–24	45–60 (61–81)
		1710	1/2–20	115–135 (156–183)
Flange-Yoke Locknut				
Flange-Yoke to Companion Flange	Spicer	SPL90, 1610, 1710	3/8–24	40–48 (54–65)
Midship Bearing Flanged Locknut				
Bracket to Crossmember	Spicer	SPL90, 1610, 1710, 1760	1/2–13	60–76 (81–88)
Bearing Mount to Bracket	Spicer	SPL90, 1610, 1710, 1760	1/2–13	60–76 (81–88)

Table 1, Fastener Torques

Special Tools

JOURNAL LOCATOR

(For installing Spicer SPL90, 1610, 1710, and 1760 U-joints in full-round yokes)

To order: Contact your Dana Corporation Spicer Service Representative.

U-JOINT REMOVAL TOOL KIT

(For removing Spicer 1610 and 1710 U-joints from full-round yokes)

To order:

Owatonna Tool Kit No. 7057 Contact: Owatonna Tool Company Owatonna, Minnesota 55060

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)

To order one of the following:

End-Yoke Puller J 7804–01 Contact: Kent-Moore Tool Division 29784 Little Mack Roseville, MI 48066–2298 Telephone: 1–800–328–6657 Telex: 244040 KMTR UR FAX: (313) 774–9870

Specifications

Yoke and Flange Remover SP–450 Contact: G & W Tool Company 907 South Dewey Wagoner, OK 74467

See **Fig. 1** for a full view of the chassis plumbing diagram.

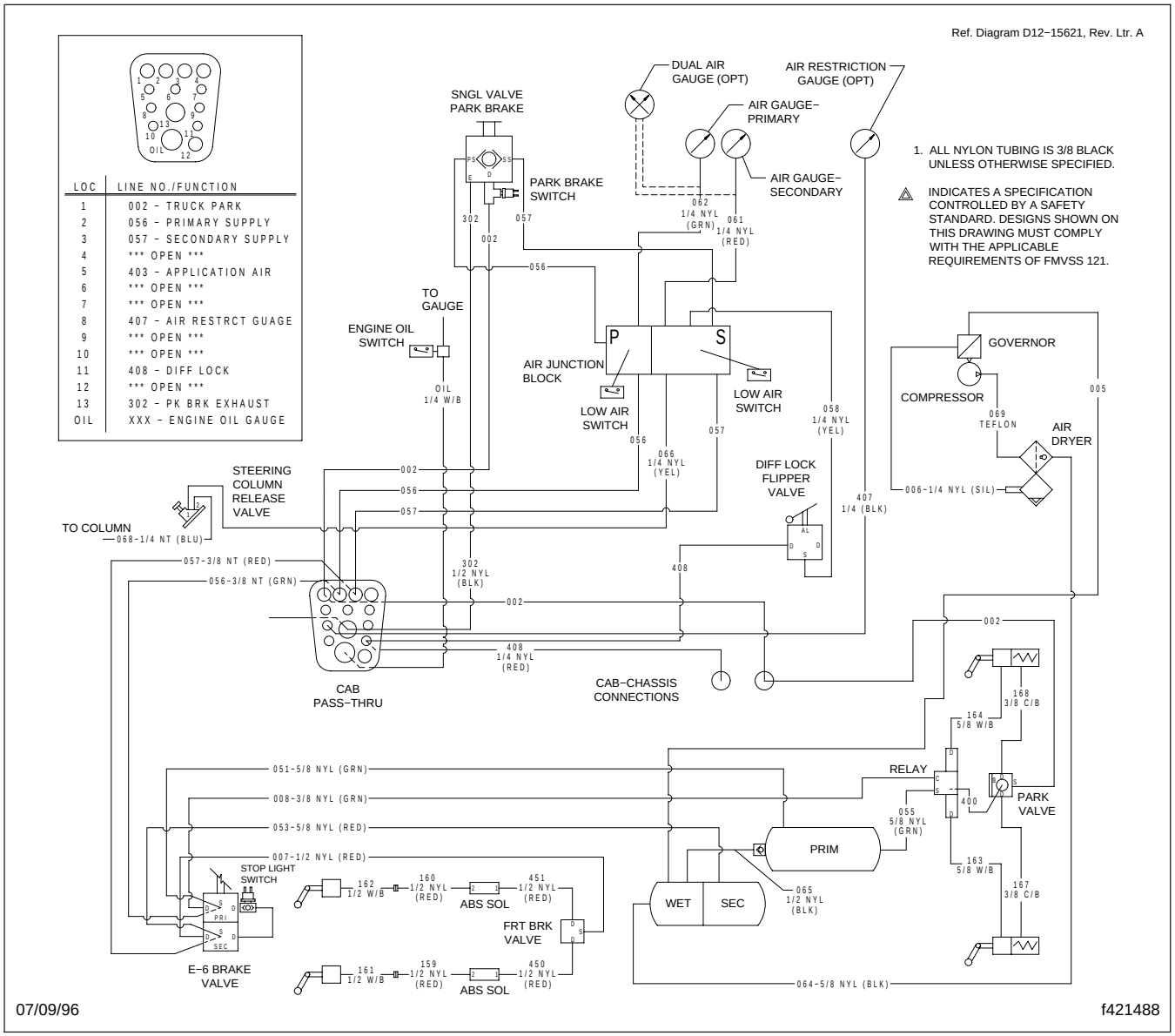


Fig. 1, Chassis Plumbing Diagram

General Information

This troubleshooting guide is designed to help locate causes of problems originating in the air brake system. The corrective measures given are not intended to replace the detailed service information found in other sections of this manual or in the component manufacturer's service manuals. If the vehicle is equipped with ABS (antilock brake system), refer to the applicable section in this group for troubleshooting the ABS system.

Before attempting to isolate the causes of an air brake system problem, do the following.

1. Check the operation of the air compressor. Refer to the engine manufacturer's service manual.

   Check the pressure levels of the air reservoirs. Refer to the pretrip inspection and daily maintenance chapter in the vehicle operator's manual.
2. Be sure that all relay valves are operating. Refer to the brake section in the chassis maintenance manual.
3. Check the operation of the brake chambers as instructed in the brake section in the chassis maintenance manual.
4. Examine all tubing for kinks, dents, and other damage. Replace damaged tubing.
5. Examine all hoses for cracks, drying out, overheating, and other damage. Replace damaged hoses.
6. Examine all air line fittings. Tighten loose connections; replace fittings that are damaged. For instructions, refer elsewhere in this group.
7. Examine leaking pipe connections for cracks or thread damage; replace as needed. If there is no damage, retighten the fitting. For instructions, refer elsewhere in this group.

Safety Precautions

⚠ WARNING

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.

Troubleshooting Tables

Problem—Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied

Problem—Vehicle Does Not Slow Down Quickly Enough When Brakes Are Applied	
Possible Cause	**Remedy**
The vehicle is overloaded.	Observe the recommended maximum load limits.
There is low air pressure in the brake system, about 60 psi (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. Adjust the air governor to the recommended specification.
The application air lines are leaking excessively.	Check the application air lines, brake valve, and the service and parking brake chambers for air leaks. Repair or replace the damaged component(s).
Brake valve delivery pressure is below normal.	Lubricate the brake valve parts; overhaul the unit, if necessary.
Wear or glazing of the brake linings is present.	Install new brake linings on the brake shoes on both sides of the axle.
Adjustment or lubrication of the brakes is needed.	Adjust or lubricate the brakes.
The automatic slack adjusters are not operating.	Lubricate the automatic slack adjusters and check for binding, damaged, or inoperative slack adjuster parts. Replace damaged or inoperative parts, or eliminate the cause of the binding.
The cam has flipped over.	Replace the linings and the cam on each end of the axle.
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. Ensure that the bearings to be installed are sufficiently lubricated as outlined in **Group 33** and **Group 35** in the chassis maintenance manual.
One or more of the brake drums is broken or cracked.	Replace the brake drum(s).
Wrong size brake linings were installed.	Replace the brake linings with the recommended size.
Wrong size brake chambers were installed.	Replace the brake chambers with the recommended size.
A camshaft bracket or chamber mounting bracket is bent or broken.	Replace the camshaft bracket or chamber mounting bracket.
The brake chamber mounting stud nuts or brake chamber mounting bracket is loose.	Tighten the brake chamber to its mounting bracket or the mounting bracket to the foundation brake housing.
There is a ruptured diaphragm in the service brake.	Replace the diaphragm.

Troubleshooting

Problem—Service Brakes Release Too Slowly

Problem—Service Brakes Release Too Slowly	
Possible Cause	**Remedy**
The brake shoe anchor pins are frozen.	Inspect the anchor pins. If damaged, replace them; if not damaged, lubricate them.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake foot valve is not returning to the fully released position.	Check for obstructions which might prevent the brake foot valve from returning to the fully released position. Remove any obstructions.
The exhaust port of the brake foot valve or quick-release valve is plugged.	Clear the exhaust port of obstructions.
The brake foot valve or quick-release valve is inoperative.	Overhaul or replace the inoperative valve, as needed.
The camshaft and bushings are binding.	Clean and lubricate the camshaft bushings.
The brake shoe return spring is weak or broken.	Replace the spring.
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. Ensure that the bearings to be installed are sufficiently lubricated as outlined in **Group 33** and **Group 35** in the chassis maintenance manual.

Problem—Service Brakes Do Not Apply or Apply Too Slowly

Problem—Service Brakes Do Not Apply or Apply Too Slowly	
Possible Cause	**Remedy**
Lubrication of the foundation brake assembly is needed.	Lubricate those components requiring periodic lubrication.
There is insufficient air pressure in the brake system.	Check all parts of the air pressure system for leaks or inoperative components.
The brake foot valve or relay valve is inoperative.	Repair or replace the brake foot valve or relay valve.
The camshaft bushings are binding.	Clean and lubricate the camshaft bushings.

Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure

Problem—Service Brakes Apply When the Parking Brakes Are Released With Air Pressure	
Possible Cause	**Remedy**
The air delivery lines to the brake chamber have been reversed.	Reverse the connections of the brake chamber air lines.
The braking mechanism is binding.	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened. Check for obstructions; remove any obstructions.

Problem—Service Brakes Do Not Release

Problem—Service Brakes Do Not Release	
Possible Cause	**Remedy**
The brake shoes are incorrectly adjusted.	Adjust the brakes. Also, make sure the slack adjuster is operating correctly. If not, overhaul or replace the slack adjuster.
The brake foot valve may not be in the fully released position.	Lubricate the brake foot valve if needed.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve.
There is restriction in the tubing, hose, or exhaust port of the brake foot valve or quick-release valve.	Check for bends or obstructions on the exhaust side of the service brakes. Remove any obstructions; plumb the air lines so that bends are minimal.
A broken power spring may be blocking the parking brake piston movement.	Replace the power spring or replace the parking brake assembly, whichever is recommended by the parking brake manufacturer.

Problem—Service Brakes Grab or Pull

Problem—Service Brakes Grab or Pull	
Possible Cause	**Remedy**
There is not enough weight on the vehicle (underloaded).	Add weight to the vehicle, reducing brake sensitivity.
Adjustment of the brakes on one axle is uneven.	Adjust the brakes.
Lubrication of the brake system components is inadequate.	Lubricate those components requiring periodic lubrication.
The brake mechanism is binding.	Lubricate the brake mechanism and make sure all parts are aligned with each other and are securely fastened.
The clevis pin or camshaft is binding at one or more wheels.	Clean and lubricate the camshaft bushings.
A brake spider is loose.	Tighten the mounting bolts or replace the brake spider.
A slack adjuster is damaged.	Replace the damaged component.
The air chamber push rods or slack adjusters are a different length.	Replace the components with the correct size and material.
The brake foot valve is inoperative.	Overhaul or replace the brake foot valve, as needed.
If equipped with cam brakes, there is a flat or dent on the S-head camshaft or on the cam roller(s).	Replace the damaged component(s).
Grease has saturated the brake linings or the linings are glazed.	Install a matched set of linings on both sets of brake shoes on that axle. Clean, turn, or replace both brake drums. For instructions on turning drums, refer to the brake manufacturer's service manual.
The brake linings are loose or broken.	Install a matched set of linings on both sets of brake shoes on that axle.
The brake linings are not a matched set. Different friction codes or different brands of brake linings are installed.	Install a new, matched set of brake linings. Clean, turn, or replace both brake drums on that axle. For instructions on turning drums, refer to the brake manufacturer's service manual.

Troubleshooting

Problem—Service Brakes Grab or Pull Possible Cause	Remedy
A brake shoe is distorted or broken.	Replace the brake shoe. Install a new, matched set of linings on both sets of brake shoes on that axle.
The pilot pads are damaged, allowing the brake drum to be installed out-of-round.	Replace the wheel hub.
A brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
One or more brake drums is scored or broken.	Replace both of the drums on that axle.

Problem—Uneven Service Brakes

Problem—Uneven Service Brakes Possible Cause	Remedy
The wrong brake linings were installed, or the linings were not replaced in pairs.	Replace the brake linings with the recommended size. Install new linings on both sets of axle brake shoes.
Grease has saturated the brake linings or the linings are glazed.	Install new linings on both axle brake shoes. Clean the brake drums.
The return spring for the brake shoe release or the service brake has broken.	Replace all broken springs.
The brake drum is out-of-round to unacceptable limits.	Turn both the brake drums on that axle. If the maximum allowable diameter of either drum has been exceeded, replace that drum. For instructions on turning drums, refer to the brake manufacturer's service manual.
A service brake chamber diaphragm is leaking.	Tighten the clamp ring. If leaks persist, replace the service brake diaphragm.
The wheel bearings are out of adjustment.	Adjust the wheel bearings, or replace them if damaged. For instructions, refer to **Group 33** or **Group 35** in this manual.
A brake spider is damaged.	Replace the brake spider.
The brake shoes are bent or stretched.	Replace the axle brake shoes on each wheel.
Grease, oil, or dirt is on the linings.	Replace the linings on each set of axle brake shoes. Clean the brake drums.

Problem—Dragging Service Brake

Problem—Dragging Service Brake Possible Cause	Remedy
The service brake return spring is broken.	Replace the service brake return spring.
The service-application air is not exhausting or not exhausting fast enough, due to blockage in the control valve, the quick-release valve, or the limiting and quick-release valve.	Test the air system valves for leakage and operation.
A brake shoe retracting spring is broken.	Replace the brake shoe retracting spring.
Binding is occurring in the camshaft linkage.	Lubricate the camshaft linkage. Replace bent or broken parts.

Problem—Insufficient Parking Brake Application When Dash Control Valve Is Activated

Problem—Insufficient Parking Brake Application When Dash Control Valve Is Activated	
Possible Cause	**Remedy**
The parking brake is not set for full stroke.	Adjust the brakes.
There is a ruptured parking brake diaphragm or ineffective piston seal.	Replace the diaphragm or parking brake piston seal.
A power spring is broken.	Replace the parking/emergency brake section.
A power spring in a parking brake is manually caged.	Release the power spring by screwing in the release bolt.

Problem—Dragging Brakes Due to 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 (not including the air compressor).	Check all valves, air lines, and connections for leakage. Repair or replace valves and lines until leakage is eliminated.
The compressor is inoperative (including excessive leakage of the compressor).	Rebuild or replace the compressor.
The air reservoir drain cock has been left open.	Close the drain cock.
The air governor cutout setting is not adjusted correctly.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
There is inadequate clearance at the compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
If so equipped, the compressor drive belt is slipping.	Adjust or replace the compressor drive belt.
Carbon is building up in the compressor cylinder head or discharge line.	Remove the carbon. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory rebuilt or a new unit.

Troubleshooting

Problem—Air Pressure Rises Above Normal

Problem—Air Pressure Rises Above Normal	
Possible Cause	**Remedy**
The air reservoir pressure dash gauge is inaccurate.	Check the dash gauge with an accurate test gauge. Replace the dash gauge as needed.
The compressor air governor is out of adjustment.	Check the setting with an accurate test gauge, then adjust the air governor to the recommended specification.
The air governor is not operating.	Repair or replace the air governor.
There is too much clearance at the air compressor unloading valve.	Repair or adjust the compressor at the unloading valve.
The air compressor unloading valve is stuck closed.	
The air compressor unloading valve cavities or the unloading valve passage is blocked with carbon.	

Problem— Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released

Problem— Air Pressure Drops Quickly With the Engine Stopped and the Brakes Released	
Possible Cause	**Remedy**
The brake foot valve is leaking.	Repair or replace the brake foot valve.
The air compressor discharge valve is leaking.	Repair or replace the discharge valve. If disassembly is not recommended by the compressor manufacturer, replace the air compressor with a factory-rebuilt or a new unit.
The air governor is leaking.	Repair or replace the air governor.

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied

Problem—Air Pressure Drops Quickly With the Engine Stopped and the Brakes Fully Applied	
Possible Cause	**Remedy**
A service or parking brake chamber is leaking.	Tighten the clamp ring(s). If leaks persist, replace the diaphragm(s) or assembly.
The brake foot valve or relay valve is leaking.	Repair or replace the component(s) or assembly.

Problem—Compressor Knocks (Continuously or Intermittently)

Problem—Compressor Knocks (Continuously or Intermittently)	
Possible Cause	**Remedy**
There is a loose drive pulley, belt, coupling, or gear (as indicated).	Tighten or replace the component. If applicable, inspect the pulley shaft for damage. Replace the shaft, if damaged.

Problem—Compressor Knocks (Continuously or Intermittently)	
Possible Cause	**Remedy**
Backlash is in the compressor drive gears on the drive coupling.	Repair or replace the compressor drive gears or drive coupling.
The air compressor bearings are damaged or worn.	Replace the bearings.
There are carbon deposits in the compressor cylinder head.	Remove the carbon deposits or replace the compressor.

Problem—Pressure Relief Valve Activates

Problem—Pressure Relief Valve Activates	
Possible Cause	**Remedy**
The pressure relief valve is out of adjustment.	Adjust the pressure relief valve, or install a new one.
There is excessive air pressure in the brake system.	Refer to the problem "Air Pressure Rises Above Normal."
Draining of the air reservoirs needs to be performed more often.	Drain the air reservoirs daily.

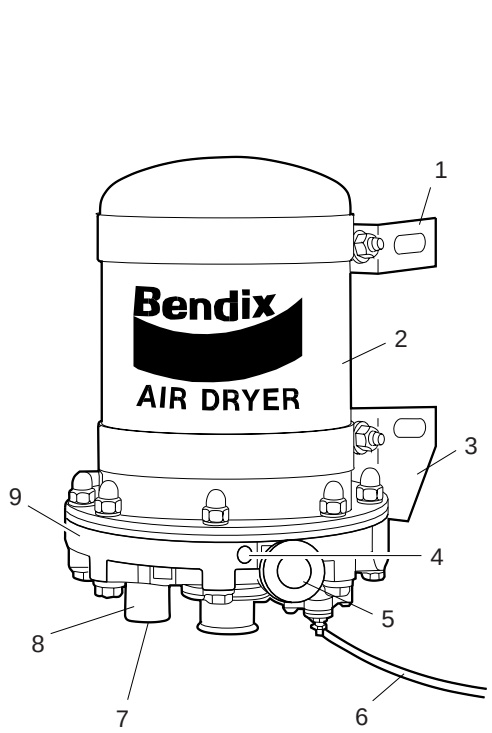
Problem—Oil or Water in the Brake System

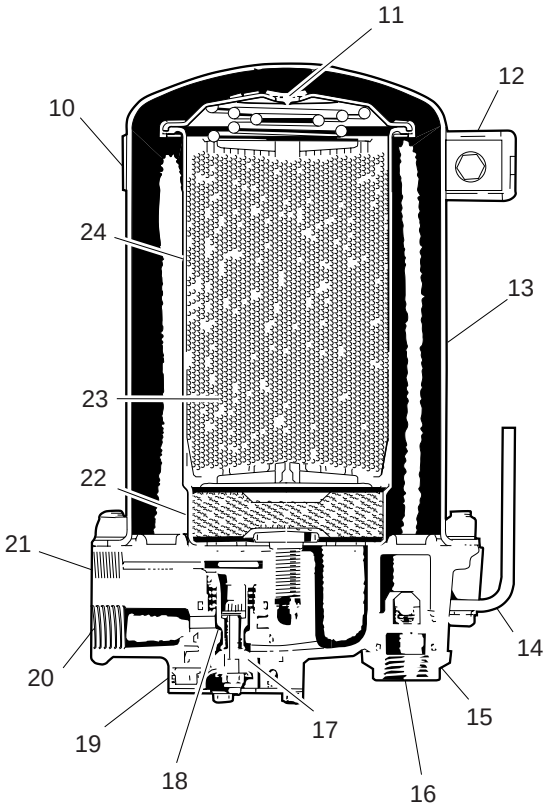
Problem—Oil or Water in the Brake System	
Possible Cause	**Remedy**
Excessive oil is passing through the air compressor.	Rebuild or replace the compressor.
If so equipped, the air compressor air strainer is dirty.	Clean the strainer or install a new one.

General Description

The function of the Bendix AD–9 air dryer is to collect and remove air system contaminants in solid, liquid, and vapor form before they enter the brake system. See **Fig. 1**.

tions 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.





09/16/94 f420867a

1. Upper Bracket
2. Outer Shell
3. Lower Bracket
4. Control Port
5. Supply Port
6. Wiring Harness
7. Delivery Port
8. Check Valve Assembly
9. End Cover
10. Upper Bracket Strap
11. Check Valve
12. Upper Bracket
13. Housing
14. Lower Bracket
15. Check Valve Assembly
16. Delivery Port
17. Purge Valve
18. Turbo Cutoff Piston
19. Purge Valve Housing Assembly
20. Supply Port
21. Control Port
22. Oil Separator
23. Desiccant Bed
24. Desiccant Cartridge

Fig. 1, Bendix AD–9 Air Dryer and Cutaway View

The AD–9 air dryer consists of the desiccant cartridge and a die-cast aluminum end cover secured to a cylindrical steel outer shell with eight capscrews and nuts. The end cover contains a check valve assembly, a safety valve, three threaded air connec-

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 with-

General Description and Principles of Operation

out 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. See **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, Pipe Thread Connection Identification

There are four versions of the AD–9 air dryer. See **Fig. 2**

- Standard:

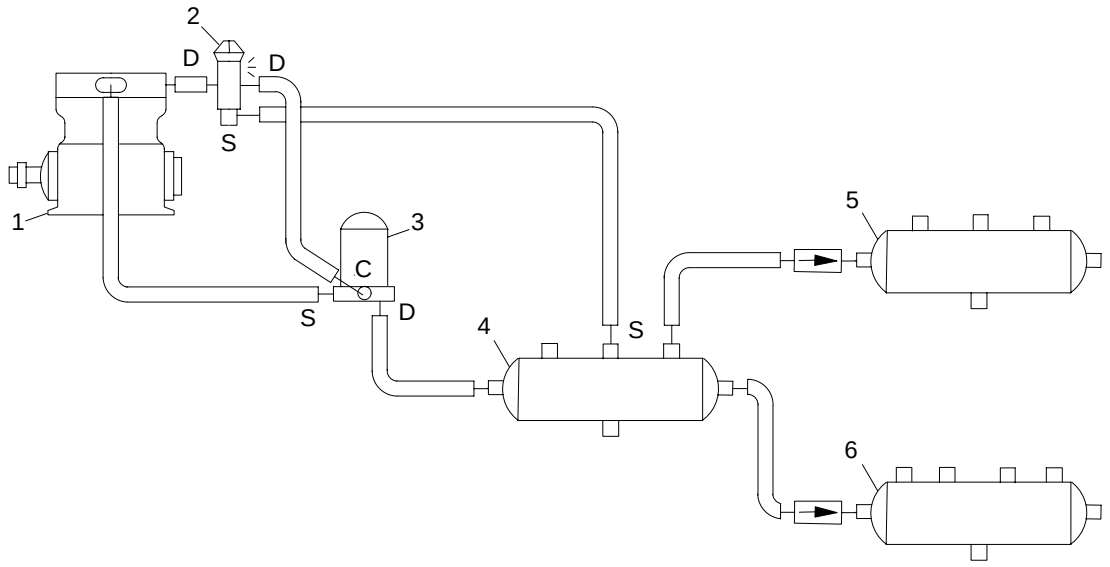
  The standard air dryer uses a metal seat turbo cutoff valve. The function of the metal seat is to prevent turbocharger boost pressure loss through the air dryer during the purge (compressor unloaded) mode. Some low level turbo air leakage can occur in the unloaded mode.

- Discharge Line Unloader Style. See **Fig. 3**:

  The discharge line unloader style air dryer is usually used on brake systems that have compressors equipped with a discharge unloader valve, but no integral unloading mechanisms. This air dryer is designed to bypass the turbo cutoff mechanism on the dryer, allowing air from the compressor to be vented out the bottom of the air dryer when the brake system is in a non-charging mode. An air governor is used on this system and replaces the discharge line unloader valve normally installed in the compressor's discharge line. This type of air dryer can be identified by the "U" stamped on the side of the purge valve housing.

- Soft Seat Air Dryer. See **Fig. 4**:

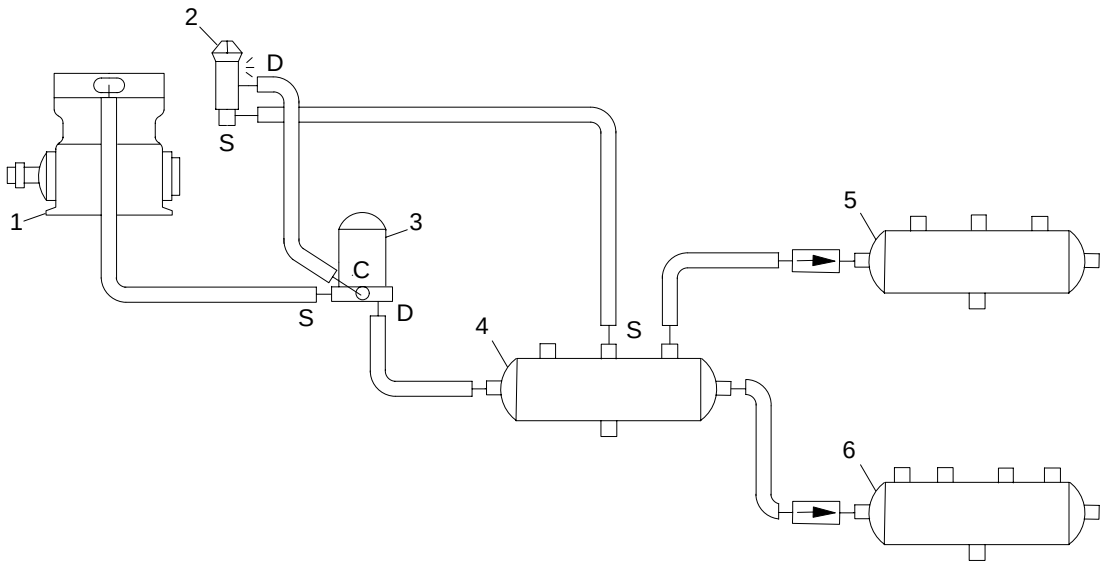
  The soft seat style air dryer is usually used on vehicles equipped with Holset "E" and "QE"



C. Control
D. Delivery
S. Supply

1. Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply
5. Primary
6. Secondary

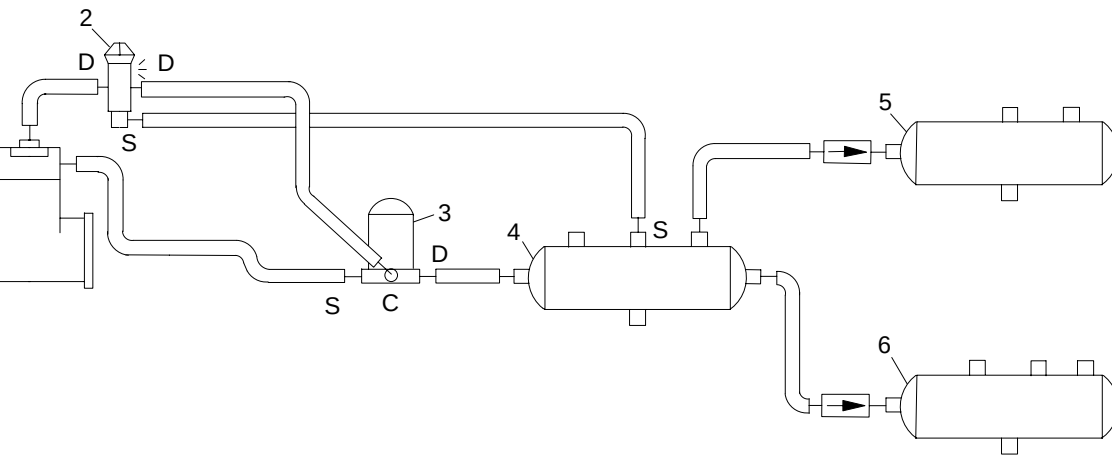
Fig. 2, Standard Air Dryer Plumbing Diagram



C. Control
D. Delivery
S. Supply

1. Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply
5. Primary
6. Secondary

Fig. 3, Discharge Line Unloader Style Air Dryer Plumbing Diagram



C. Control
D. Delivery
S. Supply

1. Holset E or QE Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply
5. Primary
6. Secondary

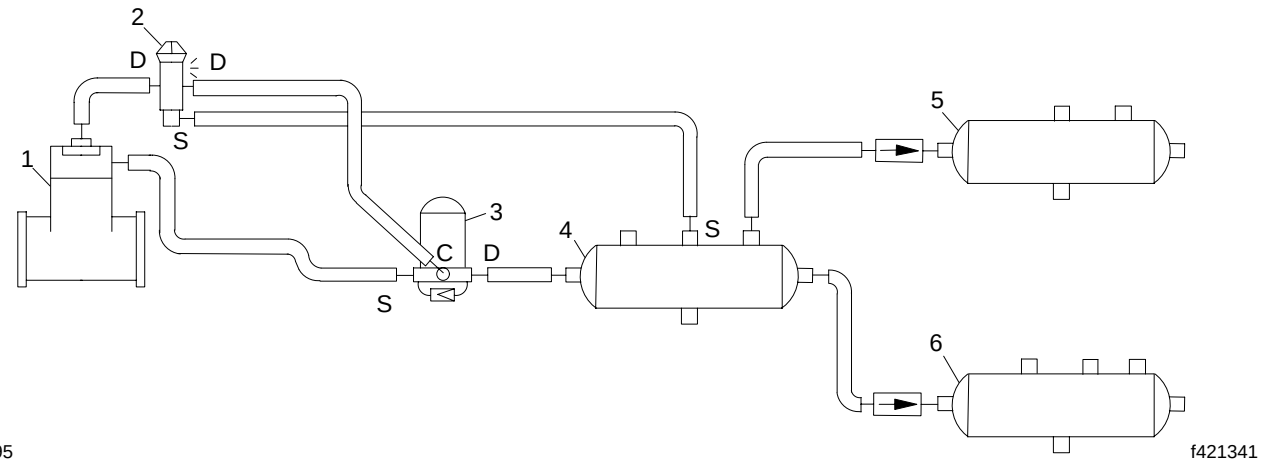
Fig. 4, Soft Seat Air Dryer Plumbing Diagram

General Description and Principles of Operation

type air compressors. This air dryer eliminates the need for the Holset ECON valve (which is plumbed in the compressor discharge line). However, external plumbing of the make-up line and make-up line check valve is still required.

- Drop-In Air Dryer. See **Fig. 5**:

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, causing contaminants to condense and drop to the bottom or sump of the air dryer end cover. See **Fig. 6**.



C. Control
D. Delivery
S. Supply

1. Holset E or QE Air Compressor
2. D–2 Governor
3. Air Dryer
4. Supply
5. Primary
6. Secondary

Fig. 5, Drop-In Style Air Dryer Plumbing Diagram

The drop-in style air dryer *can only be used* on vehicles equipped with Holset "E" and "QE" type air compressors. This air dryer eliminates any external plumbing requirements (such as the ECON valve, make-up line, and make-up line check valve). All of these components are an integral part of the air dryer.

Principles of Operation

The AD–9 air dryer alternates between two operational modes or cycles during operation: the charge cycle and the purge cycle.

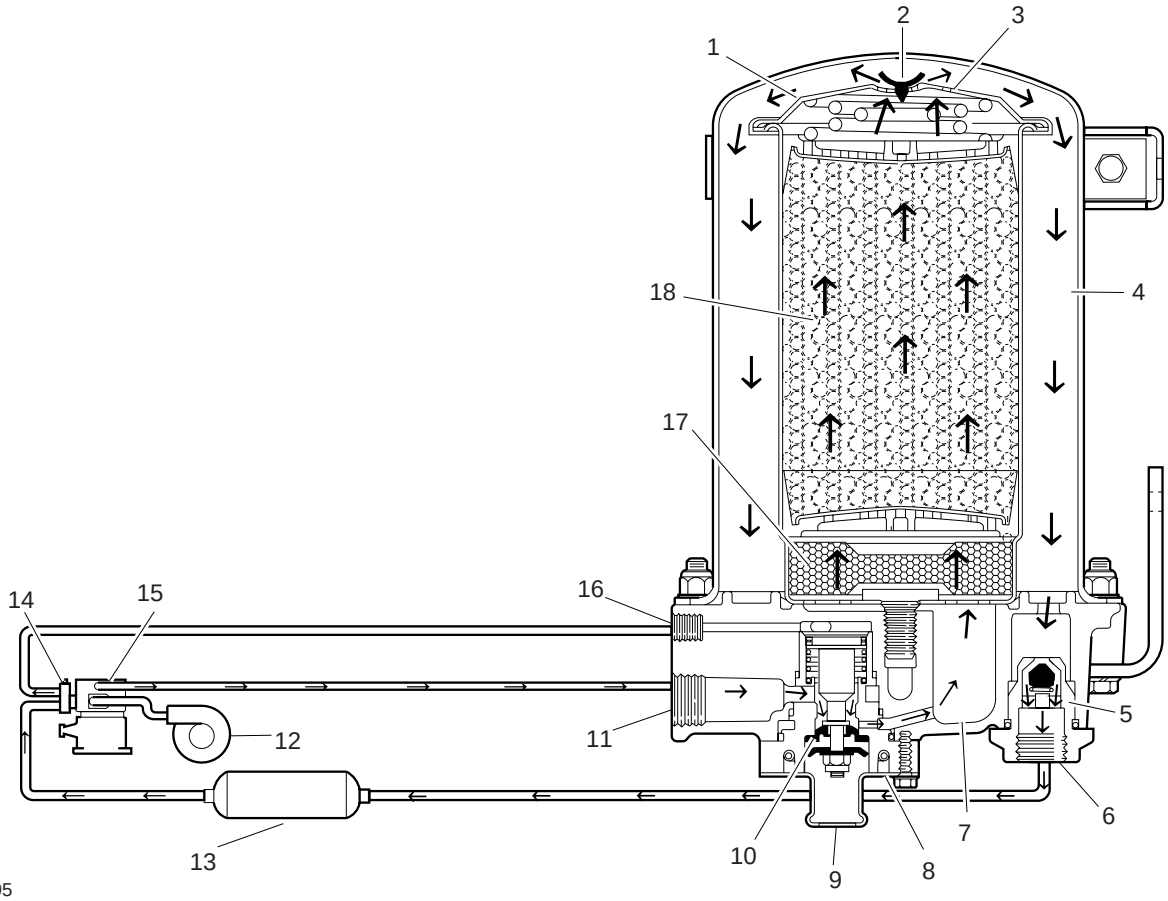
Charge Cycle

When the compressor is loaded (compressing air), pressurized air, along with oil, oil vapor, water, and water vapor flow through the compressor discharge

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.



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. 6, AD–9 Charge Cycle

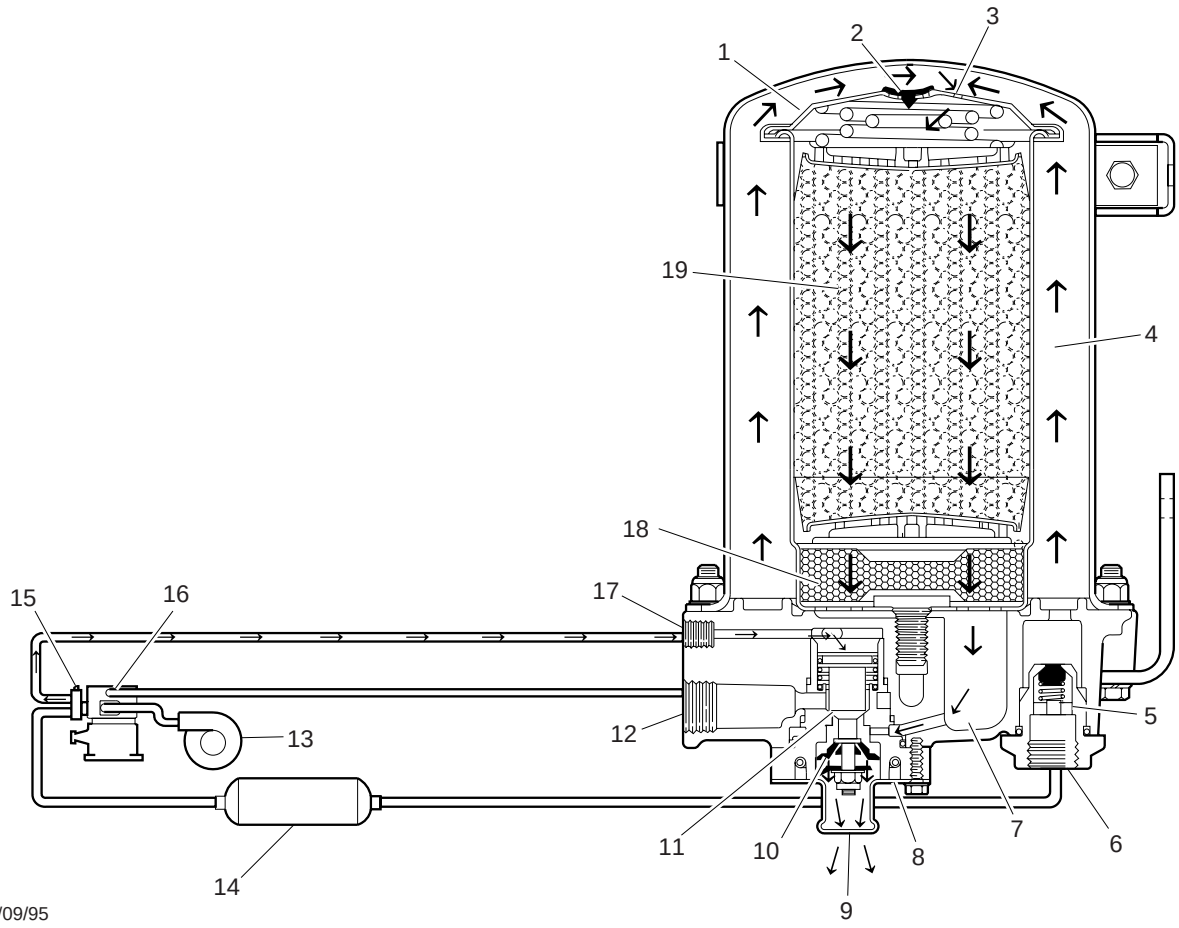
Dry air flows out of the purge volume through the single check valve assembly and out the delivery port to the first (supply) reservoir of the air system.

The air dryer remains in the charge cycle until air brake system pressure builds to the governor cutout setting.

Purge Cycle

When the brake system pressure reaches the governor cutout setting, the compressor unloads (air compression stopped), and the purge cycle of the air dryer begins. When the governor unloads the compressor, it pressurizes the unloader mechanism and line connecting the governor unloader port to the AD–9 end cover control port. The purge piston moves in response to air pressure causing the purge

General Description and Principles of Operation



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. 7, AD–9 Purge Cycle

valve to open to atmosphere and partially close off the supply of air from the compressor. See **Fig. 7**. This is further discussed under "Turbo Cutoff Feature."

Contaminants in the end cover sump are expelled immediately when the purge valve opens. Also, air that was flowing through the desiccant cartridge changes direction and begins to flow toward the open purge valve. Oil and solid contaminants collected by the oil separator are removed by air flowing from the desiccant drying bed to the open purge valve.

The initial purge and desiccant cartridge decompression last only a few seconds and are signaled by an

audible burst of air at the AD–9 exhaust. The actual reactivation of the desiccant drying bed begins as dry air flows from the purge volume through the 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.

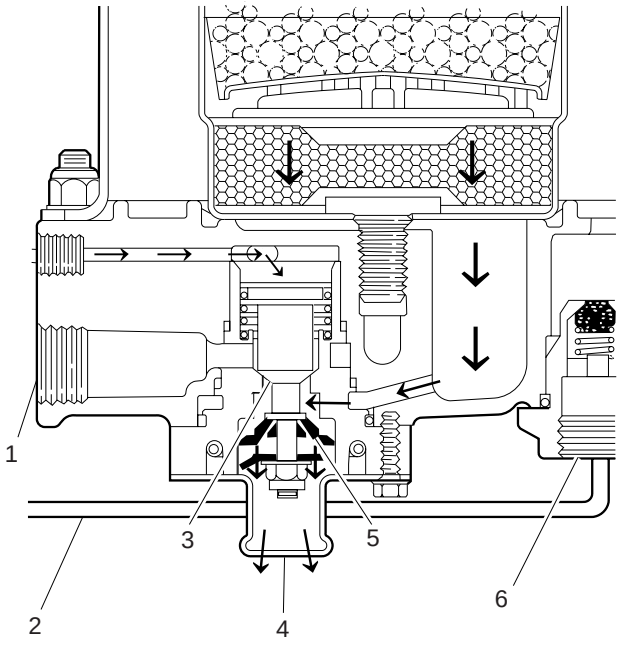
The purge valve will remain open after the purge cycle is complete, and will not close until air brake system pressure is reduced and the governor signals the compressor to charge.

NOTE: The air dryer should be periodically checked for operation and tested for leaks. Refer to the brake section in the 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. 8**.

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.



1. Supply Port
2. Discharge Line
3. Turbocharger Cutoff Piston
4. Exhaust
5. Purge Valve
6. Check Valve Assembly

Fig. 8, AD–9 Turbo Cutoff

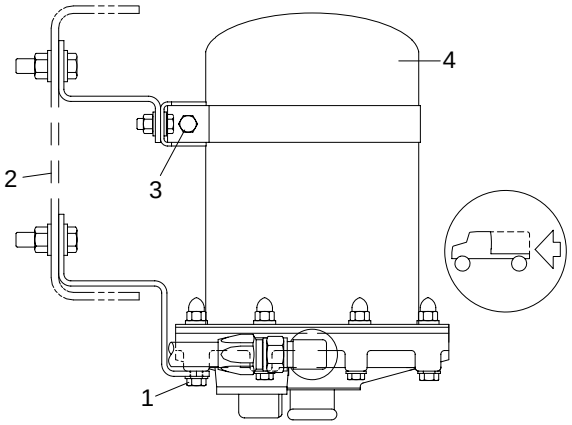
Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the tires and stop 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



1. End Cover Fastener
2. Left Frame Rail
3. Upper Bracket Strap Capscrew
4. Air Dryer

Fig. 1, Air Dryer Mounting

⚠ WARNING

WARNING: Before working on or around air brake systems and components, read the safety precautions in Subject 100. Failure to do so could result in personal injury.

1. Park the vehicle on a level surface and chock the tires.
2. Completely drain all of the reservoirs.
3. Remove the air dryer. See **Fig. 1**.
   - 3.1 Mark and disconnect the three air lines from the end cover, and note the position of end cover ports relative to the vehicle.
   - 3.2 Unplug the vehicle wiring harness from the heater and thermostat assembly connector on the exhaust cover.
   - 3.3 Loosen the capscrew securing the upper bracket strap.
   - 3.4 Remove, save, and mark the two end cover capscrews, locknuts, and four special washers that retain the lower mounting bracket to the end cover. Also mark the two holes of the end cover (these receive the two longest capscrews.)
   - 3.5 Remove the air dryer from its mounting brackets.

Installation

⚠ WARNING

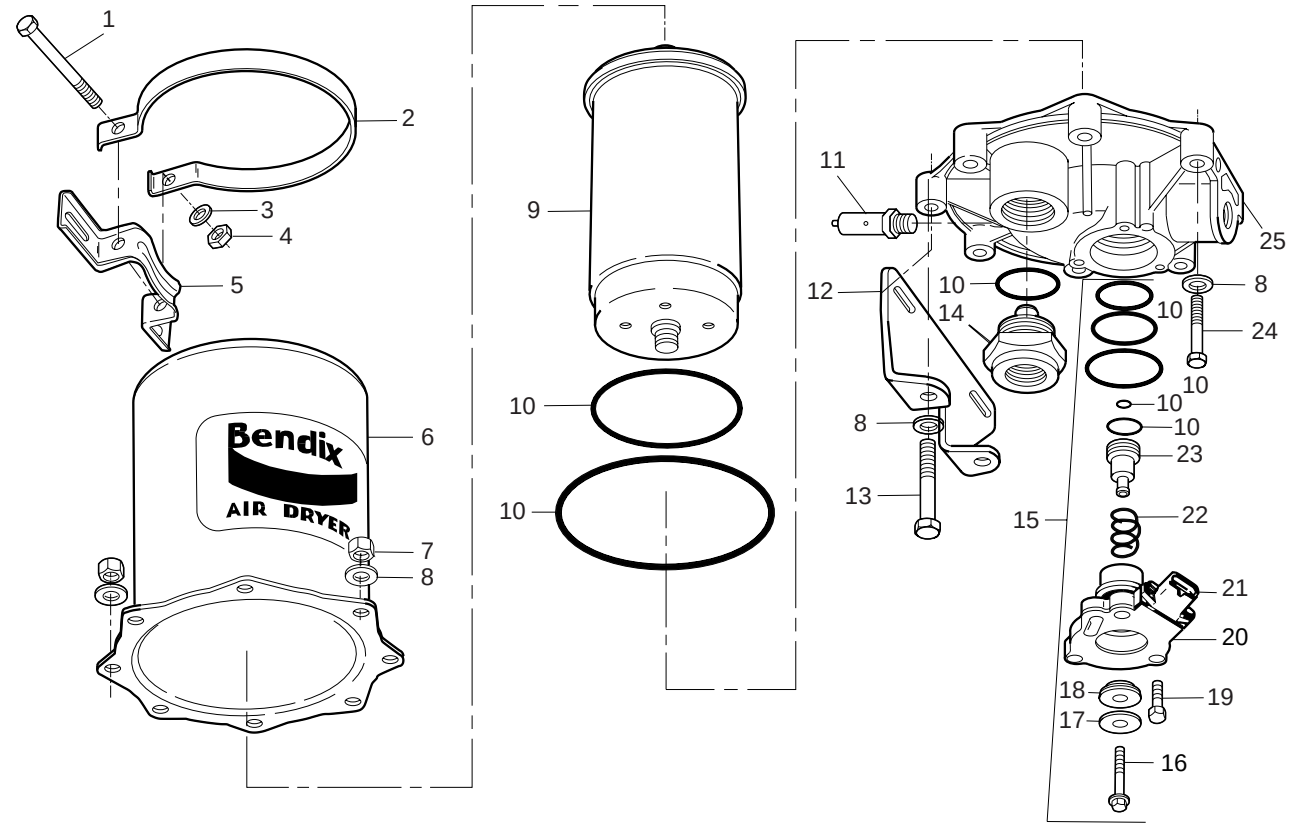
WARNING: Before working on or around air brake systems and components, read the safety precautions in Subject 100. Failure to do so could result in personal injury.

1. Install the assembled air dryer on the vehicle. See **Fig. 1**.
   - 1.1 Position the air dryer up 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.
   - 1.2 Using the two longest capscrews, four special washers, and two locknuts, secure the air dryer to the lower bracket. Tighten the two remaining capscrews 270 to 385 lbf·in (3060 to 4340 N·cm).
   - 1.3 Tighten the capscrew and nut on the upper mounting bracket strap 80 to 120 lbf·in (900 to 1360 N·cm).
   - 1.4 As marked earlier in "Removal," connect the three air lines to the ports on the end cover.
   - 1.5 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.
2. Test the air dryer following instructions in the brake section in the chassis maintenance manual.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

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



08/09/95 f421383

1. 5/16-Inch x 4-1/2 Inch Upper Bracket Capscrew
2. Upper Bracket Strap
3. 5/16-Inch Lockwasher
4. 5/16-Inch Locknut
5. Upper Mounting Bracket
6. Housing
7. Locknut
8. 3/8-Inch Special Washer
9. Desiccant Cartridge
10. O-Ring
11. Safety Valve
12. Lower Mounting Bracket
13. 3/8-Inch Capscrew (Long)
14. Check Valve Assembly
15. Purge Valve Assembly
16. Purge Valve 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

WARNING

WARNING: Before working on or around air brake systems and components, read the safety precautions in Subject 100. Failure to do so could result in personal injury.

CAUTION

CAUTION: While servicing the air dryer, don't 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 Fig. 1. Refer to Subject 110.
2. Remove the check valve assembly and O-ring. Remove the O-ring from the check valve assembly.
3. Remove the purge valve housing assembly.
   - 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.
   - 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.
   - 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 capscrews (Ref. 24), locknuts (Ref. 7), and twelve special washers (Ref. 8) that secure the end cover to the housing (Ref. 6). Separate the end cover and desiccant cartridge (Ref. 9) from the housing (Ref. 6).
7. Remove the end-cover-to-outer-housing O-ring.
8. Don't remove the safety valve (Ref. 11) from the end cover unless it is known to be inoperative. If replacement is needed, apply thread sealant or Teflon® tape on the threads of the replacement valve and tighten 120 to 400 lbf·in (1360 to 4520 N·m). Make sure the drain hole (slot) is facing down.
9. Place a strap or chain wrench around the desiccant cartridge (Ref. 9) so that it is about 2 to 3 inches (5 to 8 cm) away from the end cover. Rotate the cartridge counterclockwise until it completely separates from the end cover.

NOTE: Torque of up to 50 lbf·ft (68 N·m) may be needed to do this disassembly.

10. Remove the desiccant cartridge O-ring from the end cover.

Cleaning and Inspection

WARNING

WARNING: Before working on or around air brake systems and components, read the safety precautions in Subject 100. Failure to do so could 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

WARNING: Before working on or around air brake systems and components, read the safety precautions in Subject 100. Failure to do so could 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.
   - 2.1 Insert the heater element into the slot in the purge valve housing until the connector contacts the housing.
   - 2.2 Gently push the connector and the thermostat to the left until the thermostat clears the cavity in the housing. Then, turn the connector to the right while pushing the thermostat all the way down into the cavity.

     Make sure that the connector is seated evenly against the housing.
   - 2.3 Install the two mounting screws. Tighten the screws 10 to 20 lbf·in (113 to 226 N·cm).
3. Assemble the purge-valve housing.
   - 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. 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.

Air Dryer Disassembly, Cleaning and Inspection, and Assembly

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.

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 capscrews, locknuts, and the twelve special washers, making sure they are positioned as referenced earlier. The two longer capscrews will be used to secure the air dryer to its mounting bracket.

6.3 Tighten the six capscrews and nuts in a star pattern (depending on lower bracket location) 270 to 385 lbf·in (3060 to 4340 N·cm). See **Fig. 2**.

NOTE: The two remaining bolt holes in the end cover and two 3/8-inch capscrews must be the ones marked during removal to ensure correct orientation of the ports and adequate length of the capscrews.

7. Connect the electrical connector to the heater and thermostat assembly.

8. Test the air dryer for proper operation. For instructions, refer to **Subject 130**.

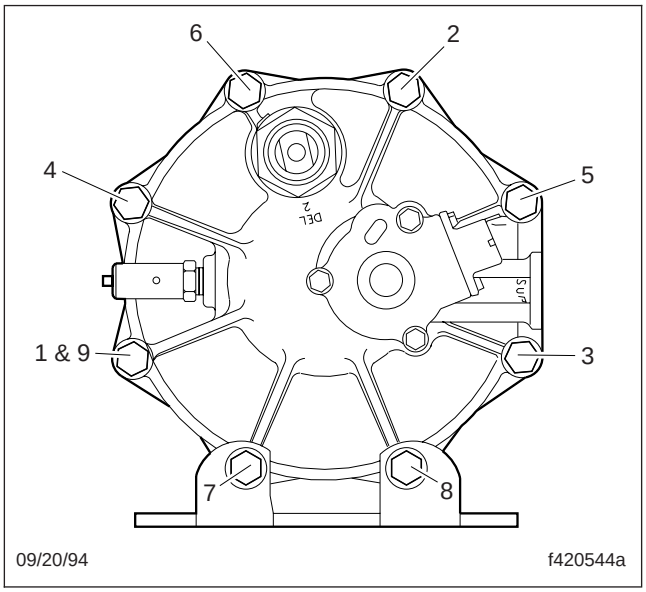


Fig. 2, End Cover to Housing Torque Pattern

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.

NOTE: Some early models of the AD–9 will have resistance readings of 1.0 to 2.5 ohms for the 12-volt heater assembly, and 4.8 to 7.2 ohms for the 24-volt heater assembly. If the resistance is higher than this, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

3. Warm the end cover assembly to over 90°F (32°C) and again check the resistance. It should exceed 1000 ohms. If it does, the thermostat and heater assembly is operating properly. If it doesn't, replace the purge-valve housing assembly, which includes the heater and thermostat assembly.

Problem—Air Dryer Is Constantly Cycling or Purging

Problem—Air Dryer Is Constantly Cycling or Purging	
Possible Cause	**Remedy**
Excessive system leakage.	Test for excessive leakage. Eliminate leaks, as needed. Allowable leakage is as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
There is excessive leakage in the fittings, hoses, and tubing connected to the compressor, air dryer, and wet tank.	Using a soap solution, test for leakage at the fittings, drain valve, and safety valve in the wet tank. Repair or replace as needed.
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.
Holset "E" type compressor.	Test the air dryer system. For instructions, refer to Bendix Product Bulletin PRO–08–19 entitled "Troubleshooting the Holset "E" Compressor System with Bendix Air Dryer."
Lack of air at the governor RES port (rapid cycling of the governor).	Test the governor for proper pressure at the RES port. Pressure should not drop below cut-in pressure when the compressor begins the unloaded cycle. If the pressure does drop, check for kinks or restrictions in the line connected to the RES port. The line connected to the RES port on the governor must be the same diameter, or larger than the lines connected to the UNL ports on the governor.

Problem—Water in the Vehicle Reservoirs

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
Desiccant cartridge assembly contains excessive contaminants.	Replace the desiccant cartridge.
Discharge line is of improper length or material.	Discharge line must consist of at least 6 ft. (1.8m) 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.

Troubleshooting

Problem—Water in the Vehicle Reservoirs	
Possible Cause	**Remedy**
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.
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.

Problem—Constant Exhaust of Air at the Air Dryer Purge Valve Exhaust; Unable to Build System Pressure	
Possible Cause	**Remedy**
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 as follows: • Single Vehicle—1 psi/min (7 kPa/min) per service reservoir • Tractor/Trailer—3 psi/min (21 kPa/min) per service reservoir
Purge valve stays open; supply air leaks to control side.	Replace the purge valve assembly O-rings.

Problem—Air Dryer Does Not Purge or Exhaust Air

Problem—Air Dryer Does Not Purge or Exhaust Air	
Possible Cause	**Remedy**
Purge control line is broken, kinked, frozen, plugged, or disconnected.	See if air flows through the purge control line when the compressor is unloaded. The purge control line must be connected to the unloader port of the governor.
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.

Troubleshooting

Problem—Desiccant Is Being Expelled from the Air Dryer Purge Valve Exhaust (May Look Like Whitish Liquid, Paste, or Small Beads); or, Unsatisfactory Desiccant Life

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, following instructions 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.

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.

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.
- Air lines 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.

WARNING

Make sure the air system has been reduced to 0 psi before attempting to remove an air line. Do not disconnect pressurized air lines as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Replacement

CAUTION

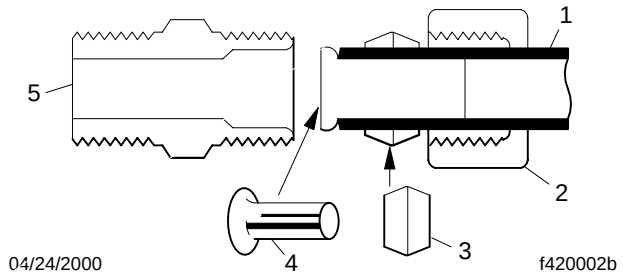
Before working on or around air brake systems and components, see Safety Precautions 100.

CAUTION

If the air line is bent to a radius smaller than the specified minimum bend radius, it may kink and shut off normal airflow to the component.

NOTE: When installing a nylon or a wire braid air line, be careful not to bend it past its minimum bend radius. For minimum bend radius values, see **Specifications 400**.

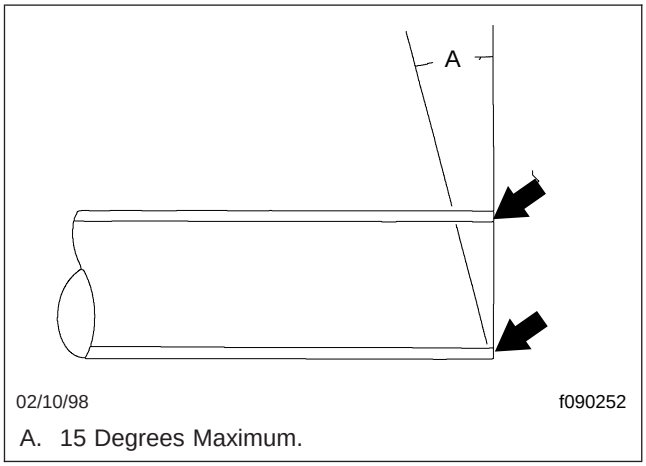
Nylon Air Lines and Compression Fittings



1. Nylon Air Line
2. Nut
3. Sleeve
4. Stainless Steel Insert
5. Body

Fig. 1, Nylon Air Line and Compression Fitting

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line. See **Fig. 1**.
   - 3.1 Loosen the fitting nut.
   - 3.2 Pull the air line out of the fitting.
4. Use pliers to remove the stainless steel insert from the fitting. Discard the insert.
5. Clean all of the fitting components.
6. Place a new stainless steel insert into the fitting body. Use thumb pressure to press it into position.
7. Check the air line end for a square cut-off that does not exceed a 15-degree angle. Check that the air line is not distorted or damaged. See **Fig. 2**.

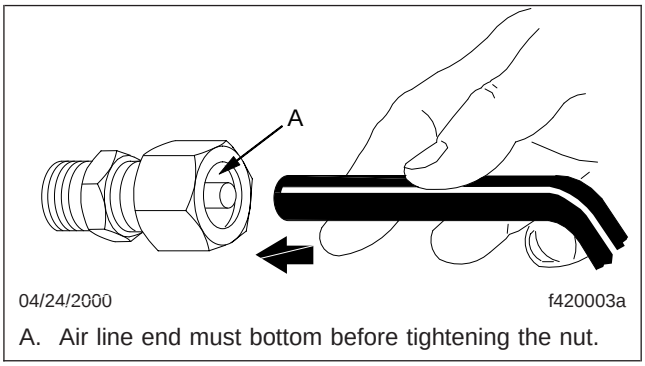


A. 15 Degrees Maximum.

Fig. 2, Check Air Line End Angle

   - 7.1 If the angle exceeds the specification, recut the air line.
   - 7.2 Use a sharp blade to prevent collapsing the air line or leaving burrs.
8. Make sure the nylon air line ends and fittings are free of grease and debris. If the air line is crimped or otherwise damaged, replace it with a new air line.
9. Install a new sleeve in the nut. Start the threads of the nut on the fitting body.
10. Insert the squared end of the air line in the fitting until it bottoms in the body of the fitting. See **Fig. 3**.
11. Tighten the nut until one thread remains visible.

Air Lines Replacement



A. Air line end must bottom before tightening the nut.

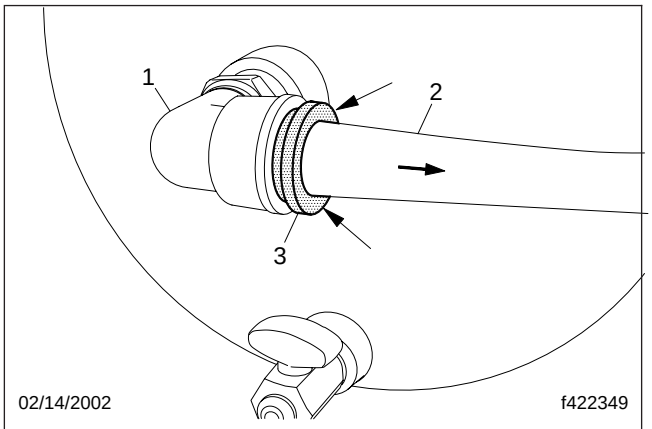
Fig. 3, Installing Nylon Air Line into Compression Fitting

12. Pull back on the air line to make sure it is fully seated.
13. Pressurize the air system. Check the air system for leaks.
14. Remove the chocks from the tires.

Nylon Air Lines and KV2 One-Touch Fittings

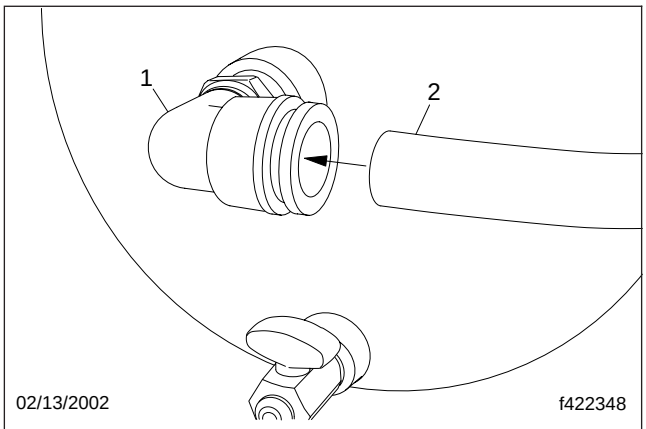
IMPORTANT: The use of a sharp air line cutter is highly recommended. This tool will insure a clean, perpendicular cut of the air line.

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. Push the air line into the fitting.
4. Press and hold the release button against the body of the fitting and remove the air line. See **Fig. 4**.
5. Remove the air line.
6. Clean any dirt or contamination from the leading edge of the air line.
7. Lubricate the leading end of the air line with light oil, petroleum jelly or silicone lubricant.
8. Insert the end of the air line into the fitting until it completely bottoms. See **Fig. 5**.
9. Pull on the air line to verify it is properly retained.
10. Pressurize the air system. Check the air system for leaks.



1. Push-to-Connect Fitting
2. Air Line
3. Release Button

Fig. 4, Push on Release Button and Remove Air Line



1. Push-to-Connect Fitting
2. Air Line

Fig. 5, Insert Air Line

11. Remove the chocks from the tires.

Wire Braid Air Lines

1. Park the vehicle on a level surface and set the parking brake. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line.
   - 3.1 Unthread the swivel fitting nut.
   - 3.2 Remove the air line assembly from the mating fitting.

4. Make sure the wire braid air line assembly is free of grease and dirt. Replace the assembly if the air line or fitting is crimped or otherwise damaged.
5. Install the air line and finger-tighten the nut.
6. Using two wrenches to prevent twisting of the air line, tighten the nut until it seats solidly. Tighten the nut one-sixth turn more.
7. Pressurize the air system. Check the air system for leaks.
8. Remove the chocks from the tires.

Fittings Replacement

WARNING

Make sure the air system has been reduced to 0 psi before attempting to remove an air line. Do not disconnect pressurized air lines as they may whip as air escapes. Failure to take all necessary precautions could result in personal injury.

Replacement

CAUTION

Before working on or around air brake systems and components, see Safety Precautions 100.

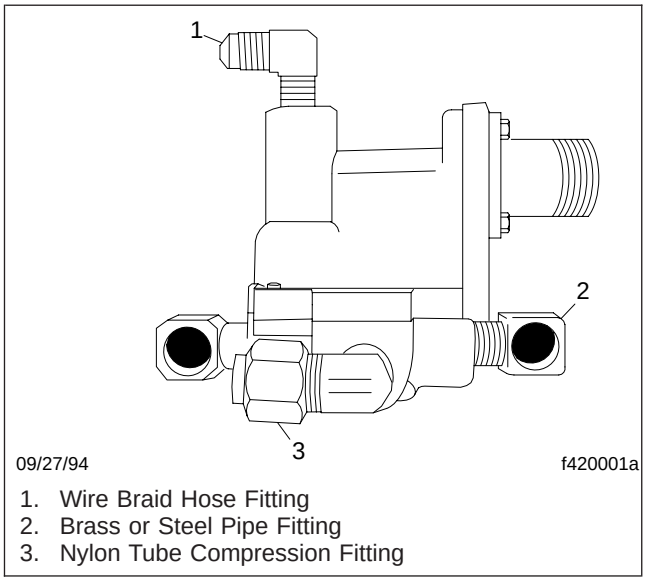
Never use diagonal pliers, a razor knife, saw or dull cutting tool to cut nylon air lines. The use of such tools leaves the air line with a sharp edge, burr or out-of-round condition which can damage the seal when the air line is inserted into the fitting. This reduces the sealing ability of the fitting. The use of a sharp air line cutter is highly recommended. This tool will insure a clean, perpendicular cut of the air line.

Brass or Steel Pipe Fittings

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. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Using an open-end wrench or similar tool, rotate the fitting counterclockwise until it is completely disengaged from the fitting port. See **Fig. 1**.
5. Make sure the fitting is free of grease, dirt, and old sealant. Apply liquid thread sealant (white) to the threads and finger-tighten securely.

NOTE: Always apply the sealant to the external thread, so that any excess will be scraped off externally rather than internally to the joint.

6. Install the fitting:
   - *For a fitting that must be positioned*, tighten one additional turn from finger-tight using a wrench. Continue to tighten the fitting clockwise until it is correctly positioned. Never turn the fitting counterclockwise to position it.
   - *For a fitting that does not require positioning*, tighten 1-1/2 additional turns from finger-tight.
7. Install the air line in the fitting. For instructions, see **Subject 110**.
8. Pressurize the air system. Check the air system for leaks.
9. Remove the chocks from the tires.



1. Wire Braid Hose Fitting
2. Brass or Steel Pipe Fitting
3. Nylon Tube Compression Fitting

Fig. 1, Screw-On Fittings

Brass or Steel Pipe Fittings on Plastic Components

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. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Remove the fitting.
5. Install the fitting. For tightening specifications, see the applicable table in **Specifications, 400**.
6. Install the air line in the fitting. For instructions, see **Subject 110**.

Fittings Replacement

7. Pressurize the air system. Check the air system for leaks.
8. Remove the chocks from the tires.

Copper Fittings

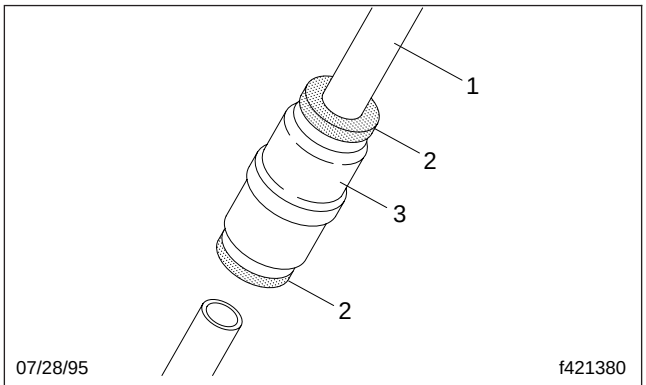
1. Park the vehicle on a level surface and apply the parking brakes. Shut down the engine. Chock the tires.
2. Drain the air system.
3. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Loosen the nut and remove the fitting.
5. Position the fitting.
6. Finger-tighten the nut.
7. Using two wrenches to prevent twisting of the air line, tighten the nut the number of turns shown in the applicable table in **Specifications 400**.
8. Install the air line in the fitting. For instructions, see **Subject 110**.
9. Pressurize the air system. Check the air system for leaks.
10. Remove the chocks from the tires.

Quick-Connect Fittings

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.

NOTE: If damaged, quick-connect fittings must be replaced as an assembly.

3. Push in on the fitting collar to release the air line.
4. Pull the air line out of the fitting. See **Fig. 2**.
5. Push the air line into the fitting.
6. Pull the collar away from the fitting to secure the air line.
7. Check and make sure that the air line is seated in the fitting.
8. Pressurize the air system. Check the air system for leaks.
9. Remove the chocks from the tires.



1. Air Line
2. Collar
3. Fitting

Fig. 2, Nylon Air Line and Quick-Connect Fitting

KV2 One-Touch Fittings

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. Remove the air line from the fitting. For instructions, see **Subject 110**.
4. Using an open-end wrench or similar tool, rotate the fitting's hexstud end counterclockwise until it is hand-loose.
5. Continue to rotate the fitting by hand until it is completely disengaged from the fitting port.
6. Clean any dirt or thread sealant from the fitting and fitting port.
7. If required, apply liquid thread sealant (white) to the threads.
8. Insert the fitting into the port and rotate it clockwise until it is hand-tight.
9. Using an open-end wrench or similar tool, tighten the fitting to the manufacturer's recommended torque. For torque specifications, see the applicable table in **Specifications 400**.
10. Rotate the fitting body by hand to the correct position.
11. Install the air line in the fitting. For instructions, see **Subject 110**.

12. Pressurize the air system. Check the air system for leaks.
13. Remove the chocks from the tires.

Specifications

Nylon Air Lines			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (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 1, Nylon Air Lines

211 Wire Braid (Medium Pressure) Air Lines *			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (mm)
4	3/16	0.52	3.00 (76)
5	1/4	0.58	3.38 (86)
6	5/16	0.67	4.00 (102)
8	13/32	0.77	4.63 (118)
10	1/2	0.92	5.50 (140)
12	5/8	1.08	6.50 (165)
16	7/8	1.23	7.38 (187)
20	1-1/8	1.50	9.00 (229)

* 211 air lines are identified by part number and size (for example, part numbers 211-4, 211-5, and so on).

Table 2, 211 Wire Braid (Medium Pressure) Air Lines

213 Wire Braid Air Lines *			
Number	Inside Diameter Inch	Outside Diameter Inch	Minimum Bend Radius inches (mm)
4	3/16	0.49	0.75 (20)
5	1/4	0.55	1.00 (25)
6	5/16	0.62	1.25 (30)
8	13/32	0.74	1.75 (45)
10	1/2	0.83	2.25 (55)
12	5/8	0.96	2.75 (70)
16	7/8	1.21	3.50 (90)
20	1-1/8	1.49	4.50 (115)

* 213 air lines are identified by two green stripes 180 degrees apart, part numbers, and size (for example, part numbers 213-4, 213-5, and so on).

Table 3, 213 Wire Braid Air Lines

KV2 Stud End Torque into Metallic Ports *		
Thread, NPTF Inch	Torque †	
	lbf·in (N·cm)	lbf·ft (N·m)
1/16	62–80 (700–900)	—
1/8	62–80 (700–900)	—
1/4	106–124 (1200–1400)	—
3/8	—	16–18 (22–24)
1/2	—	21–22 (28–30)

* Aluminum, zinc, steel and brass ports.
† The component in which the KV2 One-Touch fitting is being installed may have torque values lower than those listed here. Please see the component supplier's recommended torque specifications.

Table 4, KV2 Stud End Torque into Metallic Ports

Specifications

Brass or Steel Pipe Fittings on Plastic Components			
Description	Port Size Inch	Torque	
		lbf·in (N·cm)	lbf·ft (N·m)
Midland Quick Release Valve	3/8	60–90 (680–1020) *	—
	1/2	—	13–17 (18–23) *
Bendix MV-2/MV-3 Valve	1/4	—	10 (14)

* Tighten to the lower torque value. If needed, turn the fittings to allow for the proper routing of the air lines.

Table 5, Brass or Steel Pipe Fittings on Plastic Components

Copper Fittings			
Number	Outside Diameter Inch	Additional Turns from Hand-Tight	
		Compression	Threaded Sleeve
2	1/8	1-1/4	1-1/2
3	3/16		
4	1/4		
5	5/16	1-3/4	
6	3/8	2-1/4	
8	1/2		
10	5/8		
12	3/4		
16	1		
20	1-1/4		

Table 6, Copper Fittings

General Information

Air reservoirs serve two main purposes:

- They store compressed air used to apply the brakes and operate other air-powered devices.
- 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.

Primary reservoirs are air sources for the brakes on the rear axles. The primary reservoir is usually mounted above the secondary reservoir on the left-hand frame rail.

A secondary reservoir is the air source for the front axle brakes. It is usually mounted on the left-hand frame rail below the primary reservoir, and, like the primary reservoir, is equipped with an inline 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.

The secondary reservoir also contains a wet tank to collect most of the water and oil condensate from the air. At the outlet port of the secondary reservoir (the port leading to the primary reservoir) is a safety valve, which protects the air system against excessive air pressure build-up.

All air reservoirs are equipped with drain valves to eject the water and oil emulsion from the tanks.

Tests

NOTE: If equipped with an automatic moisture-ejection valve, refer elsewhere in this group for leak testing.

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. Proceed to **Subject 110**.

If leaks occur on the surfaces of the air reservoir, replace the tank; refer to **Subject 120**.

Drain Valve Replacement and Leak Elimination

NOTE: If equipped with an automatic moisture-ejection valve, refer elsewhere in this group for instructions.

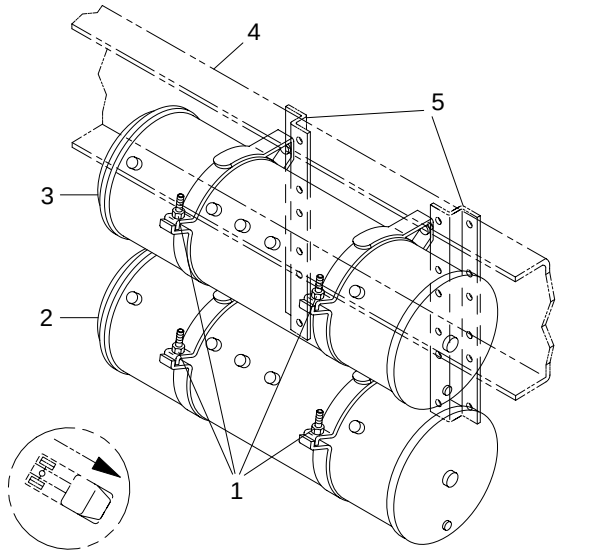
1. Apply the parking brakes, and chock the tires.
2. Drain the air system, using the instructions in the vehicle operator's manual.
3. Using two wrenches (hold the coupler in place with one of them), unscrew the drain valve from the coupler. Clean off the threads inside the coupler on the reservoir, 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 one and one-half additional turns (use two wrenches if installing the drain valve).
5. Perform a leak test after completing the installation. If leaks occur at the joint of the drain valve and coupler, tighten the valve up to one additional turn to stop the leaks.
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 vehicle 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**.



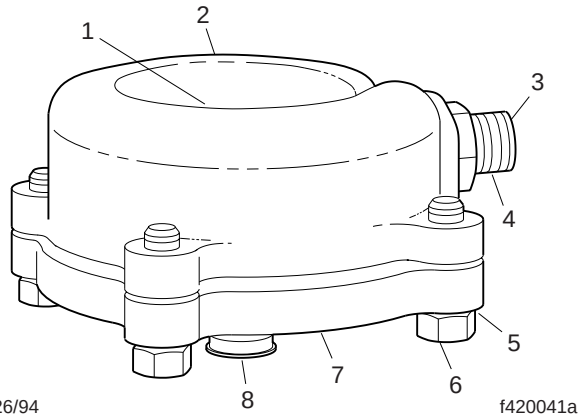
1. Strap Fasteners
2. Secondary Air Reservoir
3. Primary Air Reservoir
4. Left-Hand Frame Rail
5. Mounting Bracket

Fig. 1, Air Reservoir, Frame Rail 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 from the tires.

General Information

The DV–2 automatic reservoir drain valve automatically removes contaminants and water from the wet-air tank each time the brakes are applied. See **Fig. 1**. The drain valve is attached to a drain cock located on the bottom of either end of the wet-air tank. Since the brake application valve is protected by a check valve between the wet-and dry-air tanks, any leak or failure will not reduce the supply of air that is in the dry part of the system. If the leak is severe, it could prevent the continued resupply of air as it is used up when applying the brakes. A failed drain valve will allow moisture to build up in the wet tank which in turn could reach the dry tank, and then travel into the air brake system where it could cause brake failure. A leaking drain valve allows wet tank leakdown which in turn can cause premature wear on the air compressor during vehicle operation as the air compressor continues to run to maintain wet tank air pressure.



1. Top Reservoir Port
2. Valve Body
3. Hexhead Nipple
4. Side Reservoir Port
5. Lockwasher (4 qty.)
6. Capscrew (4 qty.)
7. Valve Cover
8. Exhaust Port

Fig. 1, DV-2 Valve

Principles of Operation

With no pressure in the system, the drain valve's inlet and exhaust valves are closed. See **Fig. 2**. Upon charging the system, a slight pressure opens the inlet valve which permits air and contaminants to collect in the sump. See **Fig. 3**. The inlet valve remains open when pressure is rising in the system until the air compressor cuts off, allowing the spring action of the valve guide in the sump cavity to close the inlet valve. The inlet valve and the exhaust valve are now both closed. See **Fig. 4**. When the wet tank pressure drops approximately 2 psi (14 kPa), the air pressure in the sump cavity opens the exhaust valve and allows moisture and contaminants to be ejected from the sump cavity until pressure in the sump cavity drops sufficiently to close the exhaust valve. See **Fig. 5**.

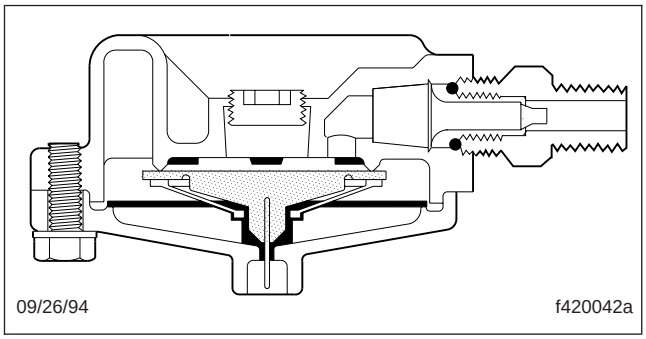


Fig. 2, No System Pressure

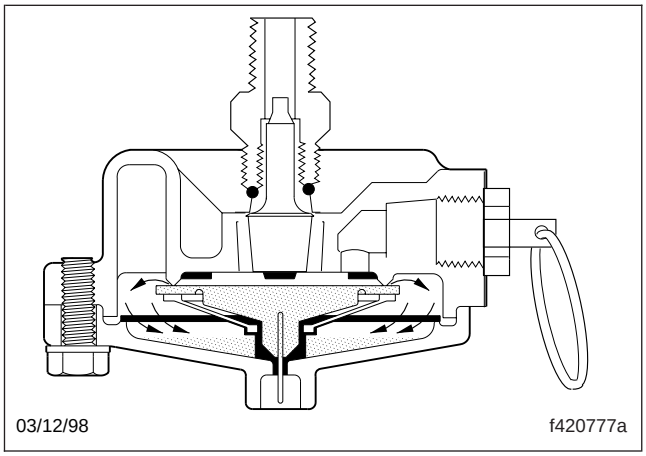


Fig. 3, Start of System Pressure Charging

The length of time the exhaust valve remains open and the amount of moisture and contaminants ejected depends upon the sump pressure and the wet tank pressure drop that occurs each time air is used from the system.

General Information and Principles of Operation

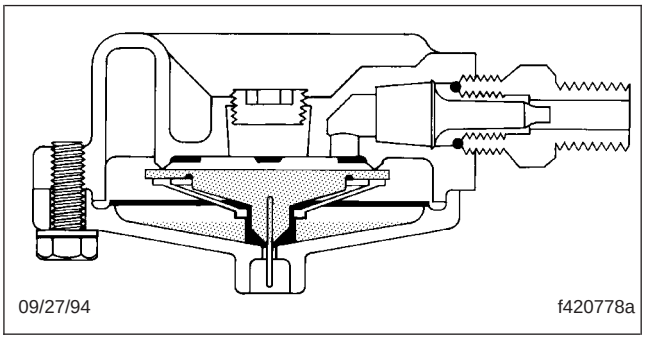


Fig. 4, System Pressure Rising

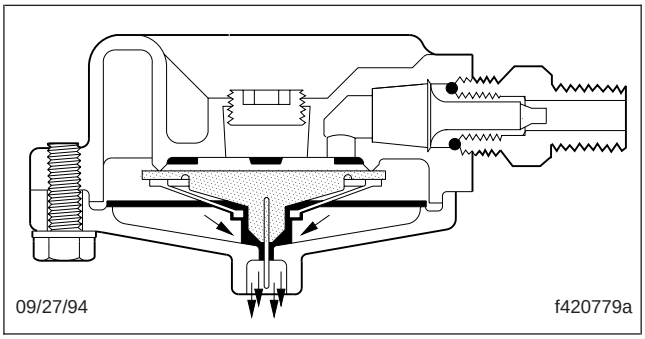


Fig. 5, Exhaust Cycle

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

1. Always chock the vehicle's wheels and stop the engine when working under a vehicle. Depleting vehicle air system pressure may cause the vehicle to roll. Keep hands away from brake chamber push rods and slack adjusters; they may apply as air system pressure drops.
2. Never connect or disconnect a hose or line containing air pressure. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been depleted.
3. Never exceed recommended air pressure and always wear safety glasses when working with air pressure. Never look into air jets or direct them at anyone.
4. Never attempt to disassemble a component until you have read and understood the recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

Operating Test

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100.**

Perform the following test after repairing or replacing the DV–2 valve to ensure that the valve is functioning properly.

With the system charged, apply the brakes several times. Each time the brakes are applied, an exhaust of air should occur from the exhaust port of the drain valve. If no air comes out, push the wire stem located inside the exhaust port. If no air comes out after pushing the wire stem, there may be a plugged filter in the adapter which should be replaced.

If the drain valve does not function properly, repair or replace it following instructions in this section.

Leakage Test

Perform the following test after repairing or replacing the DV–2 valve to ensure that the valve is functioning properly.

With the system charged and pressure stabilized in the system, there should be no leaks at the drain valve exhaust port. A constant slight exhaust of air at the drain valve exhaust port could be caused by excessive leakage in the air brake system.

If the drain valve is leaking excessively, repair or replace it following instructions in this section.

Removal

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Chock the tires, and drain the air system.
2. Remove the drain valve assembly from the end of the wet tank air reservoir.

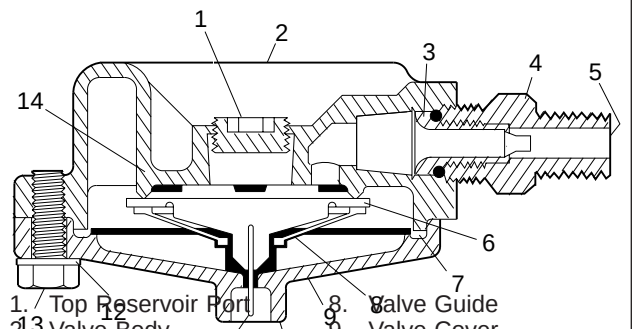
Installation

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

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. Close the drain cocks to the wet and dry air reservoirs. Start the vehicle engine to pressurize the air system.
4. Leak test the drain valve following the instructions in **Subject 110**.

Drain Valve Disassembly, Cleaning and Inspection, and Assembly

Disassembly



1. Top Reservoir Port
2. Valve Body
3. Filter Retainer
4. Hexhead Nipple
5. Side Reservoir Port
6. Inlet and Exhaust Valve
7. Valve Sealing Ring
8. Valve Guide
9. Valve Cover
10. Exhaust Port
11. Wire Stem
12. Lockwasher (4 qty.)
13. Capscrew (4 qty.)
14. Inlet Valve Seat

Fig. 1, DV-2 Valve, Cutaway View

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

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. See **Fig. 1**.
3. Remove the valve cover and sealing ring.
4. Remove the valve guide), and the inlet and exhaust valve from the valve body.
5. Remove the hexhead nipple from the valve body.

Cleaning and Inspection

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

⚠ WARNING

WARNING: Use eye protection when using compressed air to clean or dry parts, as permanent harm to eyes could result from flying debris.

1. Wash all metal parts of the drain valve in an approved cleaning solvent. Dry the metal parts of the disassembled moisture ejection valve with compressed air.
2. Wipe all rubber parts clean with a clean cloth. Examine all rubber parts for wear cracks, tears, or other deterioration. If any rubber parts are worn, cracked, torn or otherwise deteriorated, replace them with new parts.
3. Examine all metal parts for wear, cracks, or other damage. If any metal parts are worn, cracked, or otherwise damaged, replace them with new parts.
4. Clean and examine the filter. If it will not clean completely, or is torn or damaged, replace it with a new filter.

⚠ CAUTION

CAUTION: Do not reassemble the drain valve with a dirty filter; to do so could result in failure of the drain valve in service.

Assembly

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

Before assembling the drain valve, apply a light film of grease on the inlet valve seat.

⚠ CAUTION

CAUTION: Do not apply oil to the inlet and exhaust valve.

1. Install the valve sealing ring into its groove in the valve cover. See **Fig. 1**.
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).

Drain Valve Disassembly, Cleaning and Inspection, and Assembly

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

Description	Torque lbf·in (N·cm)
Valve Cover Capscrews	72–96 (820–1080)
Hexhead Nipple (to valve body)	48–72 (540–820)

Table 1, Torque Values

General Description

The Rockwell automatic slack adjuster has two main functions:

- As a lever, it converts the straight-line force of the brake chamber push rod to torque on the brake camshaft. Rotation of the camshaft forces the brake shoes against the brake drum.
- As an automatic adjuster, it automatically maintains brake chamber push rod stroke, which controls lining-to-drum clearance during operation.

With an automatic slack adjuster, brakes adjust automatically when needed. As long as the push-rod stroke doesn't exceed the desired length, no adjustment takes place. Adjustment is made on the return stroke, as air is released and the forces in the gearset are low. The force to make an adjustment comes directly from the brake shoe return spring and the brake chamber return spring.

Principles of Operation

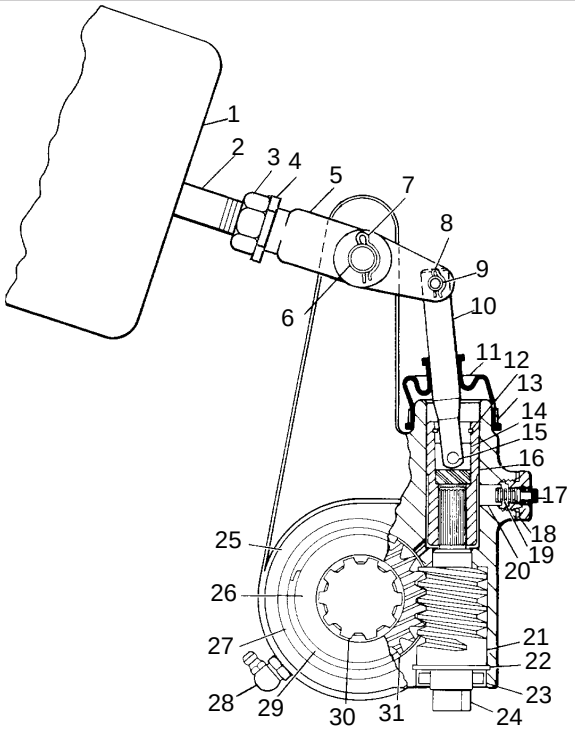
The externally splined end of the worm fits the internal splines on the actuator . See **Fig. 1**. Angled serrations on the spring-held pawl correspond with serrations on the actuator exterior. The serrations are formed to allow free upward movement of the actuator, and to lock in on the actuator serrations on a downward movement. As the brake is applied, the brake chamber push rod, connected to the end of the clevis, moves outward, forcing the slack adjuster arm to turn on the brake camshaft centerline. The actuator rod is connected to the clevis at one end, and to a small piston at the other end.

NOTE: The slack adjuster may be equipped with a quick-connect clevis, or a one-piece clevis. See **Fig.2**.

As the slack adjuster arm moves, the actuator rod is moved upward and outward, pulling the piston upward.

When lining wear becomes excessive, the brake chamber push-rod stroke goes beyond the desired length. The piston then makes contact with the retaining ring and pulls up the actuator. As the actuator moves upward and reaches a preset distance, it slides over one serration on the pawl. When the push rod moves back toward the brake chamber, the actuator is forced downward. Because the serrations in the pawl and actuator are now locked in, the actuator, following the curve of its serrations as it moves downward, turns slightly. This action causes the worm to turn, advancing the gear and the camshaft to automatically adjust the brake.

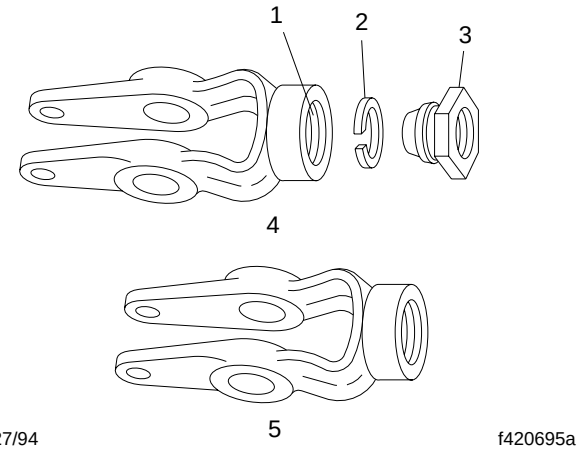
General Description and Principles of Operation



05/22/95 f420176c

1. Brake Air Chamber
2. Brake Chamber Push Rod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Cotter Pin (large)
8. Cotter Pin (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 Screw)
17. Pressure Relief Capscrew (shown 90 degrees out of position)
18. Gasket
19. Pawl Spring
20. Pawl Assembly
21. Worm
22. Worm Retaining Snap Ring
23. Worm Seal
24. Manual (Worm) Adjusting Nut End
25. Slack Adjuster
26. Gear
27. Gear Thrustwasher
28. Grease Fitting (if equipped)
29. Gear Retaining Ring
30. Camshaft Splines
31. Gear-to-Body Seal

Fig. 1, Rockwell Slack Adjuster



1. Retaining Ring Groove
2. Retaining Ring
3. Collar
4. Quick-Connect Clevis
5. One-Piece Clevis

Fig. 2, Clevis Options

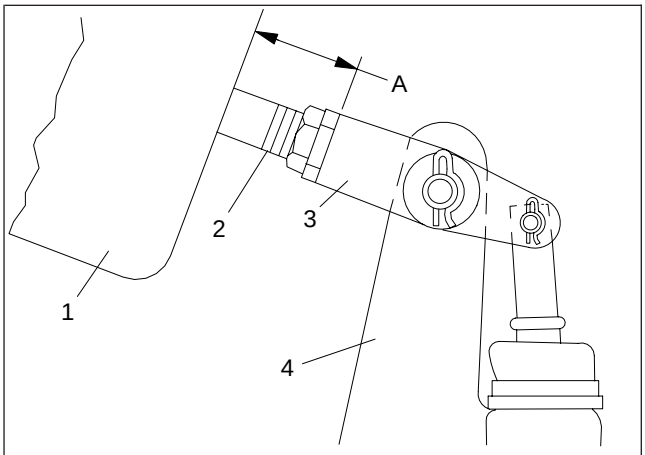
Removal

1. Park the vehicle on a level surface, and chock the tires. If the rear slack adjusters will be removed, release the parking brakes, then cage the power spring of the parking brake chamber.

⚠ WARNING

WARNING: Possible loss of brake chamber air pressure will cause sudden application of the parking brakes, which could result in personal injury. Manually cage each parking brake chamber power spring in the release (no application) position before continuing.

2. Mark or measure the position of the clevis on the brake chamber push rod. See **Fig. 1**.



A. Mark or measure this distance.
1. Brake Chamber
2. Brake Chamber Push Rod
3. Clevis
4. Slack Adjuster

Fig. 1, Mark or Measure the Position of the Clevis

3. Remove the cotter pins from the clevis pins. Remove the clevis pins.
4. Remove the pressure relief capscrew, spring, and pawl assembly from the slack adjuster housing. See **Fig. 2**, Refs. 17, 19, and 20. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

⚠ CAUTION

CAUTION: Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pawl assembly. If equipped with a pull-pawl assembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

5. Using a wrench, turn the manual adjusting nut, and move the slack adjuster away from the clevis. See **Fig. 4**.
6. Remove the snap ring and washers that attach the slack adjuster to the brake camshaft and 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, and then remove them. Save them for later installation.
9. If replacing the clevis, loosen the clevis jam nut. Remove the clevis and jam nut from the brake chamber push rod.

Installation

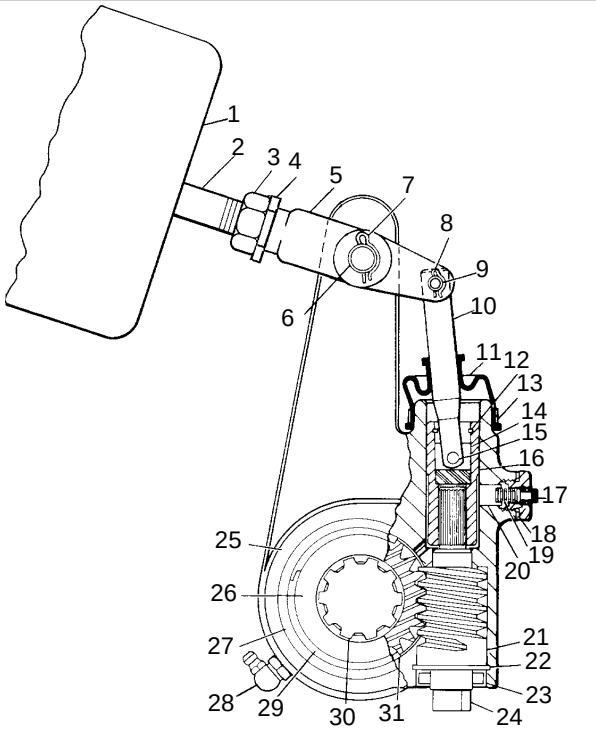
1. Inspect parts, and then prepare the slack adjuster for installation.
   - 1.1 Check the brake camshaft splines for wear or corrosion.
   - 1.2 Coat the camshaft splines and the splines of the slack adjuster gear with Rockwell lubricant 0–637, Southwest SA 8249496, or an equivalent.

   IMPORTANT: These lubricants provide corrosion protection. Do not mix these lubricants with other types.

   - 1.3 Apply the service brake and parking brake several times. Make sure the return spring retracts the push rod quickly and completely. Replace the return spring or brake chamber if needed.
2. If previously removed, install the clevis and jam nut.

   Check that the clevis is in the same position on the brake chamber push rod as marked or mea-

Slack Adjuster Removal and Installation



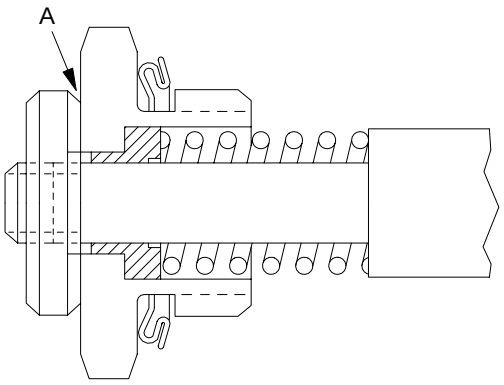
1. Brake Air Chamber
2. Brake Chamber Push Rod
3. Clevis Jam Nut
4. Quick-Connect Collar (if equipped)
5. Clevis
6. Clevis Pin (large)
7. Cotter Pin (large)
8. Cotter Pin (small)
9. Clevis Pin (small)
10. Actuator Rod
11. Boot
12. Piston Retaining Ring
13. Boot Retaining Clamp
14. Actuator Piston
15. Roller (Pin)
16. Actuator (Adjusting Screw)
17. Pressure Relief Capscrew (shown 90 degrees out of position)
18. Gasket
19. Pawl Spring
20. Pawl Assembly
21. Worm
22. Worm Retaining Snap Ring
23. Worm Seal
24. Manual (Worm) Adjusting Nut End
25. Slack Adjuster
26. Gear
27. Gear Thrustwasher
28. Grease Fitting (if equipped)
29. Gear Retaining Ring
30. Camshaft Splines
31. Gear-to-Body Seal

Fig. 2, Rockwell Automatic Slack Adjuster

sured during removal. Do not tighten the jam nut against the clevis.

NOTE: Use a clevis with a 1/2–20 UNF thread if equipped with type 9, 12, or 16 brake chambers. Use a clevis with a 5/8–18 UNF thread size if equipped with type 20, 24, 30, or 36 brake chambers.

3. Install the slack adjuster.



A. Insert screwdriver here.

Fig. 3, Pull-Pawl Assembly (sectional view)

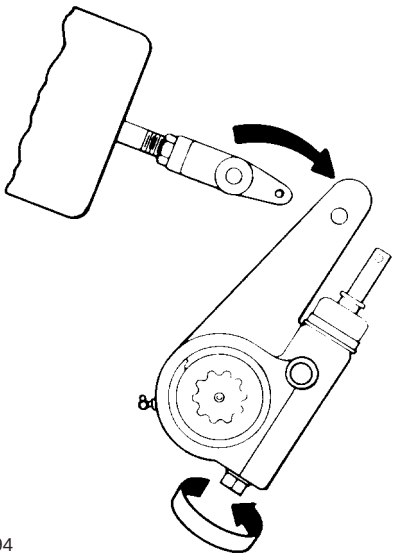
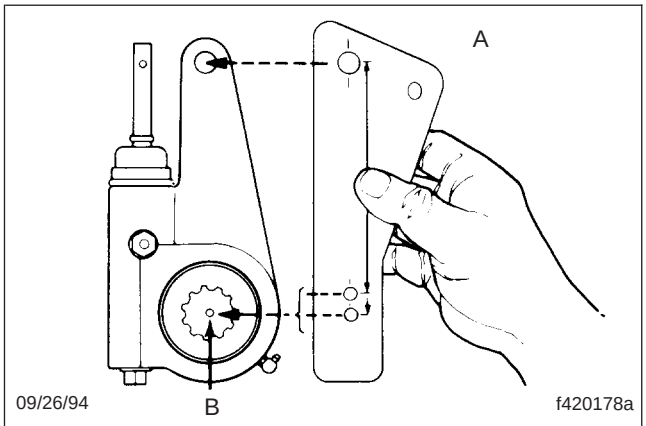


Fig. 4, Turn the Manual Adjusting Nut

3.1 If installing a new slack adjuster, use an installation template and measure the new slack adjuster to make sure it is the same length as the slack adjuster that was removed. See **Fig.5**. Refer to the appropriate table in **Specifications, 400** for the length of slack adjusters that should be used with various sizes of brake chambers.

NOTE: Depending on the type of brakes used (disc or drum) on a tractor or trailer,



A. Measure slack adjuster arm length.
B. Camshaft Center

Fig. 5, Use an Installation Template

several types of installation templates are used. They can be made using the measurements provided in **Fig. 6**. Or, they can be ordered from:

Attn: Literature Distribution Rockwell International 2135 W. Maple Road Troy, Michigan 48084

3.2 Position the slack adjuster on the camshaft.

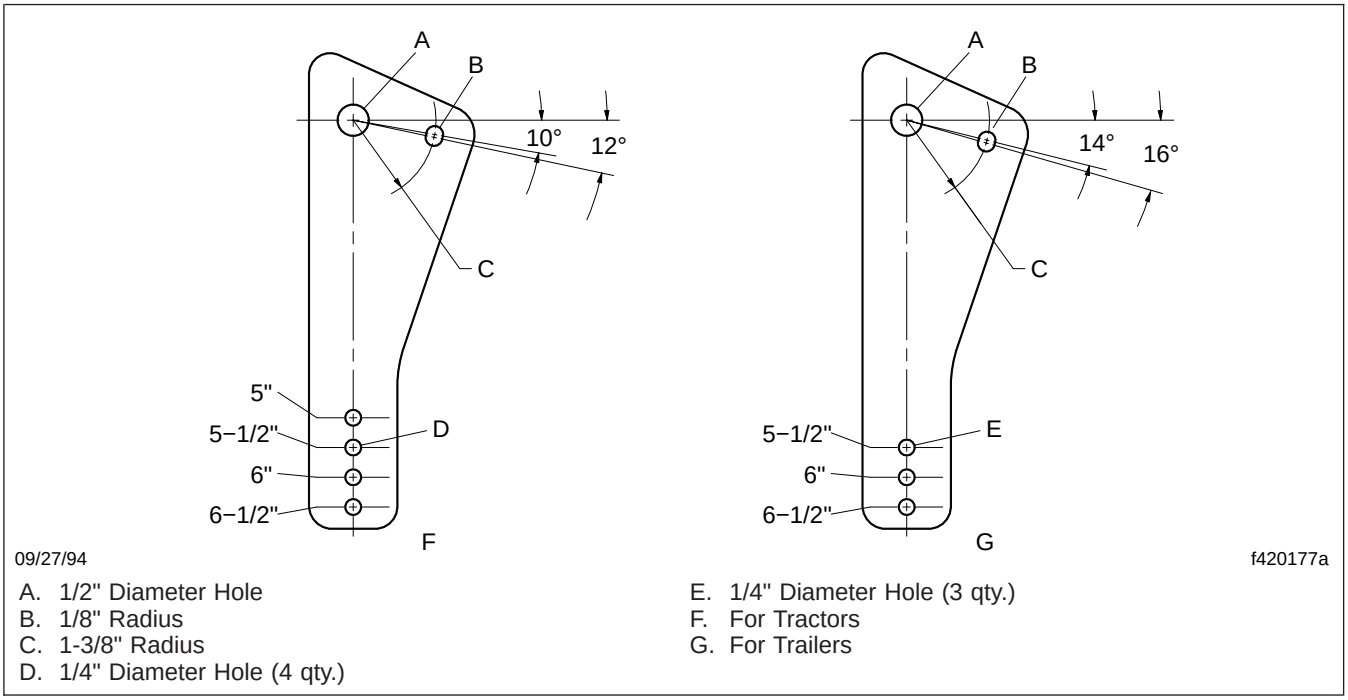
3.3 Install the spacing washers and the snap ring that attach the slack adjuster to the camshaft. Add enough washers to limit the camshaft end play to 0.060 inch (1.5 mm). Check the end play using the instructions in the brake chamber section in this manual.

3.4 If installing a new slack adjuster, remove the pressure relief capscrew, spring, and pawl assembly from the slack adjuster housing. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

⚠ CAUTION

CAUTION: Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pawl assembly. If equipped with a pull-pawl as-

Slack Adjuster Removal and Installation



A. 1/2" Diameter Hole
B. 1/8" Radius
C. 1-3/8" Radius
D. 1/4" Diameter Hole (4 qty.)
E. 1/4" Diameter Hole (3 qty.)
F. For Tractors
G. For Trailers

Fig. 6, Dimensions for Installation Templates

sembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

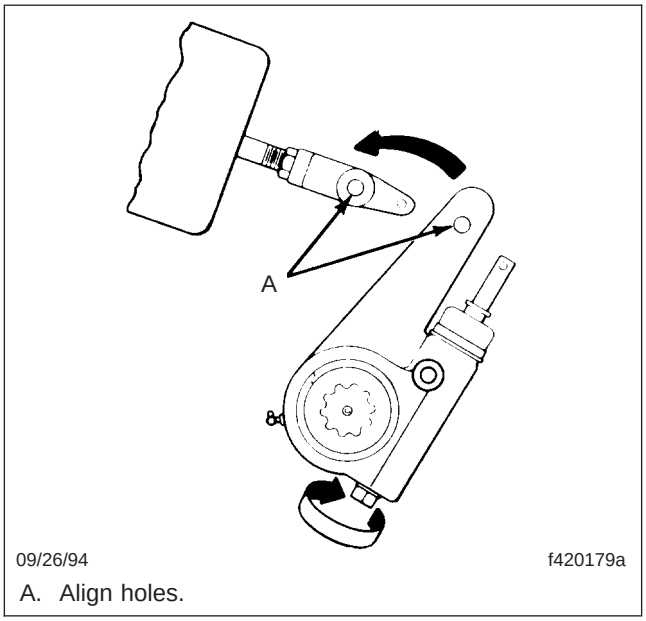
3.5 Using a wrench, turn the manual adjusting nut to align the hole in the slack adjuster housing with the large hole in the clevis. See **Fig.7**.

3.6 With the brakes fully released, place the applicable installation template over the clevis and camshaft end. See **Fig.8**.

3.7 Insert the large clevis pin through the large holes in the template and the clevis.

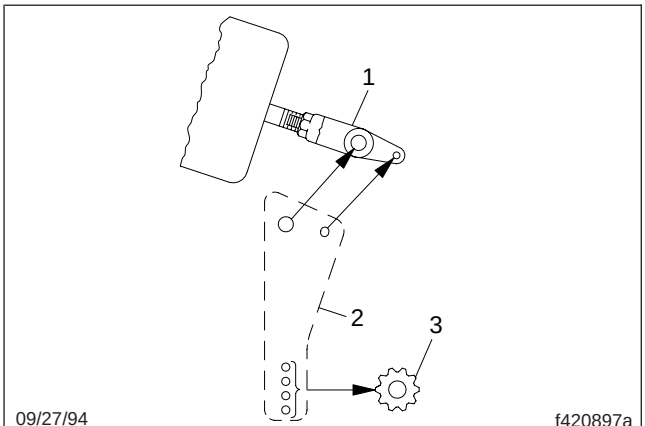
3.8 Select the hole in the template that matches the length of the slack adjuster. Hold the template in place on the center of the camshaft with a pencil.

3.9 Look through the small hole in the template and see if the small hole in the clevis is completely visible. If the hole in the clevis is not completely visible, adjust the position of the clevis on the push rod until the small clevis hole is completely visible. Place the small clevis pin through the template and clevis to make sure the alignment is correct. Remove the template. Be sure the small clevis pin is inserted



A. Align holes.

Fig. 7, Align the Large Holes in the Clevis and the Slack Adjuster



1. Clevis
2. Template
3. Camshaft End

Fig. 8, Place Template over the Clevis and Camshaft End

through the hole in the actuator rod. Install and lock new cotter pins to secure the clevis pins.

IMPORTANT: Make sure that there is at least 1/2 inch (13 mm) of thread engagement between the clevis and the push rod. Also, check that the push rod doesn't extend through the clevis more than 1/8 inch (3.2 mm). See **Fig. 9**. If needed, either cut the push rod, install a new push rod, or install a new brake chamber.

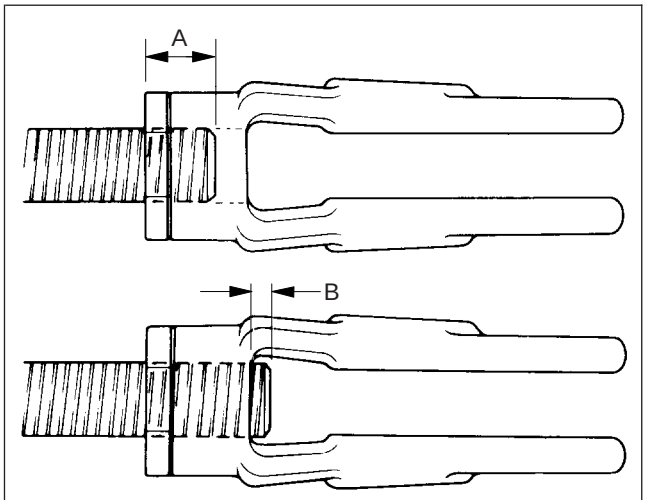
3.10 For 1/2–20 UNF threads, tighten the clevis jam nut 20 to 30 lbf·ft (27 to 41 N·m). For 5/8–18 UNF threads, tighten the jam nut 25 to 50 lbf·ft (34 to 68 N·m).

4. Set the free-stroke.

4.1 Turn the manual adjusting nut counterclockwise until the brake linings contact the brake drum.

4.2 Set the approximate clearance between the linings and the drum: turn the adjusting nut clockwise one-half turn.

4.3 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 10**, Ref. B.



A. Minimum 1/2" (13 mm)
B. Maximum 1/8" (3.2 mm)

Fig. 9, Check Push Rod Engagement

4.4 Use a pry bar to move the slack adjuster, and apply the brakes. Again, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 10**, Ref. A.

The difference between the two measurements is the initial free-stroke, and sets the clearance between the linings and the drum.

The free stroke must be:

drum brakes—5/8 to 3/4 inch (16 to 19 mm);

disc brakes—7/8 to 1-1/8 inch (22 to 29 mm).

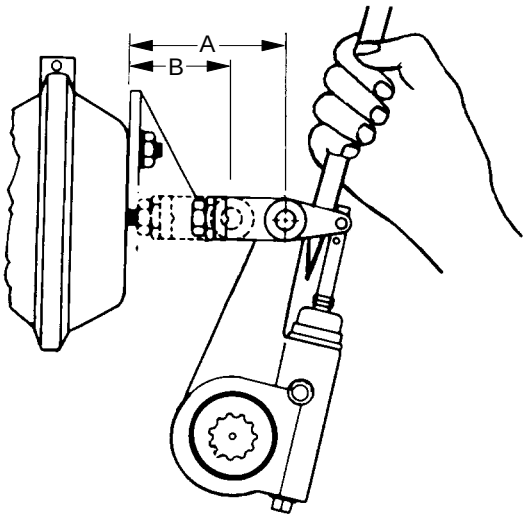
If the free stroke is incorrect, turn the adjusting nut one-eighth turn, as shown in **Fig. 11**. Measure the stroke again, and adjust until it is correct.

5. Measure the brake chamber stroke, and adjust as needed.

5.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig.12**, Ref. A.

5.2 Build air pressure to 100 psi (689 kPa). Shut down the engine. Fully apply the

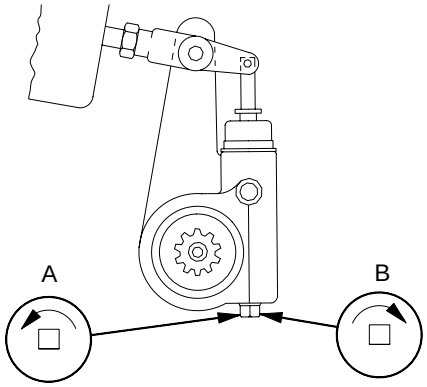
Slack Adjuster Removal and Installation



09/27/94 f420180a

NOTE: For a drum brake, A minus B must equal 5/8" to 3/4" (16 to 19 mm). For a disc brake, A minus B must equal 7/8" to 1-1/8" (22 to 29 mm).

Fig. 10, Measuring Free-Stroke



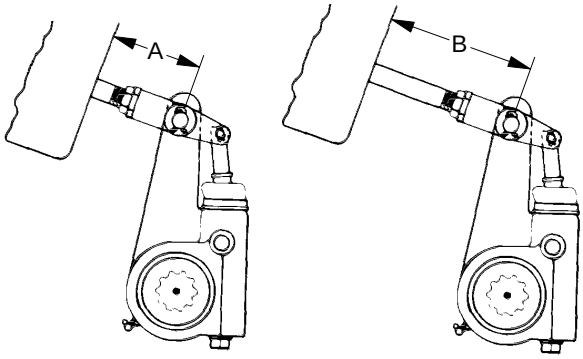
07/05/95 f420181a

A. Shorten stroke.
B. Lengthen stroke.

Fig. 11, Turn the Adjusting Nut

brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 12**, Ref. B. The difference between the measurements is the brake chamber stroke.

5.3 The brake chamber stroke must be less than the measurements shown in the appropriate table in **Specifications, 400**. If



10/20/93 f420182a

NOTE: Measure distance A with the brakes released; measure distance B with the brakes applied.

Fig. 12, Measuring Adjusted Brake Chamber Stroke

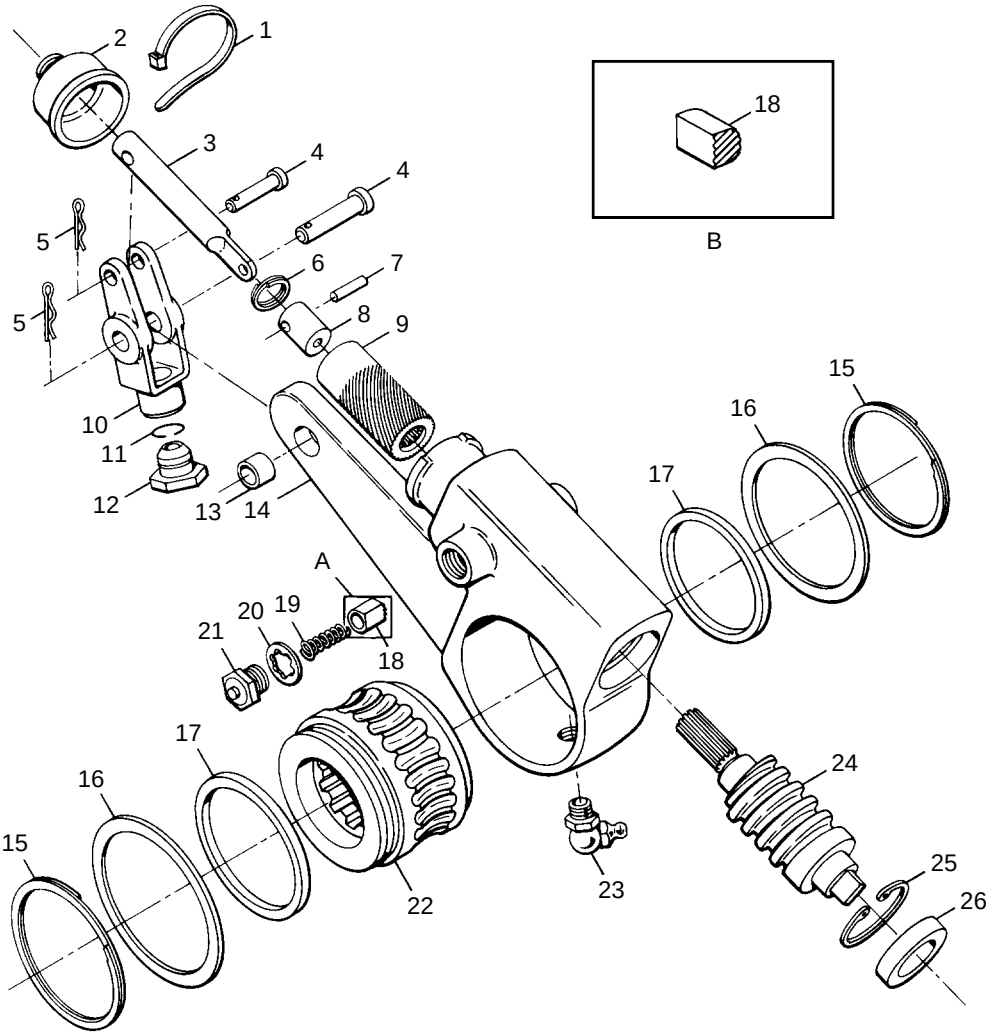
needed, turn the adjusting nut to adjust the brake chamber stroke.

If the stroke varies or remains greater than the specified range, check the brake components, including the camshafts, camshaft bushings, anchor pins, rollers, chamber brackets, clevis, and clevis pins. For instructions, refer to the applicable brake section in this group.

6. Install the pawl assembly, spring, and the pressure relief capscrew. Tighten the capscrew 15 to 20 lbf·ft (20 to 27 N·m). Or, remove the screwdriver from the pull-pawl assembly (if equipped).
7. If equipped with a grease fitting, lube the slack adjuster through the grease fitting until the lubricant is forced out through the pressure relief fitting (or pawl slot), or through the gear splines around the inboard snap ring.
8. 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.
9. Remove the chocks from the tires.

Slack Adjuster Disassembly, Cleaning and Inspection, and Assembly

Disassembly



09/27/94 f420070a

A. See Detail B.
B. End view showing serrations.

1. Boot Retaining Clamp
2. Boot
3. Actuator Rod
4. Clevis Pin
5. Cotter Pin
6. Piston Retaining Ring
7. Roller (Pin)
8. Actuator Piston
9. Actuator
10. Clevis
11. Clevis Retaining Ring (if equipped)
12. Quick-Connect Collar (if equipped)
13. Large Clevis Pin Bushing
14. Slack Adjuster Housing
15. Gear Retaining Ring
16. Gear Thrustwasher
17. Gear-to-Body Seal
18. Adjusting Pawl
19. Pawl Spring
20. Gasket
21. Pressure Relief Capscrew
22. Gear
23. Grease Fitting (if equipped)
24. Worm
25. Worm Retaining Snap ring
26. Worm Grease Seal

Fig. 1, Slack Adjuster (exploded view)

Slack Adjuster Disassembly, Cleaning and Inspection, and Assembly

1. Remove the slack adjuster. See **Fig. 1**. For instructions, refer to **Subject 100**.
2. Cut the boot retaining clamp, and remove the clamp from the rubber boot.
3. Remove the boot and the actuator (adjusting sleeve) from the housing. See **Fig. 2**. You may need to first work the boot off of the housing before removing the actuator.

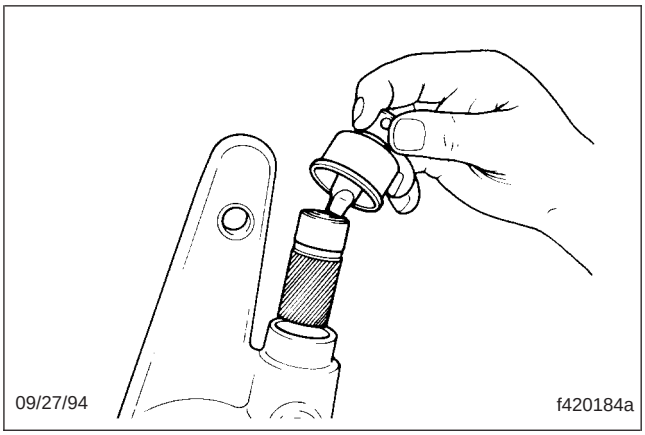
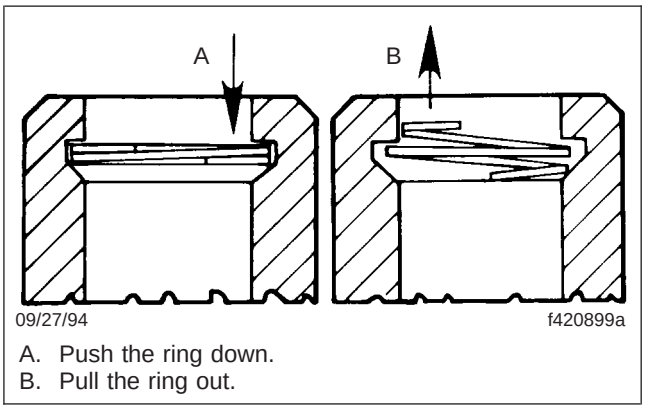


Fig. 2, Removal of the Actuator

4. Using a small screwdriver, press down the piston retaining ring and force it out of the groove. See **Fig. 3**. Using pliers, unwind the ring and pull it out.



A. Push the ring down.
B. Pull the ring out.

Fig. 3, Removal of the Internal Piston Retaining Ring

5. Pull the actuator rod, piston, and pin from the actuator bore.
6. Using a small hammer and brass drift punch, remove the pin from the rod and piston. See **Fig. 4**.

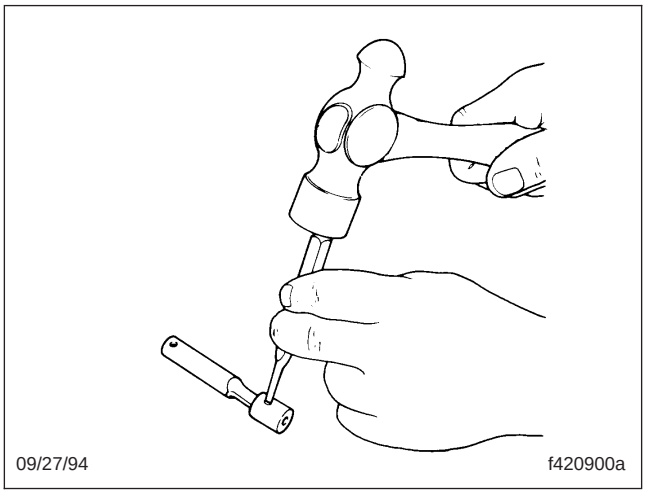


Fig. 4, Remove the Pin from the Rod and Piston

7. Using a small screwdriver, pry the grease seal from around the worm. See **Fig. 5**.

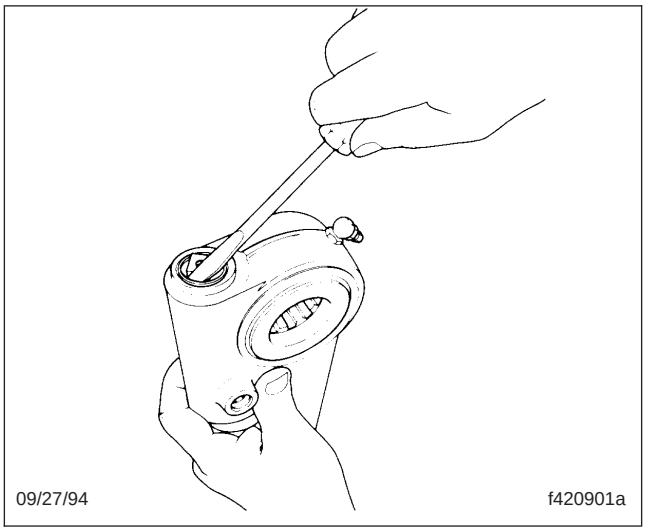


Fig. 5, Pry out the Grease Seal

8. Using snap ring pliers, remove the retaining ring from the worm. See **Fig. 6**.
9. Using a wrench, turn the manual adjusting nut, and wind the worm out of the bore.

Slack Adjuster Disassembly, Cleaning and Inspection, and Assembly

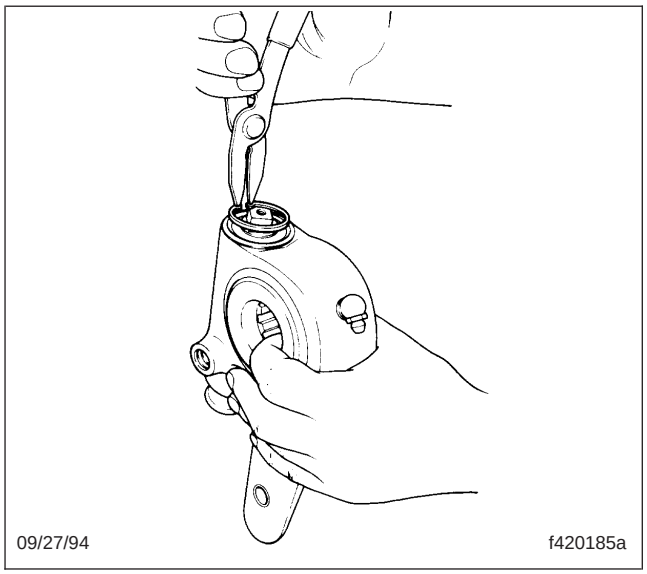


Fig. 6, Remove the Worm Retaining Ring

10. On one side of the housing, insert a small screwdriver into the notch at the end of the retaining ring. Remove the end of the retaining ring from the groove.

    Unwind the ring by hand and pull it out of the groove. See **Fig. 7**. Remove the thrustwasher.

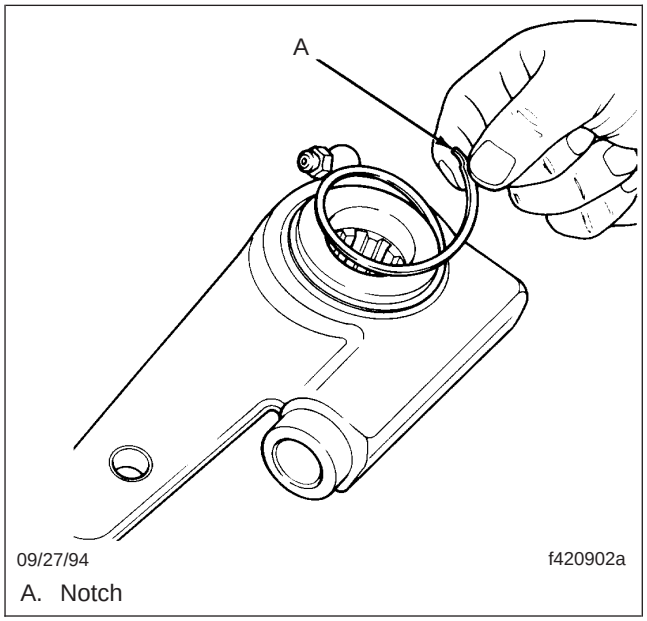


Fig. 7, Remove the Gear Retaining Ring

11. Push the gear far enough out of the housing to remove one gear seal.

    Push the gear far enough out of the opposite side of the housing to remove the other gear seal. Remove the gear from the housing.

Cleaning and Inspection

CAUTION

CAUTION: Don't clean ground or polished parts in a hot solution tank or with water-and-alkaline solutions, such as sodium hydroxide, orthosilicates, or phosphates. Also, don't use solvent-type cleaners on any nonmetallic parts. Doing so could damage the parts.

1. Clean the slack adjuster parts.
   - 1.1 Clean all parts having ground and polished surfaces (such as the worm, worm gear, and inner bores of the slack housing) with solvent-type cleaners, such as emulsion cleaners, carbon tetrachloride, or petroleum solvents (excluding gasoline).
   - 1.2 Dry all parts immediately after cleaning. Use soft, clean, lint-free absorbent paper towels, or wiping rags free of abrasive material such as lapping compound, metal filings, or contaminated oil.
2. Inspect all parts for wear or damage.
   - 2.1 Inspect all parts for wear or stress. Replace as needed.
   - 2.2 Inspect the seals, and discard if they show any signs of damage.
   - 2.3 Check the condition and fit of the large clevis pin bushing in the arm of the slack adjuster. Don't remove the bushing unless it is worn or egg-shaped.
3. If storing parts for any length of time, treat them with a good rust preventative, and wrap them in special paper or other material designed to prevent corrosion.

Slack Adjuster Disassembly, Cleaning and Inspection, and Assembly

Assembly

1. Coat all parts and the gear bore with a grease recommended in the appropriate table in **Specifications 400**.
2. Install the gear into the housing. See **Fig. 1**.
   - 2.1 Place the gear, without the gear seals, into the housing. Keep one seal groove outside the housing.

     Make sure the gear goes straight into the bore. If needed, use a small rawhide mallet to tap the gear into place.
   - 2.2 Install a seal into the groove. See **Fig. 8**.

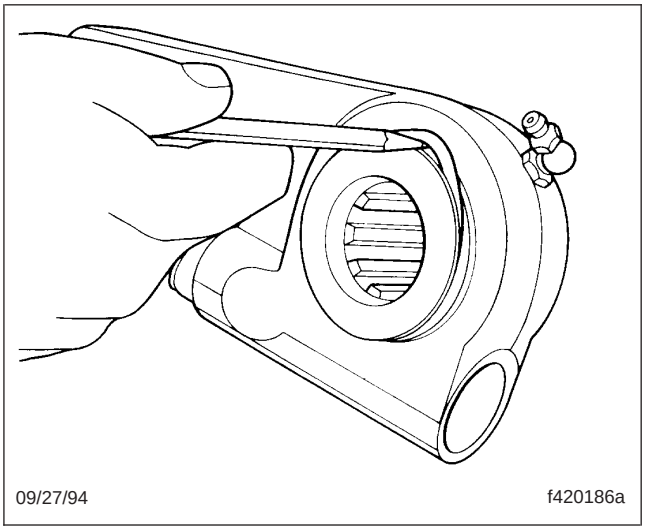


Fig. 8, Install a Seal

CAUTION

CAUTION: Do not push the side of the gear that has the seal installed through the housing. Damage to the seal will occur when it passes the sharp edges of the intersecting worm bore.

   - 2.3 Push the gear far enough out the opposite side of the housing so you can see the other seal groove.
   - 2.4 Install the seal in the groove, and push the gear into the housing.
   - 2.5 On one side of the gear, position a thrustwasher around the gear and against the housing. Spread out the retaining ring coil. Put one end of the coil into the groove in the outer diameter of the gear. Work around the gear and press the coil into the groove.
   - 2.6 Repeat this step for the other side of the gear.
3. Install the worm into the housing.
   - 3.1 Place the worm into the bore, then turn the adjusting nut to wind the worm to the bottom of the bore.
   - 3.2 Install the retaining snap ring.
   - 3.3 Place the grease seal over the worm bore, with the lips facing outward and the metal retainer facing toward the inside of the bore. See **Fig. 9**. Using a hammer and a 1-3/16 inch seal driver, install the seal.

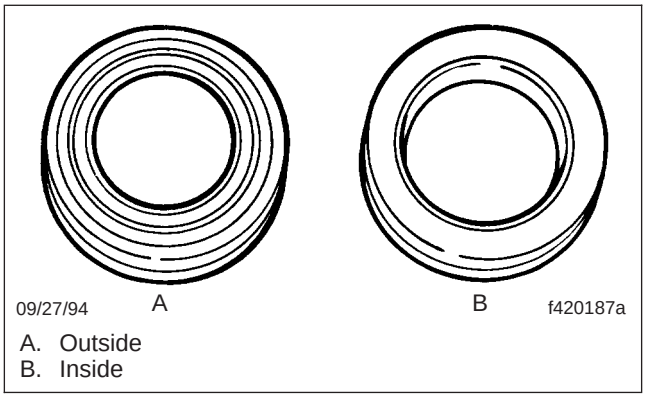


Fig. 9, Grease Seal Placement

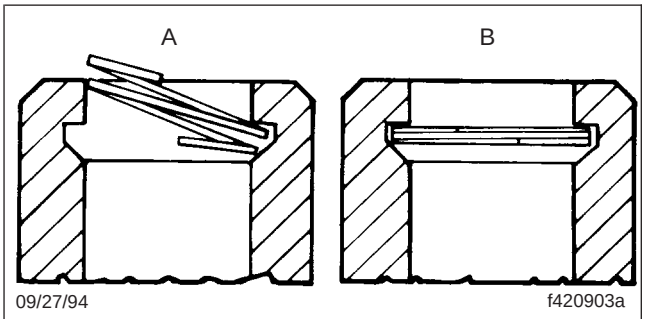
CAUTION

CAUTION: Failure to install the grease seal properly could allow contaminants to enter the housing and damage the parts.

4. Assemble the actuator, rod, and piston.
   - 4.1 Using a small hammer and brass drift punch, install the pin that connects the piston and actuator rod.
   - 4.2 Insert the actuator rod and piston into the actuator (adjusting sleeve).
   - 4.3 Slide the piston retaining ring over the rod. Spread out the coils of the ring. Using a small screwdriver, press one end of the ring into the groove. See **Fig. 10**. Press

on the ring and work it around the groove until it is completely seated in the groove.

See if the ring is seated correctly. You will not be able to pull the piston out of the actuator if the ring is seated correctly.



A. Start bottom coil.
B. Tuck ring into groove.

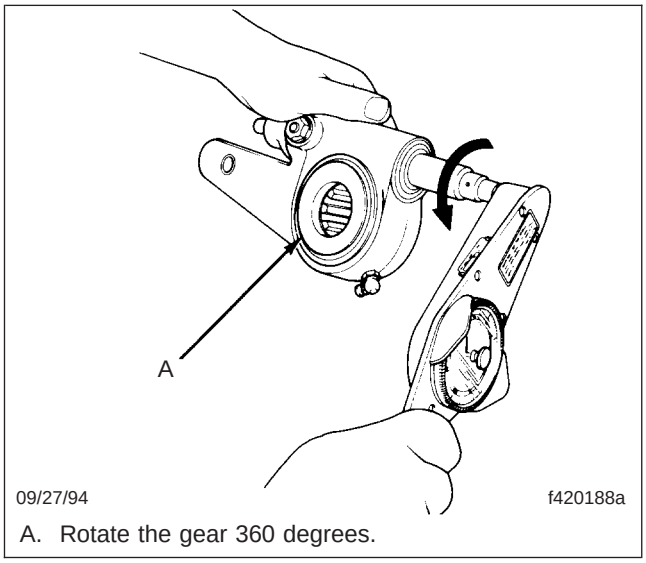
Fig. 10, Installation of the Internal Piston Retaining Ring

5. Slide the actuator assembly along the splines of the worm and into the slack housing.
6. Lubricate the actuator rod with grease, then slip the boot over the rod. Attach the boot to the housing with a silastic coating and a new retaining clamp.

   Make sure that the top of the boot fits on the round part of the rod, not the tapered part.

   Seal the top part of the boot with a silastic coating.
7. If previously removed, install a new bushing into the large clevis pin hole in the arm of the slack adjuster.
8. Lubricate the slack adjuster through the grease fitting (if equipped) until the lubricant is forced out through the pressure relief fitting (or pawl slot), or through the gear splines around the inboard snap ring.
9. Attach a lbf·in/N·cm torque wrench to the adjusting nut. Watch the torque scale while turning the gear 360 degrees. See **Fig. 11**. If the torque remains 25 lbf·in (280 N·cm) or less, the slack adjuster is working correctly.

   If the torque is more than 25 lbf·in (280 N·cm), the slack adjuster is not working correctly. Disassemble the slack, and check for correct assembly and alignment of parts.



A. Rotate the gear 360 degrees.

Fig. 11, Slack Adjuster Torque Check

10. Install the slack adjuster. For instructions, refer to **Subject 100**.

Specifications

Slack Adjuster Arm Length inches (mm)	Chamber Size
5 (127)	9, 12, 16, 20, 24, 30
5-1/2 (140)	9, 12, 16, 20, 24, 30, 36
6 (152)	24, 30, 36
6-1/2 (165)	30, 36

Table 1, Slack Adjuster Arm Lengths

Chamber Size	Maximum Chamber Stroke	
	Cam Brake	Disc Brake
9	Less than 1-3/8 inches (35 mm)	Currently not used
12	Less than 1-3/8 inches (35 mm)	Currently not used
16	Less than 1-3/4 inches (44 mm)	Less than 2 inches (51 mm)
20	Less than 1-3/4 inches (44 mm)	Less than 2 inches (51 mm)
24	Less than 1-3/4 inches (44 mm)	Less than 2 inches (51 mm)
24 *	Less than 2 inches (51 mm)	Less than 2-1/4 inches (57 mm)
30	Less than 2 inches (51 mm)	Less than 2-1/4 inches (57 mm)
36	Less than 2-1/4 inches (57 mm)	Currently not used

* Long stroke.

Table 2, Maximum Adjusted Brake Chamber Strokes

Lubricant Type	Temperature
Rockwell 0–616–A Texaco Thermotex EP No. 1 Shell Darina No. 1 Texaco Hytherm EP No. 1 Aralub 3837 Tribolube 12, Grade 1 Rockwell 0–692 Amoco Super Permalube No. 2 Citco Premium Lithium EP No. 2 Exxon Ronex MP No. 2 Kendall L–427 Super Blu No. 2 Mobilith AW No. 1 Sohio Factran EP No. 2	Above –40°F (–40°C)
Rockwell 0–645 Mobil 28	Below –40°F (–40°C)

Table 3, Lubricant Specifications

General Description

The Bendix driveline parking brake is designed to hold the vehicle on a grade. The parking brake is manually operated, and has a mechanical linkage; it doesn't rely on hydraulic or air pressure. It is installed only on vehicles with hydraulic brakes.

The parking brake is mounted on the rear of the transmission, between it and the driveshaft. See **Fig. 1**. The main parts of the brake are the drum, brake shoes, return springs, support plate, cam, actuating lever, brake cable, and brake lever assembly. See **Fig. 2** and **Fig. 3**.

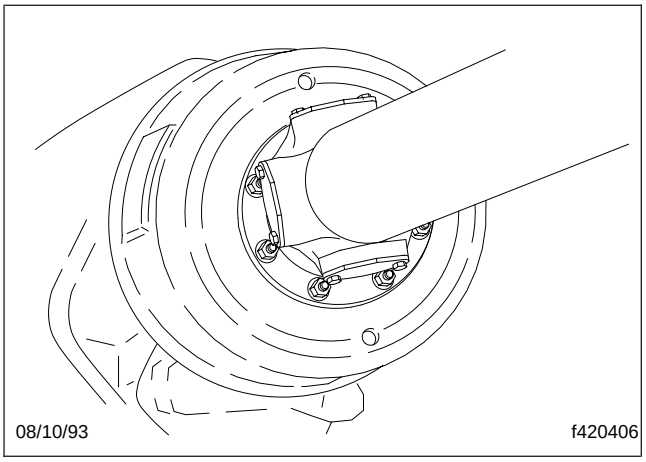
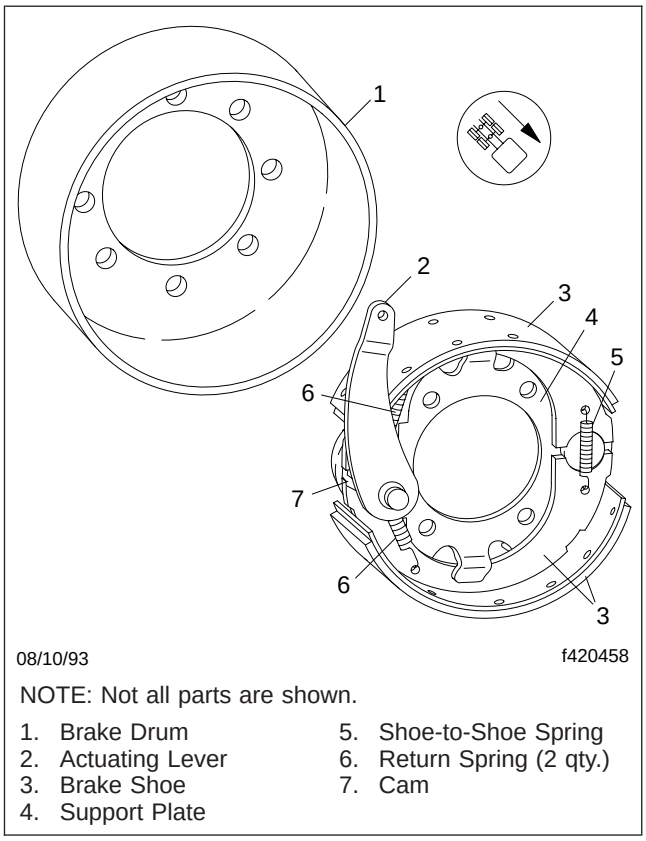


Fig. 1, Parking Brake Mounting

The brake drum and the driveline companion flange are bolted to the transmission companion flange, which is attached to the transmission shaft. The support plate is bolted to the rear of the transmission. The brake shoes are held in place by the return springs, the shoe-to-shoe spring, and by the support plate. The brake cable runs from the actuating lever to inside the cab, where it is controlled by the parking brake lever assembly. See **Fig. 4**. A knob at the end of the parking brake lever is used to adjust the cable length to compensate for brake shoe wear.

Principles of Operation

When the brake lever is pushed down, the brake cable pulls the actuating lever, turning the cam. The cam pushes the brake shoes outward against the brake drum. Because the support plate and the shoes are mounted in a fixed position on the transmission, and the brake drum is attached to the end of the driveshaft, the driveshaft is prevented from turning. This keeps the vehicle from rolling. See **Fig. 5** and **Fig. 6**.



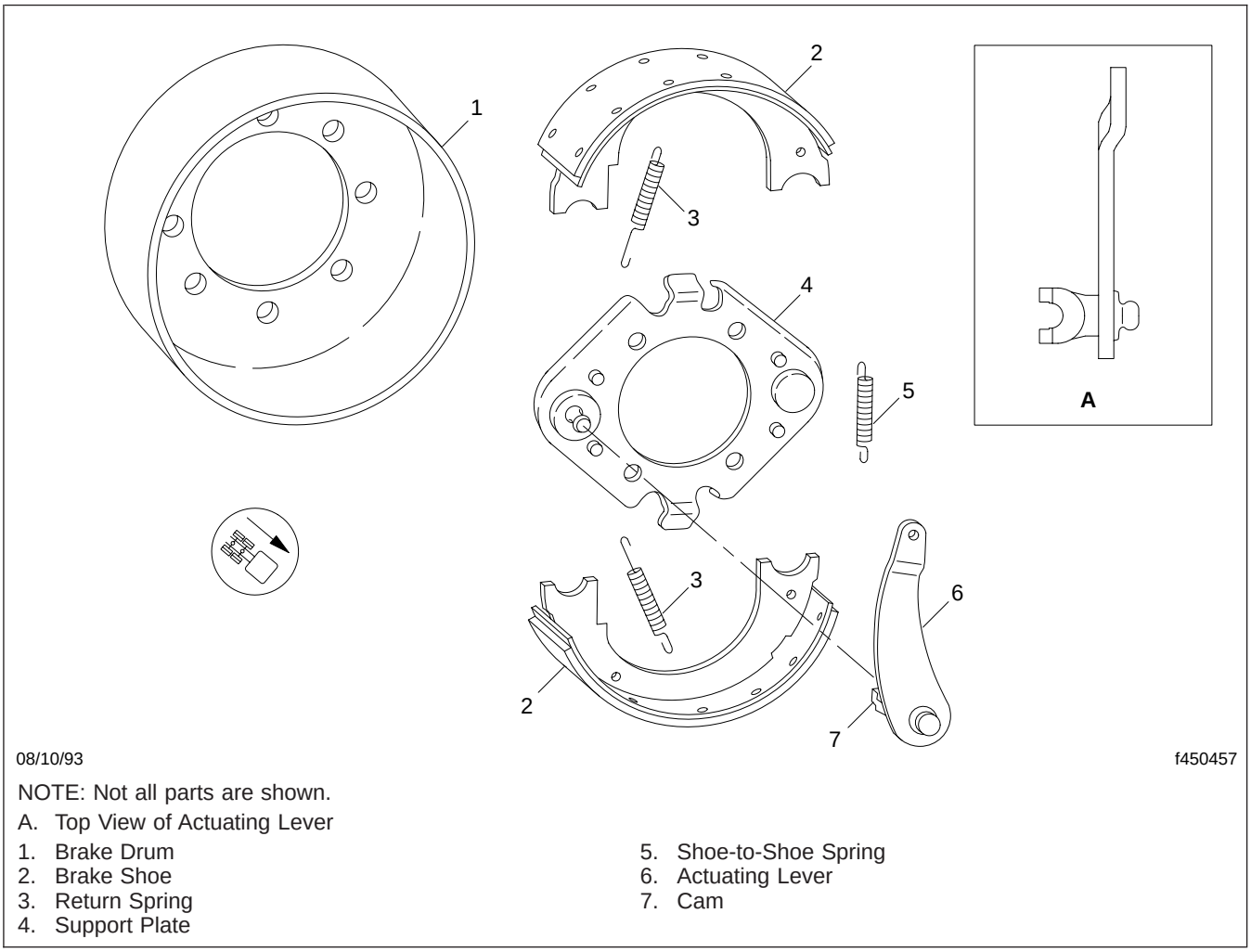
NOTE: Not all parts are shown.

1. Brake Drum
2. Actuating Lever
3. Brake Shoe
4. Support Plate
5. Shoe-to-Shoe Spring
6. Return Spring (2 qty.)
7. Cam

Fig. 2, Assembled Parts

When the parking brake lever is released, the tension on the cable is removed. The actuating lever and cam return to their original position, and the brake return springs and shoe-to-shoe spring pull the brake shoes away from the brake drum. The driveshaft is then free to move, and the vehicle can be moved.

General Description and Principles of Operation

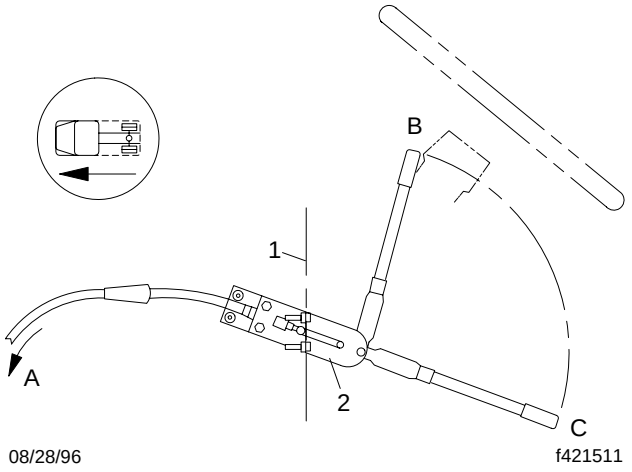


NOTE: Not all parts are shown.

A. Top View of Actuating Lever

1. Brake Drum
2. Brake Shoe
3. Return Spring
4. Support Plate
5. Shoe-to-Shoe Spring
6. Actuating Lever
7. Cam

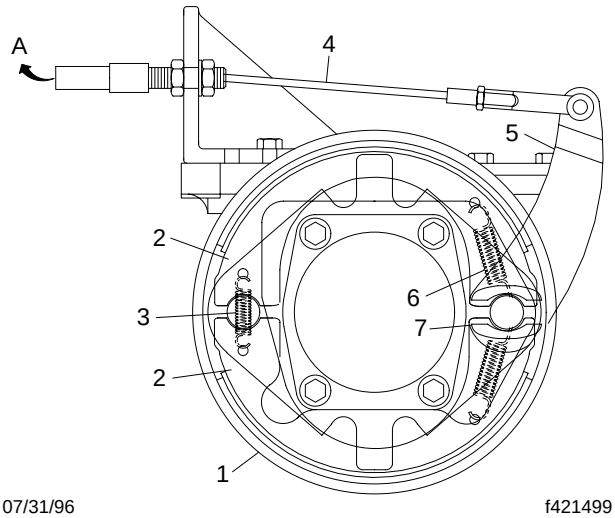
Fig. 3, Exploded View



08/28/96 f421511

A. To the parking brake
B. Parking brake engaged
C. Parking brake released
1. Rear Face of Cowl
2. Parking Brake Lever Assembly

Fig. 4, Lever Assembly

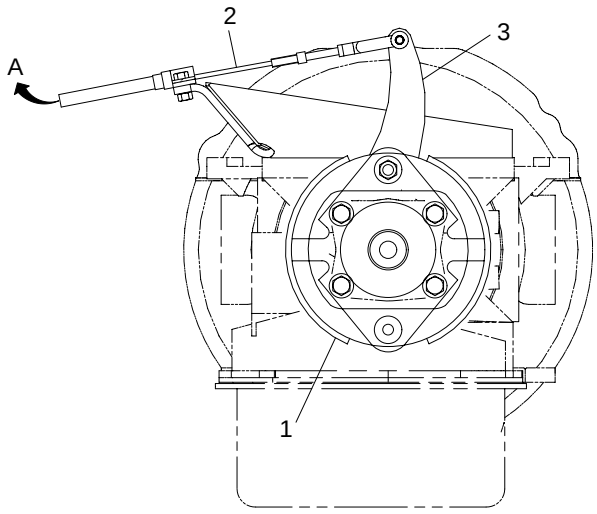


07/31/96 f421499

NOTE: Not all parts are shown.

A. To parking brake lever in the cab.
1. Brake Drum
2. Brake Shoe
3. Shoe-to-Shoe Spring
4. Brake Cable
5. Actuating Lever
6. Return Spring
7. Cam

Fig. 5, Fuller Transmission Installation Shown



07/30/96 f421500

NOTE: Not all parts are shown.

A. To parking brake lever in the cab.
1. Parking Brake
2. Brake Cable
3. Actuating Lever

Fig. 6, Allison Transmission Installation Shown

Safety Precautions

Because most brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Because medical experts believe that long-term exposure to some non-asbestos fibers could also be a health hazard, also observe the following precautions if servicing non-asbestos brake linings.

Exposure to airborne brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

During brake servicing, wear an air purifying respirator with high-efficiency filters. The respirator and filter must be approved by NIOSH or MSHA, and worn during all procedures.

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency (HEPA) filters be used during brake repairs. Under this system, the entire brake assembly is placed within the cylinder and the mechanic works on the brake through sleeves attached to the cylinder. Compressed air is blown into the cylinder to clean the assembly, and the dirty air is then removed from the cylinder by the vacuum.

If such an enclosed system is not available, or can't be used, clean the brake assembly in the open air. During disassembly, carefully place all parts on the floor to minimize creating airborne dust. Using an industrial vacuum cleaner with an HEPA filter system, remove dust from all the brake parts. After vacuuming, remove any remaining dust using a rag soaked in water and wrung until nearly dry.

⚠ WARNING

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 NIOSH or MSHA. Wear a respirator at all times when disassembling the parking brake, starting with removal of the drum and continuing through assembly.

Replacement

WARNING

WARNING: Before starting the procedure below, read the 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. Chock the tires. Apply the parking brake to keep the brake drum in place when the driveline is disconnected.
2. Remove the driveline midship bearing carrier from the frame crossmember.
   - 2.1 Put a jackstand under the driveline at the rear of the midship bearing.
   - 2.2 Remove the bolts holding the midship bearing carrier to the bracket on the frame crossmember. See **Fig. 1**.

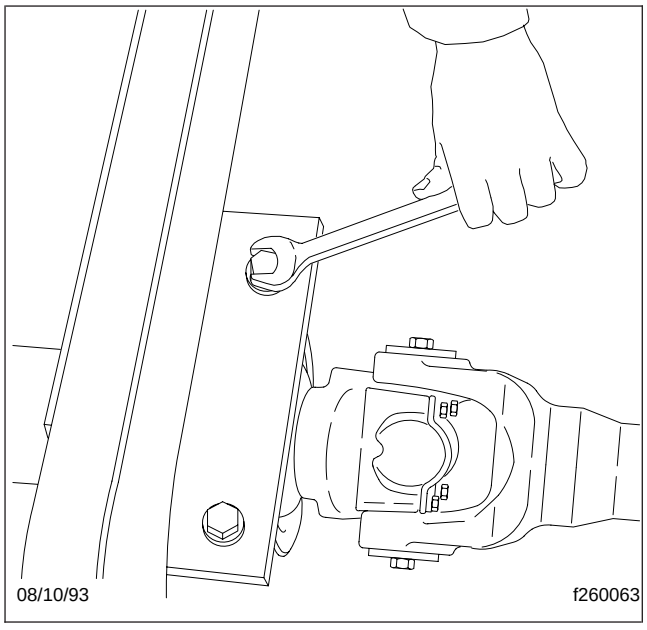


Fig. 1, Remove the Midship Bearing Carrier Bolts

   - 2.3 Lower the driveline and midship bearing carrier onto the jackstand. It should rest securely on the jackstand.
3. Disconnect the driveline companion flange from the transmission companion flange. See **Fig. 2**. Slide out the driveline, and lower it to the floor. See **Fig. 3**.

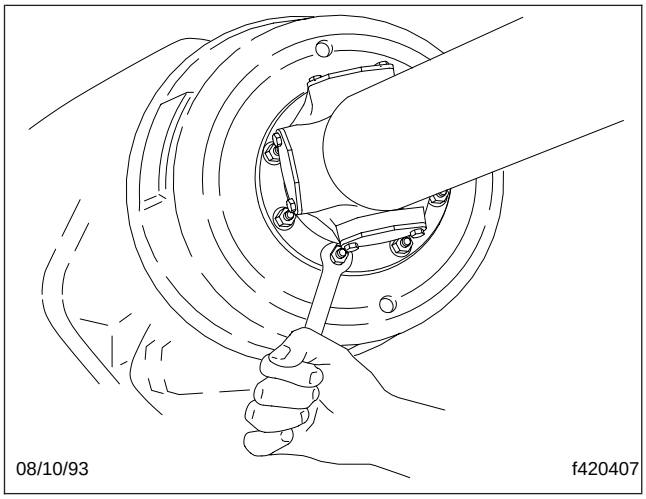


Fig. 2, Disconnect the Driveline Companion Flange

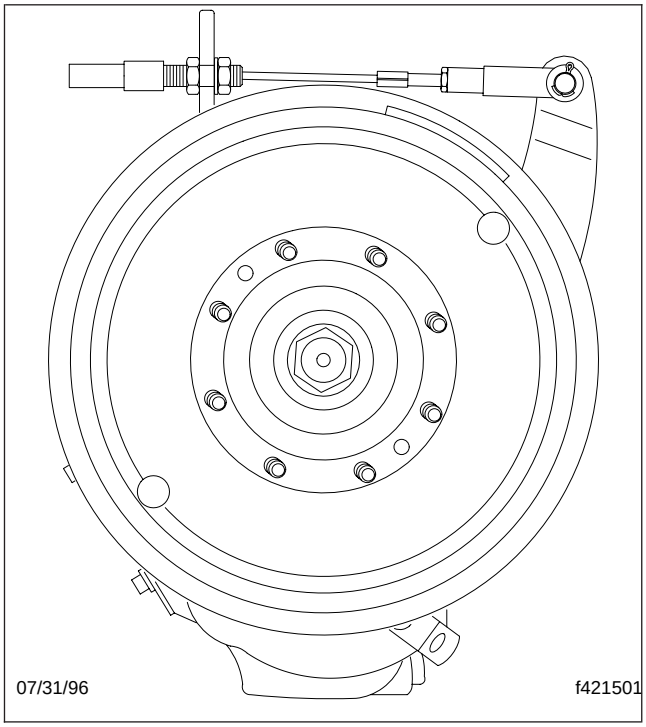


Fig. 3, Driveline Removed

4. Release the parking brake.
5. Pull the brake drum off the transmission companion flange. See **Fig. 4**.

Brake Shoe Replacement

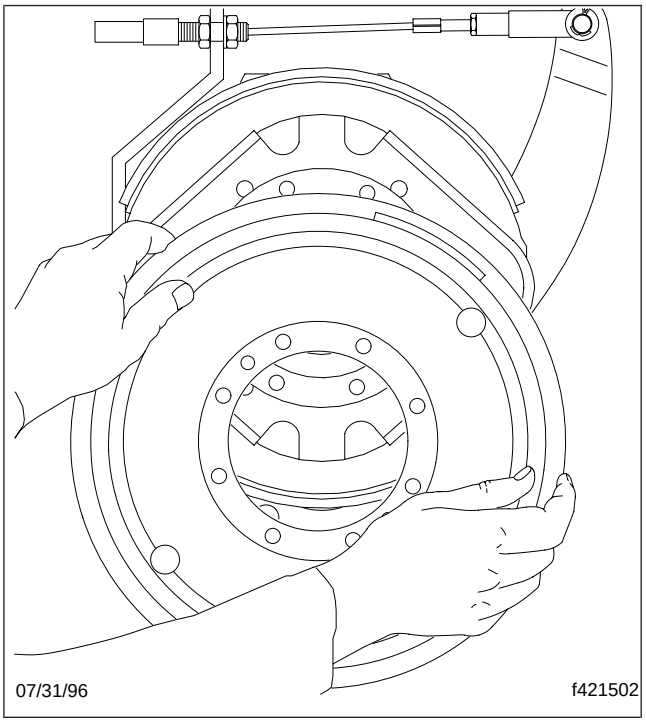


Fig. 4, Pull Off the Brake Drum

6. Disconnect the brake cable from the actuating lever. See **Fig. 5**.

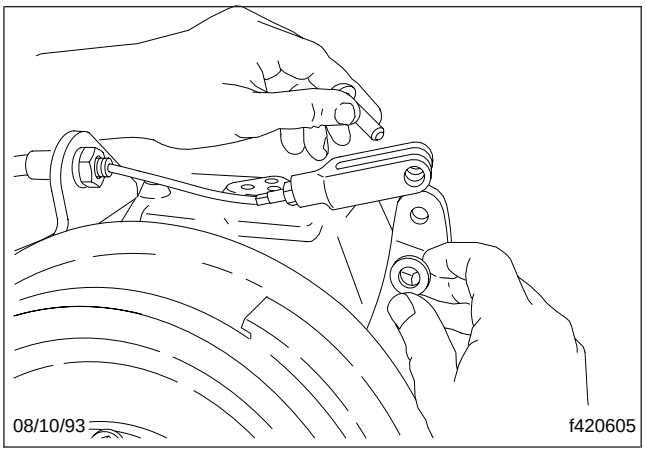
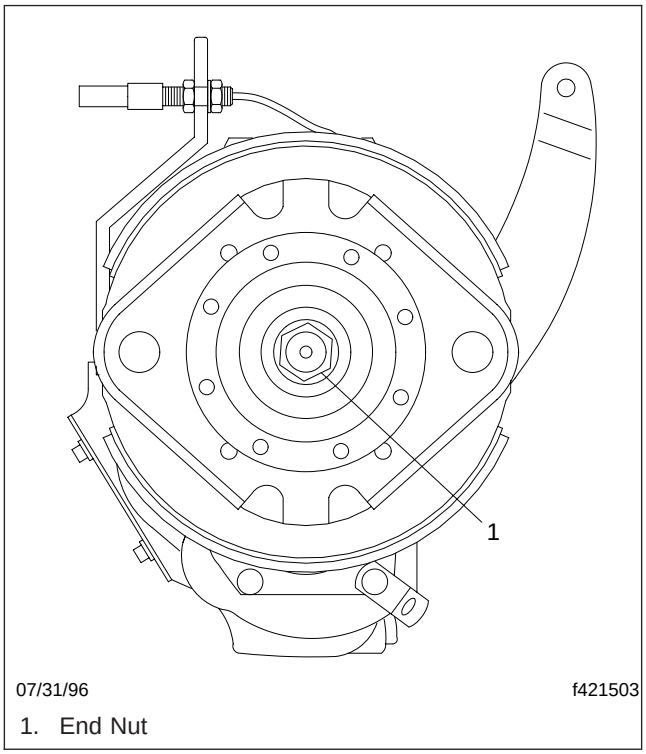


Fig. 5, Disconnect the Brake Cable

7. Remove the large end-nut from the transmission shaft. See **Fig. 6**. Remove the companion flange.
8. Remove the supporting plate and brake shoes as a unit.
9. Disassemble the brake parts. See **Fig. 7**.



1. End Nut

Fig. 6, Remove the Large End-Nut

9.1 Remove the actuating lever and cam assembly.

9.2 Remove the brake shoes from the supporting plate.

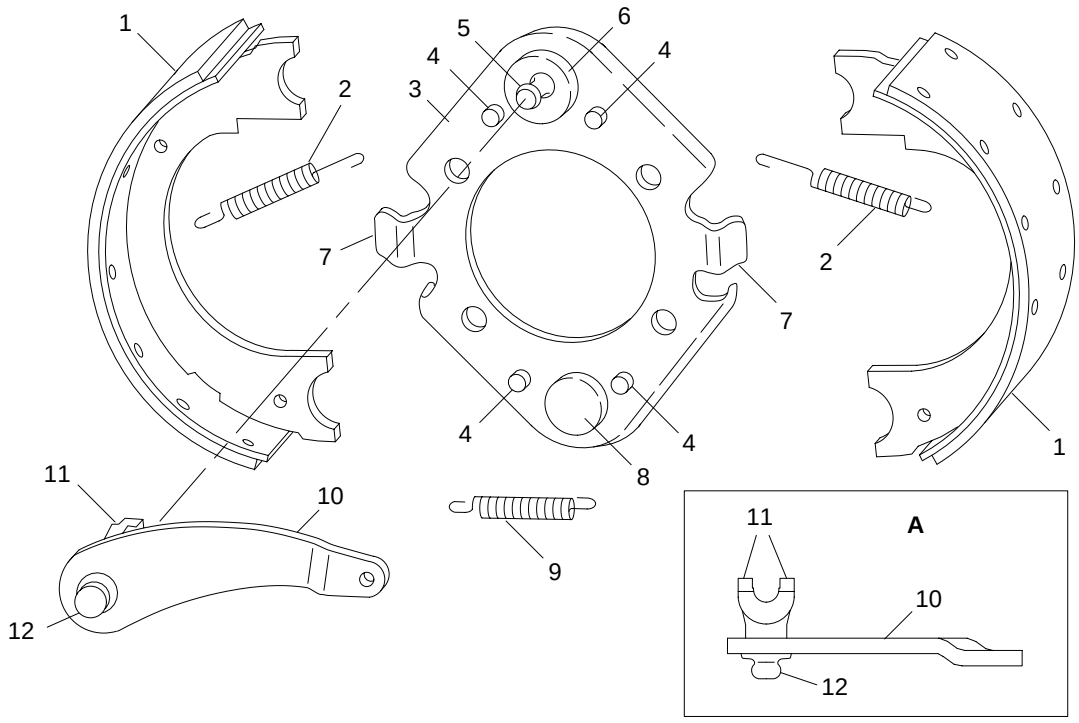
⚠ WARNING

WARNING: Wear safety glasses when removing the brake shoe return springs. Brake shoe return springs are under tension, and may release unexpectedly, which could cause personal injury.

9.3 Using a suitable spring removal tool, carefully remove the two brake shoe return springs.

9.4 Spread the brake shoes apart to release tension on the shoe-to-shoe spring.

9.5 Remove both brake shoes from the support plate, then remove the shoe-to-shoe spring.



A. Top view of actuating lever.

1. Brake Shoe
2. Return Spring
3. Support Plate
4. Shoe Bearing Surface
5. Nib
6. Upper Anchor Pin
7. Support Plate Lug
8. Lower Anchor Pin
9. Shoe-to-Shoe Spring
10. Actuating Lever
11. Cam Lugs
12. Cam Ball

Fig. 7, Brake Assembly

10. Clean all the parts. Check for damage and corrosion, and replace parts if needed. Check the support plate for cracks or bending. Replace it if needed.

CAUTION

CAUTION: Don't let any grease get on the brake drum or linings. Grease on these parts will reduce the effectiveness of the driveline parking brake. If brake linings become contaminated, replace them.

11. Using NLGI grade 2 brake grease, lightly grease the following parts. See **Fig. 7**.
    - the cam lugs and ball;
    - the mating surfaces of the brake shoe webs and the support plate lugs;
    - the support plate anchor pins;
    - the shoe bearing surfaces;
    - the ends of the brake shoe webs.
12. Install new brake shoes. See **Fig. 7** and **Fig. 8**.
    - 12.1 Position the brake shoes on the support plate.

    NOTE: Position the support plate so the anchor pin with the nib is at the top.

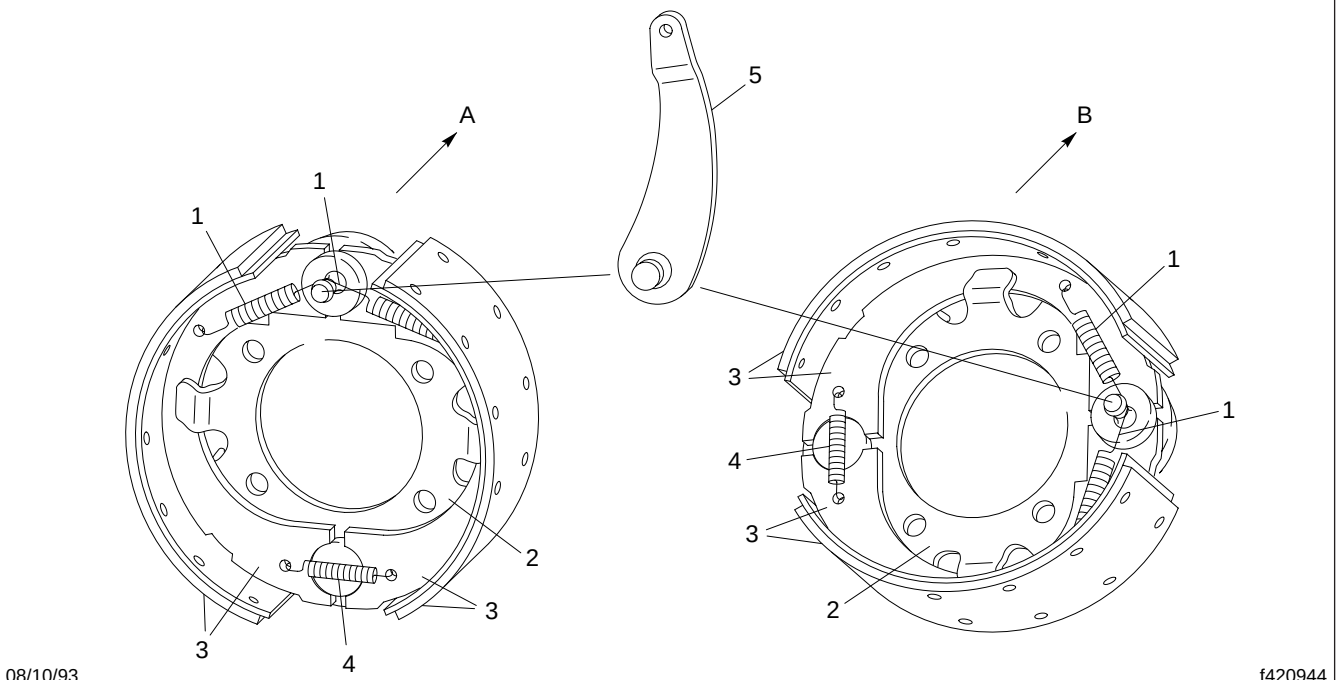
    - 12.2 Install a new shoe-to-shoe spring in the hole of each brake shoe.

Brake Shoe Replacement

12.3 Using a twisting motion, install the lower ends of the brake shoes over the lower anchor pin.

12.4 Put the upper ends of the brake shoes against the upper anchor pin, making sure the shoe webs are underneath the guide lugs of the support plate.

15. Install the large end-nut on the end of the transmission shaft. See **Fig. 6**. Tighten the nut.
    - On Fuller transmissions—325 lbf·ft (440 N·m).
    - On Allison transmissions—145 lbf·ft (197 N·m).



A. To Allison transmission.
1. Return Spring
2. Support Plate
3. Brake Shoe
B. To Fuller transmission.
4. Shoe-to-Shoe Spring
5. Actuating Lever and Cam Assembly

Fig. 8, Brake Shoe Assembly

12.5 Install two new return springs on the nib of the upper anchor pin and in the hole of each brake shoe.

12.6 Install the actuating lever and cam assembly on the anchor pin with the nib.

13. Using the four hexbolts, nuts, and washers, position the support plate and brake shoe assembly on the transmission adapter. See **Fig. 8**. Tighten the nuts 85 lbf·ft (115 N·m).

14. Install the transmission companion flange over the splines of the transmission shaft.

16. Install the brake drum onto the studs of the transmission companion flange.

17. Connect the driveline companion flange to the transmission companion flange.

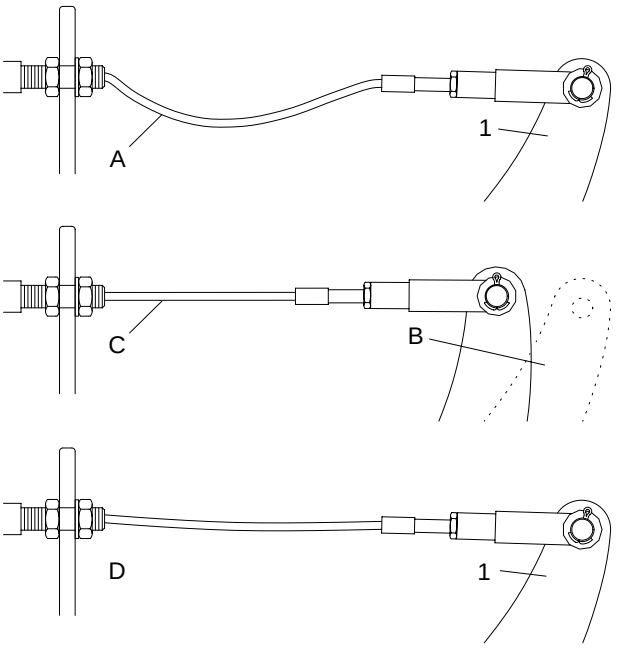
17.1 Place the driveline companion flange so its holes fit over the studs on the transmission companion flange.

17.2 Install the eight nuts and washers on the studs. See **Fig. 2**. Tighten them 45 lbf·ft (61 N·m).

18. Connect the brake cable to the actuating lever.

18.1 Check the length of the brake cable. It should be just long enough to let the clevis hole align with the hole in the actuating lever, without moving the actuating lever. See **Fig. 9**.

If the brake cable is too loose or too tight, loosen the jam nut, then screw the clevis in or out until its holes line up with the hole in the actuating lever (without moving the lever). See **Fig. 10**.



A. Too loose.
B. Correct position of actuating lever.
C. Too tight.
D. Correct cable adjustment.
1. Actuating Lever

Fig. 9, Brake Cable Tightness

18.2 Tighten the jam nut firmly.

18.3 Install the clevis pin through the clevis and actuating lever holes.

18.4 Install the washer and a new cotter pin on the clevis pin.

18.5 Check the brake cable again for any slack. If it still needs adjusting, do it in the cab by turning the ring on the handle of the parking brake lever, See **Fig. 11**.

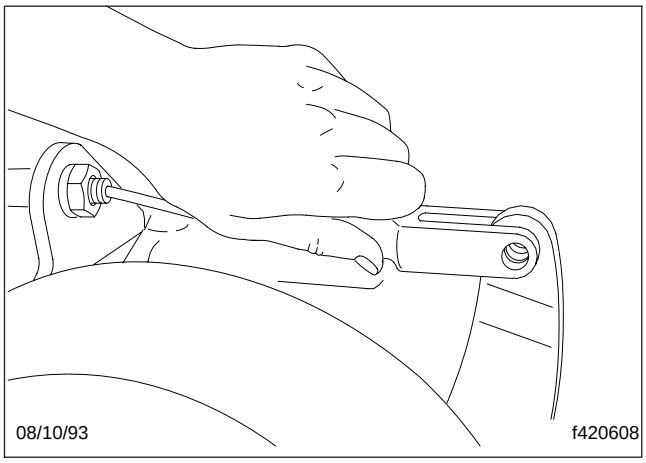
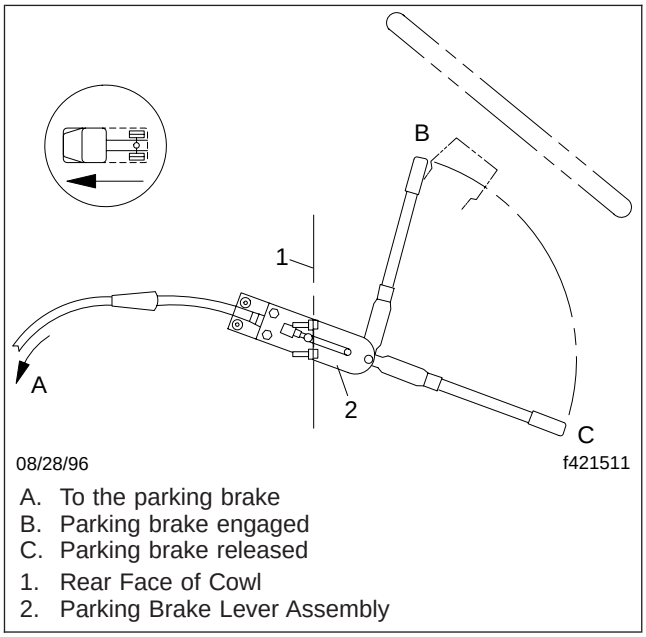


Fig. 10, Align the Lever and Clevis Holes



A. To the parking brake
B. Parking brake engaged
C. Parking brake released
1. Rear Face of Cowl
2. Parking Brake Lever Assembly

Fig. 11, Lever Assembly

19. Attach the driveline midship bearing carrier to the bracket on the frame crossmember. Tighten the fasteners 91 lbf·ft (123 N·m).

Troubleshooting

Problem—The Parking Brake Won't Hold the Vehicle on a Grade

Possible Cause	Remedy
The brake shoe linings are worn down.	Replace the brake shoes.
The brake drum is cracked.	Replace the drum.
The brake drum is worn down, or heavily scored.	Replace the drum.
The brake cable is binding.	Repair or replace the cable.
There is too much slack in the brake cable.	Adjust the brake cable.
The brake shoe linings have grease on them.	Replace the brake shoes, then clean the inside of the drum.

Problem—The Parking Brake Won't Release

Possible Cause	Remedy
The brake cable is too tight.	Adjust the brake cable.
The brake shoe return springs are missing, detached, or broken.	Check the return springs. Install them or replace them as needed.
The contact points between the brake shoe webs and the actuator strut are corroded or dirty.	Check the area, and clean and lubricate as needed.
The parking brake lever in the cab is binding.	Check the parking brake lever assembly for damage or corrosion. Repair or replace as needed.

Problem—The Parking Brake Makes Noises While the Vehicle Is Moving

Possible Cause	Remedy
The parking brake drum is loose.	Check the brake drum mounting bolts. Tighten as needed.
The brake shoes or backing plate is loose.	Check the brake shoes, return springs, and backing plate mounting bolts. Tighten, repair, or replace, as needed.
There is dirt inside the brake drum.	Remove the brake drum and clean it. Also clean the other brake parts.

Specifications

Description	Torque	
	lbf·ft (N·m)	lbf·in (N·cm)
Transmission End-Nut		
Fuller	325 (440)	—
Allison	145 (197)	
Support Plate Mounting Bolts	85 (115)	—
Brake Drum Mounting Bolts	45 (61)	—
Midship Bearing Carrier Mounting Bolts	91 (123)	—
Cable Bracket Jam Nut (on top of transmission)	—	80 (900)

Table 1, Fastener Torques

General Description and Principles of Operation

The dual circuit brake valve (foot valve) controls the air supply and delivery of the dual circuit brake system. The brake valve is mounted on the firewall. See **Fig. 1**.

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.

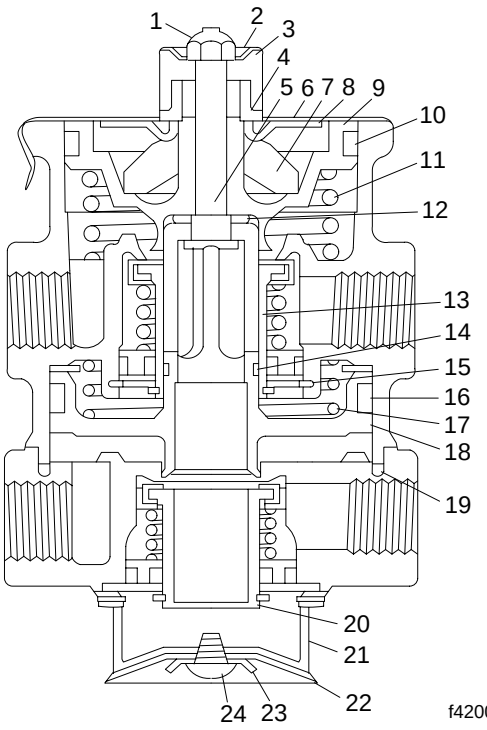
HOLDING

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.



1. Locknut
2. Spring Seat
3. Stem Spring
4. Spring Seat Nut
5. Primary Piston Stem
6. Primary Piston Retainer
7. Rubber Spring
8. Spring Seat
9. Primary Piston
10. Primary Piston O-Ring
11. Primary Piston Return Spring
12. Small Washer
13. Upper Inlet and Exhaust Valve Assembly
14. Small O-Ring
15. Retaining Ring
16. Large O-Ring
17. Relay Piston Spring (if equipped)
18. Relay Piston
19. Rubber Seal Ring
20. Lower Inlet and Exhaust Valve Assembly
21. Exhaust Cover
22. Exhaust Diaphragm
23. Washer
24. Phillips Head Screw

Fig. 1, Bendix E-6 Dual Circuit Foot Valve (sectional view)

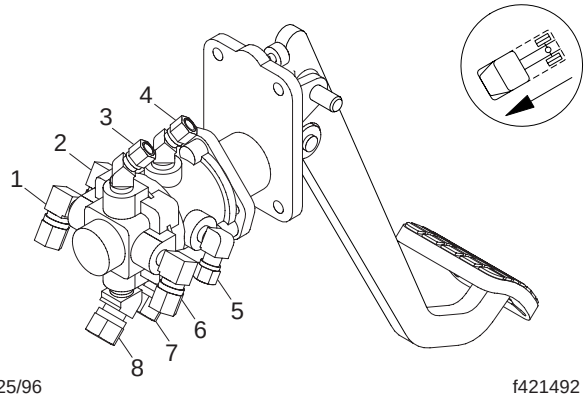
Bendix E–6 Brake Valve Operating and Leakage Checks

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 brakes' 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 the 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 on the brake valve. See **Fig. 1**.



1. Supply Circuit to Front Brake Valve
2. Primary Delivery Circuit to Tractor Protection Valve
3. Secondary Supply Circuit to Dash Valve
4. Primary Supply Circuit to Dash Valve
5. Delivery Circuit to Rear Brake 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).
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

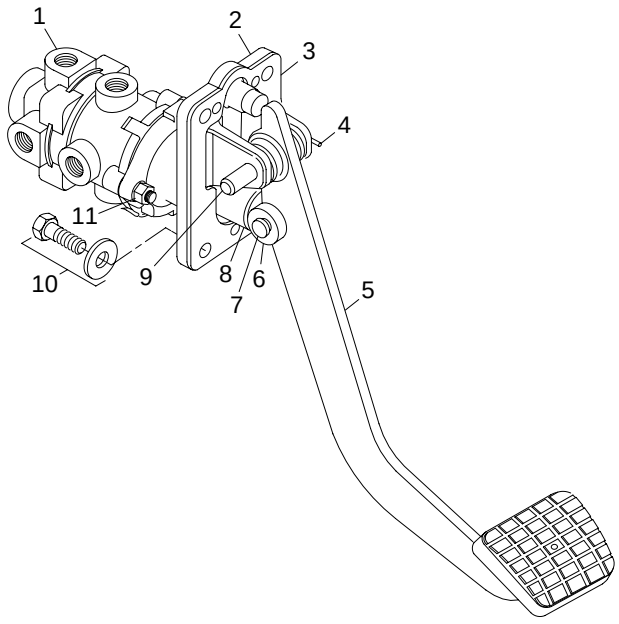
1. Make and hold a pressure application of 80 psi (552 kPa).
2. Check the air line fittings for leaks: tighten or replace fittings as needed.
3. Coat the exhaust port and body of the valve with a soap solution, and check for leakage. The leakage permitted is a one-inch bubble in 3 seconds.

   If tthe 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.

Bendix E–6 Brake Valve Removal and Installation

Removal



07/25/96 f421491

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

1. Chock the tires, then tilt the hood. For instructions, refer to the vehicle operator's manual.

⚠ WARNING

WARNING: When draining the air system, don't look into the air jets or direct them toward another person, because dirt or sludge particles may be in the airstream. Don't 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. See **Fig. 1**.
4. Remove the brake valve.
   - 4.1 Remove the 5/16-18 capscrews and flatwashers that attach the brake valve and mounting adaptor to the front cab mount plate.
   - 4.2 Remove the 5/16-18 locknuts and washers that attach the brake valve to the mounting adaptor.
   - 4.3 Remove the plunger from the mounting adaptor. Wipe off the old grease from the plunger and adaptor.
5. Note the locations and positions of the double check valves (if equipped), then remove them from the brake valve. Clean off the dirt and old sealant from the threads of the valves and elbows.

Installation

⚠ WARNING

WARNING: When applying sealant, make sure that excess sealant doesn't 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 each of the double check valves and the elbows.

   Install the double check valves and elbows in the ports of the brake valve. Tighten each valve finger-tight, then tighten them one additional turn with a wrench. As needed, further tighten them until they are properly positioned. See **Fig. 1**.
2. Lubricate the adaptor bore and the sliding surface of the brake plunger with an approved silicone-based grease, Dow Corning 55 O-Ring Lubricant (formerly Molykote DC–55M), or Loc-

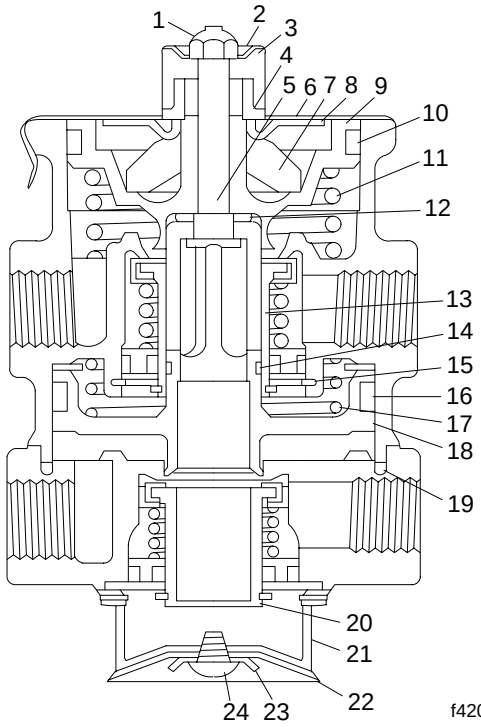
Bendix E–6 Brake Valve Removal and Installation

tite® V–755 O-Ring Lubricant. Install the plunger in the mounting adaptor.

3. Using the 5/16–18 locknuts and washers, attach the mounting adaptor to the brake valve. Tighten the capscrews 10–13 lbf·ft (14–18 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 10–13 lbf·ft (14–18 N·m).
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. For instructions, refer to the vehicle operator's manual.
8. Perform the operating and leakage checks. For instructions, refer to **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.

Bendix E–6 Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

Disassembly



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)

1. Remove the valve from the vehicle. See **Fig. 1**. For instructions, refer to **Subject 110**.
2. Remove the screw that attaches the exhaust diaphragm and washer to the exhaust cover.
3. Remove the four screws that attach the exhaust cover to the lower valve body.
4. Remove the lower inlet and exhaust valve assembly.
5. Remove the four hexhead capscrews and washers that attach the lower and upper valve bodies. Separate the valve bodies.
6. Remove the rubber seal ring from the lower valve body.
7. Apply thumb pressure to the primary piston, then lift out and up on the three lock tabs of the primary piston retainer.

⚠ WARNING

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.

8. Using a 3/8-inch wrench, hold the locknut on the threaded end of the primary piston stem. Insert a screwdriver in the exhaust passage through the center of the valve, and engage the slotted head of the stem.
9. Using the screwdriver to keep the stem from turning, remove the locknut, spring seat, and the stem spring.
10. Being careful to avoid damaging the valve seats, remove the relay piston, relay piston spring, and the primary piston and primary piston return spring.
11. Remove the small washer from the cavity in the lower side of the primary piston.
12. Turn the spring seat nut counterclockwise, and separate the spring seat nut, spring seat, and the rubber spring. Remove the primary piston O-ring.
13. Remove the small and large O-rings from the relay piston.

Bendix E–6 Brake Valve Disassembly, Cleaning and Inspecting, and Assembly

14. Remove the retaining ring. Remove the upper inlet and exhaust valve assembly.

Cleaning and Inspecting

Wash all metal parts in mineral spirits and dry them thoroughly with compressed air. Inspect the valve seat surfaces of the pistons and the valve housings for conditions that could cause leakage. Inspect air line fittings for corrosion, and replace corroded fittings.

Assembly

NOTE: Keep the work area, tools, and brake valve parts clean during assembly.

1. Using Dow Corning 55-M pneumatic grease, or equivalent, lightly grease all the new O-rings, O-ring grooves, piston bores, and all sliding surfaces. See **Fig. 1**.
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

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 (222 N). When installing these springs, use care to prevent them from flying out and possibly causing personal injury. Manually or mechanically hold down these springs when installing the locknut.

12. Push down and hold the primary and relay pistons in the upper valve body.
13. Place the stem spring over the spring seat nut. Place the spring seat over the stem.
14. Install the locknut on the stem. Tighten the locknut 20 to 30 lbf·in (220 to 340 N·cm).
15. Install the primary piston retainer over the piston. Make sure that all three lock tabs have engaged the outer lip of the valve body.
16. Install the rubber seal ring in the lower valve body.
17. Attach the lower and upper valve bodies. Install the four hexhead capscrews and washers. Tighten the capscrews 11 lbf·ft (15 N·m).
18. Install the lower inlet and exhaust valve assembly.
19. Install the four screws that attach the exhaust cover to the lower valve body.
20. Install the screw that attaches the exhaust diaphragm and washer to the exhaust cover.
21. Install the brake valve. For instructions, refer to **Subject 110**.

General Description

The Bendix hydraulic disk brake system consists of a power booster, a master cylinder and reservoir, hydraulic lines (both rigid and flexible), a brake rotor on each wheel hub, and a brake caliper and pad assembly at each rotor. See **Fig. 1**.

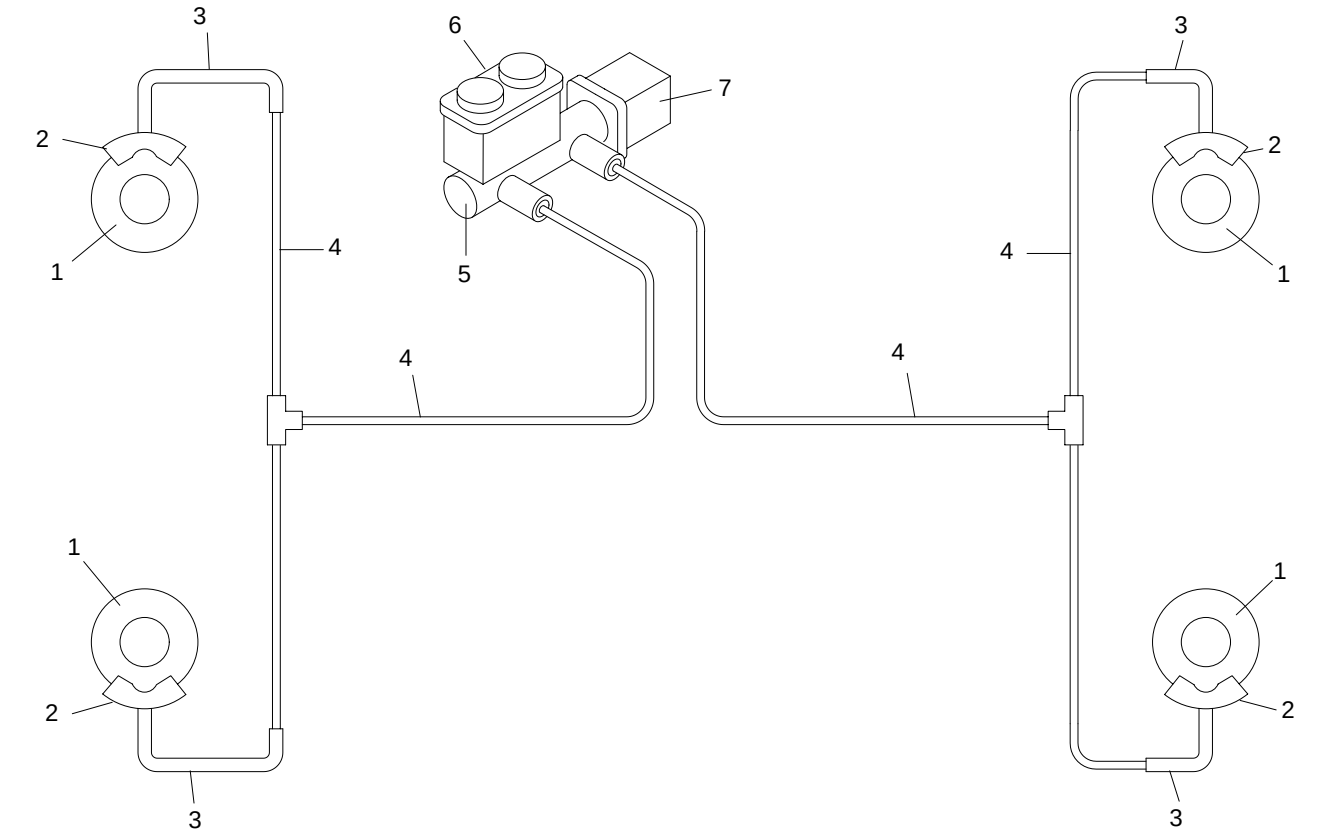
There are two completely separate hydraulic systems, which use different and incompatible hydraulic fluids, lines, and seals. See **Fig. 2**.

- The power booster system, which provides power to the brake master cylinder, and uses power steering fluid. It is plumbed into the power steering system.
- The service brake system, consisting of the master cylinder, the brake hydraulic lines, and the brake calipers. It uses DOT 3 approved brake fluid.

POWER BOOSTER

The Bendix Hydro-Max II® power booster, mounted on the firewall, is attached to the rear of the master cylinder. See **Fig. 3**. It consists basically of a reaction piston, a power piston assembly, an end-cap assembly, and a back-up electric pump.

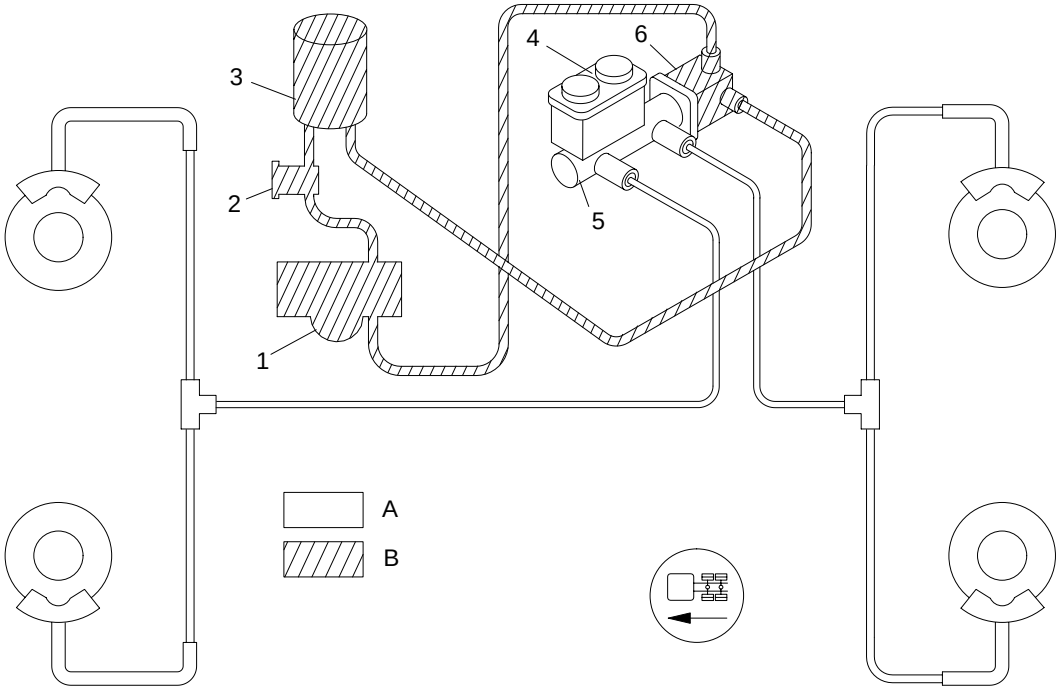
At the rear of the power piston—and inside it—is the reaction piston. The power piston assembly is connected to the brake pedal by way of the brake pedal



1. Rotor
2. Caliper and Pad Assembly
3. Flexible Brake Line
4. Rigid Brake Line
5. Master Cylinder
6. Reservoir
7. Power Booster

Fig. 1, Brake System Major Parts

General Description and Principles of Operation



03/07/94 f420369a

A. Brake System (brake fluid)
B. Brake Booster and Power Steering System (power steering fluid)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Brake Master Cylinder Reservoir
5. Brake Master Cylinder
6. Power Booster

Fig. 2, Brake System Major Parts

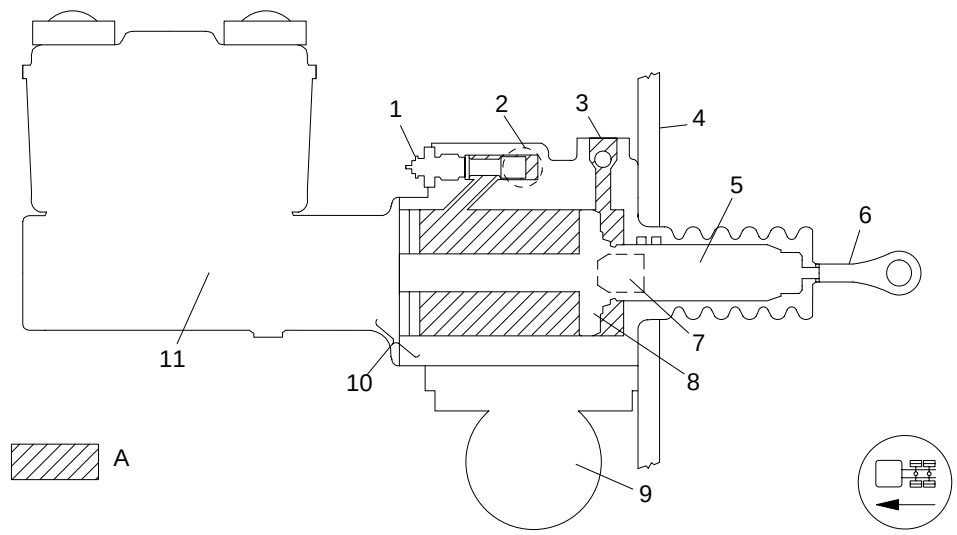
rod. Surrounding the reaction piston is the power piston assembly, the forward end of which fits through the end-cap assembly, and rests against the rear of the brake master cylinder. The end-cap assembly prevents the power steering fluid in the power booster from mixing with the brake fluid in the master cylinder.

The power booster is connected to the vehicle's power steering system, which supplies it with pressurized power steering fluid. The power booster supply port is connected to the power steering pump via the steering gear, and the return port is connected to the power steering reservoir. A flow switch activates the back-up pump if, for any reason, the power steering pump doesn't supply the power booster with fluid.

MASTER CYLINDER

The brake master cylinder functions as a dual supply system: the primary system supplies pressurized brake fluid to the rear brakes; the secondary system supplies it to the front brakes. See **Fig. 4**. For safety, each system is independent of the other, so a problem with one set of brakes won't affect the function of the other.

The master cylinder, attached to the front of the power booster, consists mainly of the primary pressure chamber, the primary piston/actuator assembly and return spring, the primary reservoir section, and the secondary pressure chamber, piston/actuator assembly, return spring, and reservoir section. See **Fig. 5**. Both pressure chambers have outlet ports that connect them to either the front or rear brake caliper assemblies by way of hydraulic lines. At the bottom of each reservoir section is a compensating



NOTE: Not all parts are shown.

A. Power Steering Fluid

1. Flow Switch
2. Return Port
3. Supply Port
4. Firewall
5. Rubber Boot
6. Brake Pedal Rod
7. Reaction Piston
8. Power Piston Assembly
9. Backup Electric Pump
10. End-Cap Assembly
11. Master Cylinder and Reservoir

Fig. 3, Power Booster Assembly

valve, which when open, connects that reservoir section with the applicable pressure chamber in the master cylinder. A pressure differential valve operates a pressure differential switch (not shown), which activates a dash warning system, should one brake system not work.

BRAKE CALIPER ASSEMBLIES

Each brake caliper assembly, attached to a wheel, consists of a housing with dual cylinders and pistons, a supply port, and a bleeder fitting. See **Fig. 6** and **Fig. 7**. The assembly fits over the rotor like a "U", with the pistons on the inboard face of the rotor. The caliper fits onto an anchor plate at the top and bottom, and the anchor plate is attached to the axle. The caliper is held in place on the anchor plate by a key, a spring (not shown), and bolt. The brake pads fit into slots in the caliper housing.

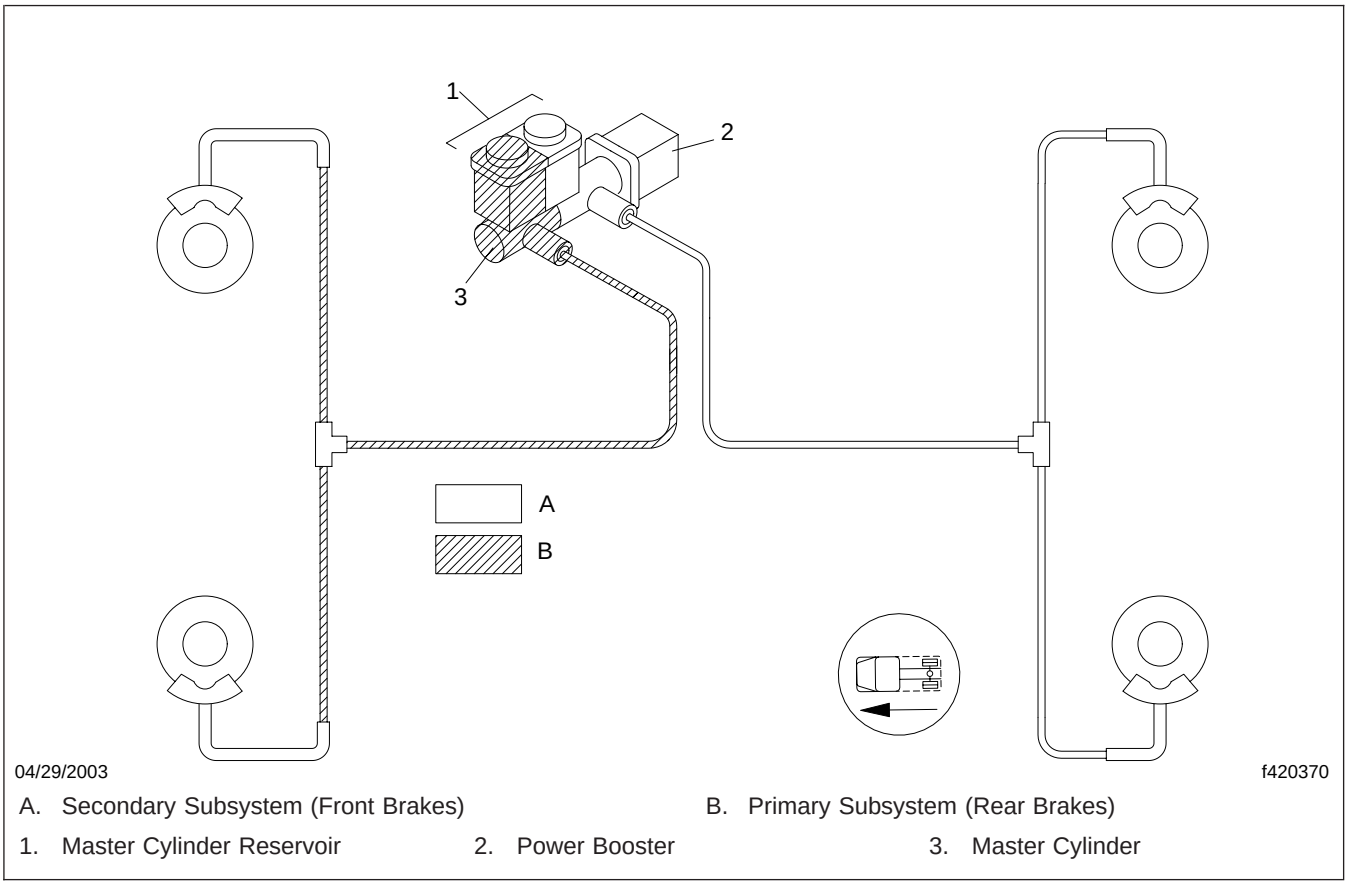
BRAKE CONTROL MODULE

The brake control module, located on the firewall (under the dash), monitors electronic signals from various sensors in the brake system. If a problem is detected, the module activates the applicable warning light and buzzer on the dashboard.

The control module has nine input terminals and three output terminals (one terminal is a ground). The output terminals are used for the brake system pressure and parking brake warning lights, and a buzzer; the input terminals are connected to sensors in the brake system that detect problems. See **Fig. 8**.

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.

General Description and Principles of Operation



A. Secondary Subsystem (Front Brakes)
B. Primary Subsystem (Rear Brakes)
1. Master Cylinder Reservoir
2. Power Booster
3. Master Cylinder

Fig. 4, Plumbing Diagram

Principles of Operation

APPLYING THE BRAKES

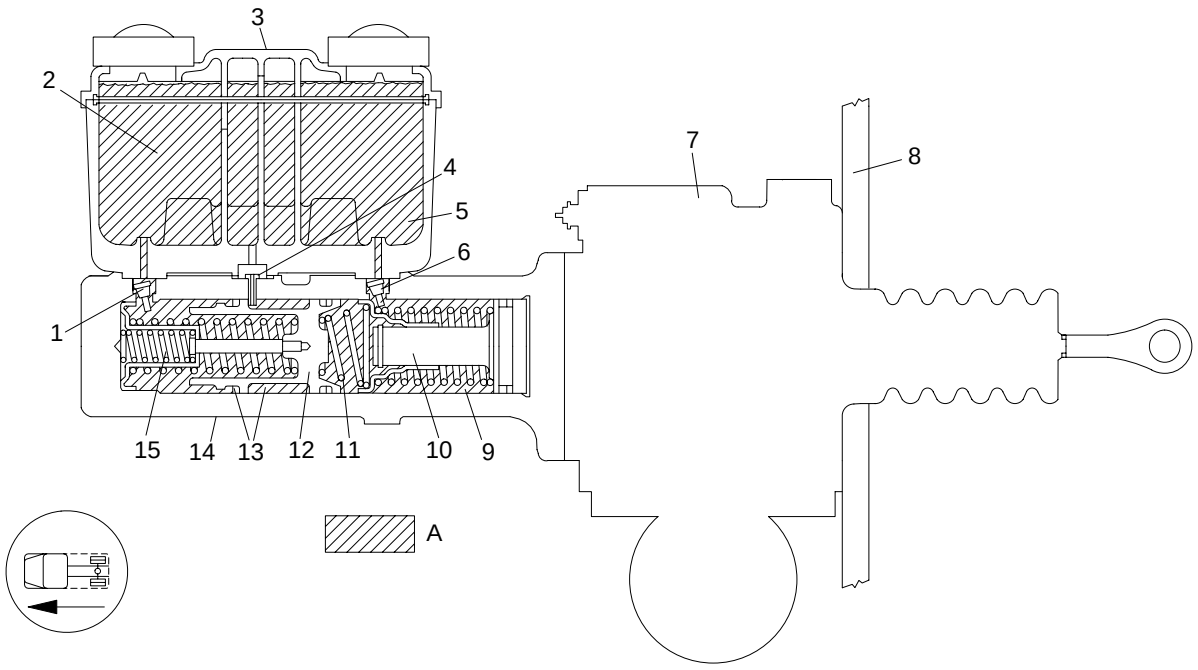
When the brake pedal is applied, the brake pedal rod pushes the actuator pin which pushes the reaction piston forward inside the power piston. See **Fig. 9**. This closes the pressure valve, which restricts the flow of power steering fluid through the power piston. The increased fluid pressure pushes the power piston forward, through the end-cap assembly, and into the master cylinder primary piston/actuator assembly.

As the primary piston/actuator assembly moves forward in the master cylinder, the primary compensating valve closes. This closes the outlet to the primary reservoir section, and causes hydraulic pressure to build up in the primary pressure chamber.

The primary piston/actuator assembly continues moving forward, and moves the secondary piston/actuator assembly. This closes the secondary compensating valve, pressurizing the secondary pressure chamber.

The primary and secondary pressure chambers are connected by outlet ports (not shown) to the primary and secondary brake lines and caliper assemblies. When pressurized brake fluid enters the caliper housings from the brake lines, the dual pistons in each caliper move outward toward the rotors, pushing the inboard brake pads against the rotors. At the same time, the caliper assemblies slide slightly inboard, causing both inboard and outboard pads to squeeze the rotors tightly, which slows down or stops the wheels.

If for any reason the power steering pump doesn't supply the power booster with fluid, the flow switch assembly turns on the electric pump and closes the return port. The check valve in the power booster supply port closes, and the check valve in the elec-



07/16/2003 f420376

NOTE: Not all parts are shown.

A. Brake Fluid

1. Secondary Compensating Valve (open)
2. Secondary Reservoir Section
3. Brake Fluid Reservoir
4. Piston Stop
5. Primary Reservoir Section
6. Primary Compensating Valve (open)
7. Power Booster Assembly
8. Firewall
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 Components

tric pump opens. The electric pump then recirculates the fluid in the power booster, maintaining emergency pressure. This provides enough reserve power for the master cylinder to pressurize the brake lines.

RELEASING THE BRAKES

When the brake pedal is released, a return spring in the power booster pushes the power piston and the reaction piston (inside the power piston) toward the rear of the booster housing, and away from the master cylinder primary piston/actuator assembly. This reduces the fluid pressure in the power booster.

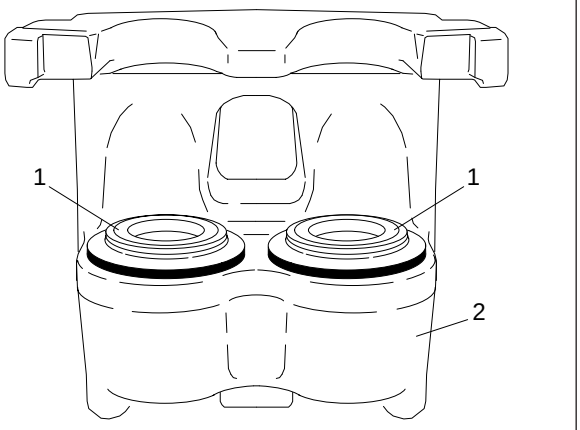
In the master cylinder, the return springs center the primary and secondary pistons. This opens up the primary and secondary compensating valves, decreasing hydraulic pressure throughout the master cylinder. The pressure in the hydraulic lines drops, which allows the dual pistons in each caliper housing to retract. The calipers slide back outboard, and the brake pads no longer squeeze the rotors, allowing the rotors and wheel hubs to turn freely.

BRAKE CONTROL MODULE

The control module, which operates on 9 to 16 volts DC, is active (monitoring the hydraulic brake system) under any of the following conditions:

- When the ignition is on;
- When the brake pedal switch is powered;

General Description and Principles of Operation



1. Piston 2. Housing

Fig. 6, Brake Caliper

- 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 control module starts a self-test mode, which lasts from about one to three seconds. The warning lights and buzzer come on, then go off if the system is working all right. The module then goes into the active mode, monitoring the hydraulic brake system. If a problem is detected, the applicable input or output terminal is activated, and a warning light and buzzer come on. The output terminals are activated as follows:

The "R" light (brake pressure) output—terminal 3—is activated when any of the following conditions exist:

- The flow switch on the power booster closes, due to a reduced flow of power steering fluid;
- The pressure differential switch on the master cylinder closes, due to a drop in pressure in either the front or rear brake system;
- The fluid level switch on the master cylinder reservoir closes, due to a drop in the fluid level;
- Too much electrical resistance is in the backup pump motor.

The "P" light (parking brake) output—terminal 2—is activated when any of the following conditions exist:

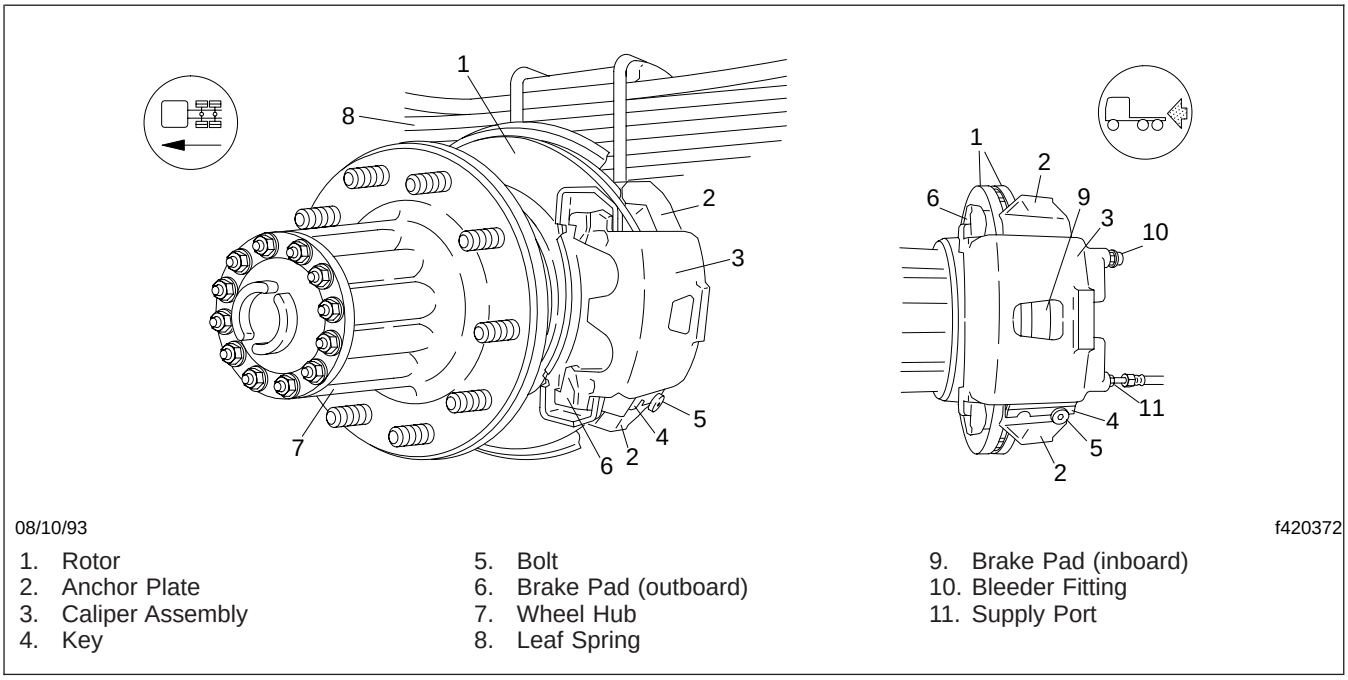
- The parking brake is applied, and the ignition is on;
- The driver's door is open, the parking brake is not applied, and the ignition is off. This condition will also cause the control module buzzer to come on.

NOTE: The vehicle is equipped with two dash buzzers: one on the control module itself, which comes on when the light "P" output (parking brake) is activated due to the driver's door being open and the parking brake not applied; and one mounted separately from the control module, which comes on when the light "R" output (brake system pressure) is activated.

See **Table 2** for information on when the input terminals are activated.

Control Module Terminal Identification		
Terminal Number	**Function**	**Circuit Number**
1	Light "P" (Parking Brake) Output	394
2	Buzzer Output	396
3	Light "R" (Brake System Pressure) Output	390
4	Ground	GND
7	Ignition Input	388
8	Parking Brake Input	309
9	Relay Input	389
10	Door Open Input	397
11	Pressure Differential Switch Input	36F
12	Brake Pedal Input	500
13	Pump Motor Input	398
14	Fluid Level Input	395
15	Flow Switch Input	393

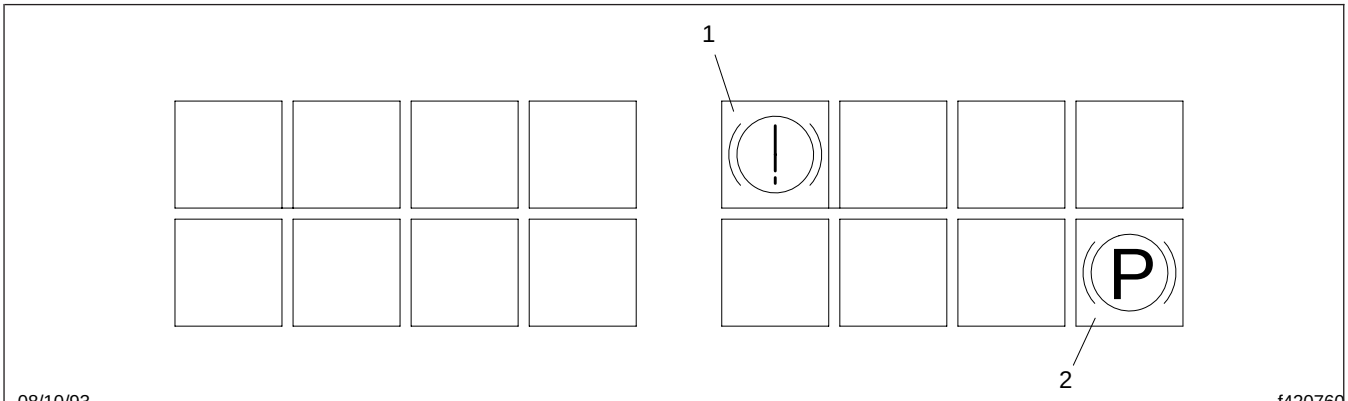
Table 1, Control Module Terminal Identification



08/10/93 f420372

1. Rotor
2. Anchor Plate
3. Caliper Assembly
4. Key
5. Bolt
6. Brake Pad (outboard)
7. Wheel Hub
8. Leaf Spring
9. Brake Pad (inboard)
10. Bleeder Fitting
11. Supply Port

Fig. 7, Rear Brake Caliper



08/10/93 f420760

1. Brake System Pressure
2. Parking Brake

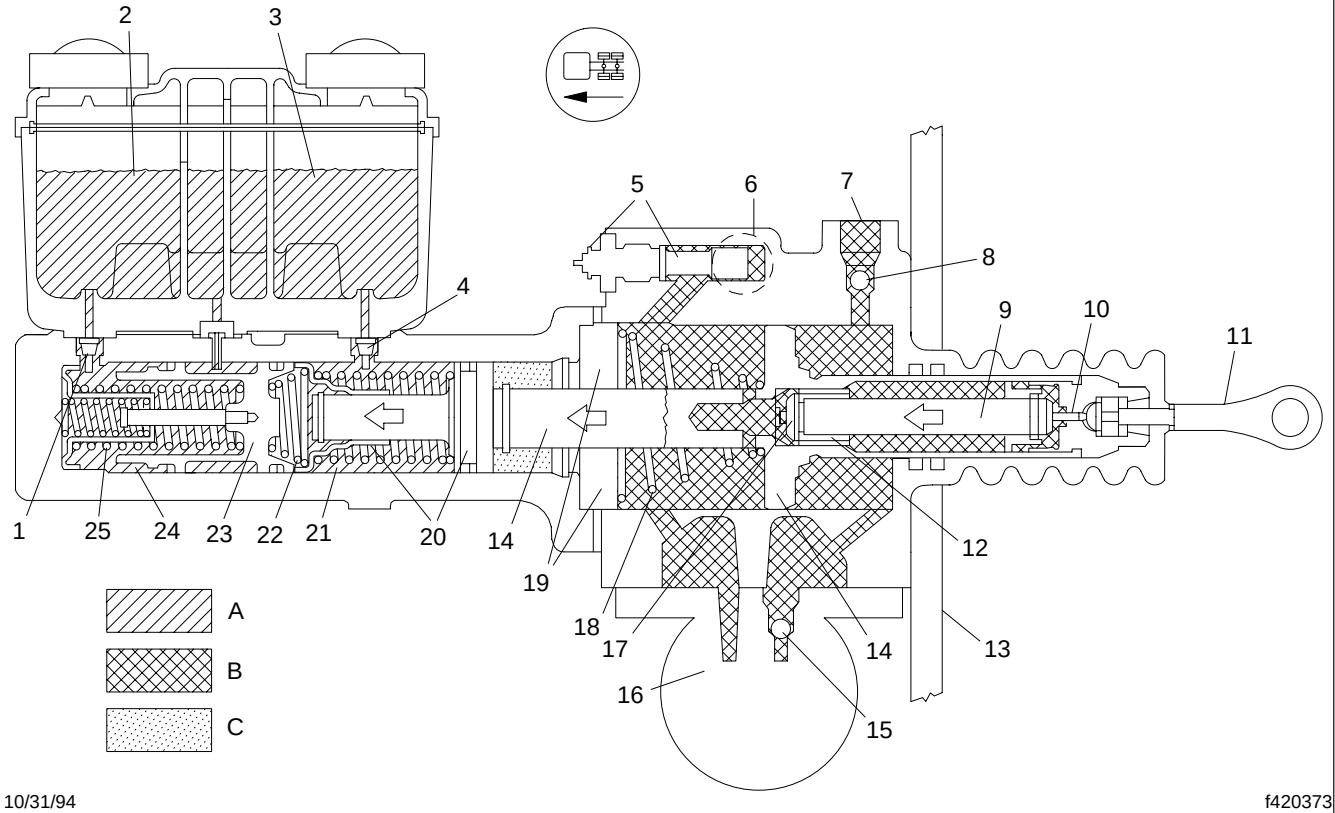
Fig. 8, Warning Lights

Input Terminals Activated			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
7	Ignition Input	388	The ignition is on.
8	Parking Brake Input	309	Parking brake is applied.

General Description and Principles of Operation

Input Terminals Activated			
Terminal Number	**Function**	**Circuit Number**	**Activated if**
9	Relay Input	389	The ignition is on or brake pedal is depressed.
10	Door Open Input	397	Driver's door open, and parking brake not applied.
11	Pressure Differential Switch Input	36F	Pressure difference between front and rear systems becomes more than 70 psi (483 kPa).
12	Brake Pedal Input	500	Brake pedal depressed.
13	Pump Motor Input	398	Electrical resistance of backup pump motor too high.
14	Fluid Level Input	395	Fluid level of master cylinder below 25 percent capacity.
15	Flow Switch Input	393	No hydraulic flow through power booster.

Table 2, Input Terminals Activated



NOTE: Not all parts shown.

A. Brake Fluid
B. Power Steering Fluid
C. Air Space

1. Secondary Compensating Valve
2. Secondary Reservoir Section
3. Primary Reservoir Section
4. Primary Compensating Valve
5. Flow Switch Assembly
6. Return Port
7. Supply Port
8. Check Valve (shown open)
9. Pressure Regulator Assembly
10. Actuator Pin
11. Brake Pedal Rod
12. Reaction Piston
13. Firewall
14. Power Piston
15. Check Valve (shown closed)
16. Electric Motor Pump Assembly
17. Pressure Valve
18. Return Spring
19. End-Cap Assembly
20. Primary Piston/Actuator Assembly
21. Primary Pressure Chamber
22. Primary Piston Return Spring
23. Secondary Piston/Actuator Assembly
24. Secondary Pressure Chamber
25. Secondary Piston Return Spring

Fig. 9, Brake System Operation

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. 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.

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

Safety Precautions

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.

Hydraulic System Bleeding

⚠ WARNING

WARNING: Before doing any of the work below, read the information under Safety Precautions, 100. Failure to read the safety precautions, and to be aware of the dangers of brake fluid, could result in injury.

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

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 don't use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Don't let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Don't let it get on brake pads or rotors.

PRESSURE BLEEDING, SERVICE BRAKE SYSTEM

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. Apply the parking brake, chock the tires, and tilt the hood.

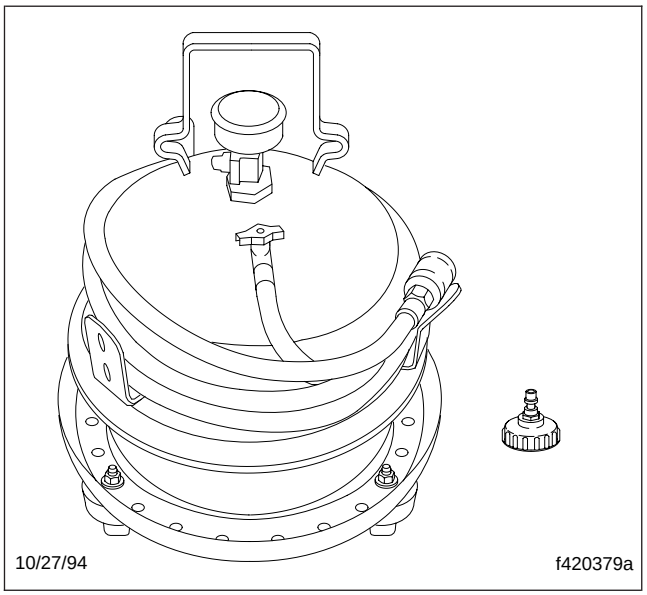


Fig. 1, Pressure Bleeder Kit

2. Connect the pressure bleeder to the brake master cylinder reservoir, following the manufacturer's instructions.
3. Fill the pressure bleeder with new DOT 3 approved brake fluid, then pressurize it according to the manufacturer's instructions.
4. Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.
5. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.
   - 5.1 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**.
   - 5.2 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. See **Fig. 2** and **Fig.3**. Then tighten the fitting firmly.
   - 5.3 Move to the left rear caliper, and repeat steps for bleeding the caliper.

Hydraulic System Bleeding

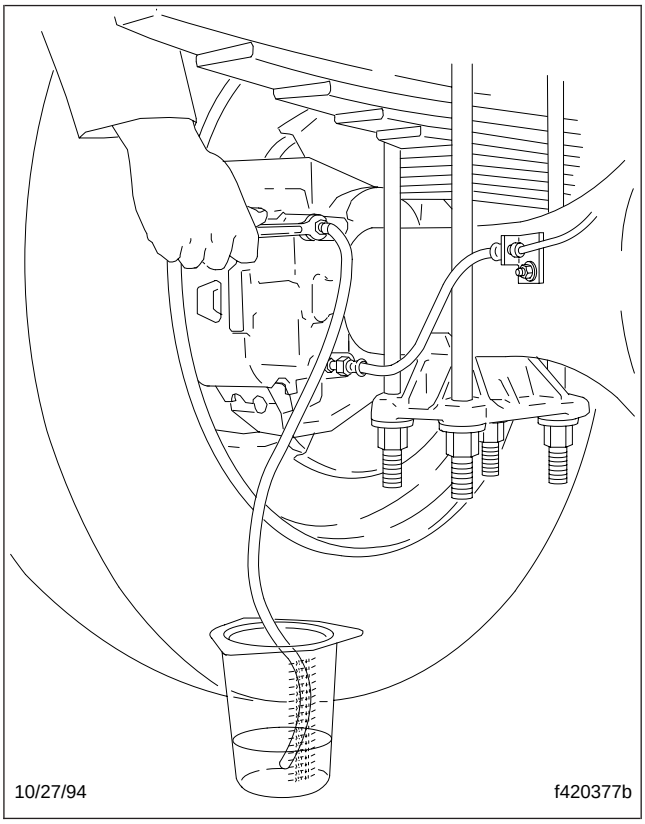
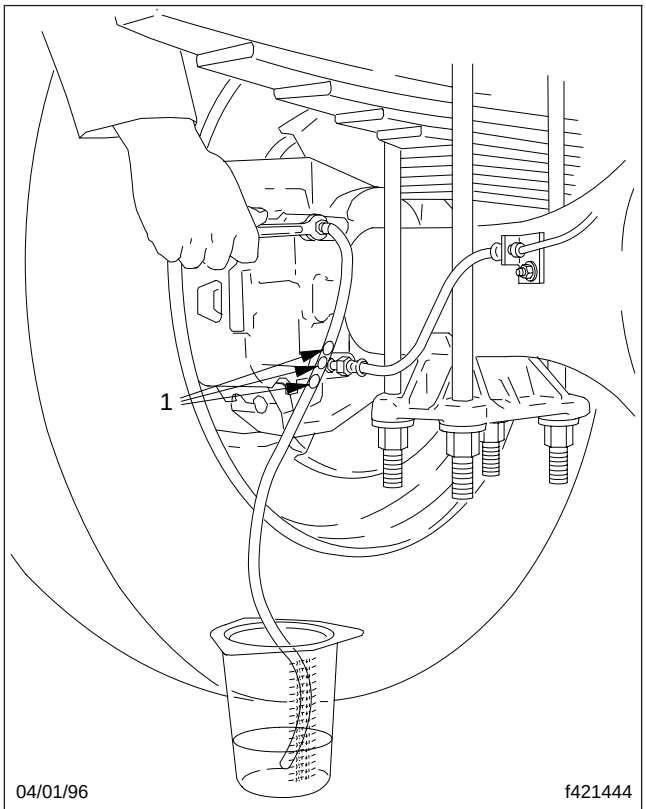


Fig. 2, Submerge the Tubing in a Container

6. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir, then connect it to the front compartment of the reservoir.
7. Bleed the front wheel brake calipers, starting at the right side.
   - 7.1 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** .
   - 7.2 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. See **Fig. 2** and **Fig.3**. Then tighten the fitting firmly.
   - 7.3 Move to the left front wheel caliper, and repeat steps for bleeding the caliper.



1. Air Bubbles

Fig. 3, Loosen the Bleeder Fitting

8. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
9. 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, go to **Troubleshooting, 300** and find the problem.
10. Lower the hood and remove the chocks.

MANUAL BLEEDING, SERVICE BRAKE SYSTEM

If you don't have pressure bleeding equipment, you can use the manual bleeding procedure.

⚠ WARNING

WARNING: Read over the information under Safety Precautions, 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: Don't 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. Apply the parking brake, chock the tires, and tilt the hood.
2. Bleed the master cylinder.
   - 2.1 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.4**. Loosen the fitting about one turn.

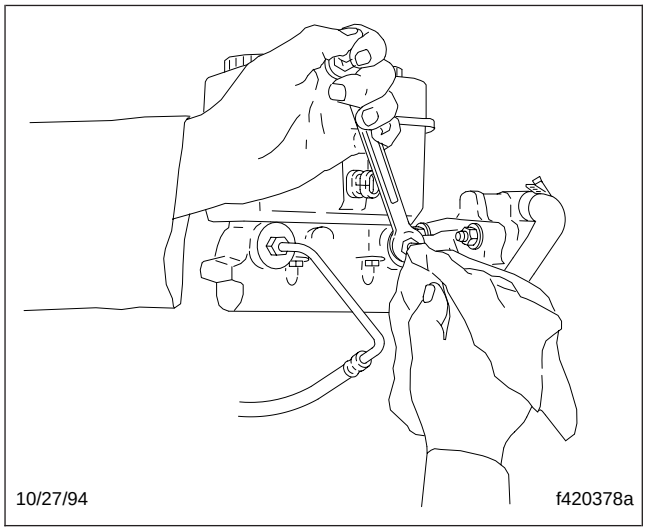


Fig. 4, Loosen the Fitting at the Rear Outlet Port

   - 2.2 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.
   - 2.3 *With the brake pedal held down,* tighten the rear hydraulic line fitting firmly.

IMPORTANT: Don't release the brake pedal until the fitting is tightened, or more air will get into the system.

   - 2.4 Release the brake pedal.
   - 2.5 Loosen the fitting again, and repeat steps for bleeding as required until no air escapes from the fitting, and the brake pedal feels firm.
   - 2.6 Check the level of the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.
   - 2.7 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.5**. Loosen the fitting about one turn.

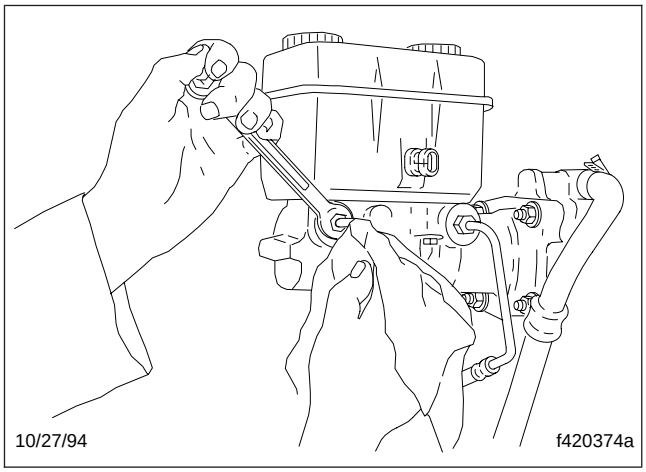


Fig. 5, Loosen the Fitting at the Front Outlet Port

   - 2.8 Repeat steps as required for the front outlet port.
   - 2.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.
3. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.
   - 3.1 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

Hydraulic System Bleeding

fits snugly. Submerge the tubing in a container of clean brake fluid. See **Fig.2**.

3.2 Loosen the bleeder fitting about 3/4 turn.

3.3 Have someone slowly push the brake pedal to the floor, then *with the brake pedal depressed,* tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it's released before you tighten the fitting, more air will get into the system.

3.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present, repeat steps as required until the fluid in the tube is completely free of air bubbles. See **Fig. 2** and **Fig. 3**.

3.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

3.6 Repeat steps for bleeding the connections for the left rear caliper, then the right front caliper, and finally for the left front caliper.

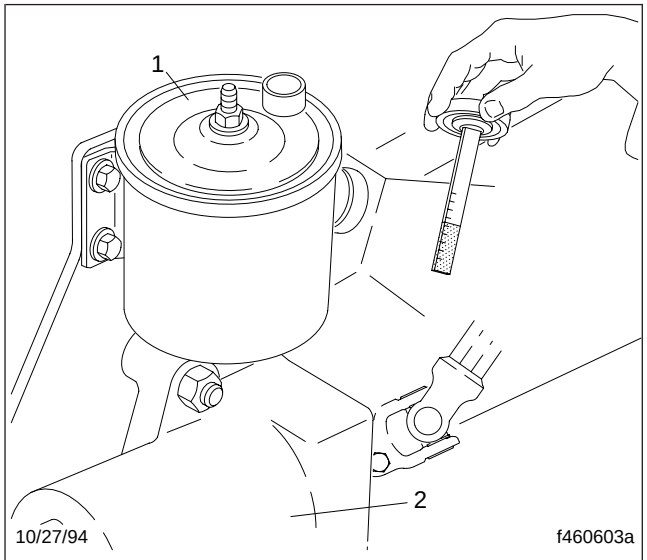
4. Lower the hood and remove the chocks.

Booster Bleeding

⚠ WARNING

WARNING: Use only clean, approved power steering fluid for the procedure below. Do not use brake fluid. Mixing brake fluid with power steering fluid will damage the seals and O-rings in the power booster, the power steering pump, and the power steering gear, resulting in possible loss of steering and personal injury.

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Check the level of fluid in the power steering reservoir. See **Fig. 1**. If needed, fill it with approved power steering fluid. See **Specifications, 400** for approved power steering fluid.



1. Power Steering Fluid Reservoir
2. Steering Gear

Fig. 1, Check the Fluid Level

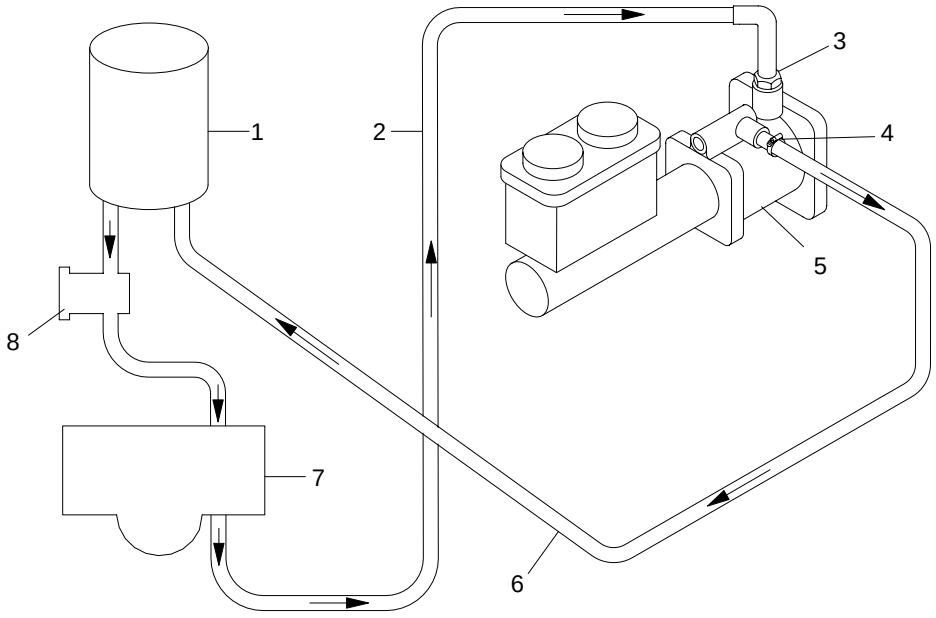
3. Crank the starter several times, but don't start the engine.
4. Check the fluid level in the power steering reservoir. Fill it if needed.
5. Crank the starter and check the fluid level again.
6. Check the operation of the brakes.
   - 6.1 With the engine off, depress the brake pedal. The dash warning light and buzzer should come on, and the electric motor assist should come on.
   - 6.2 Start the engine. Depress the brake pedal. The dash warning light and buzzer should not come on; neither should the electric motor. If they do, go to **Troubleshooting, 300** and find the problem; otherwise, stop the engine. Check the fluid level in the power steering reservoir. Fill it if needed.
7. Lower the hood, then remove the chocks.

Replacing Hydraulic Lines

POWER BOOSTER SYSTEM

The power booster is plumbed into the power steering system, and uses the same type of high pressure rubber hoses as that system.

The power booster has two hoses connected to it: one from the steering gear to the booster supply port, and one from the booster return port to the power steering reservoir. See **Fig. 1**.



04/23/2003 f420463a

1. Power Steering Reservoir
2. Hydraulic Supply Line
3. Steel Fitting
4. Hose Clamp
5. Power Booster
6. Hydraulic Return Line
7. Power Steering Gear

Fig. 1, Power Booster Plumbing

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Replace the power booster hoses if they are leaking or show signs of cracking, softening, or bulging. Replace the entire hose if there are problems; don't repair it.

   2.1 Remove all hose clamps and tie straps used for routing the hose.

   2.2 Using a shop towel over the fittings to catch any power steering fluid, disconnect both ends of the hose being replaced.

   2.3 Install the new hose.

   If replacing the booster supply hose, tighten the supply port connection 22 lbf·ft (30 N·m), and the outlet connection on the power steering gear 41 lbf·ft (56 N·m).

   If replacing the booster return hose, tighten the hose clamps at the booster return fitting and the power steering reservoir firmly.

   2.4 Install the hose clamps and replace any tie straps removed above.

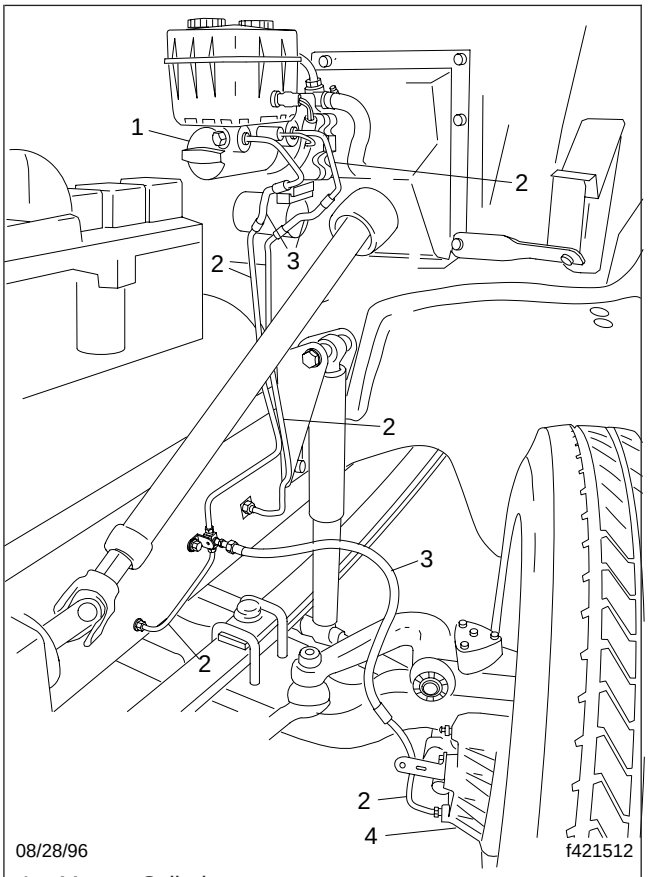
   Check the routing of the hose. Make sure it's away from heat sources and moving parts, such as the steering driveline.
3. Bleed the power booster system, following the instructions under **Subject 115** for instructions.

Replacing Hydraulic Lines

4. Lower the hood, then remove the chocks.

SERVICE BRAKE SYSTEM

The service brake system has two types of hydraulic brake lines: rigid steel tubing and flexible rubber hose. See **Fig. 2**.



1. Master Cylinder
2. Steel Tubing
3. Rubber Hose
4. Caliper

Fig. 2, Service Brake System Brake Lines

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.

If a brake line is leaking, replace the whole section of line. Replace flexible brake hoses if they show signs of cracking, softening, or bulging.

1. Apply the parking brake and chock the tires.
2. Locate the leak in the brake line, then determine the length and configuration (if a steel line) of the section involved.
3. If necessary, loosen and remove any brackets holding the brake line to the frame or axle, so that you can remove the damaged section.
4. Put a container under the connection on one side of the leak, then disconnect the line. Plug both ends of the connection.

   Repeat at the connection on the other side of the leak.
5. Remove the plugs installed earlier, then install the new section of brake line, and tighten the connections 15 lbf·ft (20 N·m).
6. Install any brackets that were removed above.
7. Bleed the brake system, following the procedure under **Subject 110**.

Replacement

WARNING

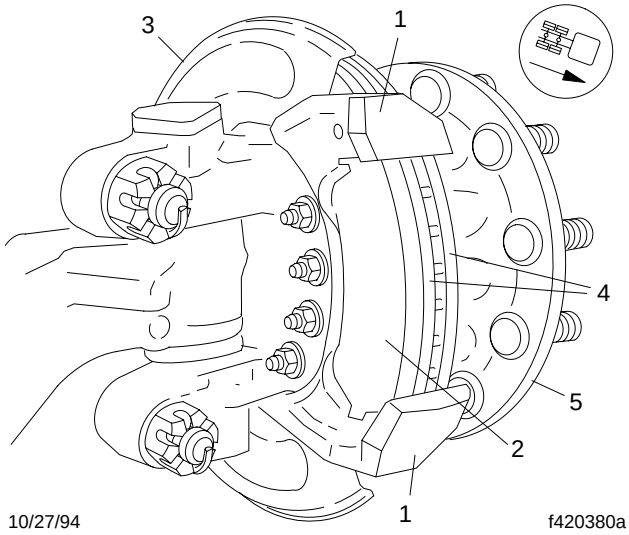
WARNING: Before starting the procedure below, read the information in Safety Precautions, 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

IMPORTANT: When replacing brake pads, always replace them on both wheels of the axle (right and left side). If the brake pad linings are worn down to the minimum thickness of 1/16 inch (1.6 mm), you must also rebuild the calipers, as dirt has probably gotten into the caliper cylinders. Refer to **Subject 140** and **Subject 145** for instructions.

1. Apply the parking brake and chock the tires of the axle you will not be working on.
2. Remove the brake caliper from the wheel. Refer to **Subject 140** for instructions.
3. Remove the brake pads.
   - 3.1 Remove the outboard brake pad from the caliper assembly.
   - 3.2 Pull the inboard pad away from the rotor and the anchor plate. See **Fig.1**.
4. Using a wet rag that is wrung out until nearly dry, clean the caliper housing (especially around the piston boots), and the dust shield.
5. Check the rotor.
   - 5.1 Check the rotor surface for discoloration, cracks, scoring, and heat checking. See **Fig.2**.

     If the rotor is cracked, has a bluish color, or has severe heat checking, replace it. If it has minor heat checking or is scored, have it resurfaced.

     IMPORTANT: If the rotor will be 1.32 inches (33.5 mm) or less after it's resurfaced, replace it.
   - 5.2 Using a vernier caliper, check the thickness of the rotor. If it is less than 1.32 inches (33.5 mm) thick, replace it.

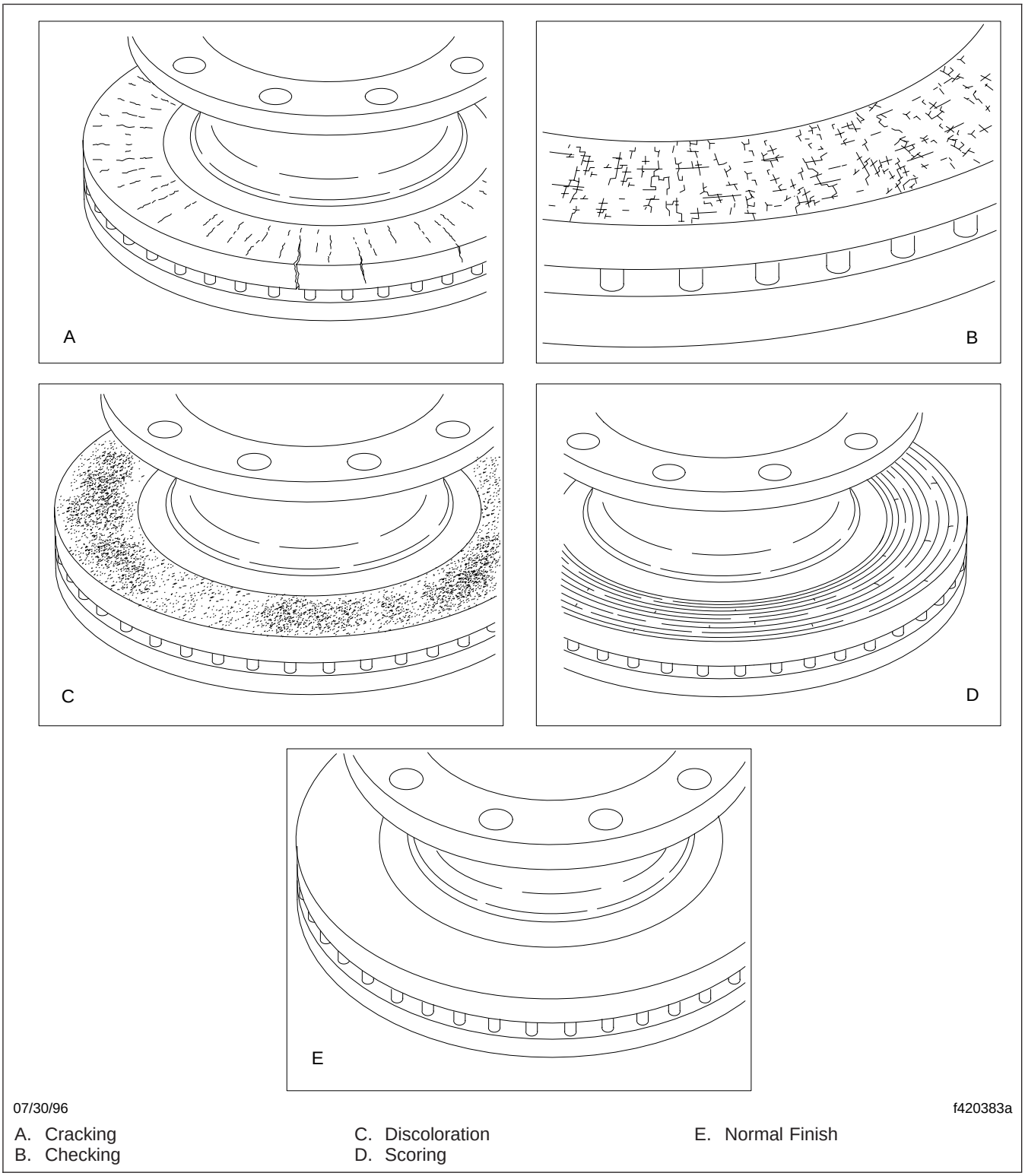


1. Anchor Plate
2. Inboard Brake Pad
3. Dust Shield
4. Rotor
5. Wheel Hub

Fig. 1, Left Front Wheel Shown (caliper removed)

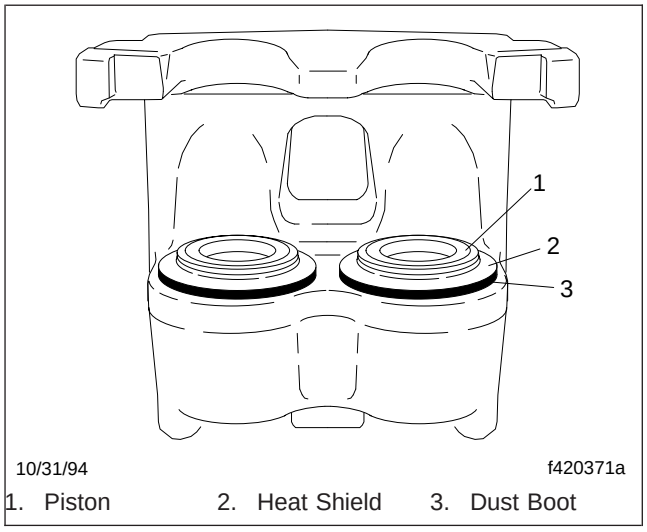
   - 5.3 Check for runout and parallelism. Refer to **Subject 155** for instructions.
6. Check the caliper.
   - 6.1 Check the piston dust boots for cracks or leaks. See **Fig.3**. Also check the piston heat shields for damage. If a problem is found, disconnect the brake hose from the caliper, plug the hose, then rebuild the caliper, following the instructions under **Subject 145**.
   - 6.2 Check the supply port and bleeder fitting ( ) on the caliper housing for damage or leaks. See **Fig.4**. If a problem is found, replace the fitting, following the instructions under **Subject 145**.
7. Clean and lubricate the sliding surfaces (V-ways) of the caliper housing and the anchor plate rails with anti-corrosion grease. See **Fig.5**.
   - 7.1 Using a fine file or emery cloth, clean the sliding surfaces (V-ways) of the caliper housing, and the corresponding surfaces of the anchor plate.

Brake Pad Replacement



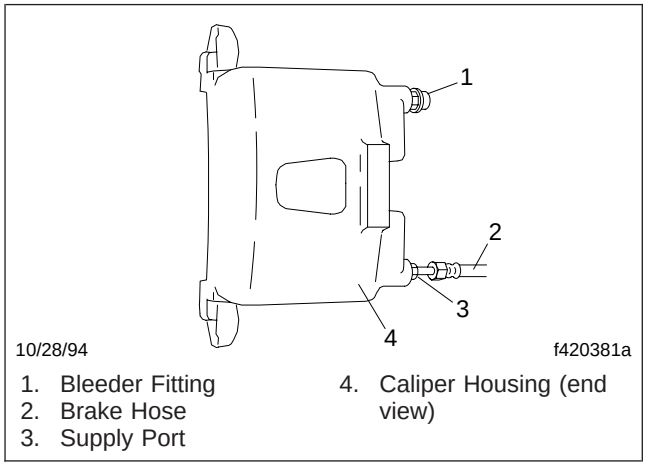
A. Cracking
B. Checking
C. Discoloration
D. Scoring
E. Normal Finish

Fig. 2, Check the Rotor Surface



1. Piston 2. Heat Shield 3. Dust Boot

Fig. 3, Check the Piston Dust Boots



1. Bleeder Fitting
2. Brake Hose
3. Supply Port
4. Caliper Housing (end view)

Fig. 4, Check the Supply Port and Bleeder Fitting

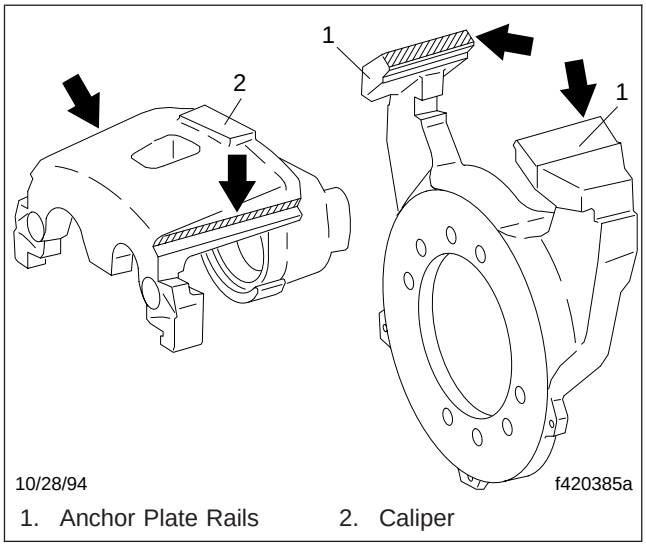
7.2 Grease the surfaces lightly with anti-corrosion grease.

8. Install the new brake pads.

WARNING

WARNING: Don't get any dirt, oil, grease, or brake fluid on the brake lining material or the rotor surfaces. To do so could cause loss of brake control, which could result in an accident causing personal injury or property damage.

8.1 Install the inboard (smaller) brake pad into the mating notches of the anchor plate, as shown in **Fig.1**. Make sure the pad lining is facing the rotor.



1. Anchor Plate Rails 2. Caliper

Fig. 5, Clean and Lubricate

8.2 Using a piece of wood and a C-clamp, push the pistons all the way into the caliper housing. See **Fig.6**. Be careful not to damage the piston heat shields. Remove the C-clamp and block of wood.

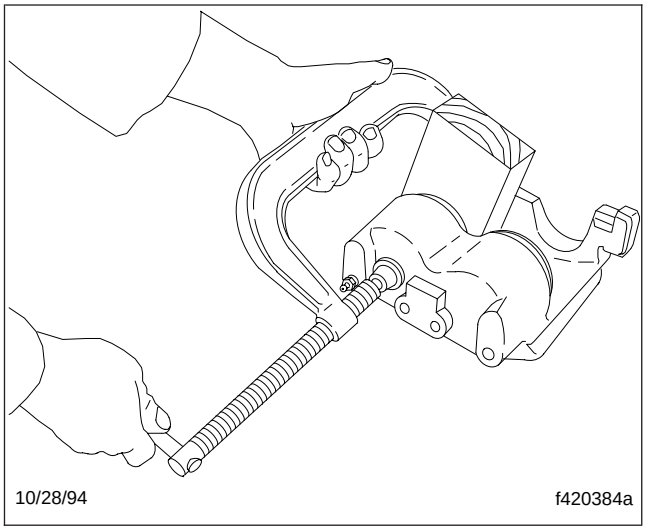
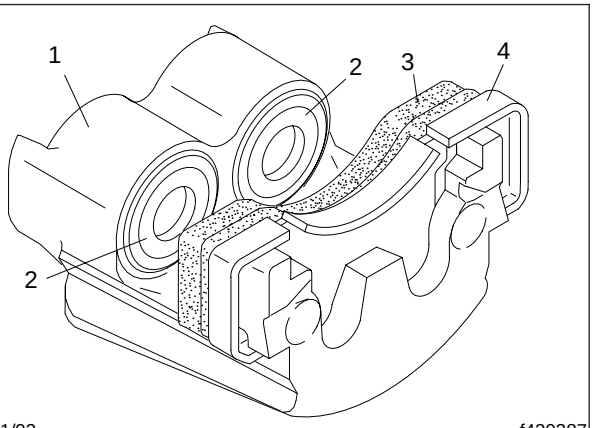


Fig. 6, Push the Pistons into the Caliper Housing

8.3 Install the outboard (larger) brake pad in the housing, with the pad lining facing the piston, as shown in **Fig.7**.

Brake Pad Replacement



1. Caliper Housing
2. Pistons
3. Brake Pad Lining
4. Outboard Brake Pad

Fig. 7, Install the Outboard Brake Pad

9. Install the caliper, following the instructions under **Subject 140**.
10. Install the tires, then remove the jackstands and lower the vehicle. Remove the chocks.
11. Pump the brake pedal until it feels firm. If it doesn't get firm, check for leaks or air in the brake system. Repair any leaks, if needed, then bleed the system, following the instructions under **Subject 110**.

⚠ WARNING

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.

12. Road test the vehicle, and seat the brake pads.

    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.*

    Repeat this step between 20 and 30 times, allowing a one-minute interval between brake applications.

Brake Caliper Removal and Installation

Removal

WARNING

WARNING: Before starting the procedure below, read the 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.

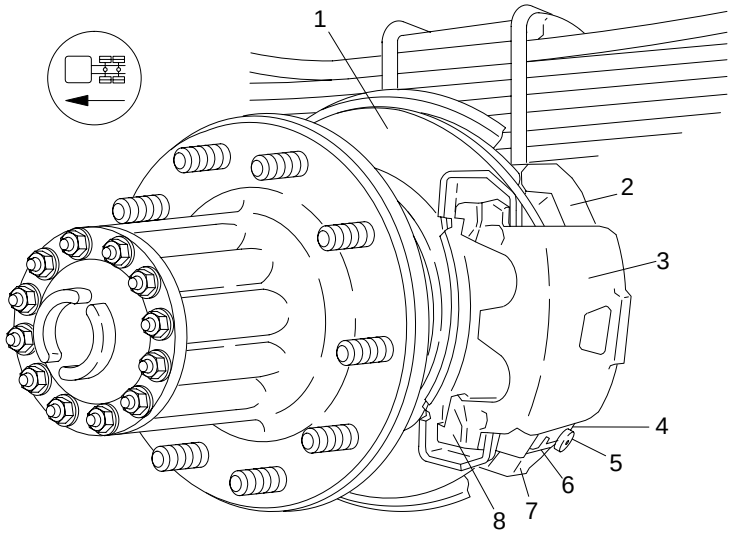
1. Apply the parking brake, chock the tires, and tilt the hood.
2. If you are removing the rear wheel caliper(s), remove half the fluid from the rear section of the master cylinder reservoir. If you are removing the front wheel caliper(s), remove half the fluid from the front section.
3. Chock the front or rear tires, depending on which axle you are working on. Then jack up the axle, and support it with jackstands.
4. Remove the road wheels.
5. Remove the brake caliper.
   - 5.1 If you are going to do work on the caliper, disconnect and plug the brake supply hose; otherwise, leave it attached.
   - 5.2 Remove the allen-head bolt that holds the key and spring assembly in place (on the upper anchor plate rail for the front wheel; on the lower rail for the rear wheel). See **Fig. 1**.
   - 5.3 Using a punch, drive out the key and spring from between the caliper and the anchor plate rail, as shown in **Fig. 2**. Save the parts.
   - 5.4 Tilt the caliper up so the outboard brake pad clears the rotor, then slide the caliper off the anchor plate rails. See **Fig. 3**. Be careful not to stretch the brake hose.

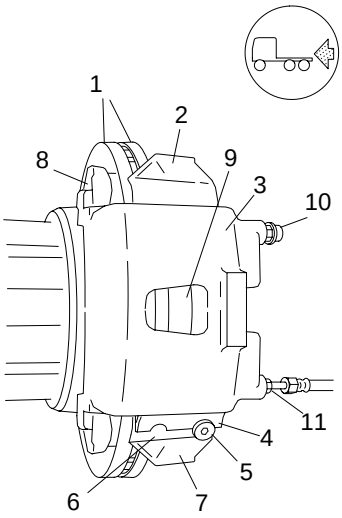
     The inboard brake pad will stay in place between the upper and lower rails of the anchor plate.
   - 5.5 If the brake supply hose is attached, support the caliper with a wire, or rest it on the axle suspension. *Don't let the caliper hang by its brake hose.*
6. Remove the outboard brake pad from the caliper housing.
7. Remove the inboard brake pad from the anchor plate. See **Fig. 4**.

Installation

1. Check the brake pad linings for wear and damage.
   - 1.1 Check the linings for wear. If they are 1/16 inch (1.6 mm) or less thick, replace the brake pads, following the instructions under **Subject 130**.
   - 1.2 Check the linings for pits, cracks, separation of the material (delaminating), or other damage. See **Fig. 5**. Replace the brake pads if they are damaged.
   - 1.3 Check the linings for glazing. If they are glazed but not otherwise damaged, deglaze the linings, using deglazing compound. Follow the manufacturer's directions.
2. Check the caliper.
   - 2.1 Check the piston dust boots for damage or leaks. See **Fig. 6**. If a problem is found, rebuild the caliper, following the instructions under **Subject 145**.
   - 2.2 Check the bleeder fitting for leaks or damage. If there are signs of leakage, check the tightness of the fitting. If the fitting is damaged, replace it. Refer to **Subject 145** for instructions.
3. Check the rotor, following the instructions under **Subject 130**.
4. Clean and lightly lubricate the sliding surfaces (V-ways) of the caliper housing and the anchor plate rails with Aeroshell Grade 5 (ES–1246) grease (don't use any type of anti-seize compound, such as Never-Seeze). See **Fig. 7**.
   - 4.1 Using a fine file or emery cloth, clean the sliding surfaces (V-ways) of the caliper housing, and the corresponding surfaces of the anchor plate rails.
   - 4.2 Grease the surfaces lightly with Aeroshell Grade 5 (ES–1246) grease (don't use any

Brake Caliper Removal and Installation

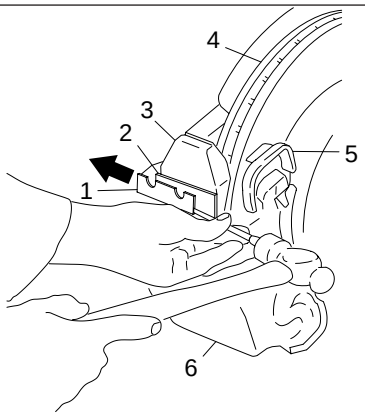




08/11/93 f420478

1. Rotor
2. Upper Anchor Plate Rail
3. Caliper Housing
4. Key
5. Allen-Head Bolt
6. Spring
7. Lower Anchor Plate Rail
8. Outboard Brake Pad
9. Inspection Hole
10. Bleeder Fitting
11. Supply Port

Fig. 1, Rear Caliper Shown

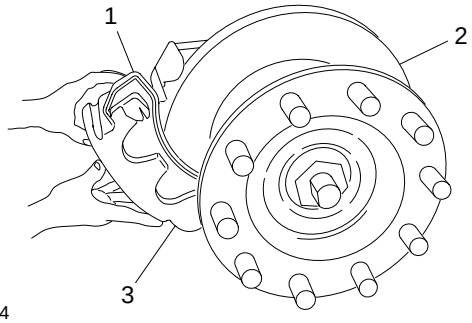


08/11/93 f420546

1. Key
2. Spring
3. Upper Rail of Anchor Plate
4. Rotor
5. Outboard Brake Pad
6. Caliper Housing

Fig. 2, Front Caliper Shown

type of anti-seize compound, such as Never-Seeze).



10/28/94 f420538

1. Outboard Brake Pad
2. Rotor
3. Caliper

Fig. 3, Slide the Caliper off the Anchor Plate Rails

5. Install the inboard (smaller) brake pad between the upper and lower rails of the anchor plate. Make sure the lining material is facing the rotor.
6. Install the caliper.
   6.1 Using a piece of wood and a C-clamp, push the pistons all the way into the cali-

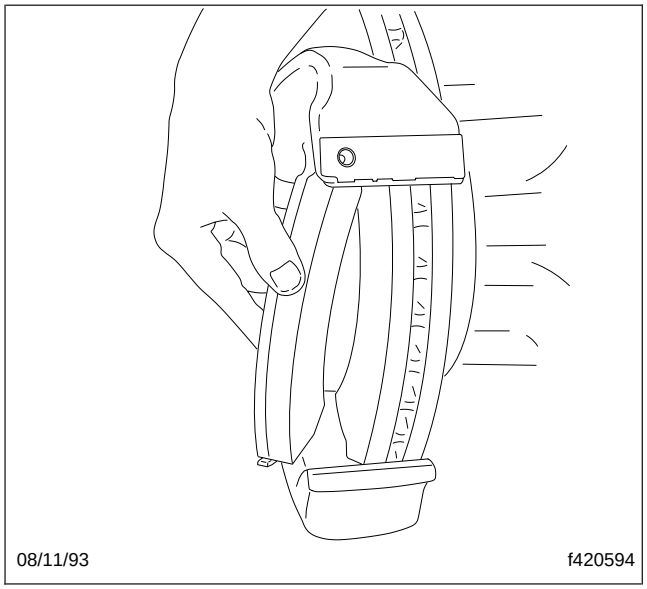
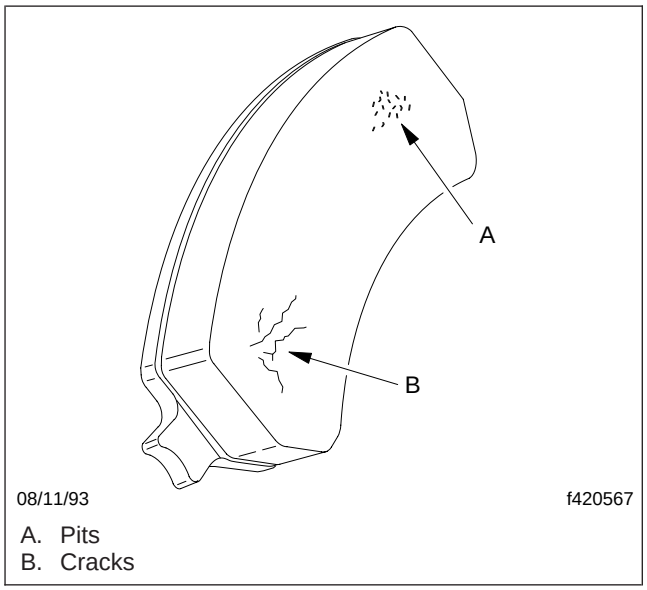


Fig. 4, Remove the Inboard Brake Pad

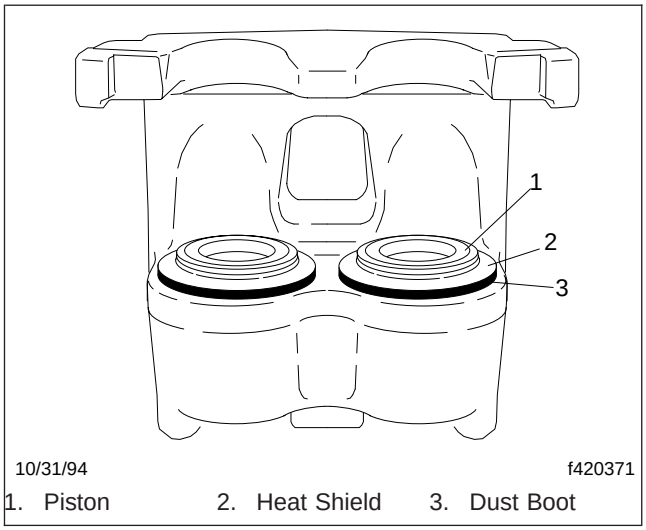


A. Pits
B. Cracks

Fig. 5, Check the Linings

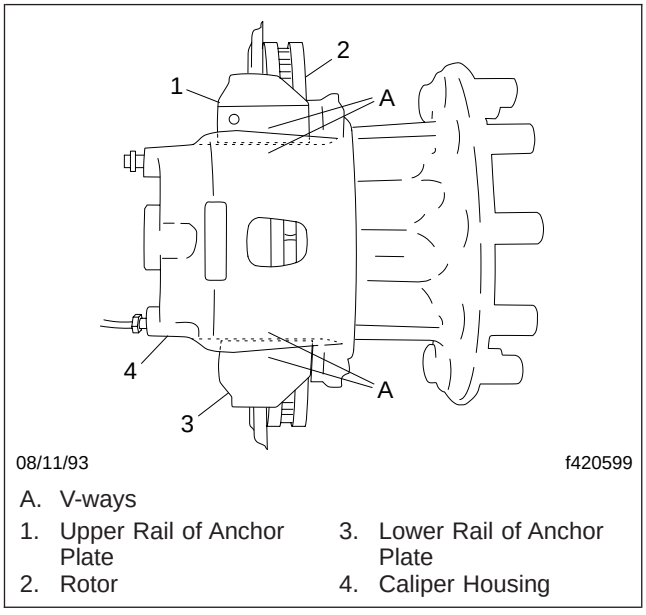
per housing. See **Fig. 8**. Be careful not to damage the piston heat shields. See **Fig.6**, Ref. 2.

6.2 Install the outboard (larger) brake pad in the housing, with the pad lining facing the piston, as shown in **Fig. 9.**



1. Piston 2. Heat Shield 3. Dust Boot

Fig. 6, Check the Piston Dust Boots



A. V-ways
1. Upper Rail of Anchor Plate
2. Rotor
3. Lower Rail of Anchor Plate
4. Caliper Housing

Fig. 7, Clean and Lightly Lubricate the Caliper Housing

6.3 Tilt the caliper housing so that the outboard brake pad will fit over the rotor, then push the caliper down onto the anchor plate rails. See **Fig. 10**.

IMPORTANT: 2.88-inch calipers have pads that are chamfered on one end. Depending on mounting location (steer axle or rear

Brake Caliper Removal and Installation

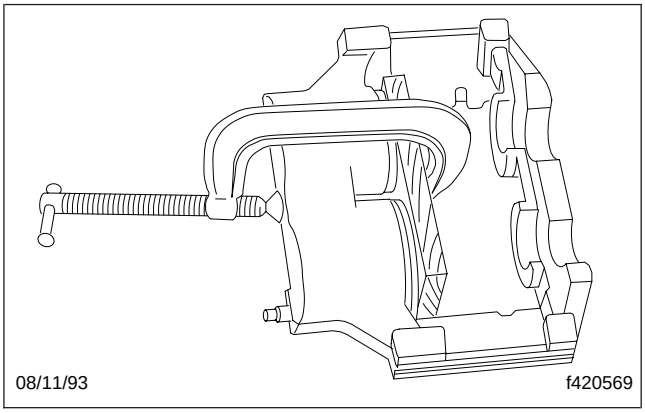
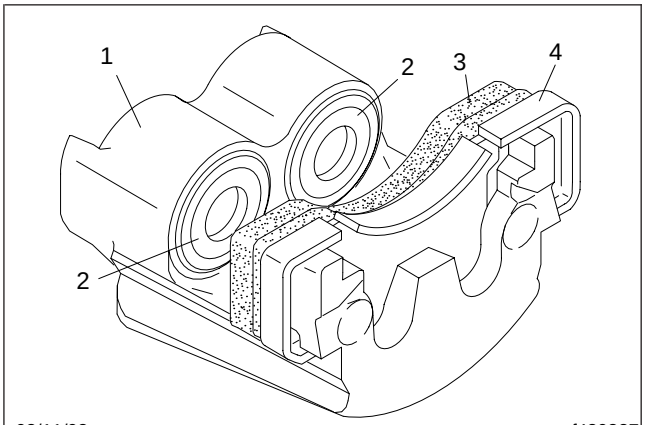


Fig. 8, Push in the Pistons



1. Caliper Housing
2. Pistons
3. Brake Pad Lining
4. Outboard Brake Pad

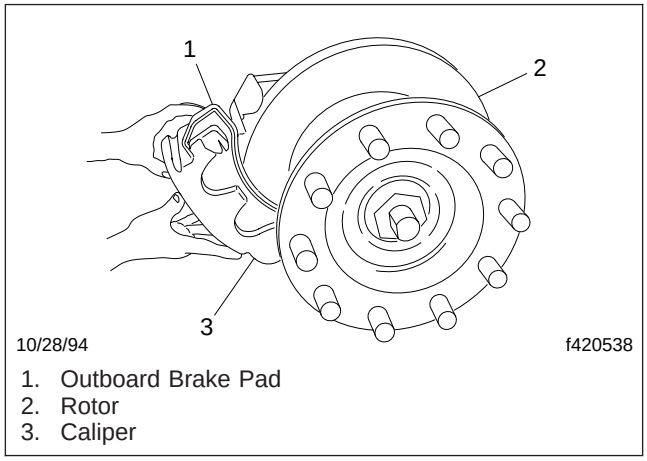
Fig. 9, Install the Outboard Brake Pad

axle), make sure that the 2.88-inch calipers are installed as shown in **Fig. 11**.

6.4 Assemble the spring and key as shown in **Fig. 12**, then install them between the caliper housing and the anchor plate rail (the upper rail for front wheel calipers, or the lower rail for rear wheel calipers).

6.5 Drive the key and spring into place, using a punch and mallet. See **Fig. 13**. Make sure the notch in the key lines up with the hole in the anchor plate rail.

6.6 Install the allen-head bolt, and tighten it 15 lbf·ft (20 N·m).



1. Outboard Brake Pad
2. Rotor
3. Caliper

Fig. 10, Push the Caliper down onto the Anchor Plate Rails

7. If the brake supply hose was disconnected, connect it; otherwise go to the next step and check the fluid level.

   7.1 Tighten the brake supply hose fitting 15 lbf·ft (20 N·m).

   7.2 Bleed the brake supply line to the caliper, following the instructions under **Subject 110**. If you have removed more than one brake caliper, bleed the entire brake system.

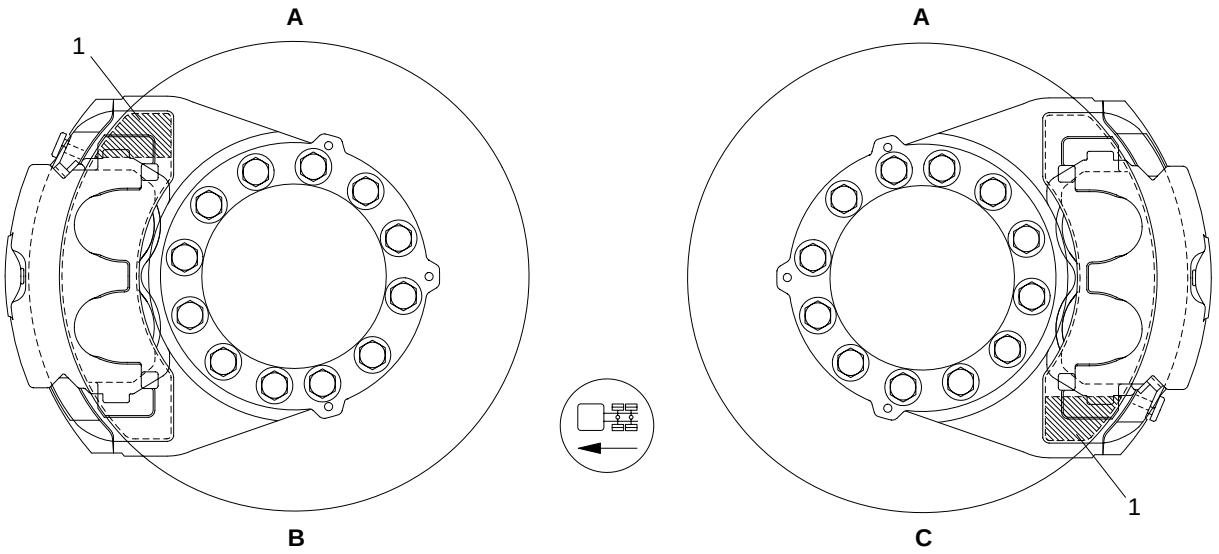
8. Check the fluid level in the master cylinder reservoir, and add the necessary amount of new DOT 3 approved brake fluid.

9. Seat the brake pads by pressing firmly on the brake pedal several times.

   If new brake pads were installed, seat them following the instructions under **Subject 130**.

10. Install the road wheels, then lower the axle.

11. Lower the hood, then remove the chocks.



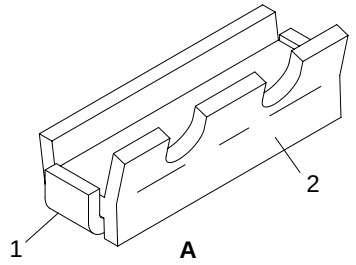
08/11/93 f420946

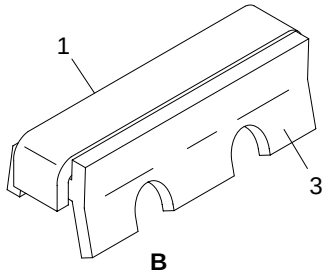
NOTE: Left-side mountings shown.

A. Top
B. Front Steer Axle Installation
C. Rear Axle Installation
1. Chamfer

Fig. 11, Caliper Installation

Brake Caliper Removal and Installation

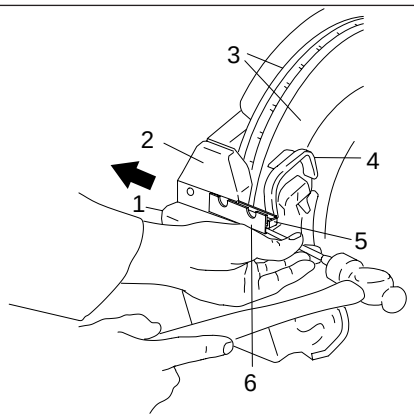




08/11/93 f420551

A. Front Caliper
B. Rear Caliper
1. Spring
2. Key (notches up)
3. Key (notches down)

Fig. 12, Assemble the Spring and Key



08/11/93 f420564

1. Caliper
2. Upper Rail of the Mounting Bracket
3. Rotor
4. Outboard Brake Pad
5. Spring
6. Key

Fig. 13, Drive in the Key and Spring

Rebuild

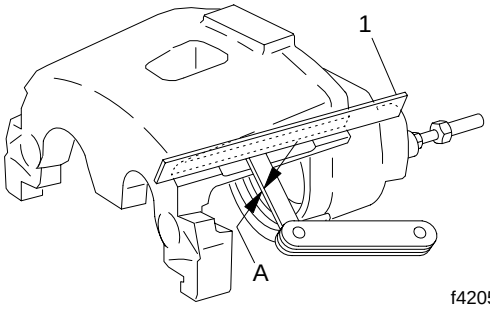
WARNING

WARNING: Before starting the procedure below, read the 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. Apply the parking brake, then chock the tires of the axle(s) you are not working on.
2. Jack up the axle and support it with jack stands.
3. Remove the road wheel.
4. Clean the outside of the caliper housing, using a damp rag.
5. Remove the caliper from the wheel, following the instructions under **Subject 140**.
6. Drain any remaining brake fluid from the caliper housing. Discard the fluid.
7. Measure the wear depth of both caliper V-ways.

   7.1 Using a wire brush, clean the V-way surfaces of the caliper housing. File smooth any deep nicks or gouges.

   7.2 Lay the caliper housing on a bench, then put a straight edge on a V-way surface, as shown in **Fig. 1** .



10/28/94 f420598a

A. 0.05 inch (1.27 mm)
1. Straightedge

Fig. 1, Put the Straight Edge on a V-way Surface

   7.3 Using a feeler gauge, measure the gap between the V-way surface and the straight edge. See **Fig. 1**. Record the measurement.

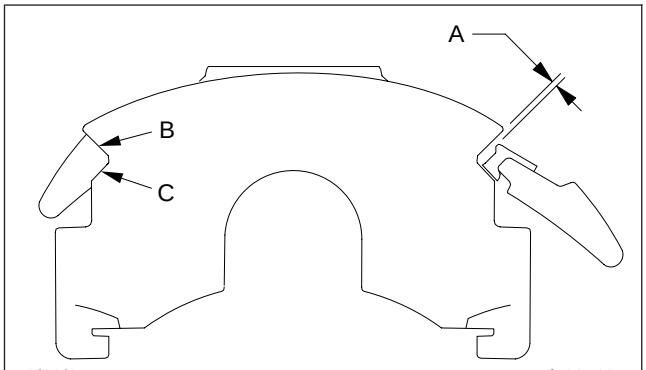
   Repeat this measurement for all the V-way surfaces. If any measurement is 0.05 inch (1.27 mm) or more, replace the caliper housing; otherwise, go to the step for checking caliper-to-anchor plate looseness.

8. Check for caliper-to-anchor plate looseness.

   8.1 Install the caliper on the rotor.

   8.2 Install a new key and the existing allen head bolt, but don't install the spring.

   8.3 Put a screwdriver in the gap (bumper gap) between the key and the V-way of the caliper. Pry up to seat the caliper against the sliding surfaces B and C, as shown in **Fig. 2**.



10/28/94 f420568a

A. 0.145 inch (3.68 mm)
B. Caliper Sliding Surface
C. Caliper Sliding Surface

Fig. 2, Measure the Bumper Gap

   8.4 Using a feeler gauge, measure the bumper gap (the distance between the key and the caliper V-way). See **Fig. 2**.

   8.5 If the bumper gap is more than 0.145 inch (3.68 mm), replace the caliper, and repeat steps checking caliper-to-anchor plate looseness. If the bumper gap is more than 0.145 inch (3.68 mm) with the new caliper installed, replace the anchor plate.

   If the bumper gap is 0.145 inch (3.68 mm) or less, check **Table 1** for the correct size wear shim to install on the anchor plate. Then remove the caliper from the rotor,

Brake Caliper Rebuild

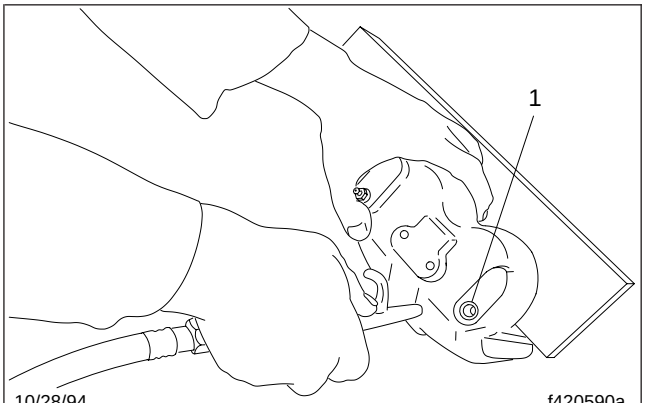
and go to the step for removing the pistons from the caliper housing.

Bumper Gap Sizes		
Bumper Gap inch (mm)		Shim Thickness inch (mm)
More than	But Not Over	
0	0.058 (1.47)	None needed
0.058 (1.47)	0.101 (2.57)	0.025 (0.64)
0.101 (2.57)	0.145 (3.68)	0.045 (1.14)
0.145 (3.68)	—	Replace the caliper

Table 1, Bumper Gap Sizes

9. Remove the pistons from the caliper housing.

9.1 Connect a compressed air line with a control nozzle to the supply port of the caliper housing. See **Fig. 3**.



1. Supply Port

Fig. 3, Connect a Compressed Air Line

9.2 Put a padded block of wood up against the outboard legs of the caliper, opposite the pistons, as shown in **Fig. 4**.

⚠ WARNING

WARNING: Be careful when using compressed air to remove the caliper pistons from their cylinders. Keep your hands away from the front of the pistons. Use only enough air pressure to ease out the pistons, or they may fly out forcibly, which could cause personal injury, or damage the pistons.

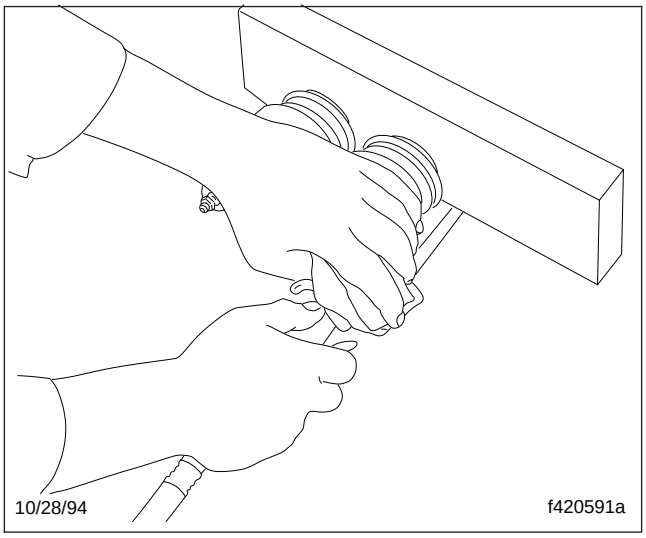
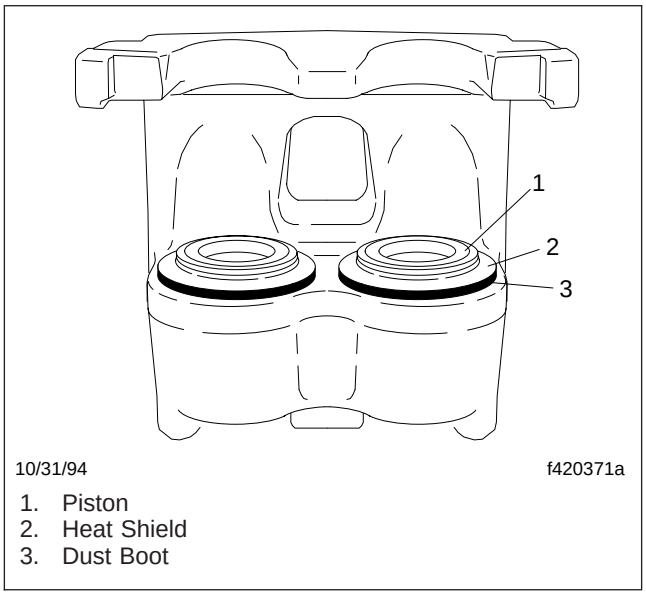


Fig. 4, Position a Padded Block of Wood

9.3 Slowly release compressed air, and ease the pistons out of the cylinders until they are up against the wooden block. Don't pop the pistons out.

9.4 Using tin snips, cut both piston heat shields, then remove them from the pistons. See **Fig. 5**.



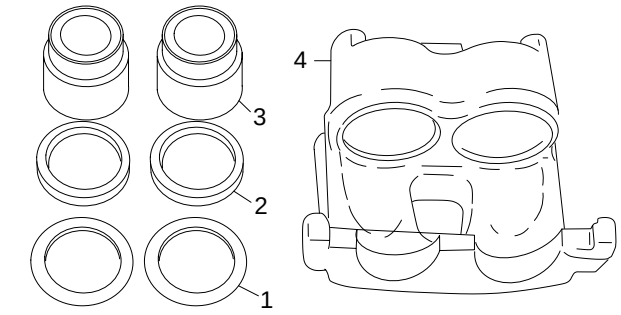
1. Piston
2. Heat Shield
3. Dust Boot

Fig. 5, Cut Both Piston Heat Shields

9.5 Pry the dust boot of one of the pistons from its seat in the cylinder, then do the

same for the other dust boot. Remove and discard both dust boots.

9.6 Remove both pistons from their cylinders. See **Fig. 6**.



1. Heat Shield
2. Dust Boot
3. Piston
4. Caliper Housing

Fig. 6, Remove the Pistons

9.7 Remove the piston seal from inside each cylinder. See **Fig. 7**.

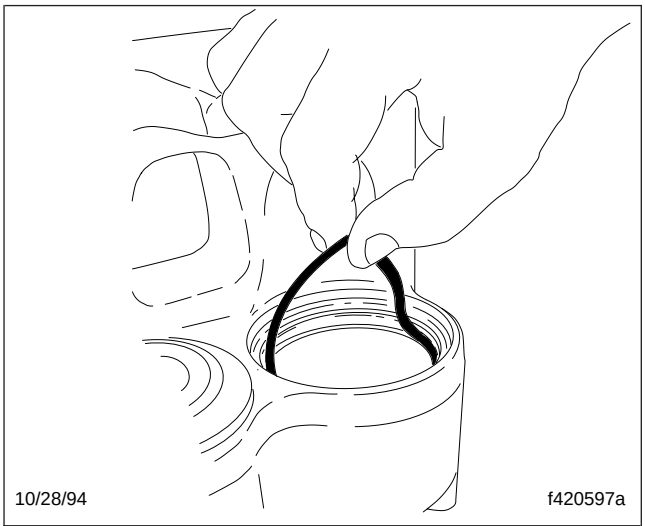


Fig. 7, Remove the Piston Seal

10. Using denatured alcohol, clean the pistons and the caliper housing. Clean both the outside of the caliper and the piston cylinders. Blow dry all the parts with compressed air.
11. Check the outside of the pistons for pitting, scoring, corrosion, or damage. If any problem is found, replace the piston.
12. Check the caliper seal grooves and dust boot seats for pitting. See **Fig. 8**. If pitting is found, replace the caliper housing. Clean any corrosion from the area between the seal groove and dust boot seat.

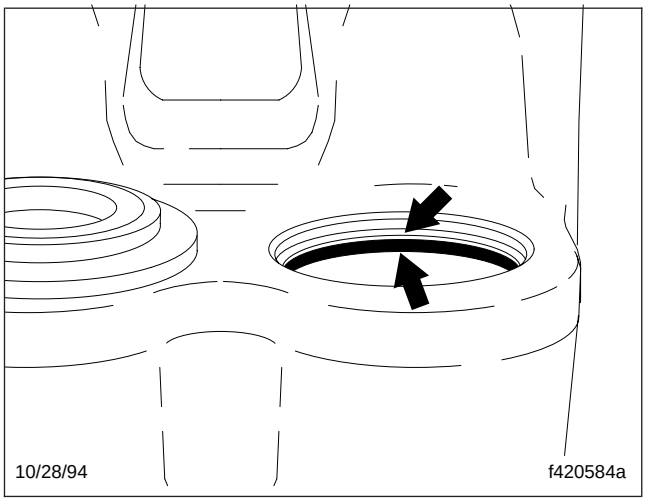
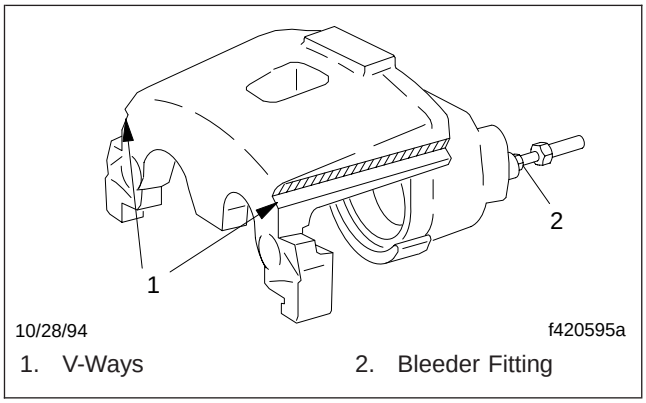


Fig. 8, Check the Caliper Seal Grooves and Dust Boot Seats

13. Check the bleeder fitting for damage or wear. If a problem is found, replace the fitting. See **Fig. 9**.



1. V-Ways
2. Bleeder Fitting

Fig. 9, Check the Bleeder Fitting

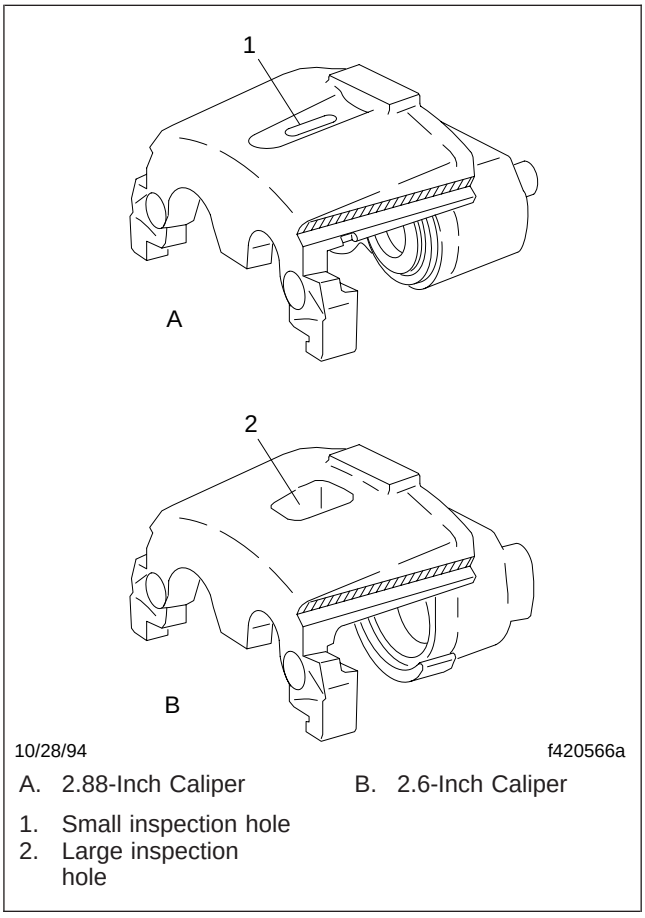
14. Install new piston seals.

    IMPORTANT: Two different types of brake calipers are used: calipers with 2.6 inch-diameter pistons, and those with 2.88 inch-diameter pistons. Make sure you use the right seals, dust boots, and heat shields, for the type of caliper you are rebuilding.

Brake Caliper Rebuild

To determine the type of caliper, check the inspection hole on the rear of the caliper housing. If it's large, the pistons are 2.6 inches in diameter; if the hole is small, they are 2.88 inches. See **Fig. 10**.

14.1 Coat a new piston seal with new, clean brake fluid See **Fig. 11**.



A. 2.88-Inch Caliper
B. 2.6-Inch Caliper
1. Small inspection hole
2. Large inspection hole

Fig. 10, Check the Caliper

14.2 Install a new piston seal in each of the cylinders. Make sure the seal is not twisted.

15. Install new dust boots on the pistons, as shown in **Fig. 12**.

16. Install the pistons.

16.1 Coat the bottom half (closed end) of one of the pistons with new brake fluid. *Don't get any brake fluid on the dust boot.*

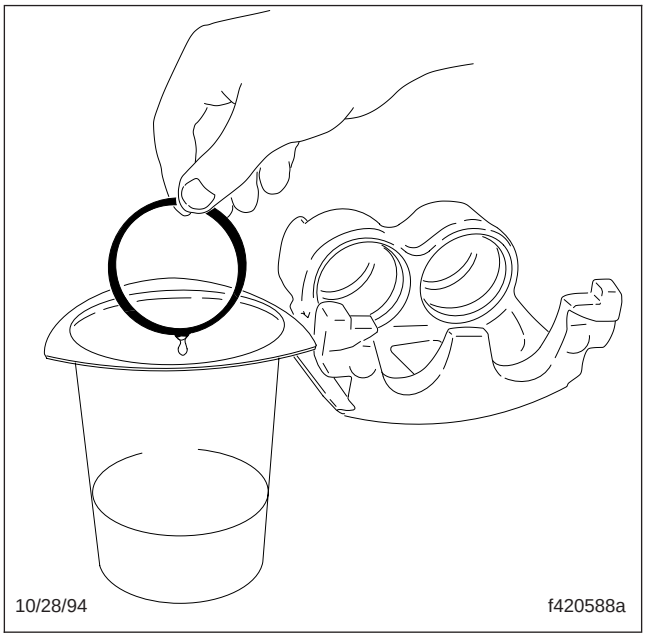


Fig. 11, Coat a New Piston Seal

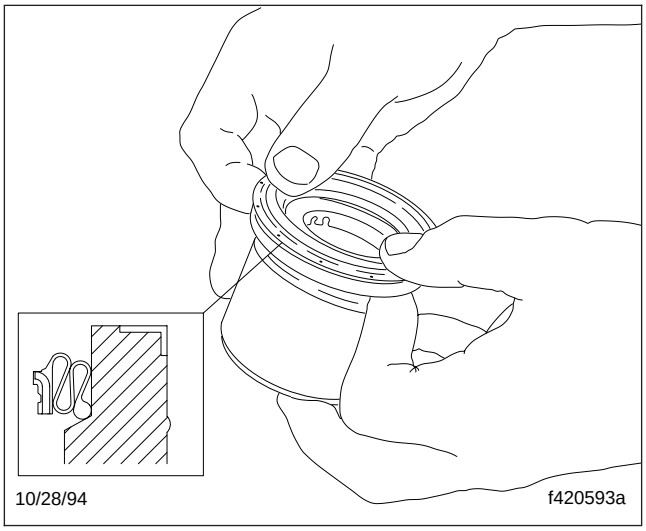


Fig. 12, Install New Dust Boots

16.2 Place the bottom (closed end) of the piston into its cylinder, making sure it is perfectly straight. See **Fig. 13**.

IMPORTANT: Make sure the piston is lined up in the cylinder perfectly straight before you install it; otherwise it will bind. If the piston binds in the cylinder, it will be impossible to install, and very difficult to remove.

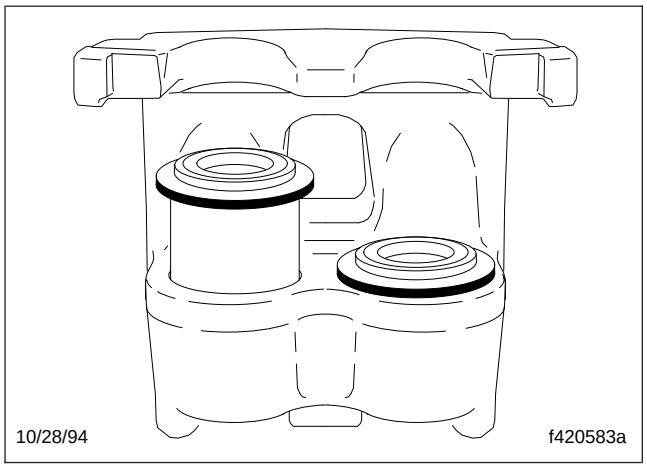


Fig. 13, Place the Bottom of the Piston into its Cylinder

16.3 Put a piece of thick metal or a block of wood over the top (open end) of the piston. Then, using a C-clamp, push the piston all the way into the cylinder until it bottoms out. See **Fig. 14**. Be careful not to damage the dust boot. If you feel resistance, the piston is in crooked. Remove it and start over.

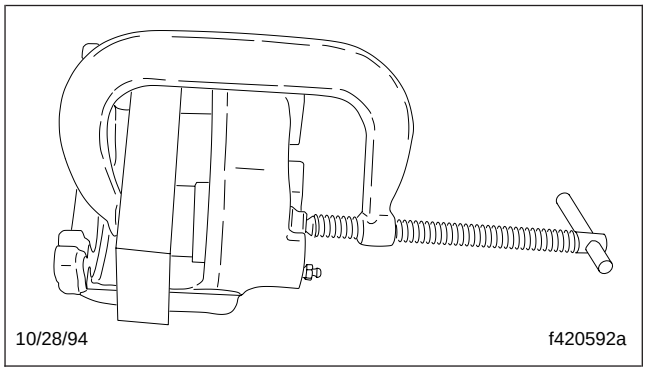


Fig. 14, Position a Piece of Thick Metal or a Block of Wood

16.4 Take the Kent-Moore special tool (KMS/ZTSE4275 for 2.88-inch pistons, or KMS/ZTSE4343 for 2.60-inch pistons), and put the side of the tool marked "Boot" against the dust boot. Then using the C-clamp, seat the dust boot into its groove in the cylinder.

16.5 Repeat the previous steps as needed for installing the other piston.

17. Install the heat shields on the pistons.

17.1 Put a new heat shield over the top of one piston as shown in **Fig. 15**. Make sure the heat shield is positioned correctly.

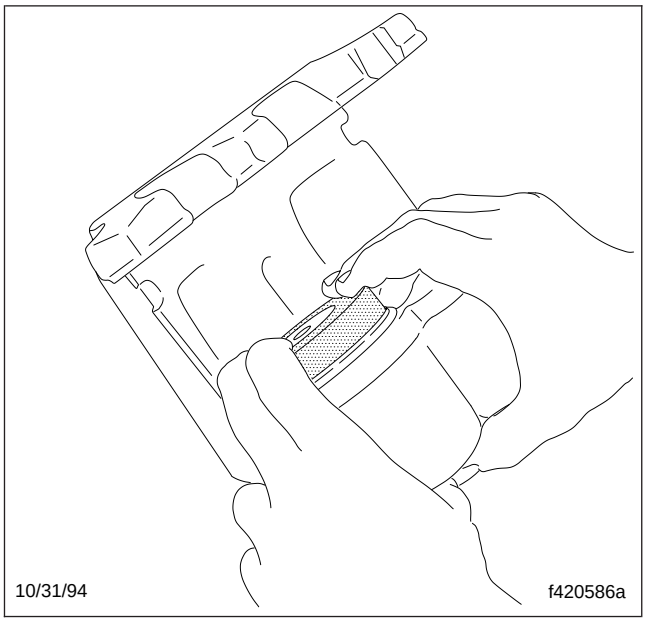


Fig. 15, Position the New Heat Shield

17.2 Put the side of the Kent-Moore special tool (KMS/ZTSE4275 for 2.88-inch pistons, or KMS/ZTSE4343 for 2.6-inch pistons) marked "Heat Shield" against the heat shield. See **Fig. 16**. Using the C-clamp, seat the new heat shield onto the piston.

18. If a wear shim is required, install the applicable wear shim, chosen according to **Table 1**, on the opposite anchor plate V-way from which the key and spring are installed. See **Fig. 17**.

19. Install the caliper on the rotor following the instructions under **Subject 140**.

20. Install the road wheel. Lower the axle and remove the chocks.

Brake Caliper Rebuild

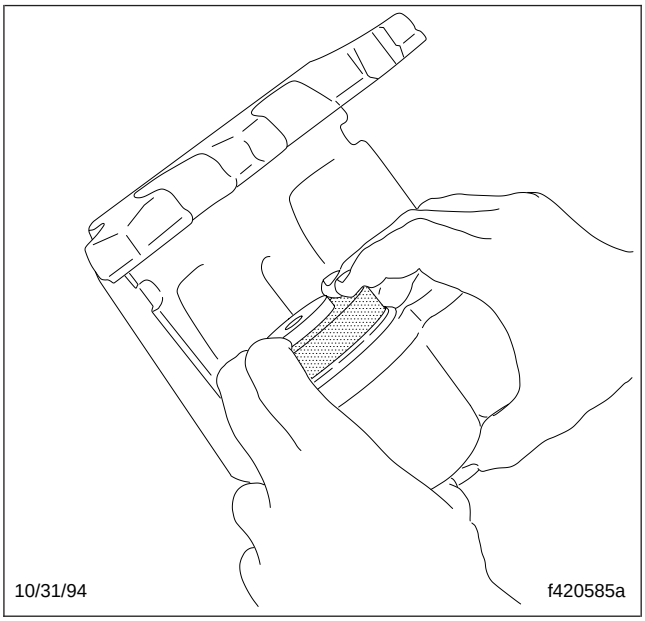
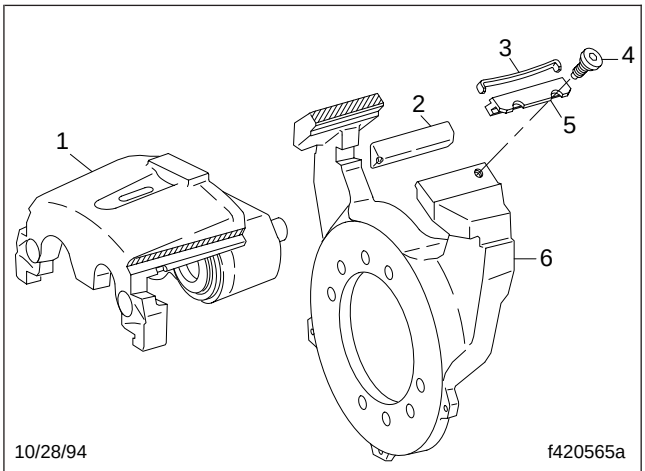


Fig. 16, Position the Kent-Moore Special Tool



1. Caliper
2. Wear Shim
3. Spring
4. Allen Head Bolt
5. Key
6. Anchor Plate

Fig. 17, Install the Wear Shim

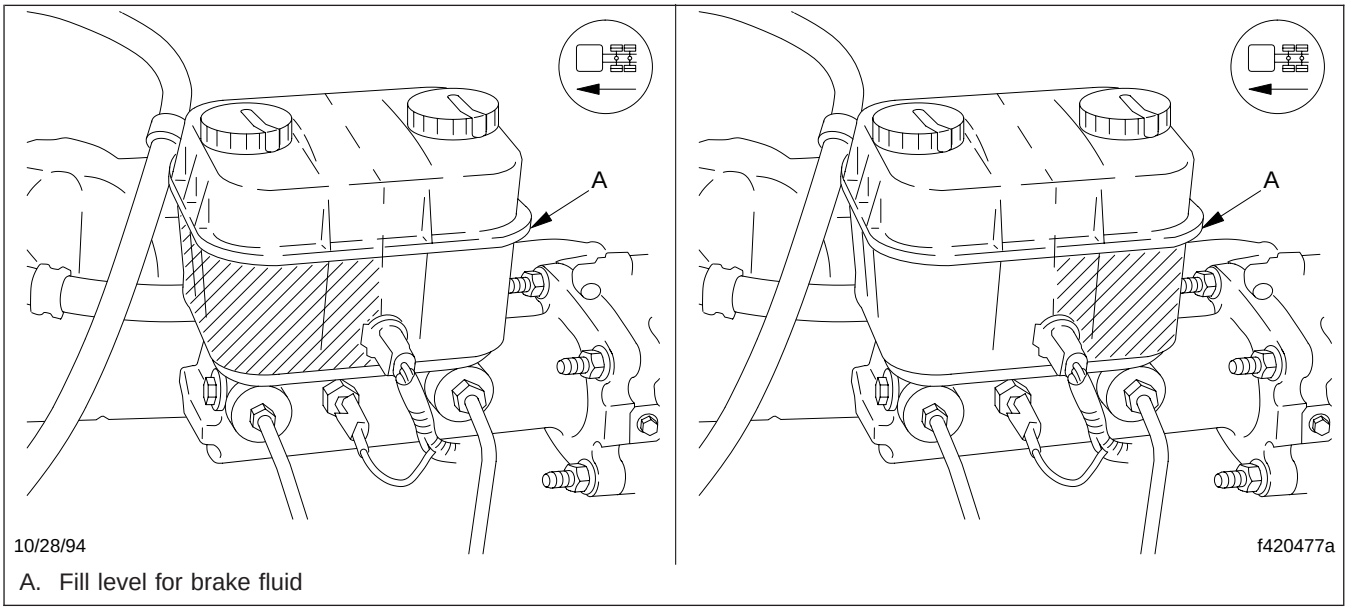
Brake Rotor Removal and Installation

WARNING

WARNING: Before starting the procedure below, read the 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.

Removal

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Remove about half 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**.



A. Fill level for brake fluid

Fig. 1, Remove Brake Fluid

3. Chock the front or rear tires, as required.
4. Jack up the vehicle, then support the axle with jackstands.
5. Remove the road wheel.
6. Remove the brake caliper from the rotor, following the instructions under **Subject 140**.
7. Remove the hub and rotor assembly from the axle, following the instructions in **Group 33** or **Group 35** in this manual. Put the hub on the floor so the rotor is facing up.
8. Remove the brake rotor from the wheel hub.
   - 8.1 Remove the hexbolts and washers that attach the rotor to the hub. See **Fig. 2**.
   - 8.2 Lift the brake rotor off the hub.

Installation

1. Install the rotor on the wheel hub.
   - 1.1 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.
   - 1.2 Install the mounting hexbolts and washers. Using a star pattern, tighten the hexbolts 130 lbf·ft (175 N·m). See **Fig. 4**.
2. Install the hub and rotor assembly on the axle, following the instructions **Group 33** or **Group 35** in this manual.
3. Install the brake caliper on the rotor, following the instructions under **Subject 140**.
4. Install the road wheel.
5. Remove the jackstands, then lower the vehicle.

Brake Rotor Removal and Installation

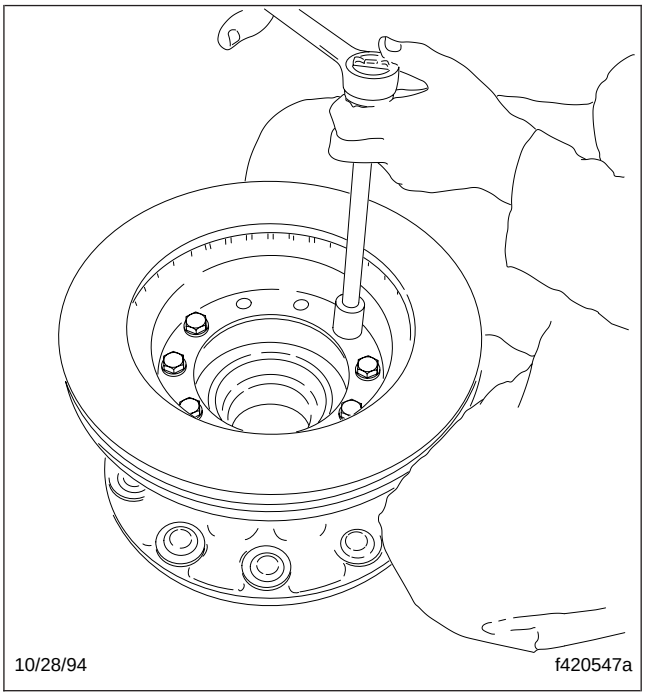


Fig. 2, Remove the Hexbolts and Washers

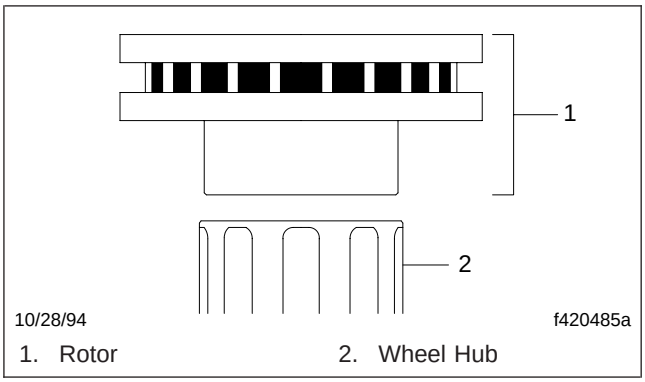


Fig. 3, Position the Rotor on the Hub

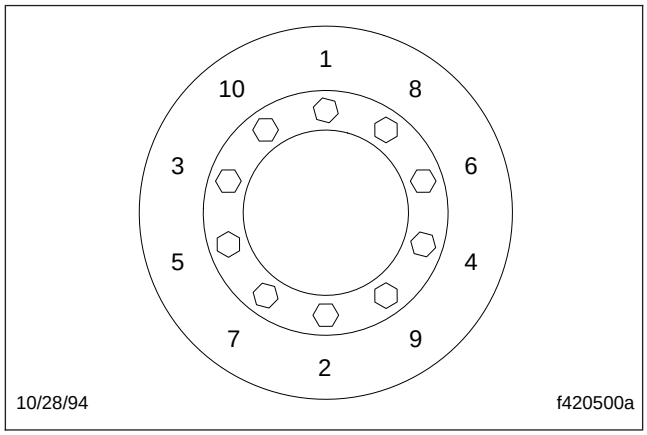


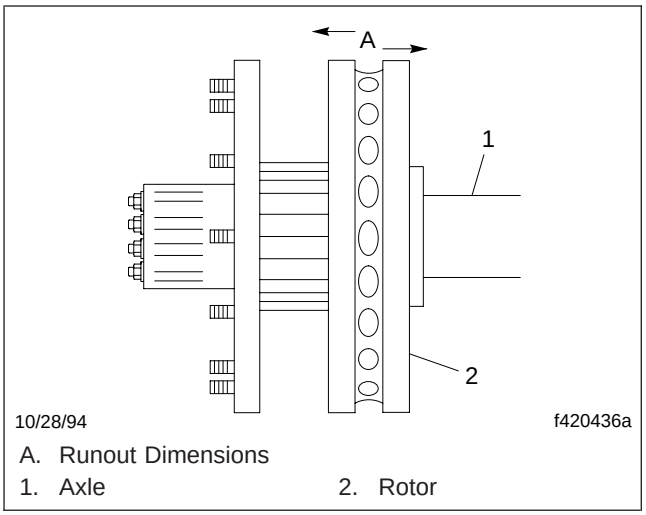
Fig. 4, Install the Mounting Fasteners

6. 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**.
7. Lower the hood, then remove the chocks.

Brake Rotor Runout and Parallelism Checking

Runout Checking

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 Dimensions
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. Then 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 **Group 33** or **Group 35** in this manual.
5. Repeat the runout measurement. If the runout is still more than 0.015 inch (0.38 mm), replace the rotor.

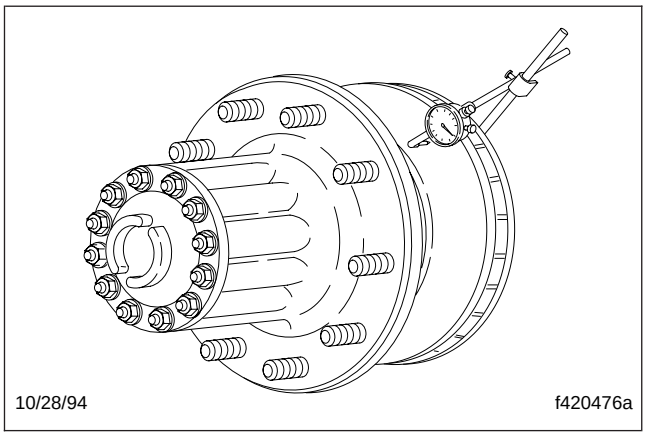
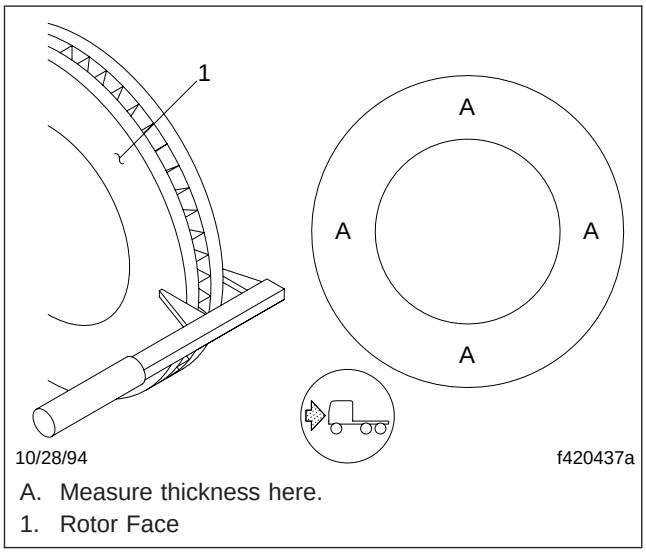


Fig. 2, Measure the Runout

Parallelism Checking

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 vernier caliper or 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, Measure the Thickness of the Rotor

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-

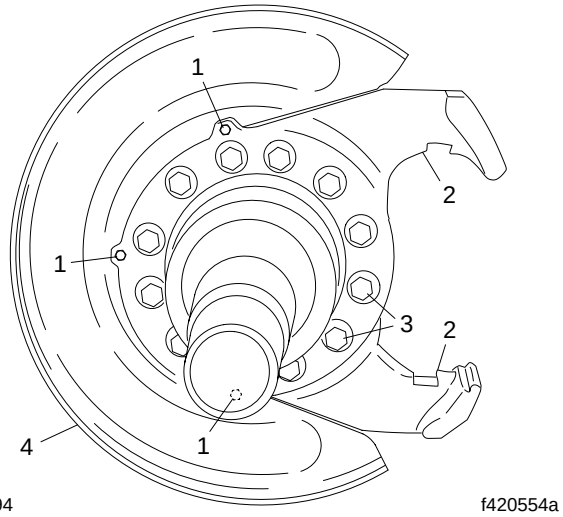
Brake Rotor Runout and Parallelism Checking

crease the overall thickness of the rotor to 1.32 inches (33.5 mm) or less, replace the rotor.

Anchor Plate Removal and Installation

Removal

1. Chock the rear or front tires, as required.
2. Jack up the vehicle, then support the axle with jackstands.
3. Remove the road wheel.
4. Remove the brake caliper from the anchor plate, following the instructions under **Subject 140**.
5. Remove the wheel hub and rotor assembly from the axle, following the instructions in **Group 33** or **Group 35** in this manual.
6. Remove the anchor plate from the axle.
   - 6.1 Remove the three screws holding the dust shield to the anchor plate, then remove the dust shield.
   - 6.2 Remove the hexbolts, washers, and nuts that hold the anchor plate to the axle. See **Fig. 1**.



1. Dust Shield Screw
2. Anchor Plate
3. Mounting Hexbolts
4. Dust Shield

Fig. 1, Remove the Fasteners

   - 6.3 Remove the anchor plate from the axle.

Installation

1. Install the anchor plate on the axle.
   - 1.1 Position the anchor plate in place against the outboard side of the axle flange, making sure the holes in both are lined up.
   - 1.2 From the outboard side of the anchor plate, install the hexbolts and washers, then install the nuts and remaining washers. See **Fig. 1**. Using a star pattern, tighten the hexnuts as follows:
     - Rear Axle; 105 lbf·ft (142 N·m)
     - Front Axle Type FC; 75 lbf·ft (102 N·m)
     - Front Axle Type FD/FF; 145 lbf·ft (197 N·m)
2. Install the dust shield on the anchor plate. See **Fig. 1**.
3. Install the wheel hub and rotor assembly onto the axle, following the instructions in **Group 33** or **Group 35** in this manual.
4. Install the brake caliper on the anchor plate, following the instructions under **Subject 140**.
5. Install the road wheel.
6. Remove the jackstands, then lower the vehicle.
7. Remove the chocks.

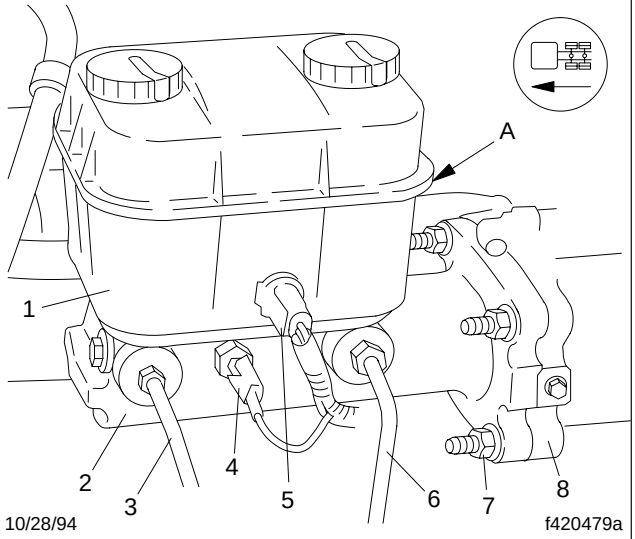
Master Cylinder Removal and Installation

Removal

WARNING

WARNING: Before starting the procedure below, read the information in Safety Precautions, 100. Failure to be aware of the dangers of brake fluid exposure could result in serious and permanent health damage.

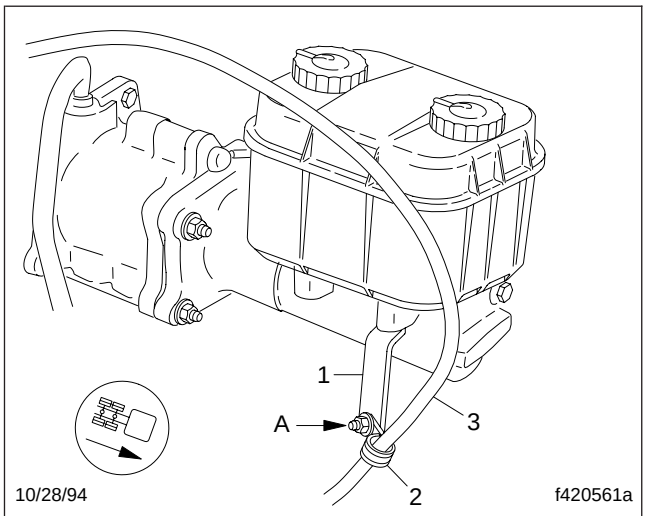
1. Apply the parking brake, chock the tires, and tilt the hood.
2. Disconnect the wires from the pressure differential switch on the master cylinder, and the fluid level sensor on the reservoir. See Fig.1.



A. Fill the reservoir sections to this level.
1. Reservoir
2. Master Cylinder
3. Front (secondary) Circuit Brake Line
4. Pressure Differential Switch
5. Fluid Level Sensor
6. Rear (primary) Circuit Brake Line
7. Flanged Hexnut
8. Power Booster

Fig. 1, Disconnect the Wires

3. Remove the accelerator cable clamp from the L-bracket attached to the front inboard side of the master cylinder. See Fig.2.



A. Disconnect here.
1. L-Bracket
2. Cable Clamp
3. Accelerator Cable

Fig. 2, Remove the Accelerator Cable Clamp

CAUTION

CAUTION: Do not let the brake fluid get on any painted surface, as it will dissolve the paint. Use a rag around fittings, or put a container underneath it to catch any fluid.

4. Disconnect the brake lines from the front and rear outlet ports of the master cylinder. See Fig.3. Plug the brake lines.
5. Remove the four flanged hexnuts that attach the master cylinder to the power booster unit. See Fig. 4.

   Remove the master cylinder and reservoir assembly from the vehicle. See Fig.5. Keep it upright so you don't spill any brake fluid from the reservoir.
6. Remove the caps from the master cylinder reservoir, then carefully invert the master cylinder and reservoir assembly, and dump the brake fluid into a container. Dispose of the brake fluid in an approved manner.

Installation

1. Bench bleed the master cylinder.

Master Cylinder Removal and Installation

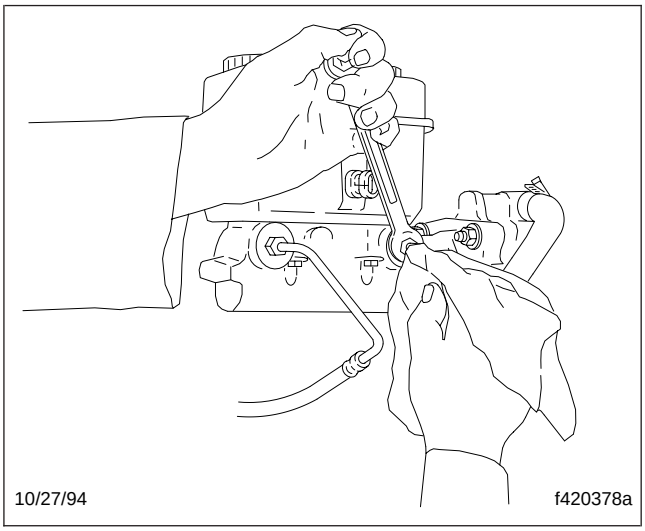
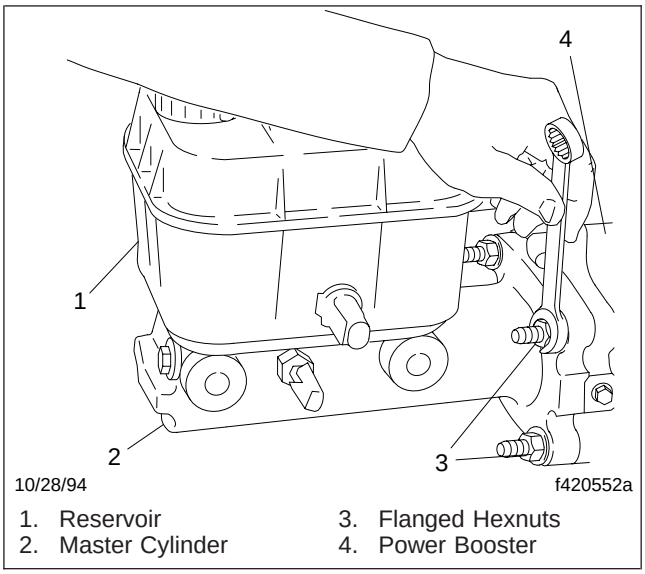


Fig. 3, Disconnect the Brake Lines



1. Reservoir
2. Master Cylinder
3. Flanged Hexnuts
4. Power Booster

Fig. 4, Remove the Flanged Hexnuts

1.1 Put the master cylinder and reservoir assembly in a vise.

1.2 Install a plastic adaptor and clear plastic hose on the primary and secondary outlet ports, as shown in **Fig.6**.

1.3 Put the other end of each tube into its section of the reservoir, as shown in **Fig.6**.

1.4 Fill the reservoir sections about half-full with new DOT 3 approved brake fluid.

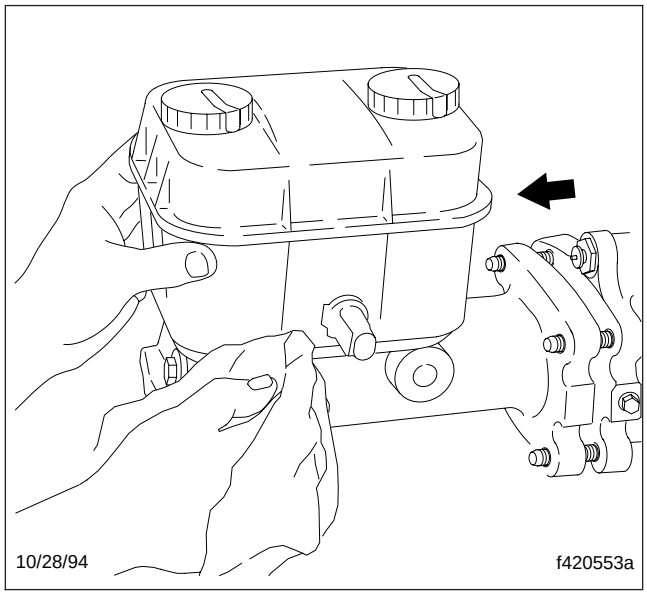


Fig. 5, Remove the Master Cylinder and Reservoir Assembly

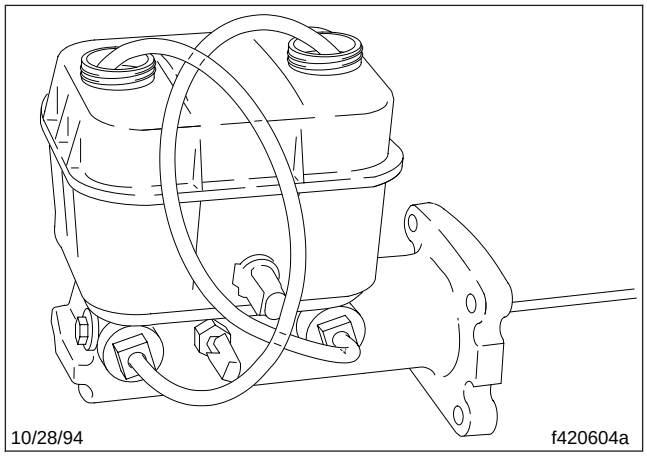


Fig. 6, Install a Plastic Adaptor and Clear Plastic Hose

1.5 Using a metal rod with a rounded end, depress and release the primary piston several times.

1.6 Reposition the master cylinder in the vise, with the front (closed) end tilted slightly up. Depress and release the primary piston again until you feel increased resistance.

2. Position the master cylinder on the front of the power booster.

3. Install the four flanged nuts on the studs of the power booster, then tighten them 25 lbf·ft (34 N·m).
4. Connect the rear brake (primary circuit) line to the rear outlet port on the master cylinder, then the front brake (secondary circuit) line to the front outlet port. Tighten the fittings 15 lbf·ft (20 N·m).
5. Connect the accelerator cable clamp to the L-bracket on the front inboard side of the master cylinder. See **Fig.2**.
6. Connect the wires to the pressure differential switch and the fluid level sensor. See **Fig.1**.
7. Fill both sections of the reservoir with new DOT 3 approved brake fluid. Fill to the raised seam on the outside of the reservoir. See **Fig.1**.
8. Bleed the entire brake system, following the instructions under **Subject 110**.
9. Lower the hood, then remove the chocks.

Master Cylinder Disassembly, Inspection, and Assembly

WARNING

WARNING: Before starting the procedure below, read the information in Safety Precautions, 100. Failure to be aware of the dangers of brake fluid exposure could result in serious and permanent health damage.

Disassembly

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Remove the master cylinder and reservoir assembly from the vehicle, following the instructions under **Subject 170**. See **Fig. 1**.
3. Remove the reservoir from the master cylinder.
   - 3.1 Remove the four flanged hexbolts that attach the reservoir to the top of the master cylinder. See **Fig. 2**. Note that one of the bolts has an L-bracket on it.
   - 3.2 Lift the reservoir off the master cylinder. Turn the reservoir over, then remove the two compensating valve seals from the bottom of it. See **Fig. 3**.
4. Remove the small O-ring, then the two compensating valves and their springs from the top of the master cylinder housing. See **Fig. 4** and **Fig. 5**.

CAUTION

CAUTION: Don't remove the piston stop at this time, or you may damage it and the piston bore in the master cylinder housing.

5. Remove the differential pressure indicator assembly from the front of the housing.
   - 5.1 Unscrew the aluminum plug at the front end of the housing. See **Fig. 6**.
   - 5.2 Using an allen wrench, remove the nylon insert underneath the aluminum plug. See **Fig. 7**.
   - 5.3 Remove the differential pressure switch from the side of the housing. See **Fig. 8**.
   - 5.4 Put a compressed air hose into the port on top of the housing where the primary compensating valve was. Put a shop towel over the hole at the front end of the housing, then place the housing so that the front end is facing down toward a padded surface; keep your hands away from the front of the master cylinder housing.

WARNING

WARNING: Be careful when using compressed air to remove the differential pressure indicator assembly from the master cylinder housing. It may come out of the housing with considerable force, which could cause personal injury or damage to the part.

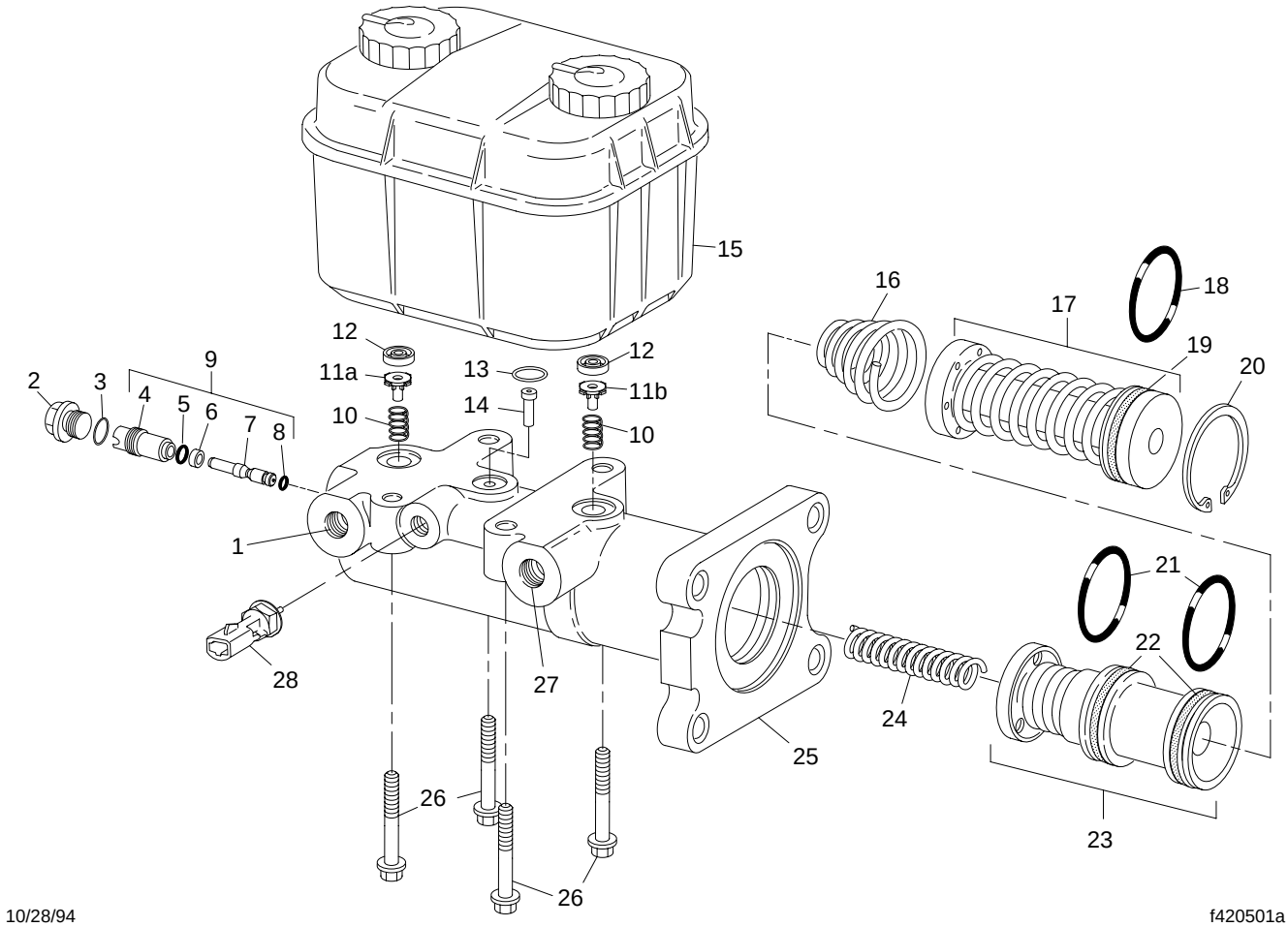
   - 5.5 Plug the primary circuit outlet, then release just enough air pressure to force out the brass spool, O-ring, and collar. See **Fig.1**. Discard the O-ring.

     Remove and discard the small O-ring (Ref. 8) from the brass spool.
6. Remove the primary piston assembly from the master cylinder bore.
   - 6.1 Put the master cylinder in a vise.
   - 6.2 Using a crossbar puller, a C-clamp, or other suitable tool, push the primary piston about 1/2 inch (13 mm) into the bore. See **Fig. 9**.
   - 6.3 With the primary piston pushed in, remove the lock ring from the open end of the bore. See **Fig. 9**. Then remove the small piston stop from the top of the master cylinder housing. See **Fig. 10**.
   - 6.4 Carefully release the tension on the primary piston, and ease it and its return spring out of the bore. See **Fig. 11**.
   - 6.5 Remove and discard the pressure seal and back-up ring from the primary piston. See **Fig.1**.

WARNING

WARNING: Be careful when using compressed air to remove the secondary piston and actuator assembly from the master cylinder bore. Make sure the open end of the bore is pointed down

Master Cylinder Disassembly, Inspection, and Assembly



1. Secondary Outlet Port
2. Aluminum Plug
3. O-Ring
4. Nylon Insert
5. Large O-Ring
6. Brass Collar
7. Brass Spool
8. Small O-Ring
9. Pressure Differential Indicator Assembly
10. Compensating Valve Spring (2 qty.)
11a Secondary Compensating Valve
11b Primary Compensating Valve
12. Compensating Valve Seal
13. O-Ring
14. Piston Stop
15. Reservoir
16. Prmary Piston Return Spring
17. Primary Piston Assembly
18. Primary Pressure Seal
19. Primary Back-Up Ring
20. Lock Ring
21. Secondary Pressure Seal (2 qty.)
22. Secondary Back-Up Ring (2 qty.)
23. Secondary Piston Assembly
24. Secondary Return Spring
25. Master Cylinder Housing
26. Flanged Hexbolts (4 qty.)
27. Primary Outlet Port
28. Pressure Differential Switch

Fig. 1, Master Cylinder Assembly

toward a padded surface. Keep your hands away from the open end of the bore to prevent injury.

7. Using compressed air, remove the secondary piston assembly from the master cylinder bore.

7.1 Connect a compressed air hose to the front compensating valve port on top of the housing. See **Fig.12**.

Master Cylinder Disassembly, Inspection, and Assembly

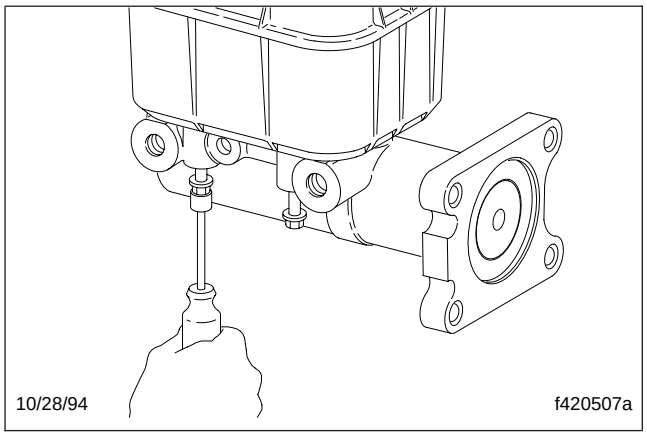


Fig. 2, Remove the Hexbolts

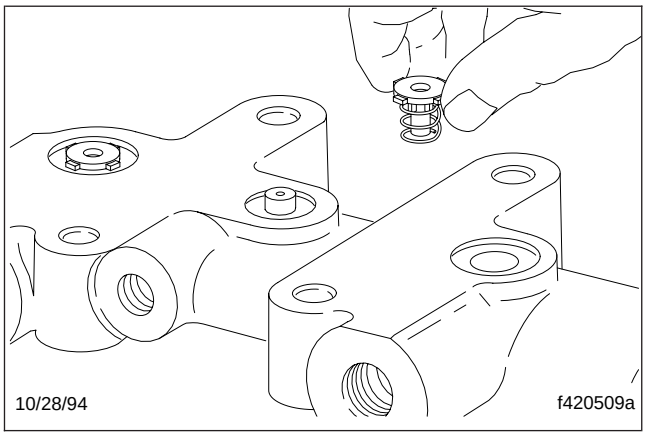


Fig. 5, Remove the Compensating Valves

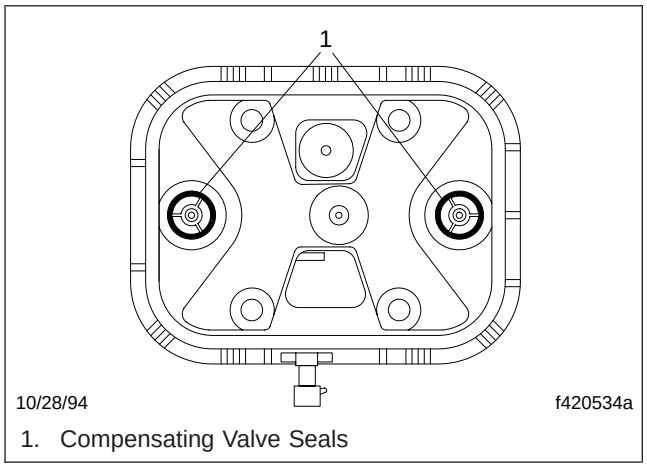


Fig. 3, Remove the Two Seals

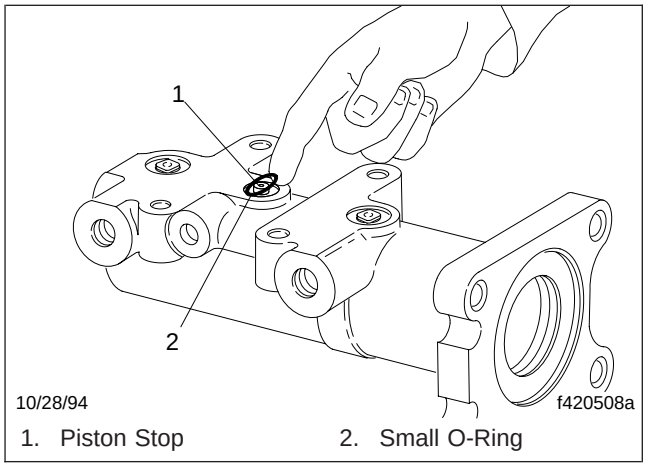


Fig. 4, Remove the Small O-Ring

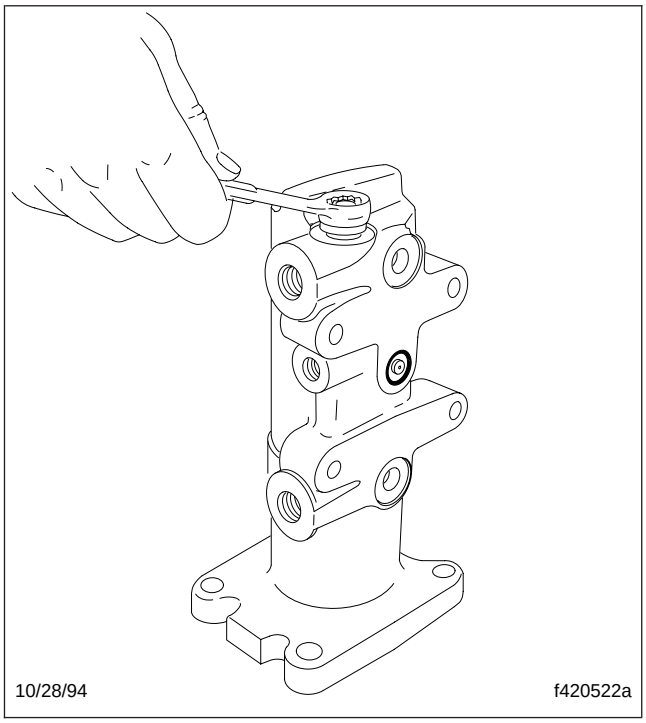


Fig. 6, Unscrew the Aluminum Plug

7.2 Plug the secondary outlet port and the hole where the pressure differential indicator was on the housing. See **Fig.1**.

7.3 With the open end of the housing bore facing down, and about an inch away from a padded surface, carefully apply just enough air pressure to remove the sec-

Master Cylinder Disassembly, Inspection, and Assembly

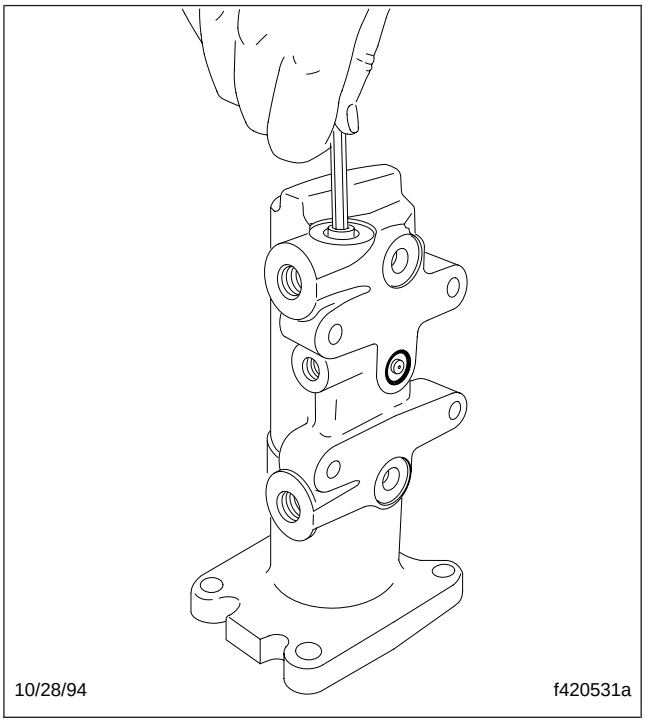


Fig. 7, Remove the Nylon Insert

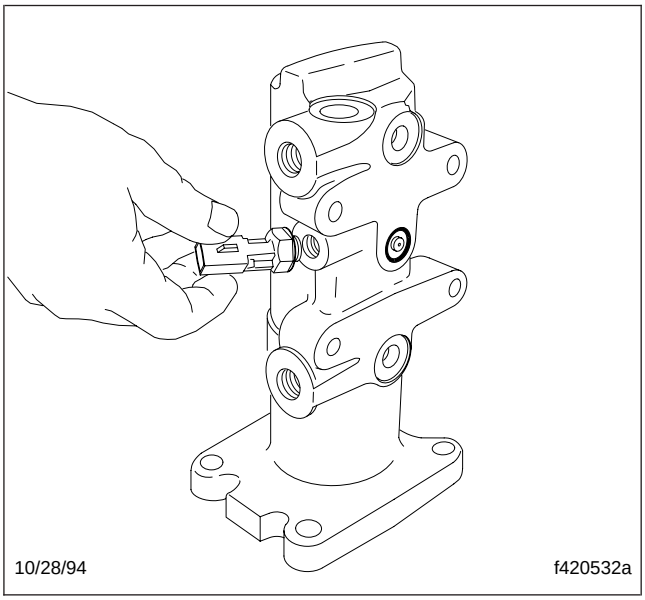
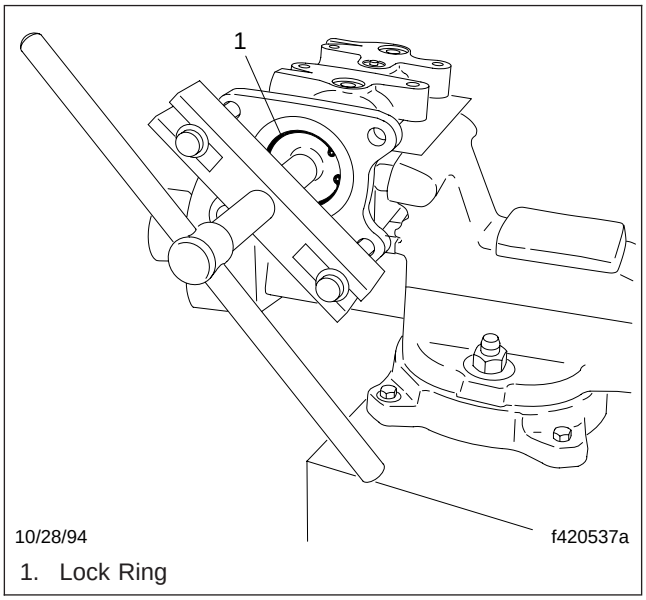


Fig. 8, Remove the Differential Pressure Switch

ondary piston assembly and its return spring from the bore; don't pop it out. See **Fig.13**.



1. Lock Ring

Fig. 9, Push the Primary Piston into the Bore

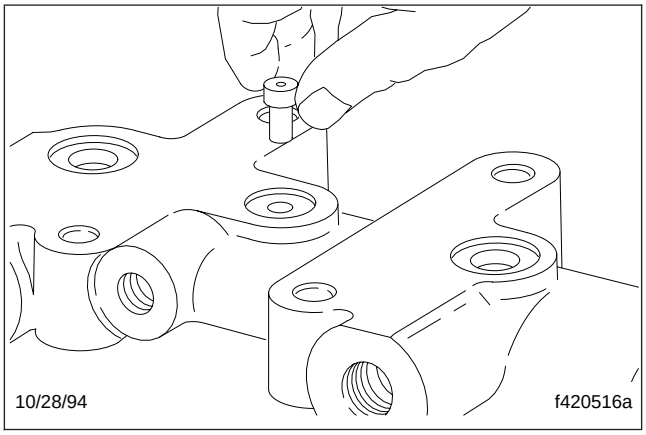


Fig. 10, Remove the Small Piston Stop

7.4 Remove and discard the pressure seal and back-up ring from the secondary piston.

Inspection

1. Check the master cylinder bore for scoring or corrosion. If the master cylinder housing is pitted, rough, or corroded, replace the entire master cylinder assembly.
2. If needed, polish any discolored or stained areas in the bore with a crocus cloth. *Don't use emery*

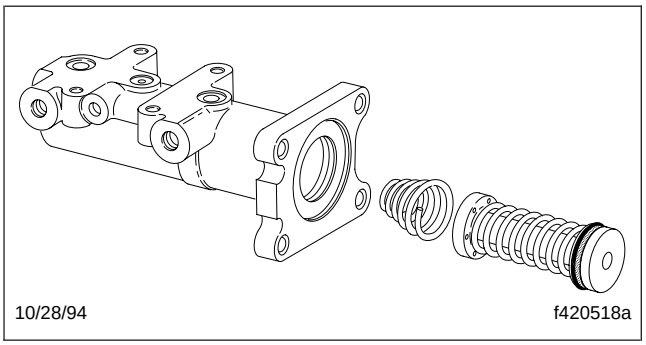
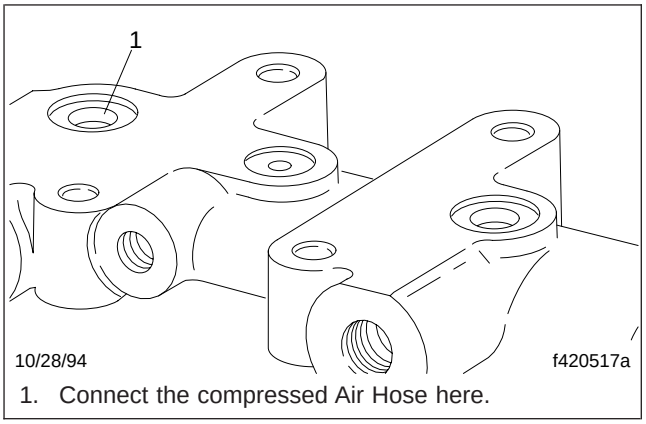


Fig. 11, Remove the Return Spring and the Primary Piston



1. Connect the compressed Air Hose here.

Fig. 12, Connect a Compressed Air Hose

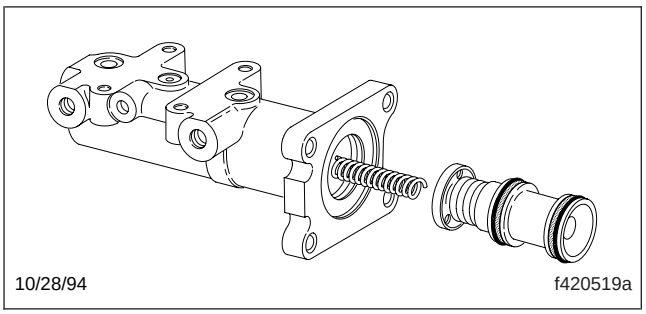


Fig. 13, Remove the Return Spring and the Secondary Piston

cloth or sandpaper; they could scratch the bore, which could cause leakage.

Assembly

IMPORTANT: When assembling the master cylinder, use new seals and rings. Don't reuse old ones.

1. Wash all the parts and the cylinder bore in clean, new DOT 3 approved brake fluid. Discard the brake fluid afterward.
2. Install the secondary piston assembly in the master cylinder bore.
   - 2.1 Install two new pressure seals and back-up rings on the secondary piston. See **Fig.1**.
   - 2.2 Lubricate the piston assembly, the seals, and the cylinder bore with clean DOT 3 approved brake fluid. See **Fig.14**.

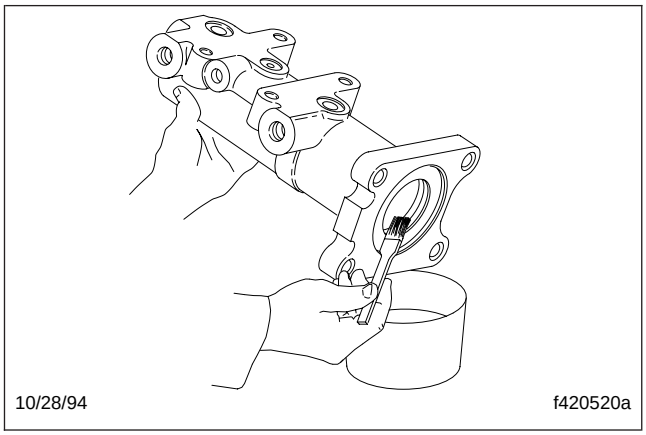


Fig. 14, Lubricate the Piston Assembly, Seals, and Cylinder Bore

   - 2.3 Put the secondary return spring on the actuator (flanged) end of the secondary piston assembly, then insert the piston assembly, spring end first, into the cylinder bore. See **Fig.1** and **Fig. 15**. Push it all the way to the bottom of the bore.
3. Install the primary piston assembly in the master cylinder bore.
   - 3.1 Install a new pressure seal and back-up ring on the primary cylinder. See **Fig.1**.
   - 3.2 Lubricate the piston assembly and the seal with new DOT 3 approved brake fluid.

Master Cylinder Disassembly, Inspection, and Assembly

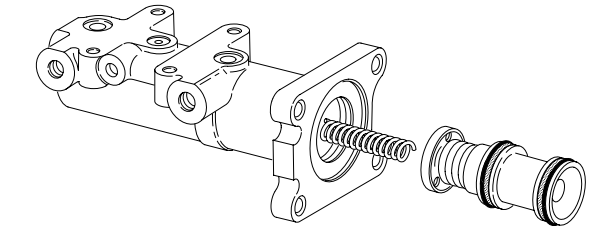


Fig. 15, Insert the Piston Assembly

3.3 Insert the small end of the primary return spring into the master cylinder bore. See **Fig.1**.

3.4 Insert the primary piston assembly into the master cylinder bore, actuator (flanged) end first. See **Fig.16**.

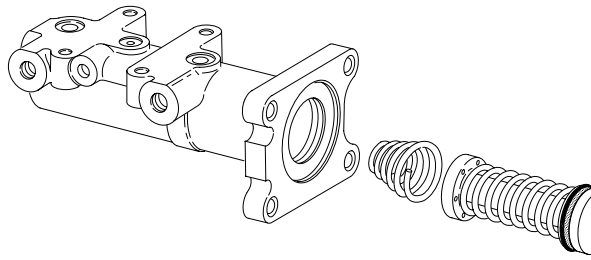
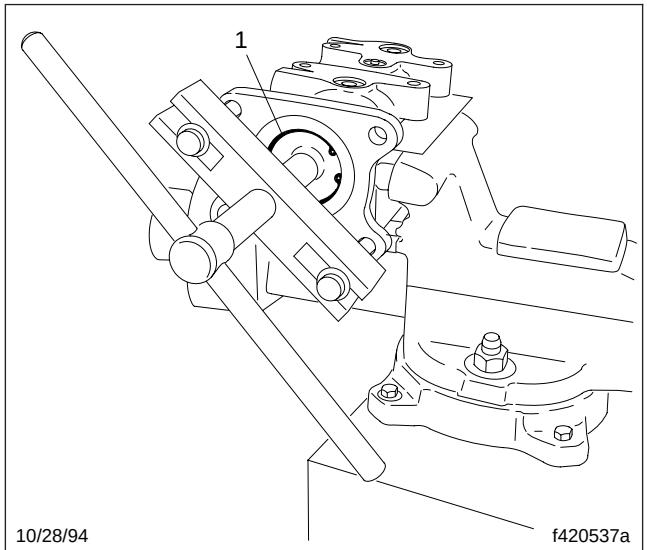


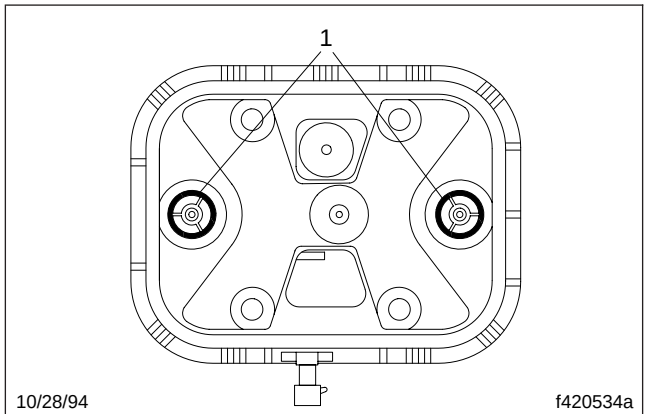
Fig. 16, Insert the Primary Return Spring

4. Put the master cylinder housing into a vise, then using a crossbar puller or a C-clamp, push the pistons far enough into the master cylinder bore to install the lock ring in its groove. See **Fig.17** .
5. Install the compensating valve seals on the bottom of the reservoir. See **Fig.18**. Make sure the seals are completely seated.
6. Using a crossbar puller or a C-clamp, push the primary piston 1 inch (25 mm) into the bore. See **Fig.19**.
7. Install the compensating valve poppets and their springs in the top of the master cylinder housing. Also install the piston stop and the O-ring. See **Fig.20**.
8. With the primary piston still pushed in, install the reservoir onto the top of the master cylinder, using the four mounting hexbolts. See **Fig.21**.



1. Lock Ring

Fig. 17, Install the Lock Ring



1. Compensating Valve Seals

Fig. 18, Install the Compensating Valve Seals

Make sure the L-bracket goes on the front inboard (when the master cylinder is installed on the vehicle) mounting hexbolt. Tighten the bolts 15 lbf·ft (20 N·m).

9. Assemble the pressure differential indicator. See **Fig.22**.

9.1 Install a new small O-ring in the groove on the end of the brass spool.

9.2 Install the collar on the brass spool.

Master Cylinder Disassembly, Inspection, and Assembly

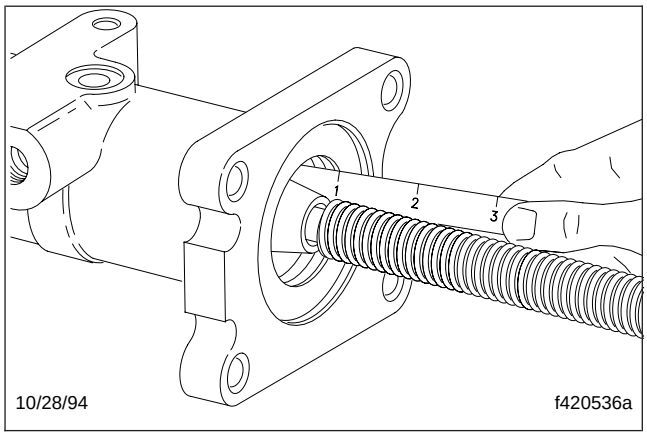


Fig. 19, Push the Primary Piston into the Bore

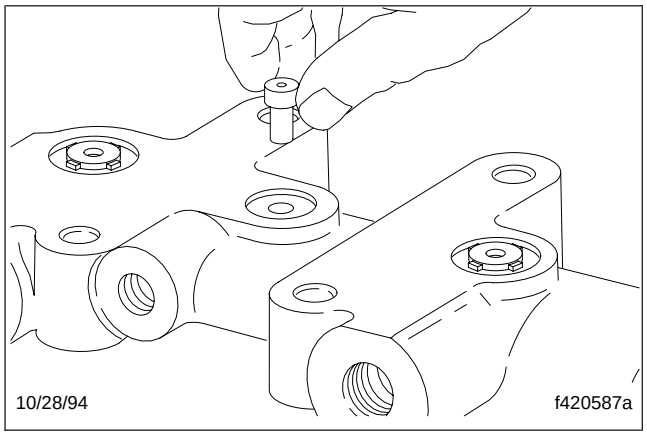


Fig. 20, Install the Compensating Valve Poppets

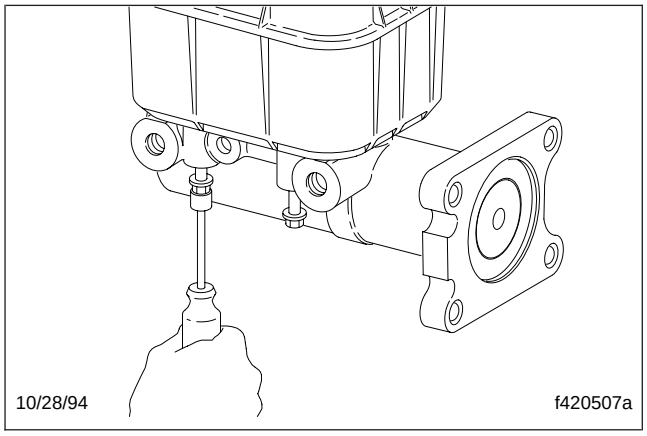


Fig. 21, Install the Reservoir

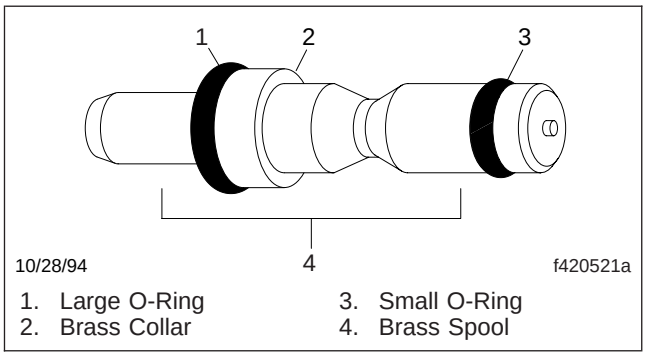


Fig. 22, Assemble the Pressure Differential Indicator

9.3 Install a new large O-ring onto other end of the brass spool, and push it down onto the collar, as shown in **Fig.22**.

10. Install the spool and collar assembly—with the collar end up—into the hole at the front of the master cylinder housing, as shown in **Fig.23**. Using a small piece of wood, seat the assembly at the bottom of its hole.

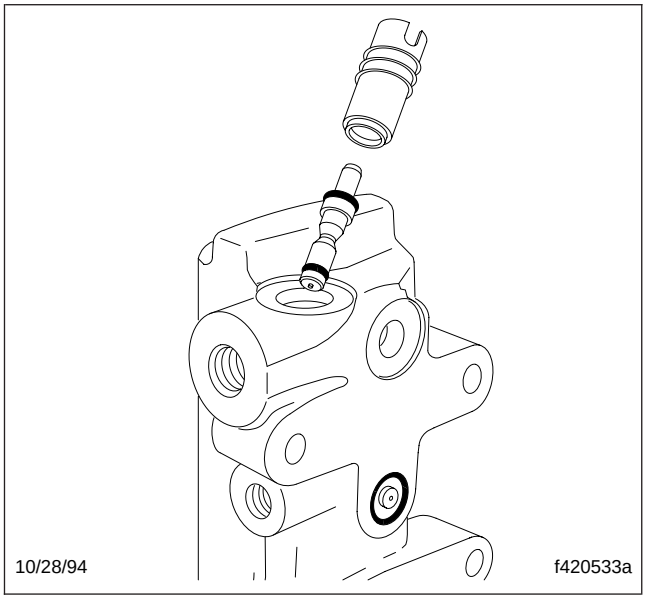


Fig. 23, Install the Spool and Collar Assembly

11. Using an allen wrench, install the nylon insert on top of the brass spool. See **Fig. 24**.

12. Install a new O-ring on the aluminum plug, then install the plug into the hole at the front of the master cylinder housing. Tighten the plug firmly. See **Fig. 1**.

Master Cylinder Disassembly, Inspection, and Assembly

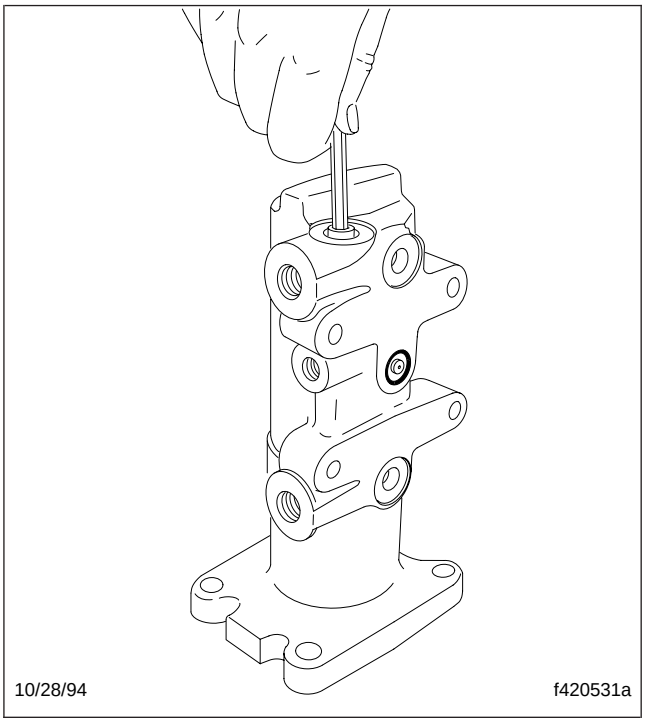


Fig. 24, Install the Nylon Insert on Top of the Brass Spool

13. Install the pressure differential switch in the side of the master cylinder housing, as shown in **Fig. 25**. Tighten it finger-tight.

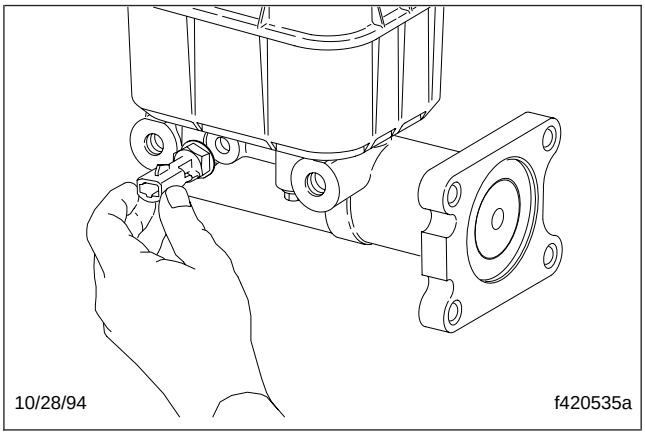


Fig. 25, Install the Pressure Differential Switch

14. Check the operation of the compensating valves by poking a wire through the hole in the bottom of each reservoir section. The compensating valves should depress easily, about 1/16 inch (1.5 mm), then spring back. If not, remove the reservoir and install it again. Check the valves again.
15. Remove the cross-bar puller or C-clamp installed to push the primary piston into the bore.
16. Bench bleed, then install the master cylinder on the booster, following the instructions under **Subject 170**.
17. Lower the hood, then remove the chocks.

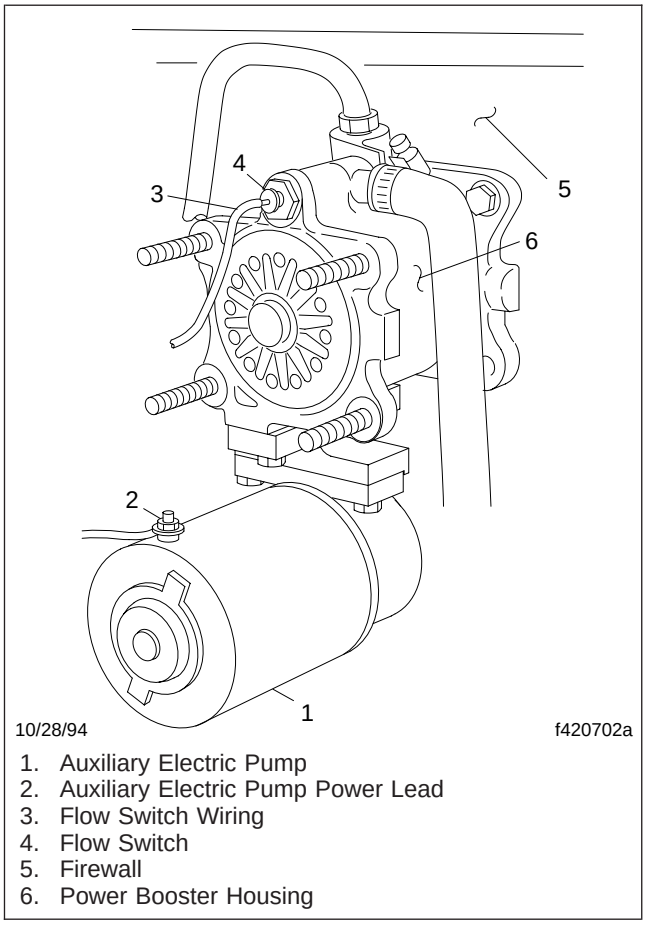
Hydro-Max II® Power Booster Removal and Installation

Removal

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Disconnect the batteries at the negative cable.
3. If not already done, disconnect the master cylinder from the power booster, following the instructions in **Subject 170**.
4. From inside the cab, disconnect the push rod from the brake pedal.
   - 4.1 Below the dash, find the clevis pin, washer, and cotter key that hold the power booster push rod to the brake pedal.
   - 4.2 Remove the cotter key, washer and clevis pin.
5. Disconnect the wiring from the auxiliary electric pump assembly. See **Fig. 1**.
6. Disconnect the wiring from the flow switch at the front of the power booster. See **Fig. 1**.
7. Using a shop towel or a container to catch any power steering fluid, disconnect the hydraulic supply and return lines from the power booster. See **Fig. 2**. Plug the lines.
8. Remove the four hexbolts and washers holding the power booster to the firewall. See **Fig. 3**. Pull the power booster straight out from the firewall, as shown in **Fig. 4**.

Installation

1. Position the power booster on the firewall so the push rod fits through the large hole and into the cab, and the four holes in the power booster line up with those on the firewall. See **Fig. 4**.
2. Install the four mounting hexbolts and washers. See **Fig. 3**. Tighten them 20 lbf·ft (27 N·m).
3. Install the master cylinder on the power booster, following the instructions in **Subject 170**.
4. Connect the hydraulic supply and return lines. See **Fig. 2**. Tighten the supply line 15 lbf·ft (20 N·m). Tighten the hose clamp on the return line firmly.

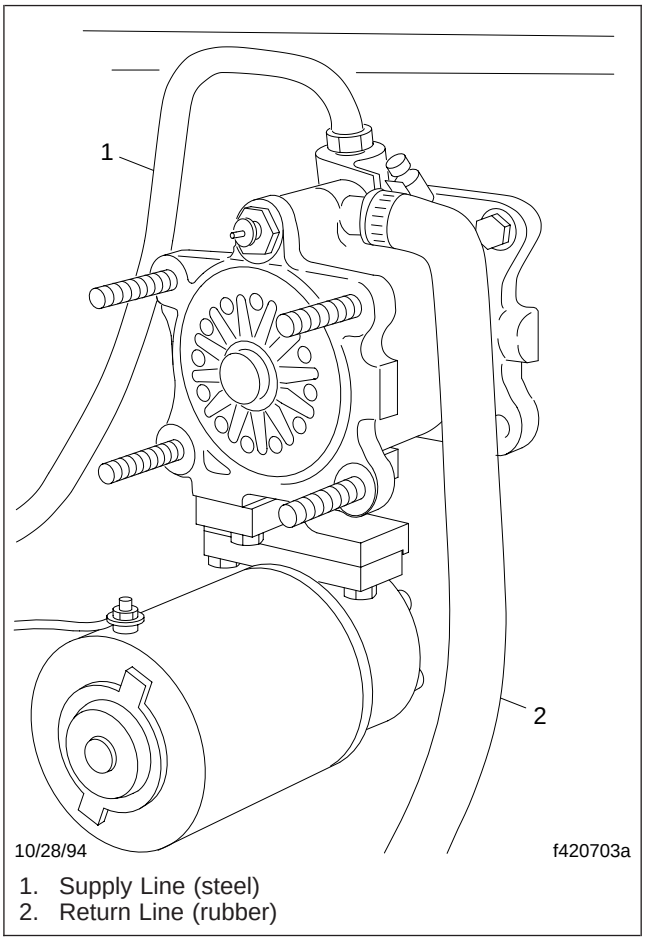


1. Auxiliary Electric Pump
2. Auxiliary Electric Pump Power Lead
3. Flow Switch Wiring
4. Flow Switch
5. Firewall
6. Power Booster Housing

Fig. 1, Disconnect the Wiring

5. Connect the wiring to the auxiliary electric pump assembly, and to the flow switch assembly. See **Fig. 1**.
6. Check the fluid level in the power steering reservoir. See **Fig. 5**. Add approved power steering fluid if needed. Refer to **Specifications, 400** for the approved power steering fluid.
7. Connect the batteries.
8. Lower the hood, then remove the chocks.
9. Bleed the power booster, following the instructions in **Subject 115**.

Hydro-Max II® Power Booster Removal and Installation



1. Supply Line (steel)
2. Return Line (rubber)

Fig. 2, Disconnect the Hydraulic Lines

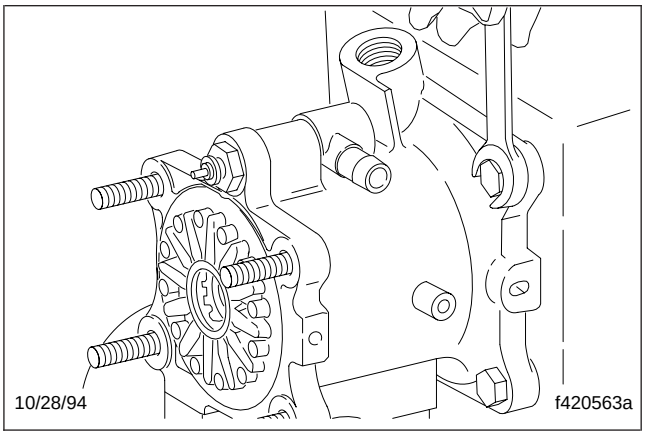


Fig. 3, Remove the Hexbolts and Washers

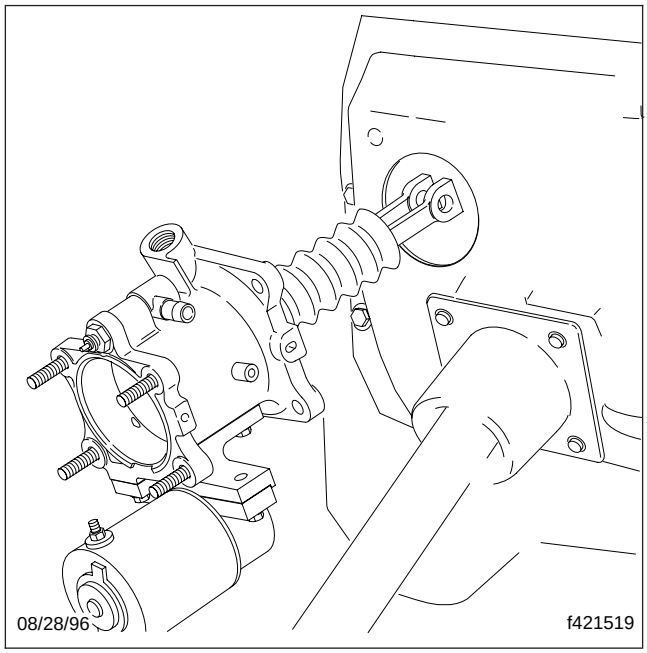
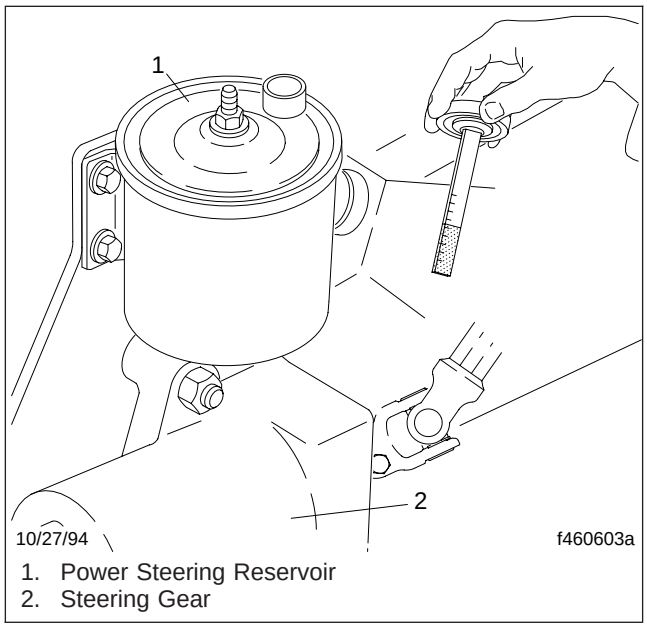


Fig. 4, Pull Out the Power Booster



1. Power Steering Reservoir
2. Steering Gear

Fig. 5, Check the Fluid Level

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly

Disassembly

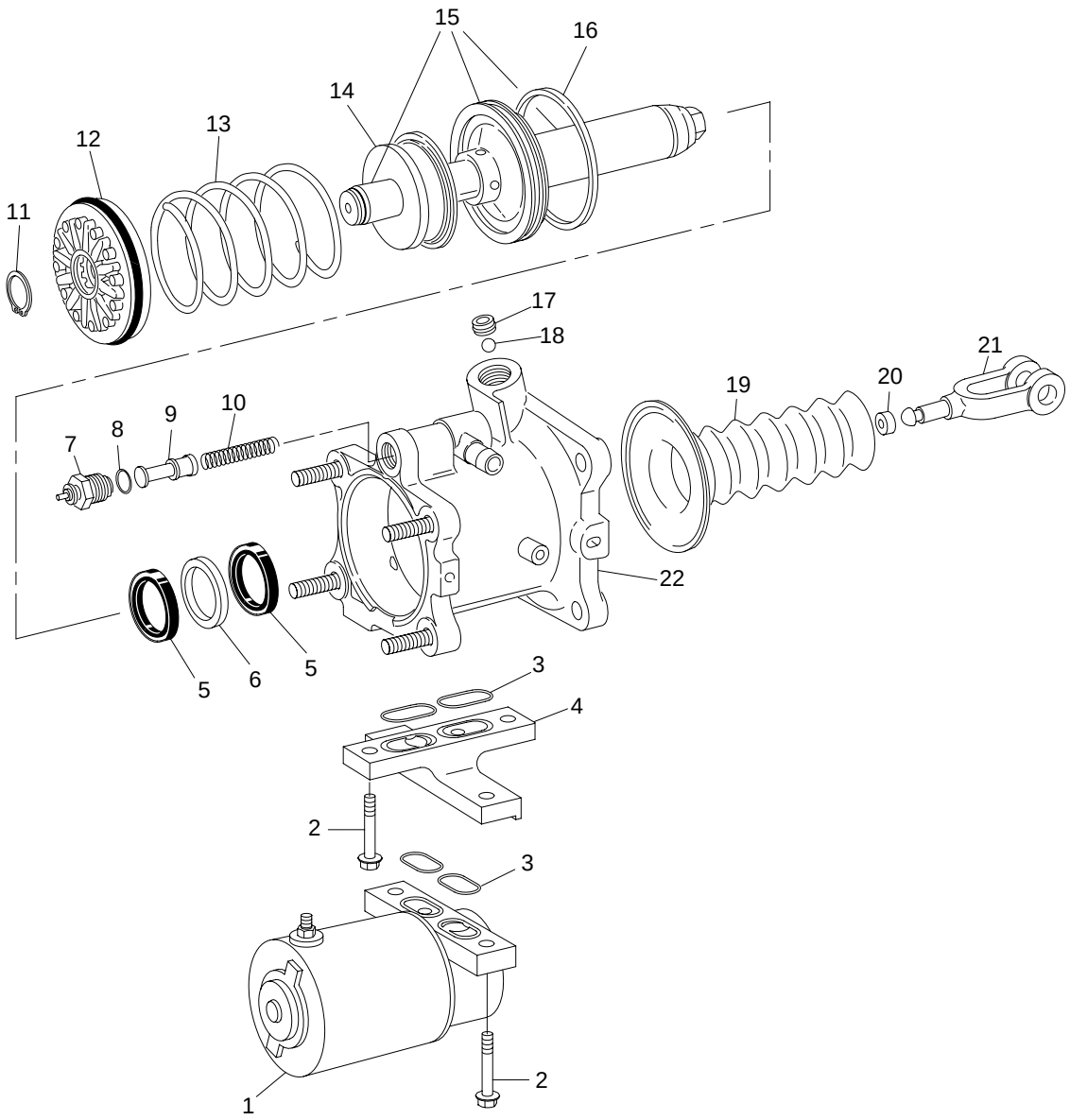
⚠ WARNING

WARNING: Always wear safety goggles or glasses when working on the power booster. Some power booster parts are under compression (such as springs, snap-rings, and the like), and they could release with some force, possibly causing injury.

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Remove the power booster from the vehicle, following the instructions in **Subject 180**.
3. Remove the auxiliary electric pump from the power booster housing. See **Fig. 1**.
   - 3.1 Hold the booster and pump assembly over a container. There are about 3 cups of fluid in the assembly.
   - 3.2 Remove the two screws that hold the pump and the adapter block to the bottom of the booster. See **Fig. 2**.

     Remove the two screws that attach the pump to the adaptor (if applicable).
   - 3.3 After the power steering fluid has been drained, remove and discard the oval seal rings from the electric pump and the adaptor block. See **Fig. 1**.
4. Remove and discard the rubber boot from the push rod. See **Fig. 1**.
5. Remove push rod from the end of the power piston. See **Fig. 1**.
   - 5.1 Put the booster unit in a padded vise so the wrench flats at the end of the power piston are in the vise jaws, as shown in **Fig. 3**.
   - 5.2 Put a round pry bar through the eyes of the push rod clevis, then pry the push rod out of the end of the power piston. See **Fig. 3**.
   - 5.3 Remove all the plastic grommet pieces from inside the power piston end and the push rod.
6. Remove the power piston assembly and the end cap from the booster housing.
   - 6.1 Place the booster housing on a padded surface, with the end cap facing down.
   - 6.2 Push down on the end of the power piston until the end cap and power piston come out of the front of the housing.
   - 6.3 Pull the power piston and end cap straight out of the booster housing; be careful not to scratch the piston or the housing bore. See **Fig. 4**.
7. Remove and discard the three input seals from the small bore at rear of the booster housing. See **Fig. 1**, Refs. 5 and 6.
8. Remove and discard the piston seal from the power piston.
9. Remove the end cap and the filter basket from the power piston.
   - 9.1 Put the end cap and power piston on a padded surface.
   - 9.2 Push down on the end cap to release the pressure on the snap ring, as shown in **Fig. 5**.
   - 9.3 Remove and discard the snap ring from the output shaft of the power piston. See **Fig. 6**.
   - 9.4 Remove and discard the end cap and the return spring. See **Fig. 6**.
   - 9.5 Remove the filter basket.
10. Remove the flow switch assembly from the front of the booster housing.
    - 10.1 Unscrew the nylon flow switch contact assembly from the housing. See **Fig. 7**.
    - 10.2 Using a small magnet, remove the flow switch piston and spring from the booster housing. See **Fig. 8**.
    - 10.3 Remove and discard the O-ring from the nylon contact assembly.
11. Using a hooked piece of wire, remove the inlet check valve from the inlet port on the booster housing. Then remove the check ball. Discard both parts. See **Fig. 9**.

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly



07/30/96 f421496

1. Auxiliary Electric Pump
2. Mounting Hexbolt
3. Oval Seal Rings (4 qty.)
4. Adaptor Block
5. Black Input Seal (2 qty.)
6. White Input Seal
7. Flow Switch Contact Assembly
8. O-Ring
9. Flow Switch Piston
10. Flow Switch Spring
11. Snap Ring
12. End Cap Assembly
13. Return Spring
14. Filter Basket
15. Power Piston Assembly
16. Piston Seal
17. Inlet Check Valve
18. Check Ball
19. Rubber Boot
20. Grommet
21. Push Rod
22. Booster Housing

Fig. 1, Power Booster Assembly

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly

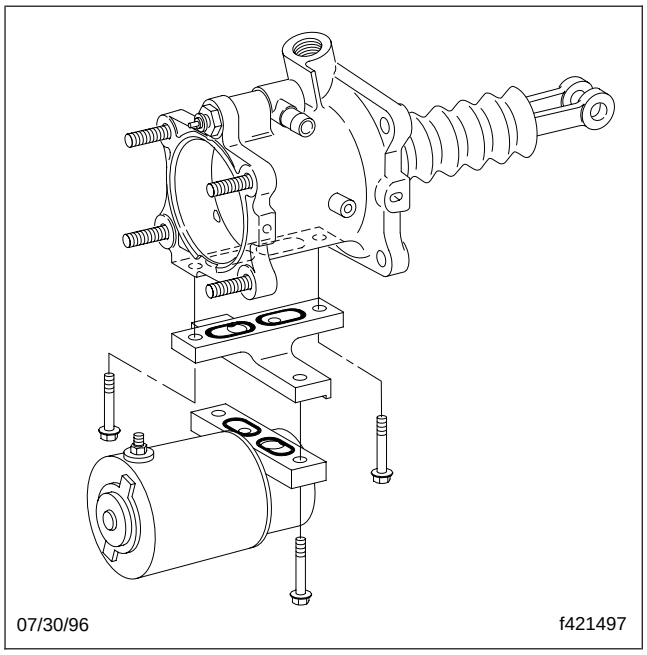
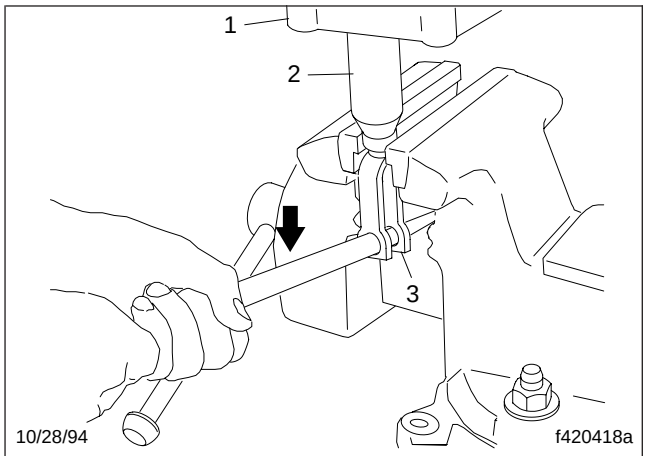


Fig. 2, Remove the Screws



1. Booster Housing
2. Power Piston
3. Push Rod Clevis

Fig. 3, Put the Booster in a Padded Vise

Inspection

1. Check the power piston surface for nicks or scratches. Pay special attention to the sealing surface and the input and output shafts. See **Fig. 10**. If there is any damage, replace the power piston assembly.

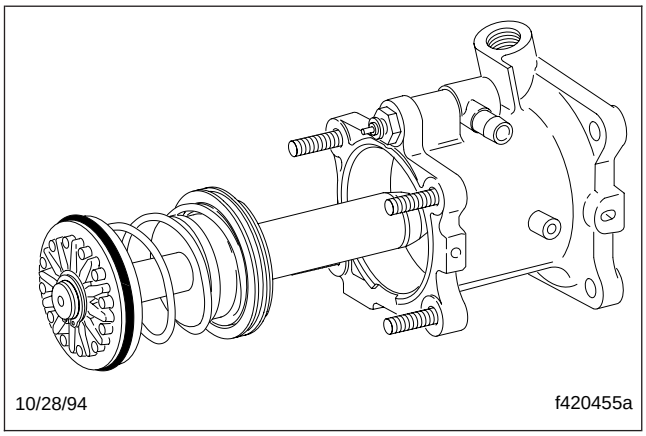


Fig. 4, Pull Out the Power Piston and End Cap

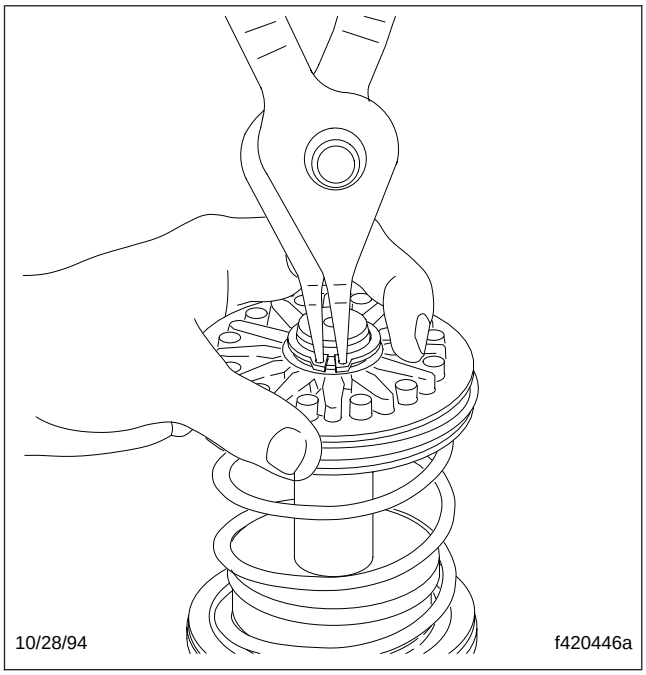
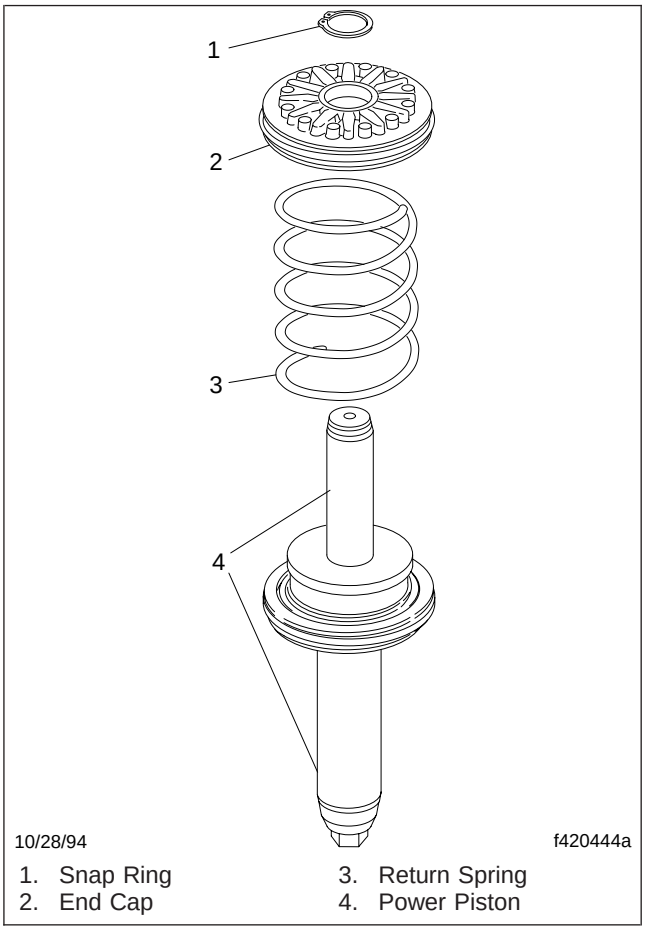


Fig. 5, Press Down on the End Cap

2. Check the bore in the booster housing. If it is grooved, nicked, or otherwise damaged, replace the entire power booster assembly.

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly



1. Snap Ring
2. End Cap
3. Return Spring
4. Power Piston

Fig. 6, Remove the Snap Ring

Assembly

⚠ WARNING

WARNING: Use only clean Dexron II® ATF for cleaning or lubricating power booster parts. Don't use brake fluid. Using other types of fluids may destroy seals and O-rings, which could cause the eventual loss of brake control, resulting in possible personal injury and property damage.

1. Using clean power steering fluid, clean and lightly lubricate all the power booster parts. See **Fig. 1**.

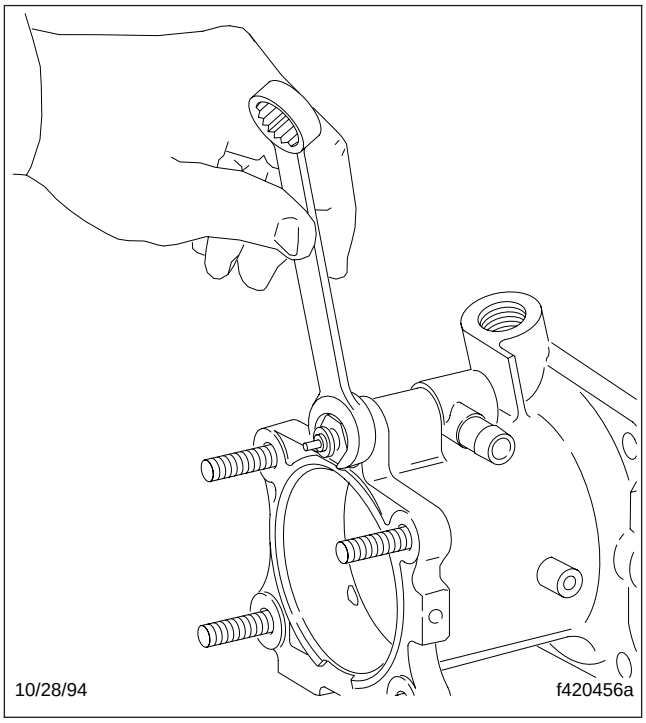
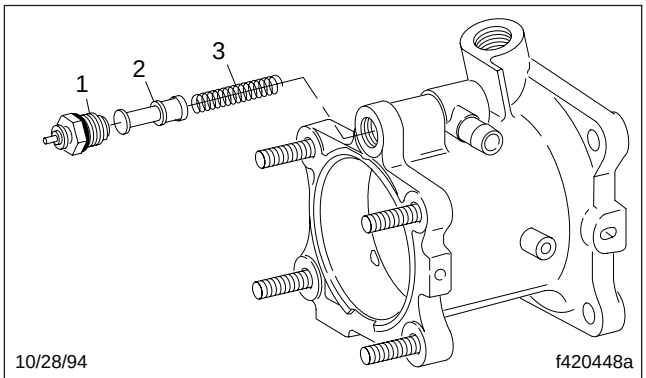


Fig. 7, Unscrew the Flow Switch Assembly



1. Flow-Switch Contact Assembly (with O-ring)
2. Flow-Switch Piston
3. Flow-Switch Spring

Fig. 8, Remove the Piston and Spring

2. Install new input seals in the small bore of the booster housing. Install the white seal between the two black ones, as shown in **Fig. 11**.
3. Install a new check ball in the inlet port on top of the booster housing, then install a new inlet check valve assembly. Make sure it's seated firmly.

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly

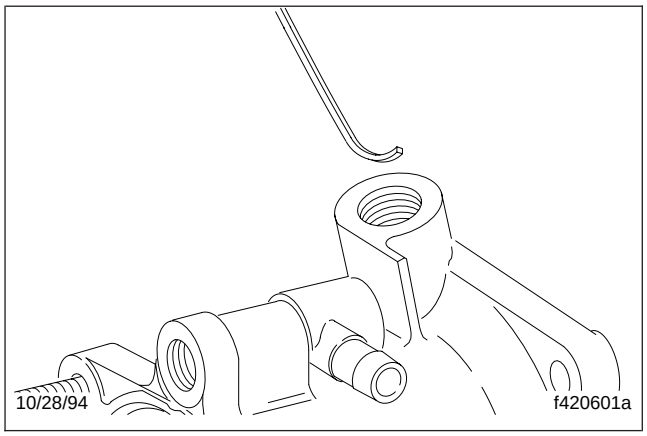
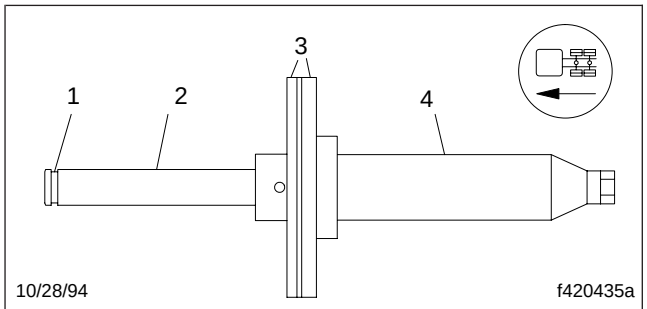


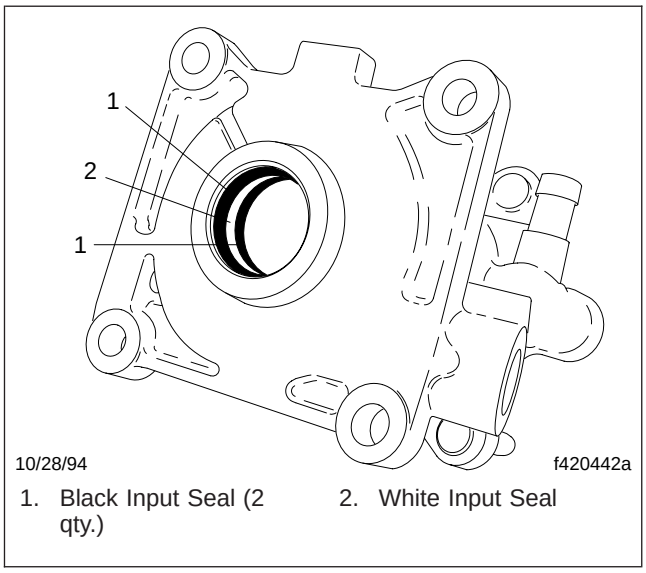
Fig. 9, Using a Hooked Piece of Wire, Remove the Inlet Check Valve and Check Ball



1. Groove
2. Output Shaft
3. Power Piston Sealing Surface
4. Input Shaft (hollow)

Fig. 10, Power Piston Assembly

4. Install the flow switch assembly in the front of the booster housing. See **Fig. 8**.
   - 4.1 Install the flow switch spring in its hole at the front of the booster housing.
   - 4.2 Install the flow switch piston.
   - 4.3 Install a new O-ring on the flow-switch contact assembly, then install the assembly in the hole at the front of the booster housing. Tighten it finger-tight.
5. Install a new filter basket—open end first—over the power piston output shaft, and push it up against the power piston.
6. Install the return spring on the power piston output shaft.



1. Black Input Seal (2 qty.)
2. White Input Seal

Fig. 11, Install New Input Seals

7. Install a new end-cap assembly on the power piston output shaft.
   - 7.1 Install a new square cut seal on the outside diameter of the new end cap, then install a new O-ring inside the small bore of the end cap.
   - 7.2 Lubricate the O-ring and lip seal in the end-cap hole with power steering fluid.
   - 7.3 Carefully install the end-cap assembly (ribbed side up) on the power piston output shaft.
   - 7.4 Keeping the end cap pushed down, install the snap ring in the groove of the power piston output shaft. See **Fig. 5**.
8. Install the power piston assembly in the booster housing.
   - 8.1 Install the power piston, larger shaft first, into the large bore at the front of the booster housing.

⚠ WARNING

WARNING: Be careful not to damage the input seals in the small bore of the booster housing when you install the power piston shaft through the small bore. If these seals are damaged, the booster assembly will leak, causing loss of brak-

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly

ing power, resulting in possible personal injury and property damage.

8.2 Carefully work the end of the power piston shaft through the small bore of the booster housing. Use a gentle twisting motion to work the shaft past the two seals in the bore. See **Fig. 11**.

IMPORTANT: If the seals are damaged by the power piston shaft, replace them. Then repeat steps for installation of the power piston.

8.3 Seat the end cap in the large bore of the housing.

9. Install a new boot on the push rod.
10. Install the push rod on the end of the power piston.

10.1 Install a new grommet on the push rod.

10.2 Put the flats of the power piston end into a padded vise, then install the push rod and the grommet firmly into the end of the power piston.

⚠ WARNING

WARNING: Be sure the push rod is seated all the way into the power piston end. If it's not, it could become disconnected later, which could result in the loss of braking control, resulting in possible personal injury and property damage.

11. Install new oval face seals on the mating surface of the auxiliary electric pump. See **Fig. 12**.
12. Install the adaptor block on the electric pump, with the machined lip on the block down, and hanging over the front edge of the electric pump. See **Fig. 13**. Tighten the mounting bolts 22 lbf·ft (30 N·m).
13. Install new oval face seals on the top of the adaptor block, then install the adaptor block and electric pump assembly on the bottom of the booster housing, as shown in **Fig. 14**. Tighten the two mounting bolts 22 lbf·ft (30 N·m).
14. Install the power booster assembly on the vehicle, following the instructions in **Subject 180**.

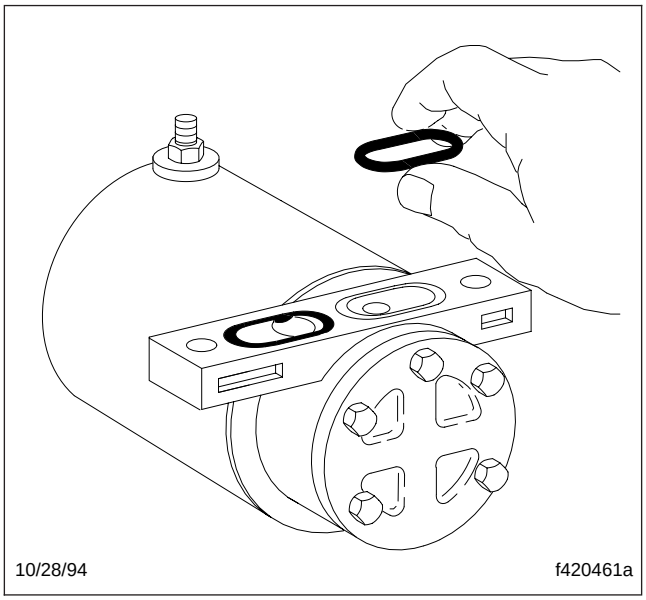
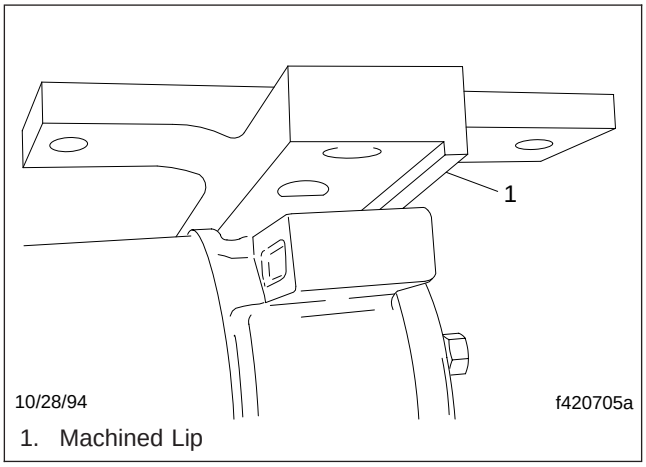


Fig. 12, Install New Oval Face Seals



1. Machined Lip

Fig. 13, Install the Adaptor Block

Hydro-Max II® Power Booster Disassembly, Inspection, and Assembly

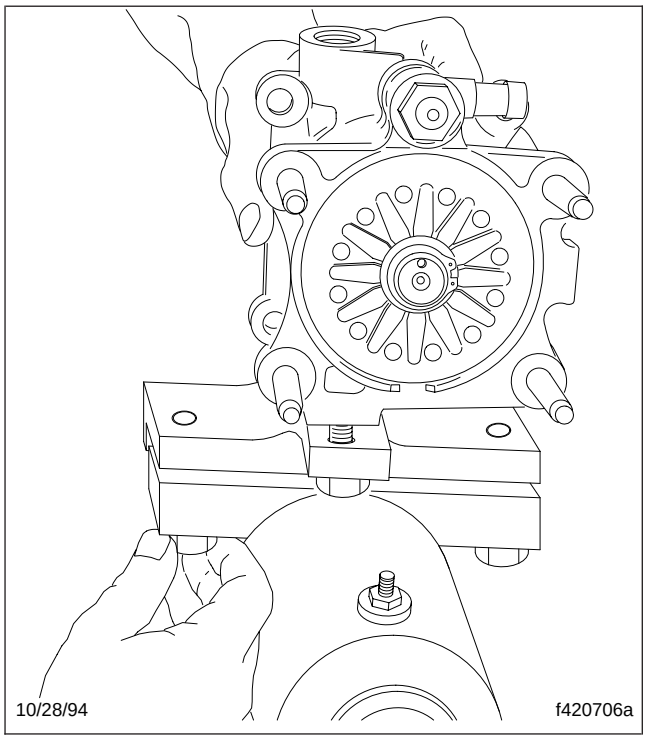


Fig. 14, Install the Adaptor Block and Pump Assembly

Troubleshooting Tables

Problem—The Brakes Pull to the Left or Right

Problem—The Brakes Pull to the Left or Right	
Possible Cause	**Remedy**
The tire pressure is too low.	Inflate the tires to the correct pressure.
The front wheels are out of alignment.	Align the front wheels. Refer to the applicable axle section.
The tires are mismatched.	Check the tire sizes, and correct as needed.
The brake lines or hoses are kinked.	Check the routing of the brake lines and hoses. Repair or replace as needed.
A caliper is loose or not working.	Repair the caliper.
The brake pads are oily.	Replace the brake pads.
The rear brakes aren't working.	Check the rear brakes, and repair or replace parts as needed.
The suspension parts are loose.	Check the front and rear suspension, and repair as needed.
The brake pads are mismatched or worn.	Replace the brake pads. Repair or replace the rotor(s) as needed.
There is grease on the pads or the rotor.	Clean the parts as needed.

Problem—Brake Noises With the Brakes Not Applied

Problem—Brake Noises With the Brakes Not Applied	
Possible Cause	**Remedy**
The front pads are worn out.	Replace the pads.
There is dust or oil on the rotors.	Clean the rotors, then check for and repair an oil leak.

Problem—Brake Noises With the Brakes Applied

Problem—Brake Noises With the Brakes Applied	
Possible Cause	**Remedy**
Incorrect brake pads are installed.	Install the correct brake pads.
A caliper is loose.	Install wear shims, or replace worn parts as needed.

Problem—Roughness, Chattering, or Pulsating Is Felt When the Brakes are Applied

Problem—Roughness, Chattering, or Pulsating Is Felt When the Brakes are Applied	
Possible Cause	**Remedy**
There is too much rotor lateral runout.	Check the lateral runout on the rotors. Repair or replace as needed.
The rotor parallelism is not to specifications.	Check the parallelism of the rotors. Repair or replace as needed.
The wheel bearings are incorrectly adjusted.	Check the end play of the front and rear wheel bearings. Adjust as needed. Refer to the applicable axle section.
A brake pad is installed backwards (steel side toward the rotor face).	Install the brake pad correctly.

Troubleshooting

Problem—Too Much Effort Is Needed to Apply the Brakes

Problem—Too Much Effort Is Needed to Apply the Brakes	
Possible Cause	**Remedy**
The brake pads are worn.	Replace the brake pads.
A caliper piston is stuck or binding.	Check the caliper pistons. Rebuild the caliper(s) as needed.
The brakes are fading due to incorrect pads.	Install the correct brake pads.
The brake pads or rotors are glazed.	Replace the glazed brake pads or rotors.
There is grease or oil on the brake pads or rotors.	Clean the brake pads or rotors.
The vehicle is overloaded.	Don't exceed rated vehicle loads.
The power booster isn't working.	Go to "System Pressure Testing," under "Troubleshooting Charts" in this subject.

Problem—Too Much Brake Pedal Travel

Problem—Too Much Brake Pedal Travel	
Possible Cause	**Remedy**
There is a leak in the hydraulic system.	Check for and repair any leaks found in either the power booster (power steering) hydraulic system, or the brake hydraulic system.
The fluid level in the master cylinder is too low.	Find the cause of the low fluid level, remedy the problem, then fill the master cylinder compartments to the correct level.
There is air in the hydraulic system.	Bleed the brake hydraulic system and the power steering system as needed.
A master cylinder cap is plugged.	Clean or replace the master cylinder cap.
The wrong type of brake fluid is in the system.	Drain the system, fill with the correct type of brake fluid, then bleed the air from the system.

Problem—The Brake Pedal Travel is Decreasing

Problem—The Brake Pedal Travel is Decreasing	
Possible Cause	**Remedy**
A compensating port in the master cylinder is plugged.	Check the compensating ports in the master cylinder through the openings at the bottom of each reservoir compartment. Unplug them if needed. If the compensating valves are stuck, remove the reservoir. Then install the compensating valves correctly.
The master cylinder pistons aren't returning.	Repair or replace the master cylinder.

Problem—The Brakes are Dragging

Problem—The Brakes are Dragging	
Possible Cause	**Remedy**
The master cylinder pistons aren't returning.	Repair or replace the master cylinder.

Problem—The Brakes are Dragging	
Possible Cause	**Remedy**
The brake lines or hoses are kinked or pinched.	Check the brake lines and hoses. Repair or replace as needed.
An inboard brake pad is incorrectly installed.	Check the inboard brake pads. Install them correctly as needed.
The power piston in the power booster isn't returning.	Repair or replace the power booster.
The brake pedal is restricted from returning.	Check the brake pedal for a restriction. Repair as needed.
The brake caliper pistons aren't returning.	Repair or replace the caliper(s) as needed. Check the brake fluid for water. Drain, flush, and fill the system if water is found.
There is a restriction or blockage inside a brake line or hose.	Go to "Residual Pressure Test," under "Troubleshooting Charts" in this subject.

Problem—The Brakes are Grabbing, or the Brake Action is Uneven

Problem—The Brakes are Grabbing, or the Brake Action is Uneven	
Possible Cause	**Remedy**
The power booster isn't working.	Repair or replace the power booster.
The brake pedal is binding.	Check the brake pedal for binding. Repair as needed.

Problem—Fluid Is Leaking Between the Power Booster and the Master Cylinder (a slight amount of moisture between the power booster and master cylinder is normal)

Problem—Fluid Is Leaking Between the Power Booster and the Master Cylinder (a slight amount of moisture between the power booster and master cylinder is normal)	
Possible Cause	**Remedy**
The master cylinder primary pressure seal or backup ring is worn or damaged.	Repair or replace the master cylinder.
The seals or O-rings in the power booster end-cap assembly are worn or damaged.	Repair or replace the power booster.

Problem—Fluid is Leaking at the Booster or the Power Steering Pump

Problem—Fluid is Leaking at the Booster or the Power Steering Pump	
Possible Cause	**Remedy**
The seals between the auxiliary electric pump and the booster are worn or damaged.	Replace the seals.
The hexbolts attaching the electric pump to the booster are loose.	Tighten the hexbolts 22 lbf·ft (30 N·m).
The power booster housing or the power steering pump is worn or damaged.	Replace the power booster or the power steering pump.
The auxiliary electric pump is worn or damaged.	Replace the electric pump.

Troubleshooting

Problem—Fluid is Leaking at the Booster or the Power Steering Pump	
Possible Cause	**Remedy**
The power booster flow switch seals are worn or damaged.	Repair the power booster.

Problem—The Power Steering Pump Is Noisy

Problem—The Power Steering Pump Is Noisy	
Possible Cause	**Remedy**
The hydraulic supply and return lines are touching the chassis.	Reroute the power booster supply and return lines.
The fluid level in the power steering reservoir is low.	Fill the power steering reservoir to the correct level.
There is air in the power steering fluid.	Bleed the power steering system.
The power steering fluid is contaminated.	Change the power steering fluid.
The power steering fluid is contaminated.	Replace the power steering pump.

Problem—The Brake Pedal Is Hard to Depress With the Engine Running

Problem—The Brake Pedal Is Hard to Depress With the Engine Running	
Possible Cause	**Remedy**
The brake pedal is binding.	Check the brake pedal linkage. Repair or replace as needed.

Problem—The Power Booster Works Sluggishly or Not at All

Problem—The Power Booster Works Sluggishly or Not at All	
Possible Cause	**Remedy**
The fluid level in the power steering reservoir is low.	Fill the power steering reservoir to the correct level.
The booster push rod is binding.	Check the linkage between the brake pedal and the booster push rod. Also check the hole in the firewall through which the push rod fits. Repair or replace parts as needed.
There is a restriction in one of the power steering hydraulic lines.	Check all the power steering system hydraulic lines. Replace as needed.
The power booster is worn or damaged.	Replace or rebuild the power booster.
There is air in the power steering hydraulic system.	Bleed the power steering hydraulic system.
The power steering pump is worn or damaged.	Repair or replace the power steering pump.
There is leakage around the check ball in the auxiliary electric pump.	Install a flow gauge on the booster inlet port. Check the pressure with the engine on, and the brakes fully applied. If the pressure is less than 5515 kPa (800 psi), replace the electric pump.

Problem—The Auxiliary Electric Pump Doesn't Work With the Engine Off and the Brake Pedal Depressed

Problem—The Auxiliary Electric Pump Doesn't Work With the Engine Off and the Brake Pedal Depressed	
Possible Cause	**Remedy**
The wiring to the electric pump is disconnected or damaged.	Check the wiring. Repair or replace as needed.
The batteries are dead.	Check the batteries. Recharge them as needed.
The brake switch is out of adjustment.	Check the brake switch, and adjust it as needed.
The brake switch is worn or damaged.	Replace the brake switch.
The wiring to the flow switch on the booster is loose, broken, or disconnected.	Check the wiring, and repair or replace as needed.
The booster flow switch is not working.	Replace the flow switch.
The relay to the electric pump isn't working.	Check the relay on the electrical mounting plate. Replace it if needed.
The electric pump isn't working.	Check the operation of the electric pump, and replace as needed.
Circuit 389A is open.	Repair circuit 389A.

Problem—The Auxiliary Electric Pump Runs Continuously When the Ignition Is Off and the Brake Pedal Is Not Depressed

Problem—The Auxiliary Electric Pump Runs Continuously When the Ignition Is Off and the Brake Pedal Is Not Depressed	
Possible Cause	**Remedy**
The brake light switch is not working, or is adjusted incorrectly.	Check the brake light switch, and repair or replace as needed.
The relay to the electric pump isn't working.	Check the relay on the electric mounting plate. Replace it if needed.

Problem—The Auxiliary Electric Pump Is Working, but There Is No Boost Power to the Brakes

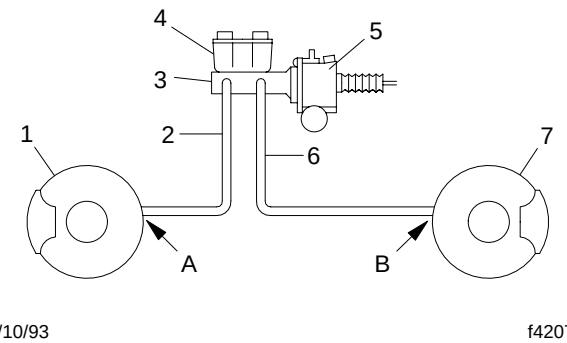
Problem—The Auxiliary Electric Pump Is Working, but There Is No Boost Power to the Brakes	
Possible Cause	**Remedy**
The battery voltage is low.	Check the batteries, and recharge them as needed.
The electric pump volatage is low.	Disconnect the wiring from the electric pump, then check the voltage at the wire. If the voltage is 10 volts or less, replace the wire. If it's more than 10 volts, replace the electric pump.

Troubleshooting Charts

RESIDUAL PRESSURE TESTING

1. Install two pressure gauges with a range of 0 to 50 psi (0 to 345 kPa)—one in the primary circuit (at the rear wheel), and one in the secondary circuit (at the front wheel). See **Fig. 1**.
2. Bleed the two circuits, following the procedure in **Subject 110**.
3. With the ignition off, lightly apply the brakes several times. Don't apply full pressure to the brake pedal, or you may damage the pressure gauges.
4. Release the brakes, then read the residual pressure on the two gauges. Record the information, then follow the procedure in **Fig. 2**.

Troubleshooting



08/10/93 f420765

A. Install gauge #2 here.
B. Install gauge #1 here.

1. Front Brake
2. Secondary Circuit
3. Master Cylinder
4. Reservoir
5. Power Booster
6. Primary Circuit
7. Rear Brake

Fig. 1, Install Pressure Gauges

SYSTEM PRESSURE TESTING

1. Install two pressure gauges with a range of 0 to 2500 psi (0 to 17 237 kPa)—one in the primary circuit (at the rear wheel), and one in the secondary circuit (at the front wheel). See **Fig. 1**.

   If you have previously done the residual pressure test, remove the two low-pressure gauges installed for that test, and replace them with the two high-pressure gauges.
2. Bleed the primary and secondary brake circuits, following the procedure under **Subject 110**.
3. Make a copy of **Table 1**. Use this copy to record the results from the next step.

Pressure Testing Questions				
Pressure Test	**Gauge 1 (installed at rear wheel)**		**Gauge 1 (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, Pressure Testing Questions

4. Start the engine, then quickly apply the brakes, using full pedal force. Hold the pedal down for 15 to 20 seconds, then record the speed of the pressure rise, the highest pressure registered on each gauge, and whether the pressure stayed constant while the pedal was depressed. See **Table 1**.
5. Using the recorded information, follow the procedure in **Fig. 3**.
6. Remove the pressure gauges, then bleed the system, following the instructions in **Subject 110**.

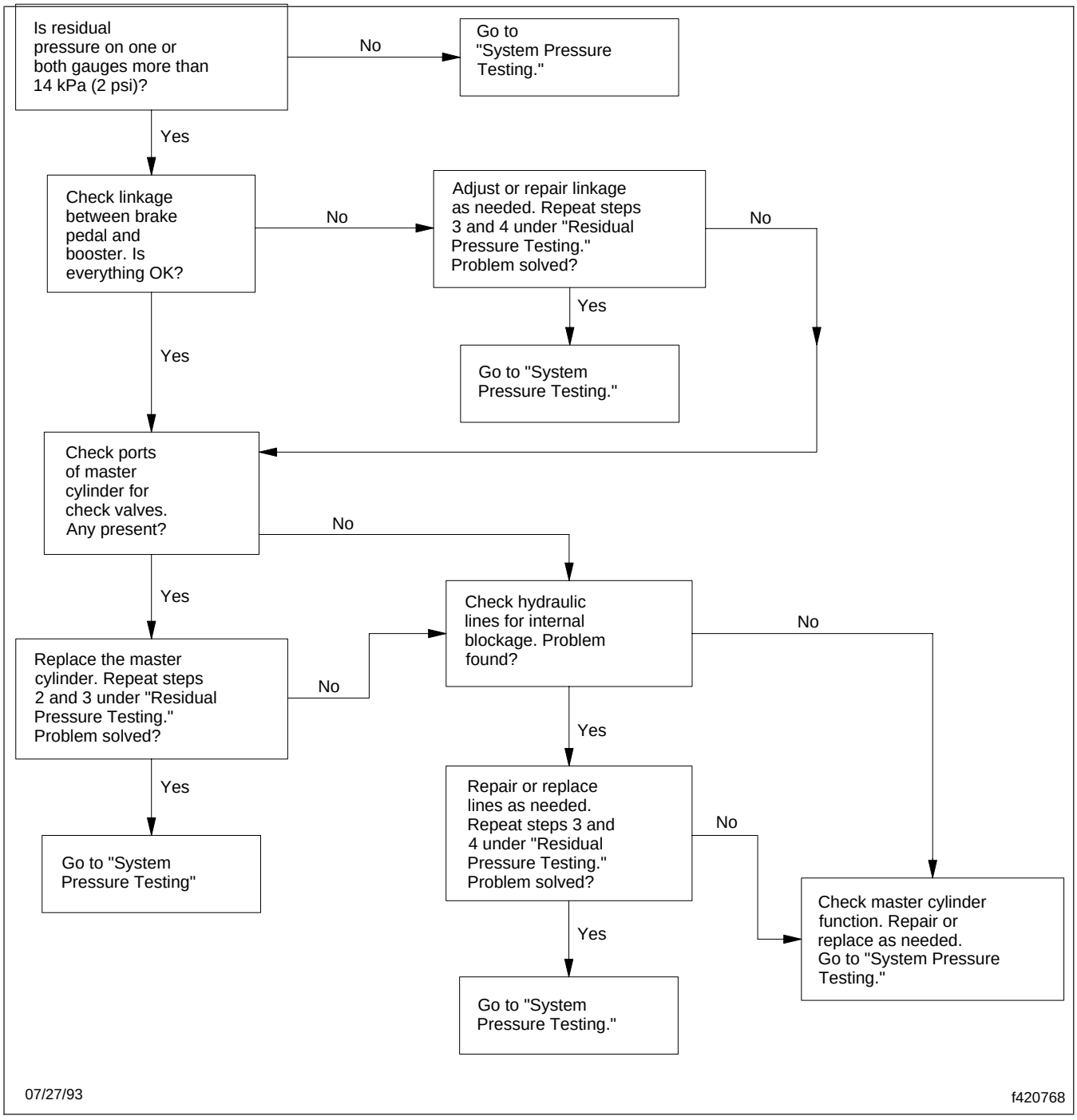


Fig. 2, Residual Pressure Testing Flow Chart

Troubleshooting

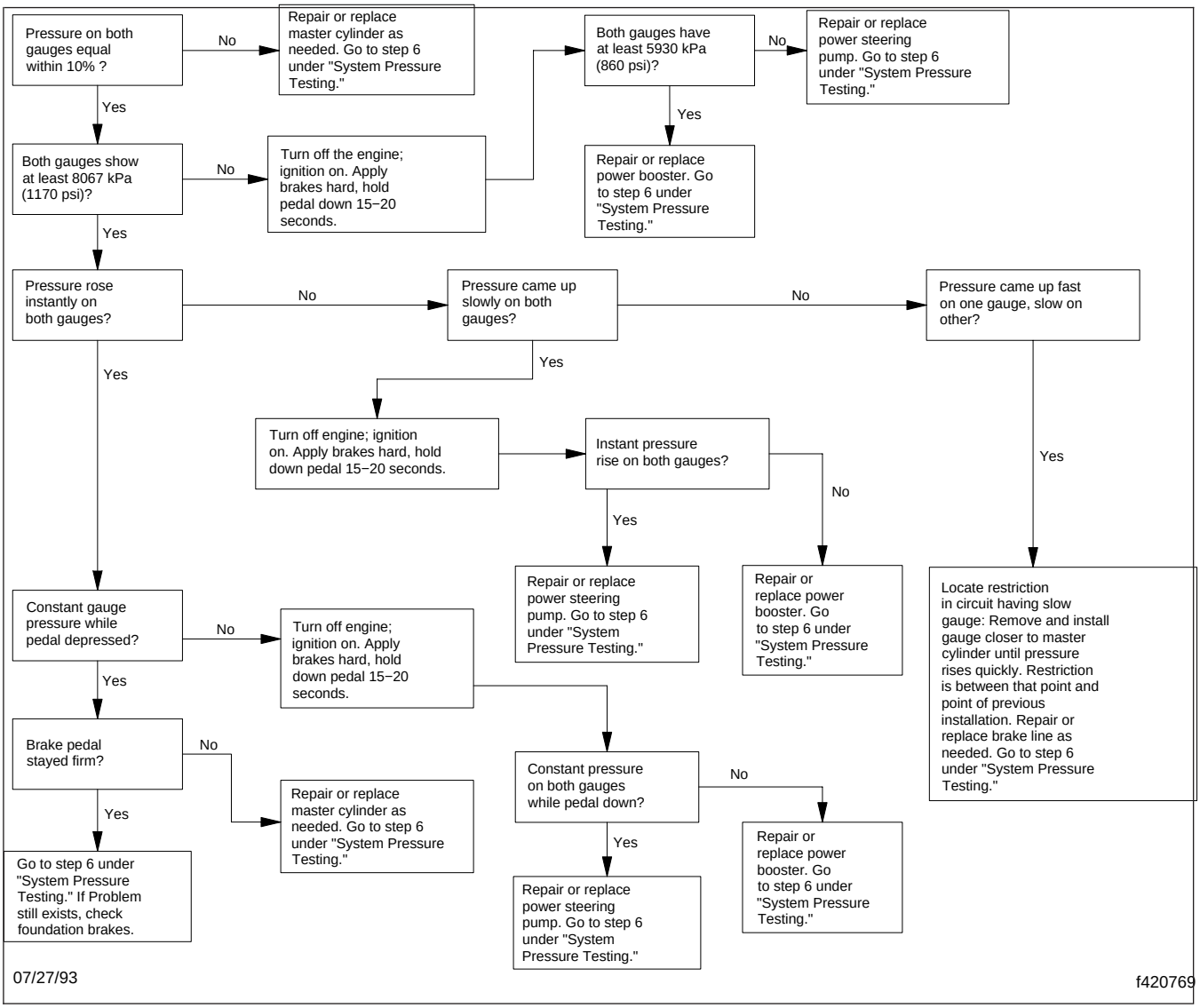


Fig. 3, System Pressure Testing Flow Chart

Specifications

See **Fig. 1** for the hydraulic brake system plumbing diagram. See **Fig. 2** for the brake control module wiring diagram.

Kent-Moore Tools, Kent-Moore Tool Division, 29784 Little Mack, Roseville, MI 48066	
Kent-Moore Part Number	**Tool**
KMS/ZTSE4276	Seating Tool for 2.88-Inch Caliper Pistons
KMS/ZTSE4343	Seating Tool for 2.6-Inch Caliper Pistons

Table 1, Kent-Moore Tools, Kent-Moore Tool Division, 29784 Little Mack, Roseville, MI 48066

Fastener Torques			
Description	**Bolt or Nut Size**	**Grade**	**Torque lbf·ft (N·m)**
Power Booster Mounting Bolts	—	—	20 (27)
Master Cylinder Mounting Nuts	—	—	28 (38)
Brake Line Tube Nuts	7/16–24	—	15 (20)
Caliper Supply Fitting	7/16–24	—	15 (20)
Allen-Head Key Retainer Bolts	—	—	18 (24)
Reservoir Mounting Hexbolts	—	—	15 (20)
Anchor Plate Mounting Hexbolts	1/2–13	8	70 (95)
Rotor Mounting Hexbolts	9/16–12	8	130 (175)
Dust Shield Mounting Bolts	—	—	15 (20)
Master Cylinder Outlet Fittings	7/16–24	—	15 (20)
Power Booster Supply Line Fitting	—	—	20 (27)

Table 2, Fastener Torques

Approved Power Steering Fluid for Power Booster	
Fluid Type	**Recommended Fluid**
Automatic Transmission Fluid	Dexron II®

Table 3, Approved Power Steering Fluid for Power Booster

Approved Brake Fluid for Brake System	
Fluid Type	**Recommended Fluid**
DOT 3	Wagner-Premium Plus Super HD Delco Supreme II Dow HD 50–4

Table 4, Approved Brake Fluid for Brake System

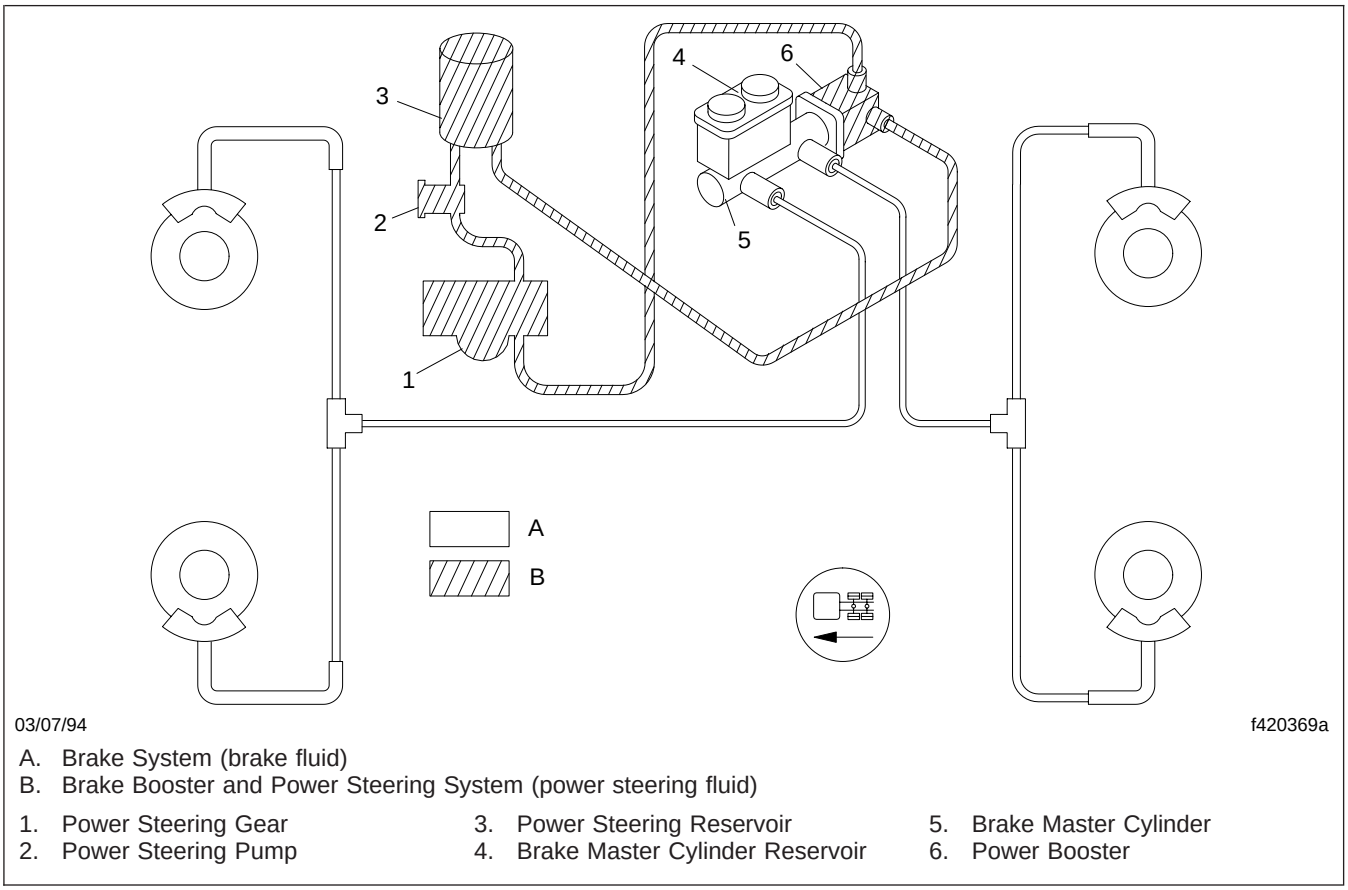
Rotor Specifications		
Maximum Allowable Lateral Runout inch (mm)	**Minimum Allowable Thickness inch (mm)**	**Maximum Difference in Parallelism inch (mm)**
0.015 (0.38)	1.32 (33.5)	0.005 (0.13)

Table 5, Rotor Specifications

Specifications

Approved Brake System Grease	
Component	**Recommended Grease**
Brake Caliper V-Ways and Anchor Plate Rails	Aeroshell Grade 5 (ES–1246)

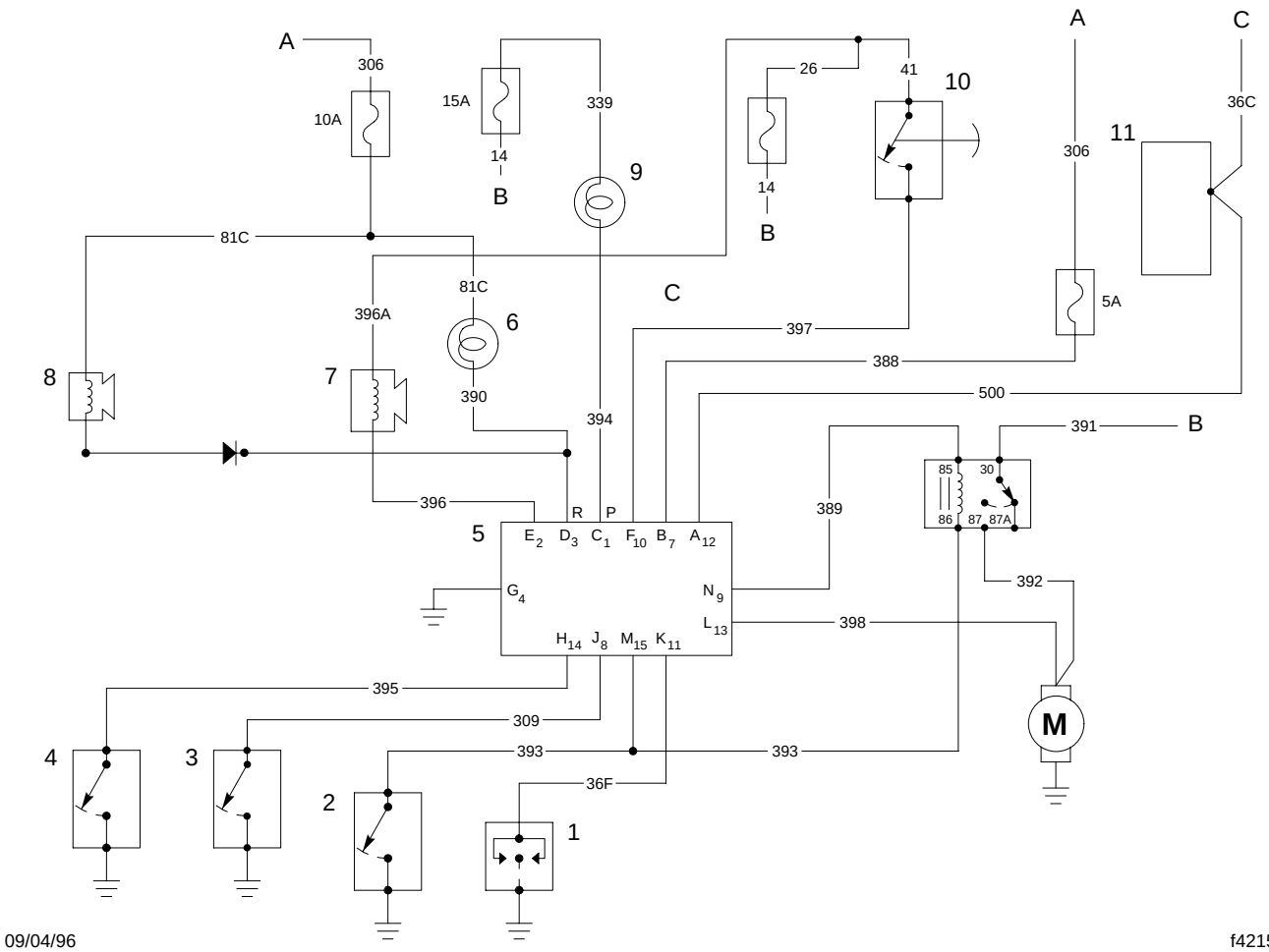
Table 6, Approved Brake System Grease



A. Brake System (brake fluid)
B. Brake Booster and Power Steering System (power steering fluid)

1. Power Steering Gear
2. Power Steering Pump
3. Power Steering Reservoir
4. Brake Master Cylinder Reservoir
5. Brake Master Cylinder
6. Power Booster

Fig. 1, Hydraulic Brake System Plumbing Diagram



NOTE: Key off, door closed.

A. To ignition switch.
B. To positive battery post.
C. To stoplight switch relay.

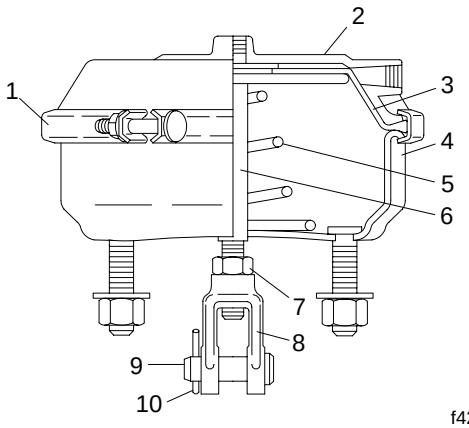
1. Pressure Differential Switch
2. Flow Switch
3. Parking Brake Switch (hydraulic)
4. Fluid Indicator Switch
5. Brake Control Module
6. Brake Pressure Indicator
7. Control Module Buzzer
8. Dash Buzzer
9. Parking Brake Indicator
10. Door Switch
11. Turn Signal Switch

Fig. 2, Brake Control Module Wiring

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 pressure cap and the chamber, which are separated by a nylon-reinforced diaphragm. A metal two-segment clamp ring holds the assemblies together. See **Fig. 1**.



1. Clamp Ring
2. Pressure Cap
3. Diaphragm
4. Chamber Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Clevis Jam Nut
8. Clevis
9. Clevis Pin
10. Cotter Pin

Fig. 1, Sectional View

In front of the diaphragm are the piston rod assembly, and a piston rod spring. The threaded piston rod assembly extends through the bottom of the chamber 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 lb (4270 N).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber pressure cap 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.

Service Brake Chamber Operating and Leakage Tests

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 applicable slack adjuster section in this group.

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

CAUTION: Don't 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. Do not tighten more than 25 to 30 lbf·ft (34 to 41 N·m).
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, refer to **Subject 110**.

Service Brake Chamber Diaphragm 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.

Replacement

1. Chock the tires.

⚠ WARNING

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

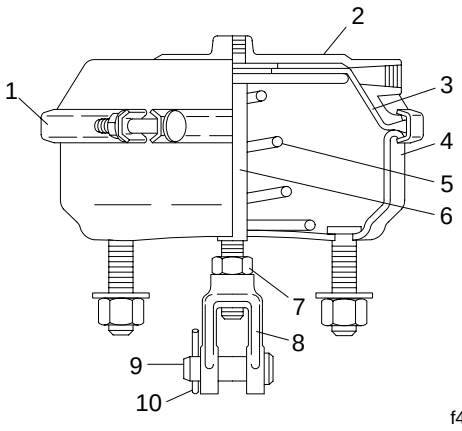
Follow the manufacturer's recommendations when working on any air device so as to avoid injury or damage from parts which, when released, are subject to mechanical (spring) or compressed-air propulsion.

2. Drain the air reservoirs and lines.
3. Back off the slack adjuster; for instructions, refer to the applicable slack adjuster section in this group. 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. Replace the diaphragm.
   - 5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 5.2 Remove the pressure cap, and replace the diaphragm.

⚠ CAUTION

CAUTION: Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

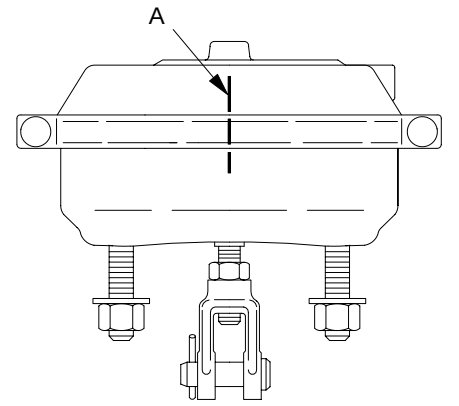
   - 5.3 Position the pressure cap and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly 25 to 30 lbf·ft (34 to 41 N·m) to eliminate leakage.
6. Release the clamp on the piston rod.
7. Do both of the tests in **Subject 100**.



08/13/96 f421326a

1. Clamp Ring
2. Pressure Cap
3. Diaphragm
4. Chamber Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Clevis Jam Nut
8. Clevis
9. Clevis Pin
10. Cotter Pin

Fig. 1, Sectional View



02/28/95 f421327

A. Reference Line

Fig. 2, Mark a Reference Line

Service Brake Chamber Diaphragm Replacement

8. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable brake section in this group.
9. Remove the chocks from the tires.

Service Brake Chamber Removal and Installation

Removal

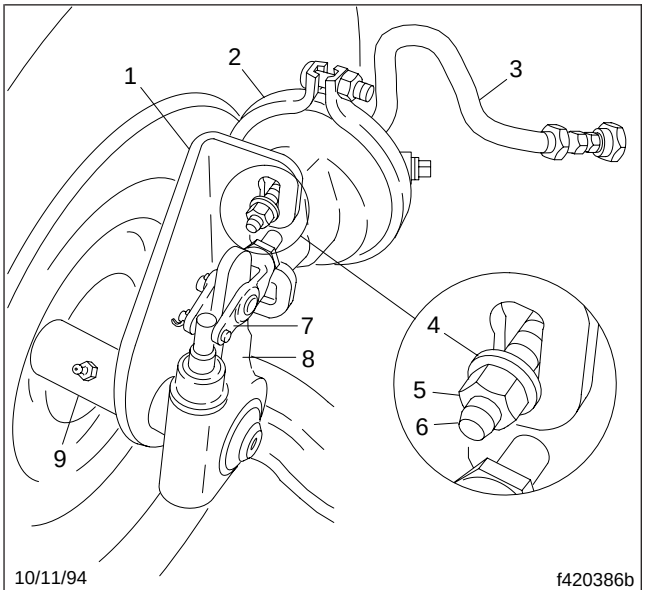
1. Chock the tires.

⚠ WARNING

WARNING: Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Don't direct the airstreams at other people. Don't 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. See **Fig. 1**.



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 (Automatic Type)
9. Camshaft Tube

Fig. 1, Brake Chamber Mounting

3. Carefully disconnect the air line from the brake chamber.
4. Remove the brake chamber.

   4.1 Remove the cotter pin(s) from the clevis pin(s).

   NOTE: Rockwell automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   4.2 Remove the clevis pin(s) from the slack adjuster.

   4.3 From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation

1. Before installing a new chamber, be sure the new chamber is the same size and make as the brake chamber on the other side of the axle. See **Fig. 1**.
2. Install the brake chamber.

   2.1 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.

   2.2 Tighten the locknuts. See **Table 1** for the correct torque value.

Description	Chamber Size (in ²)	Torque lbf·ft (N·m)
Brake Chamber Mounting-Stud Locknuts	16	35–40 (47–54)
	20	100–115 (136–156)
	24	100–115 (136–156)

Table 1, Mounting Stud Locknut Torque Values

   2.3 Connect the clevis pins to the slack adjuster.

   2.4 Install and lock the cotter pin(s) to secure the clevis pin(s).

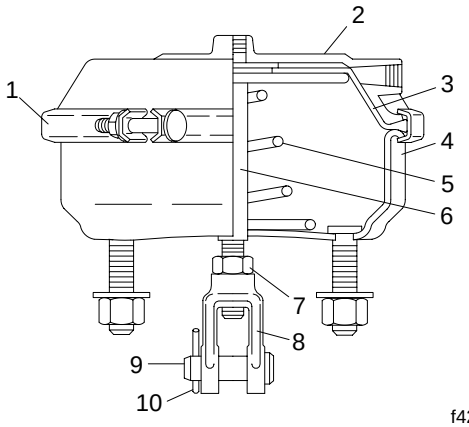
Service Brake Chamber Removal and Installation

NOTE: Gunite and Rockwell automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

3. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable brake section in this group.
4. Connect the air line to the brake chamber.
   - 4.1 Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
   - 4.2 Before connecting the air line, make sure the fittings are clean and free of debris.
   - 4.3 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.
5. Do both of the tests in **Subject 100**.
6. Remove the chocks from the tires.

Service Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

Disassembly



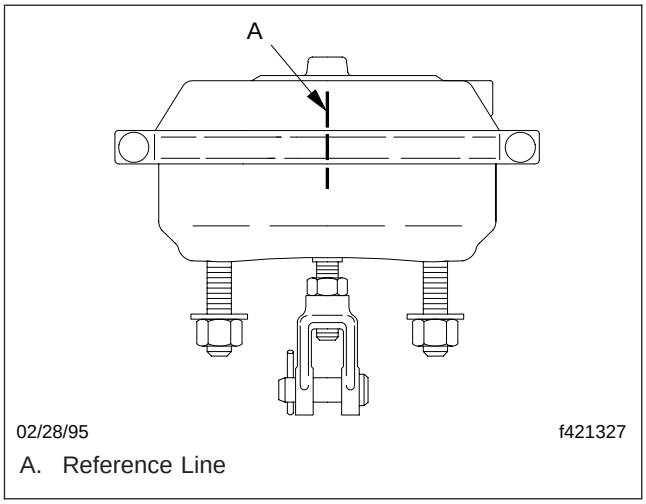
08/13/96 f421326a

1. Clamp Ring
2. Pressure Cap
3. Diaphragm
4. Chamber Assembly
5. Piston Rod Spring
6. Piston Rod Assembly
7. Clevis Jam Nut
8. Clevis
9. Clevis Pin
10. Cotter Pin

Fig. 1, Sectional View

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. 1** and **Fig. 2**.
2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Disassemble the brake chamber.
   - 3.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 3.2 Remove the pressure cap and the diaphragm.
   - 3.3 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.
   - 3.4 Remove the piston rod assembly and spring.



02/28/95 f421327

A. Reference Line

Fig. 2, Mark a Reference Line

Inspection and Cleaning

1. Clean all metal parts with cleaning solvent.
2. Inspect all parts for wear or damage; replace as needed.
   - 2.1 Check the pressure cap and the chamber for dents. If any are too deep to be pounded out, replace as needed.
   - 2.2 Check the diaphragm for wear or deterioration and replace it if needed.
   - 2.3 Inspect all other parts not considered serviceable. Replace if needed.

Assembly

1. Stand the piston rod assembly upright on a flat surface (if the chamber was removed from the vehicle). See **Fig. 1**.
2. Assemble the brake chamber.
   - 2.1 Place the return spring on the piston rod.
   - 2.2 Place the chamber on the piston rod assembly, and press the chamber down, working against the tension of the spring,

Service Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

until the chamber bottoms out on the flat surface. Clamp the rod at the chamber, making sure to protect the rod from damage. Insert the piston rod assembly through the chamber and clamp the rod (if the chamber wasn't removed from the vehicle).

2.3 Place the diaphragm in the chamber.

⚠ CAUTION

CAUTION: Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

2.4 Position the pressure cap and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly 25 to 30 lbf·ft (34 to 41 N·m) to eliminate leakage.

3. Install the clevis locknut and clevis, and release the clamp on the piston rod.
4. If the brake chamber was removed from the vehicle, install it. For instructions, refer to **Subject 120**.
5. Do both of the tests found in **Subject 100**.

Specifications

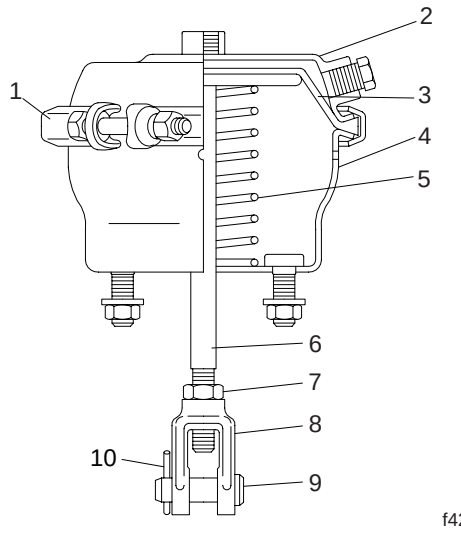
Description	Chamber Size (in^2)	Torque lbf·ft (N·m)
Brake Chamber Mounting-Stud Locknuts	16	35–40 (47–54)
	20	100–115 (136–156)
	24	100–115 (136–156)

Table 1, Mounting-Stud Locknut Torque Values

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
10. Cotter Pin

Fig. 1, 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 lb (436 kg).

When the brake pedal is depressed, air pressure from the brake valve passes through the port in the brake chamber cover to move the diaphragm and piston rod assembly forward. This compresses the spring, and applies a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

When the brake pedal is released, compressed air behind the diaphragm exhausts through the quick release valve. The spring then allows the piston rod assembly and diaphragm to return to their previous positions.

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. Refer to the vehicle maintenance manual for instructions.

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

CAUTION: Don't 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, refer to **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, refer to **Subject 110**.

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.

Replacement

1. Chock the tires.

⚠ WARNING

WARNING: Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Don't direct the airstreams at anyone. Don't 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.

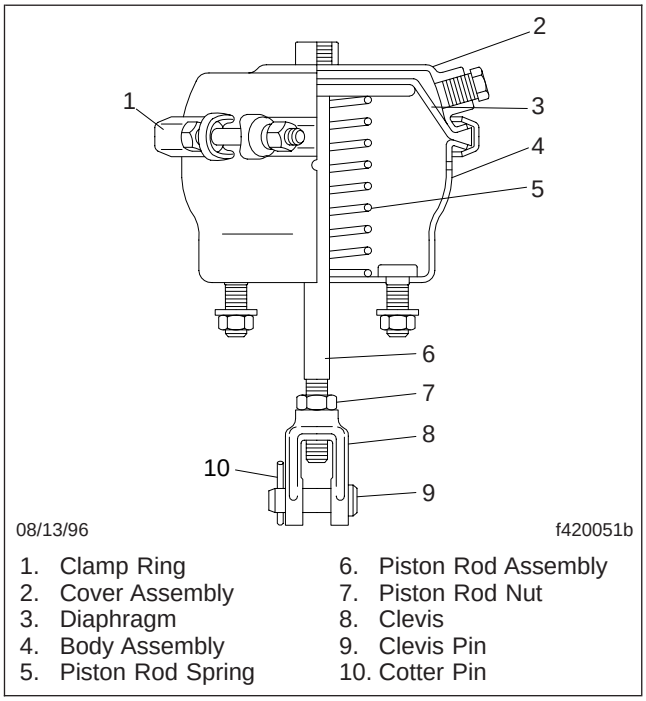
2. Drain the air reservoirs and lines.
3. Back off the slack adjuster; for instructions, refer to the applicable slack adjuster section in this manual. Pull out the piston rod. See **Fig. 1**. Clamp the rod at the chamber body to protect it from damage.
4. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 2**.
5. Replace the diaphragm.
   - 5.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 5.2 Remove the cover assembly, and replace the diaphragm.

⚠ CAUTION

CAUTION: Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

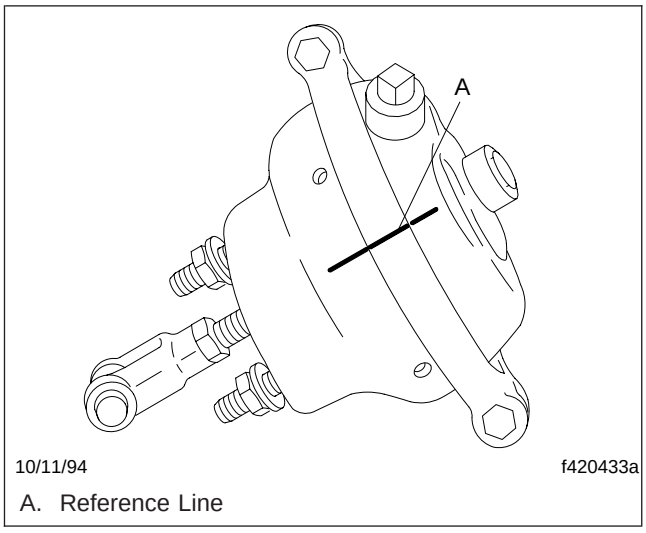
   - 5.3 Position the cover assembly and clamp ring (aligning the reference marks), and install the clamp ring bolt and flange nut. Tighten the flange nuts evenly to eliminate leakage. For acceptable torque ranges, refer to **Specifications, 400**.

6. Release the clamp on the piston rod.



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
10. Cotter Pin

Fig. 1, Sectional View



A. Reference Line

Fig. 2, Mark a Reference Line

Diaphragm Replacement

7. Do both of the tests in **Subject 100**.
8. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable brake section in this manual.
9. Remove the chocks from the tires.

Brake Chamber Removal and Installation

Removal

1. Chock the tires.

⚠ WARNING

WARNING: Wear safety goggles when draining the air system or loosening an air line because dirt or sludge could fly out at high speeds. Don't direct the airstreams at other people. Don't 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.

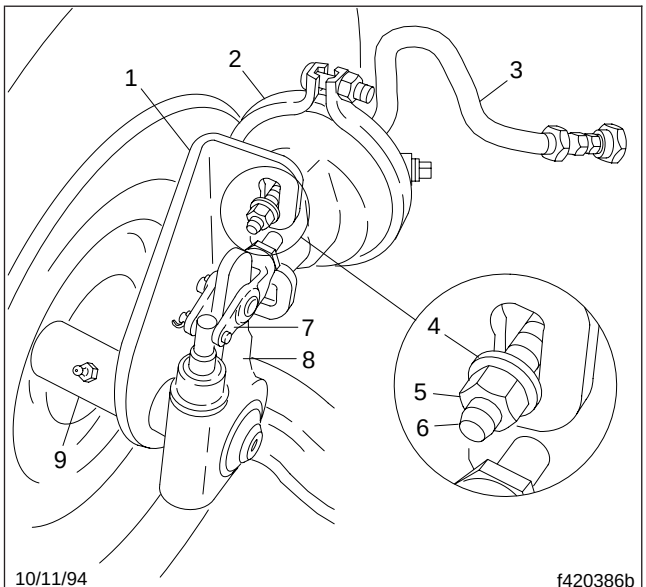
2. Drain the air reservoirs and lines.
3. Carefully disconnect the air line from the brake chamber. See **Fig. 1**.
4. Remove the brake chamber.
   - 4.1 Remove the cotter pin(s) from the clevis pin(s).

   NOTE: Rockwell automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   - 4.2 Remove the clevis pin(s) from the slack adjuster.
   - 4.3 From each mounting stud, remove any installed nuts and washers. Remove the brake chamber from the vehicle.

Installation

1. Before installing a new chamber, be sure the new chamber is the same size and make as the brake chamber on the other side of the axle. See **Fig. 1**.
2. Install the brake chamber.
   - 2.1 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.



1. Chamber Mounting Bracket
2. Brake Chamber
3. Air Line
4. Hardened Flatwasher (2 qty.)
5. Prevailing Torque Locknut (2 qty.)
6. Chamber Mounting Stud (2 qty.)
7. Clevis Assembly
8. Slack Adjuster (Automatic Type)
9. Camshaft Tube

Fig. 1, Brake Chamber Installation

   - 2.2 Tighten the locknuts. See **Table 1** for the correct torque value.

Brake Chamber Removal and Installation

Description	Chamber Size (in ^{2})	Torque lbf·ft (N·m)
Brake Chamber Mounting-Stud Locknuts	12	38–43 (52–58)
	16 (7/16–14 stud)	38–43 (52–58)
	16 (1/2–13 stud)	60–65 (81–88)
	16 (1/2–20 stud)	60–65 (81–88)
	20	120–130 (162–176)
	24	120–130 (162–176)

Table 1, Mounting-Stud Locknut Torque Values

2.3 Connect the clevis pin(s) to the slack adjuster.

NOTE: Gunite and Rockwell automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

2.4 Install and lock the cotter pin(s) to secure the clevis pin(s).

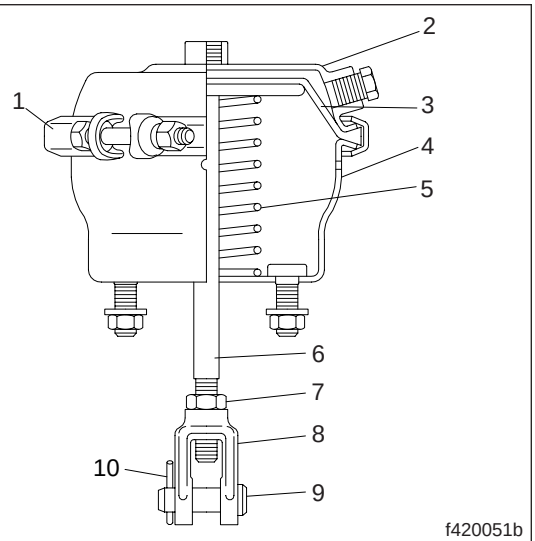
3. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable foundation brake section in this manual.
4. Connect the air line to the brake chamber.
   - 4.1 Check that the hoses are properly supported and, if needed, clamped to provide good clearance.
   - 4.2 Before connecting the air line, make sure the fittings are clean and free of debris.
   - 4.3 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.
5. Do both of the tests in **Subject 100**.
6. Remove the chocks from the tires.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

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.

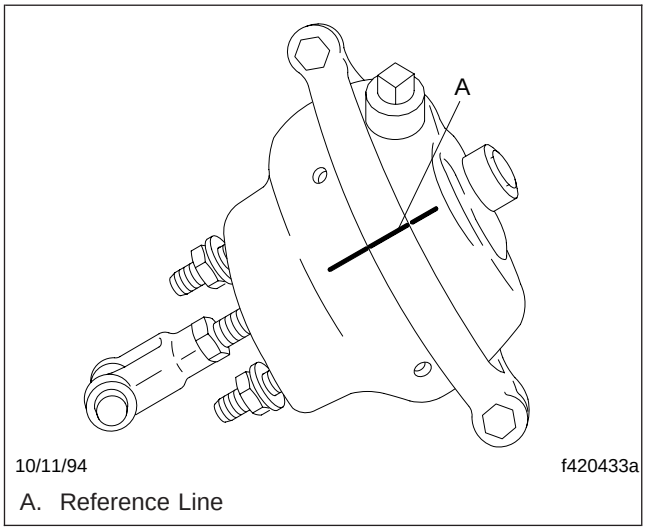
1. Before disassembly, mark a reference line along the chamber to allow the parts to be reassembled later in their old positions. See **Fig. 1** and **Fig. 2**.



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
10. Cotter Pin

Fig. 1, Sectional View

2. Pull out the piston rod. Clamp the rod at the chamber body to protect it from damage.
3. Disassemble the brake chamber.
   - 3.1 Remove one clamp ring bolt and flange nut completely and loosen the other bolt and flange nut enough to remove the clamp ring.
   - 3.2 Remove the cover assembly and the diaphragm.
   - 3.3 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.
   - 3.4 Remove the piston rod assembly and spring.



A. Reference Line

Fig. 2, Mark a Reference Line

Inspection and Cleaning

1. Clean all metal parts with cleaning solvent.
2. Inspect all parts for wear or damage; replace as needed.
   - 2.1 Check the cover and the body for dents. If any are too deep to be pounded out, replace as needed.
   - 2.2 Check the diaphragm for wear or deterioration and replace it if necessary. Midland recommends replacement of the diaphragm whenever the service brake chamber is opened for inspection.
   - 2.3 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). See **Fig. 1**.
2. Assemble the brake chamber.

Brake Chamber Disassembly, Inspection and Cleaning, and Assembly

2.1 Place the return spring on the piston rod.

2.2 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 rod at the body, 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).

2.3 Place the diaphragm in the body.

CAUTION

CAUTION: Don't overtighten the clamp ring. This can distort the flange sealing surface, or the clamp ring itself.

2.4 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, refer to **Specifications, 400**.

3. Install the clevis locknut and clevis, and release the clamp on the piston rod.
4. If the brake chamber was removed from the vehicle, install it. For instructions, refer to **Subject 120**.
5. Do both of the tests found in **Subject 100**.

Description	Chamber Size (in ^{2})	Torque lbf·ft (N·m)
Brake Chamber Mounting-Stud Locknuts	12	38–43 (52–58)
	16 (7/16–14 stud)	38–43 (52–58)
	16 (1/2–13 stud)	60–65 (81–88)
	16 (1/2–20 stud)	65–70 (88–95)
	20	120–130 (162–176)
	24	120–130 (162–176)

Table 1, Mounting-Stud Locknut Torque Values

Description	Chamber Size (in ^{2})	Torque lbf·in (N·cm)
Clamp Ring Flange Nuts	12	200 to 250 (2260 to 2820)
	16	200 to 250 (2260 to 2820)
	20	110 to 225 (1240 to 2540)
	24	150 to 225 (1700 to 2540)

Table 2, Clamp Ring Torque Values

Description	Chamber Size (in ^{2})	Torque lbf·ft (N·m)
Piston Rod Nuts	12	20–30 (27–41)
	16 (7/16-inch stud)	20–30 (27–41)
	16 (1/2-inch stud)	20–30 (27–41)
	20	33–90 (45–122)
	24	33–90 (45–122)

Table 3, Piston Rod Nut Torque Values

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 push rods and slack adjusters; the brakes may apply as air system pressure drops.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure and always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Never attempt to disassemble a component until you have read and understood recommended procedures. Some components contain powerful springs and injury can result if not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

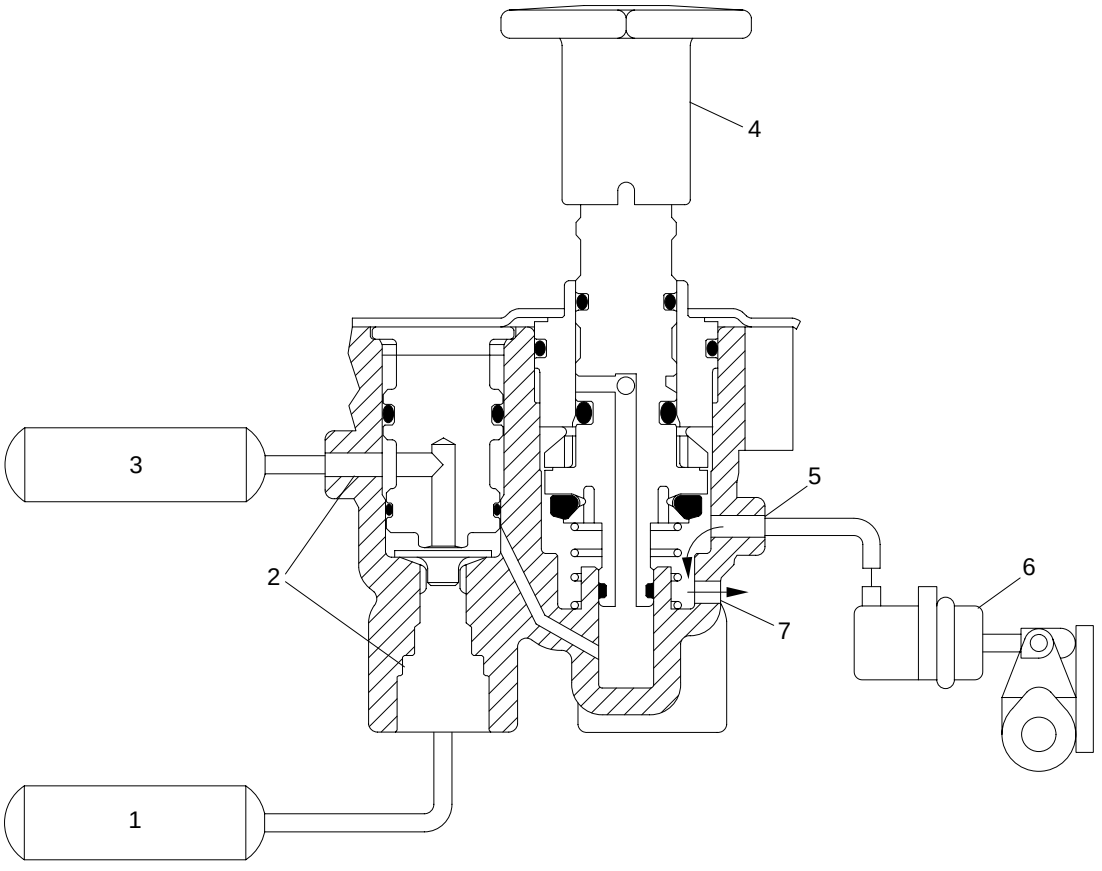
Parking Brake Hand Valve Tests

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 up the air pressure to the normal operating level.
3. With the valve knob pulled out, supply either supply port with 120 psi (827 kPa) of pressure. Push the valve knob in. Air pressure should rise in the delivery line and 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 Hand 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, repair the valve or replace it following instructions under **Subject 130**.

Leak Testing

1. Chock the tires.
2. Supply the valve with 120 psi (827 kPa) from the primary reservoir supply port.
3. With the valve knob pulled out, coat the exhaust port and the plunger stem with a soapy solution. Leakage at either fitting should not exceed a 1-inch (2.5-cm) bubble every five seconds.There should be no leakage from the secondary reservoir supply port.
4. Supply the valve with 120 psi (827 kPa) from the secondary reservoir supply port. There should be no leakage from the primary reservoir supply port.
5. With the valve knob pushed in, coat the exhaust port and the plunger stem with a soapy solution. Leakage at the fittings should not exceed a 1-inch (2.5-cm) bubble every three seconds. If it does, replace or repair the valve, following instructions in **Subject 130**.

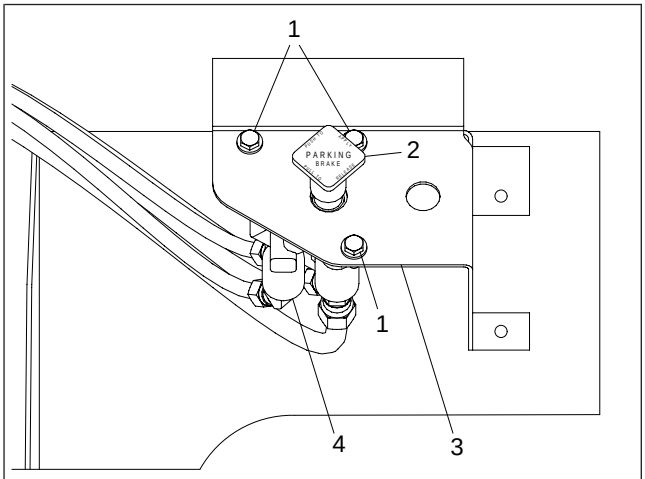
Parking Brake Hand Valve Removal and Installation

Removal

WARNING

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. See **Fig. 1**.



1. Mounting Screw
2. Knob
3. Mounting Bracket
4. Parking Brake Valve

Fig. 1, Parking Brake Valve Mounting

3. Mark the air lines for later reference, then disconnect them from the valve assembly.

NOTE: The primary supply line is green; the secondary supply line is red; the exhaust line is black and 1/2-inch (13-mm) in diameter; the delivery line is black and 3/8-inch (9.6-mm) in diameter.

4. Remove the three screws that attach the valve to the bracket. Remove the valve.

Installation

1. Position the valve assembly in the bracket. Install the mounting screws.
2. Connect the air lines to the applicable fittings.
   - 2.1 Tighten the fittings hand tight.
   - 2.2 Using a wrench, tighten the fittings until the connections feel firm.
   - 2.3 Tighten the fittings an additional one-sixth turn.
3. Screw the valve knob onto the valve stem.
4. Leak test the fittings, following the instructions in **Subject 110**.

Parking Brake Hand Valve Disassembly and Assembly

Disassembly

1. Remove the valve assembly from the dash, following the instructions in **Subject 120**.
2. Put the valve assembly in a soft-jawed or padded vise. See **Fig. 1**.
3. Remove the screws that attach the cover to the body. Remove the cover.
4. Pull the plunger stem and remove the plunger and guide spool from the body.
5. Remove and discard the plunger spring.
6. Using a screwdriver (if needed), carefully remove the check valve seat from the body. Use care not to damage either the check valve seat or the valve body.
7. Remove and discard the check valve seat O-rings.
8. Turn the body upside down and gently tap it on a flat surface to remove the check valve. Discard the check valve.
9. Remove the guide spool from the plunger. Remove and discard the O-ring.
10. Remove and discard the O-rings from the plunger. Also, remove and discard the exhaust seal.

Assembly

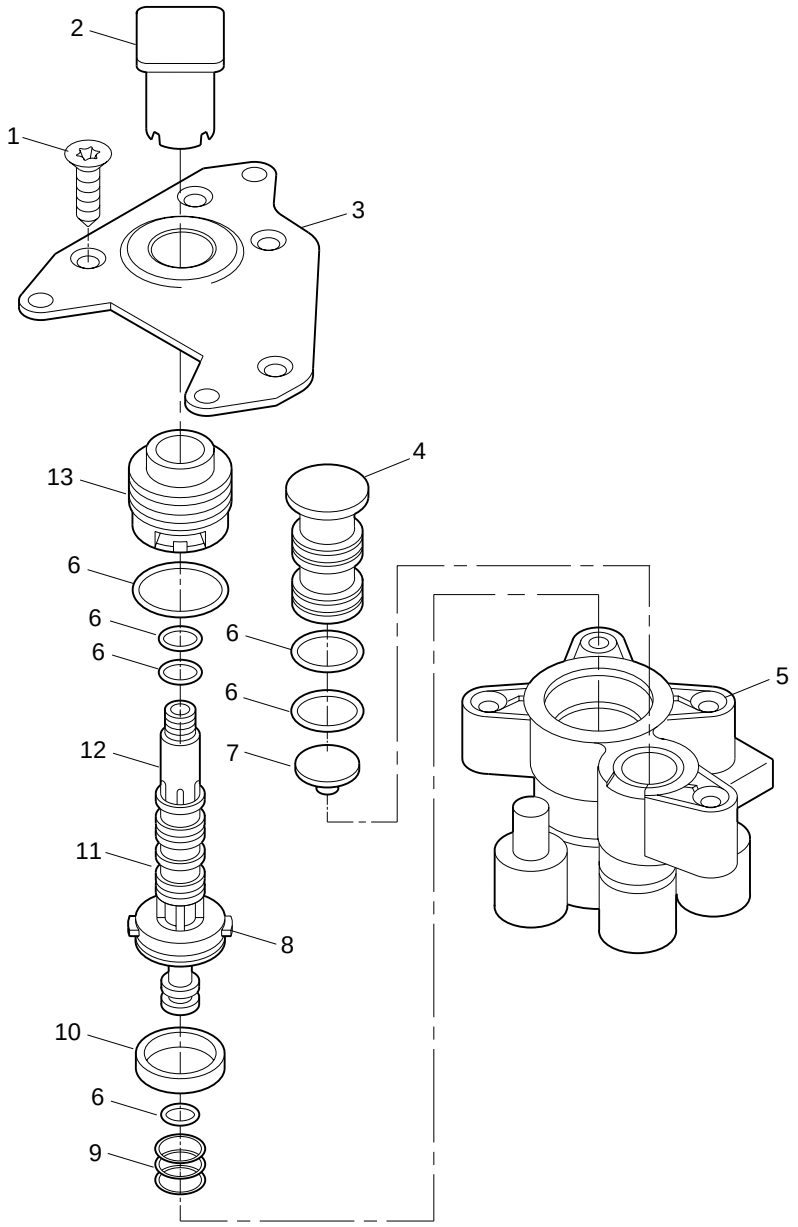
1. Clean and dry all the parts. See **Fig. 1**.
2. Check all the parts. Replace a part if any wear or damage is found.
3. Lightly grease all the parts—including the new parts from the maintenance kit—with Dow Corning 55 silicone pneumatic grease or equivalent.
4. Position the check valve in its seat in the body with the flat surface of the valve facing up. If needed, reach into the body to make sure that the valve is seated evenly in the bore.
5. Install the O-rings on the check valve seat and install the assembly into the body. Make sure that the check valve seat is even with the valve body surface.
6. Install the plunger spring into the body. Make sure that the spring is upright and seated properly in the body bore.

NOTE: The plunger spring should surround the protrusion or "lip" at the bottom of the body bore.

7. Install the O-rings onto the plunger, then install the plunger into the body.

   For ease of installation, line up the plunger's index tabs with the spaces in the body bore.
8. Install the O-ring on the guide spool. Install the spool over the plunger and into the body. Firmly press the guide spool into position.
9. Install the screws that attach the cover to the body. Tighten the screws 35 lbf·in (400 N·cm).
10. Install the valve in the dash, then leak test it. Follow the instructions in **Subject 120** for installation and **Subject 110** for leak testing.

Parking Brake Hand Valve Disassembly and Assembly



07/18/95 f421348

1. Screw
2. Valve Knob
3. Cover
4. Check Valve Seat
5. Valve Body
6. O-Ring
7. Check Valve
8. Index Tab
9. Plunger Spring
10. Exhaust Seal
11. Plunger
12. Plunger Stem
13. Guide Spool

Fig. 1, Exploded View

General Description

The pressure relief valve protects the air brake system against excessive air pressure build-up. See **Fig. 1**. The valve has a spring-loaded cap and O-ring assembly which will exhaust air from the reservoir, if pressure rises above the valve's pressure setting. This setting is determined by the force of the spring.

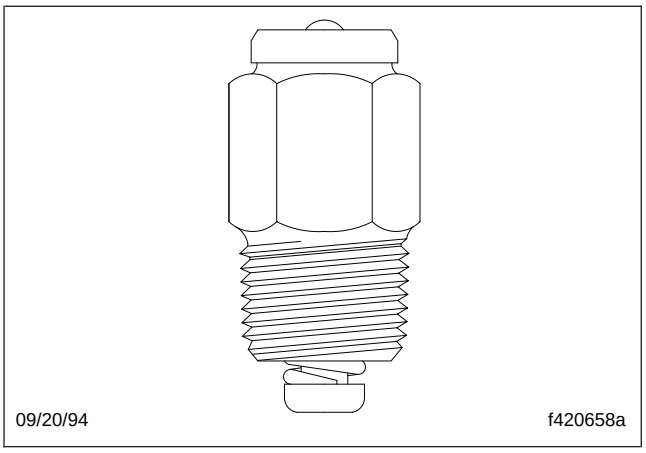


Fig. 1, Pressure Relief Valve

Principles of Operation

To illustrate the operation of the pressure relief valve, note that the governor cut-out pressure on all Freightliner vehicles is set at a maximum 125 psi (862 kPa). A pressure relief valve with a setting of 150 psi (1034 kPa) is then used. Should system pressure rise to approximately 150 psi (1034 kPa), air pressure will force the cap and O-ring assembly off its seat, and allow the reservoir pressure to vent to the atmosphere. See **Fig. 2**.

When the reservoir pressure decreases sufficiently, the spring force will seat the cap and O-ring assembly, sealing off reservoir pressure. This will occur at approximately 135 psi (931 kPa) for the 150 psi (1034 kPa) valve. Note that the desired pressure setting of the pressure relief valve is determined by the governor cut-out pressure. The opening and closing pressures of the pressure relief valve should always be in excess of the governor cut-out pressure setting.

Normally, the pressure relief valve remains inoperative and only functions if, for any reason, the reservoir pressure rises above the setting of the valve. Constant exhausting of the pressure relief valve can

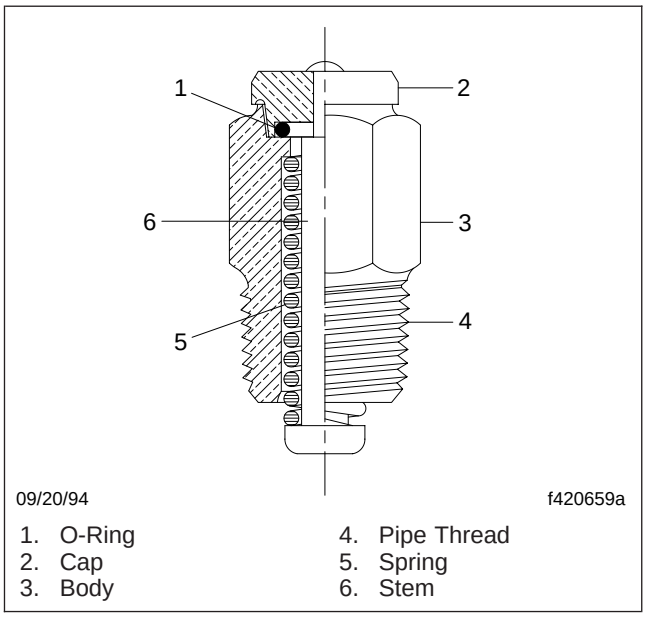


Fig. 2, Relief Valve Components

be caused by a faulty pressure relief valve, faulty governor, faulty compressor unloading mechanism, or a combination of any of the preceding.

Operating Check

With air pressure built up in the system, proceed as follows:

⚠ WARNING

WARNING: Wear safety goggles when exhausting the air system because debris could fly out at high speed. Failure to take all necessary precautions could result in personal injury.

1. With your index finger and thumb, pull the cap of the valve, removing the spring load from the O-ring. Air should exhaust from the valve. See **Fig. 1**.

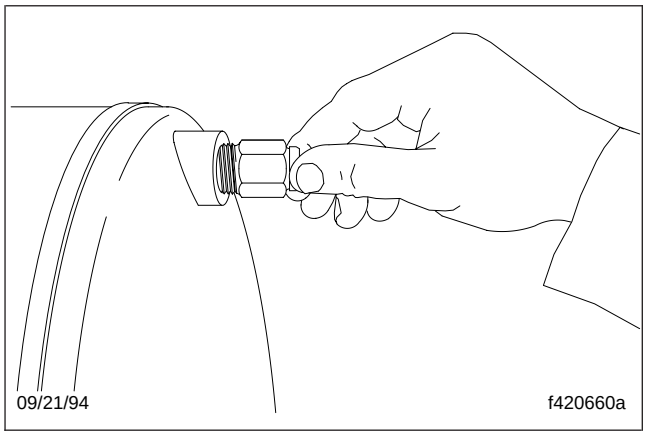


Fig. 1, Pull the Cap of the Valve

2. Release the cap; the airflow should stop.

   Failure of a valve to pass the operating test indicates the valve should be replaced, using the instructions in this section.

Leakage Check

Coat the exhaust port with a soap solution. Leakage resulting in a 1-inch (2.5-cm) bubble in 5 seconds is permitted. Excessive leakage indicates dirt in the valve or a faulty O-ring or seat. The valve should be replaced, using the instructions in this section.

Removal

1. Chock the tires, and drain the air reservoirs.
2. Using a wrench, unscrew the valve from the reservoir. See **Fig. 1**.

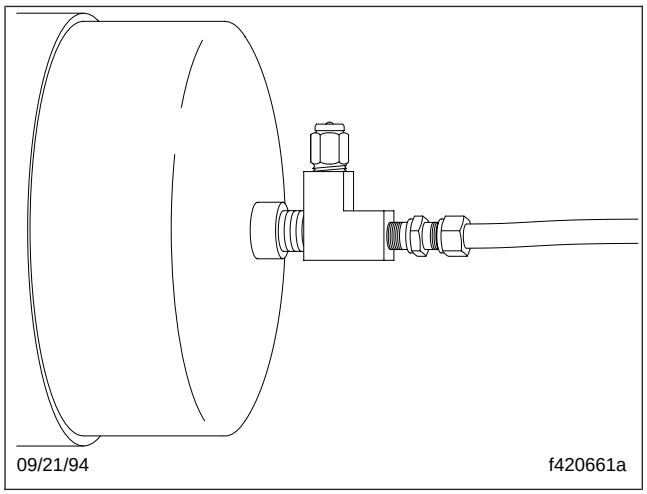


Fig. 1, Unscrew the Valve

Installation

1. Apply a small quantity of Loctite® 242, or an equivalent sealant, to the valve threads.

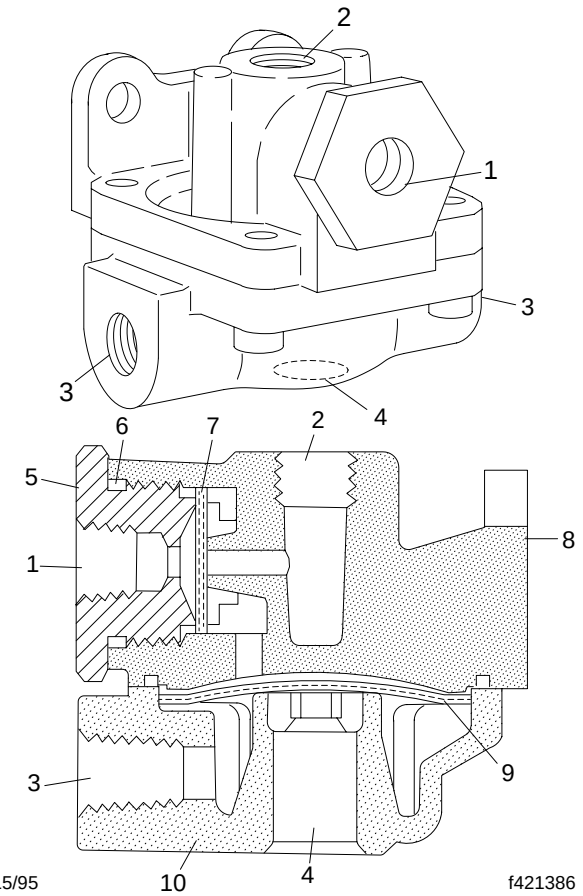
⚠ WARNING

WARNING: Make sure that excess sealant does not get inside either the male or female fittings. This would allow loose foreign material inside the plumbing, and may clog a valve. This could result in an unexpected loss of brake control, which could cause property damage or personal injury.

2. Install the valve and tighten it finger-tight. With a wrench, tighten it 1-1/2 additional turns past finger-tight.
3. Perform the operating and leakage checks on the valve and the valve fitting. For instructions, refer to **Subject 100**.

General Information

The QR–1C quick release valve is a dual function valve. See **Fig.1**. Its primary function is to speed up the release of air pressure from the service brake chambers. Additionally, the valve works as an anti-compound device. The double check valve feature prevents a service and parking brake application from occuring at the same time.



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. 1, QR-1C Valve and Cross Section

The QR–1C valve is generally mounted near the rear axle. A balance line from the relay valve delivery port (port 2 on the WABCO combination valve) 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.

Principles of Operation

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 parking brakes.

Safety Precautions

When working on or around air brake systems and components, observe the following precautions.

1. Chock the tires and stop 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; they may apply as air system 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 not properly disassembled. Use only proper tools and observe all precautions pertaining to use of those tools.

QR–1C Quick Release Valve Operating and Leakage Tests

Operating and Leakage Tests

⚠ WARNING

WARNING: Before working on or around air brake systems and components, review the safety precautions in Subject 100. Failure to do so could result in personal injury.

The following tests should also be performed after repairing or replacing the QR–1C valve to ensure that it is functioning properly.

1. Chock the tires.
2. Drain the air system.
3. Release the parking brakes.
4. 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 one-inch (25-mm) bubble in five 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 QR–1C valve should exhaust air at the exhaust port.
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 one-inch bubble in five 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.

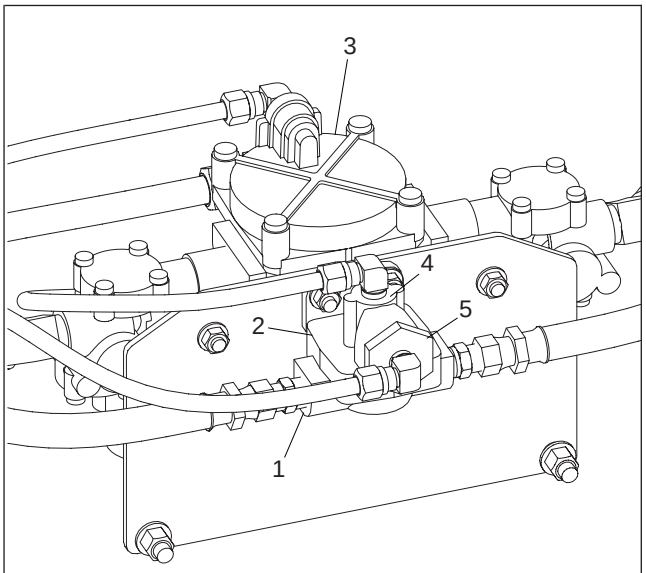
QR–1C Quick Release Valve Removal and Installation

Removal

WARNING

WARNING: Before working on or around air brake systems and components, review the safety precautions in Subject 100. Failure to do so could result in personal injury.

1. 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. See **Fig. 1**.



08/26/96 f421509

1. Delivery Port
2. Quick Release Valve
3. Combination Solenoid Control Valve
4. Balance Port
5. Supply Port

Fig. 1, QR-1C Valve Mounting (plumbing and location will vary depending on vehicle configuration)

4. Remove the mounting bolts and the valve.

Installation

WARNING

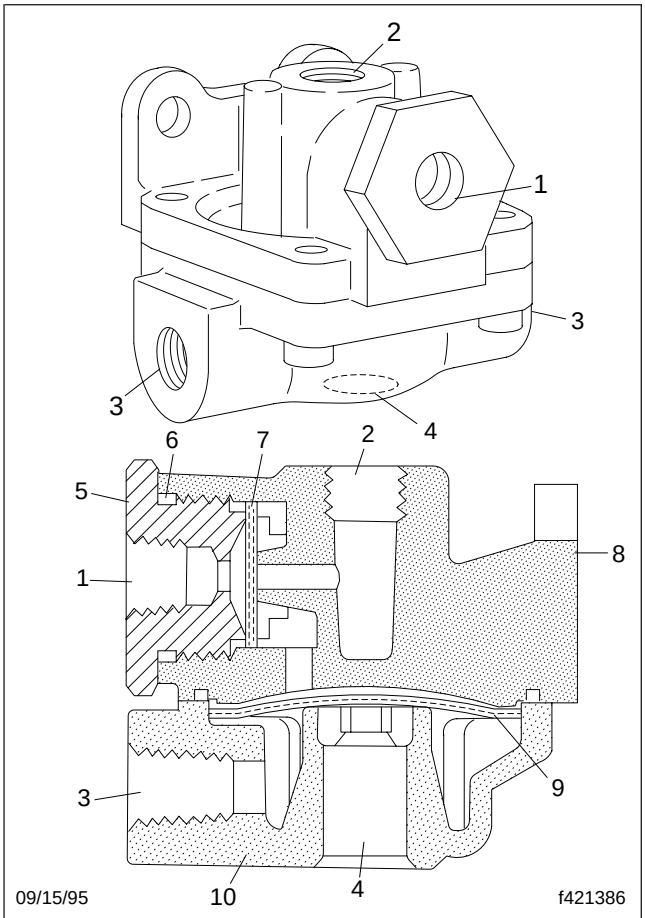
WARNING: Before working on or around air brake systems and components, review the safety precautions in Subject 100. Failure to do so could result in personal injury.

1. Install the quick release valve with the exhaust port facing down. Securely tighten the mounting bolts. See **Fig. 1**.
2. Connect the air lines to the quick release valve in the locations previously marked.
3. Perform the operating and leakage tests in **Subject 110**.

QR–1C Quick Release Valve Disassembly, Cleaning and Inspection, and Assembly

Disassembly

1. Remove the quick release valve from the vehicle following the instructions in **Subject 120**.
2. Mark the valve body and cover for ease of installation. See **Fig. 1**.



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. 1, QR-1C Valve and Cross Section

3. Remove the cap nut at the supply port. Remove the sealing ring from the cap nut.
4. Remove the double check diaphragm.
5. Remove the four screws holding the valve cover on the valve body.
6. Separate the cover from the body and remove the sealing ring and the quick release diaphragm.

Cleaning and Inspection

1. Clean all metal parts in mineral spirits. Wipe all rubber parts clean.
2. It is recommended that all rubber parts and any other part showing signs of wear or deterioration be replaced with genuine Bendix parts.

Assembly

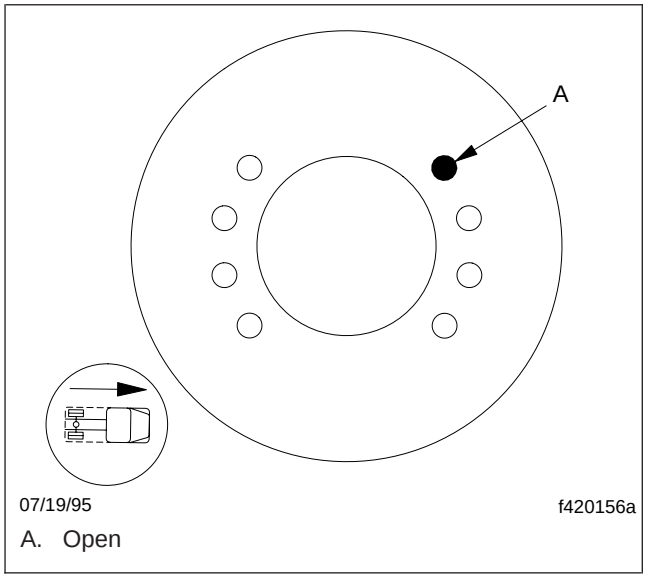
1. Install the sealing ring on the cap nut.
2. Install the double check diaphragm in the valve body.
3. Install the cap nut. Tighten the nut 150 to 400 lbf·in (1700 to 4520 N·cm).
4. Install the quick release diaphragm in the cover.
5. Install the valve cover on the body. Tighten the screws 30 to 60 lbf·in (340 to 680 N·cm) evenly and securely.
6. Install the quick release valve, following the instructions in **Subject 120**.
7. Do the operating and leakage test as instructed in **Subject 110**.

General Description

Rockwell "Q" Plus Series brakes are actuated by an S-type cam head, which is forged integrally with the camshaft and supported with nylon bushings. Cam pressure is applied through the cam rollers.

These brakes are used on both the front steer axle and rear axles.

Rockwell steer axles have seven holes for attaching the spider to the axle flange. There is an eighth hole left open on the brake spider, on both left and right sides of the steer axle. See **Fig. 1**. The seven holes used for attachment of the spider to the axle flange are 0.656 inch in diameter. The eighth hole is oversized at 0.687 inch in diameter.



A. Open

Fig. 1, Brake Spider

As of March 1, 1994, Rockwell began attaching an identifying label to the web of all on-highway shoe and lining assemblies. The label is made of Mylar, and is attached with a heat-resistant adhesive. At the same time, the lining edge code changed to the new Rockwell lining designation. The new lining edge code will show the supplier lining designation and the corresponding Rockwell designation. See **Table 1**.

Edge Codes		
Vendor Code		**Desig.**
Abex	931–162	R301
	197	R201
	1083–7	R501
	1083–63	R401
Carlisle	E145–A	R202
	NAB–9ML	R302
	NAB10	R502
	NAB11	R402
Ferodo	NAB456	R403
	867	R203

Table 1, Edge Codes

The label will include three lines of information. See **Fig. 2**. The first line identifies the shoe as "Q PLUS" or "BRAKES" (non-Q Plus). The second line gives the new Rockwell aftermarket lining material designation. See "Rockwell Designation" in **Table 1**. The third line gives the service part number to use for replacing the shoe and lining assembly.

Principles of Operation

When the brake pedal is depressed, compressed air enters the brake chamber, causing the diaphragm to move a push rod assembly.

The push rod, which is connected to a slack adjuster, turns the slack adjuster and brake camshaft. As the camshaft turns, the S-head, which is between the brake shoe rollers, 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 the push rod to their released positions.

General Description and Principles of Operation

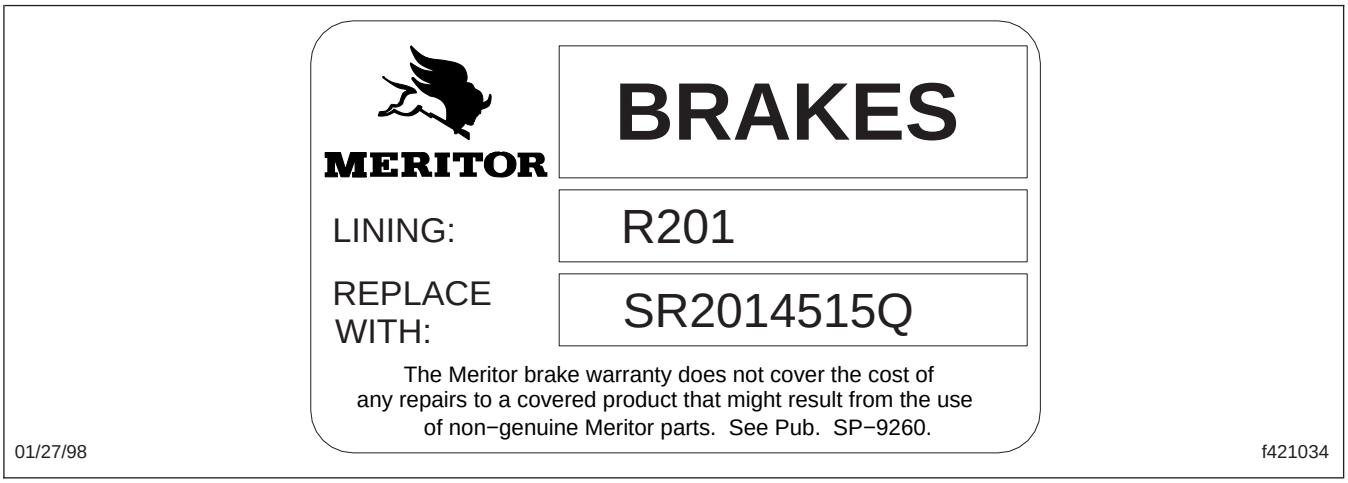


Fig. 2, Rockwell Brake Shoe Lable, Example

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 chamber pushrods and slack adjusters, which may apply as air pressure drops.
- Disconnect the batteries.
- Never connect or disconnect a hose or line containing compressed air. It may whip as air escapes. Never remove a component or pipe plug unless you are certain all system pressure has been released.
- Never exceed recommended air pressure. Always wear safety glasses when working with compressed air. Never look into air jets or direct them at anyone.
- Do not remove, disassemble, assemble, or install a component until you have read and understand the service procedures. Some components contain powerful springs, and injury can result if not properly disassembled. Use the correct tools and observe all precautions pertaining to use of those tools.
- Replacement hardware, tubing, hose, fittings, etc. should be the equivalent size, type, length, and strength of the original equipment.
- Make sure when replacing tubes or hoses that all of the original supports, clamps, or suspending devices are installed or replaced.
- Replace devices that have stripped threads or damaged parts. Repairs requiring machining should not be attempted.
- Prior to returning the vehicle to service, make certain all components and systems are restored to their proper operating condition.

Asbestos and Non-Asbestos Safety

⚠ WARNING

Wear a respirator at all times when servicing the brakes, starting with the removal of the wheels and continuing through assembly. Breathing brake lining dust (asbestos or non-asbestos) could cause lung cancer or lung disease. OSHA has set maximum levels of exposure and requires workers to wear an air purifying respirator approved by MSHA or NIOSH.

Because some brake linings contain asbestos, you should know the potential hazards of asbestos and the precautions to be taken. Exposure to airborne asbestos brake lining dust can cause serious and possibly fatal diseases such as asbestosis (a chronic lung disease) and cancer.

Because medical experts believe that long-term exposure to some *non-asbestos* fibers could also be a health hazard, the following precautions should also be observed if servicing non-asbestos brake linings.

Areas where brake work is done should be separate from other operations, if possible. As required by OHSA regulations, the entrance to the areas should have a sign displayed indicating the health hazard.

During brake servicing, an air purifying respirator with high-efficiency filters must be worn. The respirator and filter must be approved by MSHA or NIOSH, and worn during all procedures.

Safety Precautions

OSHA recommends that enclosed cylinders equipped with vacuums and high-efficiency 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

WARNING: Before starting the procedure below, read the 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.

Removal

1. Park the vehicle on a level surface, apply the parking brakes, and chock the tires.
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. Remove the wheels and brake drums. For instructions, refer to **Group 33** or **Group 35** in this manual.

⚠ CAUTION

CAUTION: Before you back off automatic slack adjusters, refer to the applicable slack adjuster section in this group, or to the manufacturer's service information for instructions. Failure to do so could damage the automatic slack adjuster.

4. Back off the slack adjusters. For instructions, refer to the applicable slack adjuster section in this group for instructions on backing off the slack adjuster.
5. If equipped with 15-inch "Q" Plus Series brakes, go to the next step.

   If equipped with "Q" Plus Series brakes, or 16-1/2 inch "Q" Plus Series brakes, remove the brake shoes.

   5.1 Push down on the bottom brake shoe, then pull on the roller retaining clip to remove the bottom cam roller. See **Fig. 1**.

   5.2 Lift the top brake shoe and pull on the roller retaining clip to remove the top cam roller.

   5.3 Lift the bottom shoe to release tension on the brake return spring. Remove the spring. See **Fig. 2**.

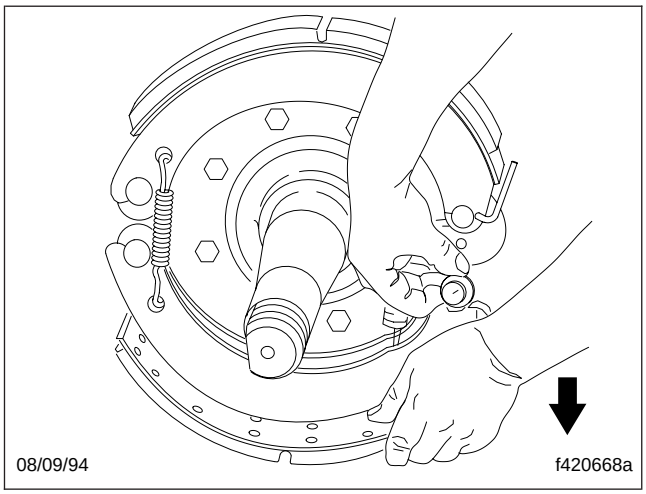


Fig. 1, Remove the Bottom Cam Roller

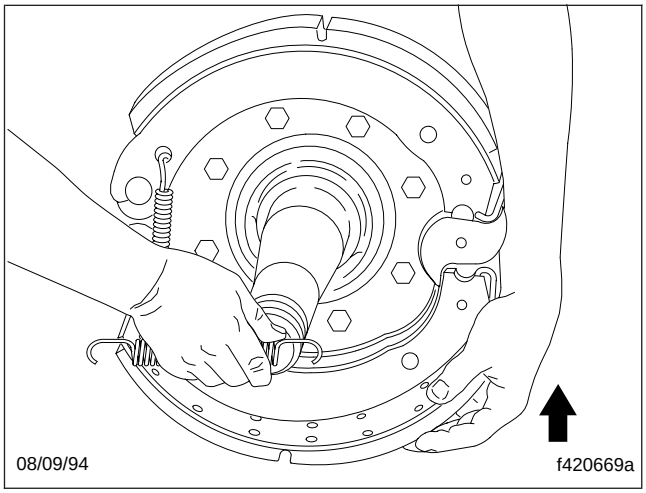


Fig. 2, Remove the Spring

   5.4 Rotate the bottom shoe to release tension on the two retaining springs. Remove the springs and brake shoes. See **Fig. 3**.

6. If equipped with 15-inch brakes, remove the brake shoes.

   6.1 Push down on the bottom brake shoe, then remove the bottom cam roller.

   6.2 Lift the top brake shoe and remove the top cam roller.

   6.3 Remove the brake shoe return spring.

Brake Shoe Removal and Installation

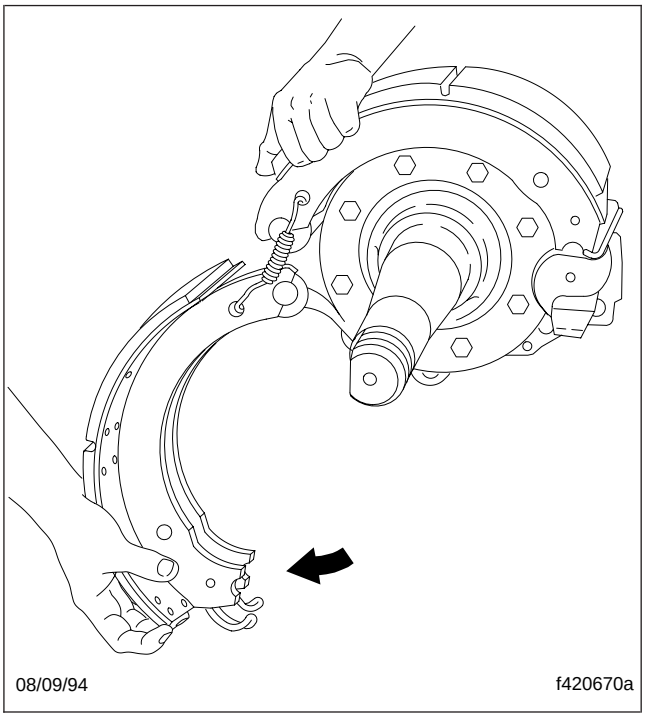


Fig. 3, Remove the Springs and Brake Shoes

6.4 Rotate the bottom shoe to release tension on the retaining spring. Remove the spring and the brake shoes.

7. Inspect the brake shoes and linings for wear or damage. For instructions, refer to **Subject 120**.

Installation

1. Apply a thin film of a temperature resistant grease (Rockwell 0–616, or an equivalent) on the anchor pins where they touch the brakes shoes. Also, apply a multi-purpose chassis grease (Rockwell 0–617–A or 09–617–B, or an equivalent) on the retainer clips, spider, and shoe rollers where they touch the brake shoes.

IMPORTANT: Don't apply any grease on the outer diameter of the roller that touches the cam head.

2. If equipped with 16-1/2 inch brakes, install the brakes shoes.

   If equipped with 15-inch brakes, go to the next step.

2.1 Place the upper brake shoe in position on the top anchor pin. Hold the lower brake shoe on the bottom anchor pin and attach two new brake shoe retaining springs. See **Fig. 4**.

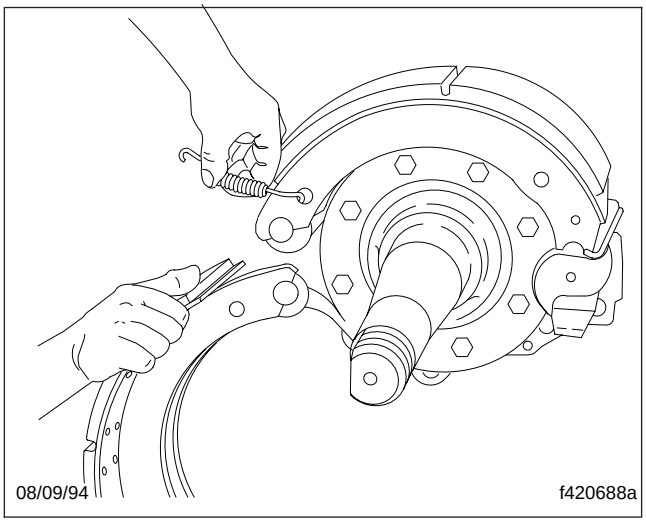


Fig. 4, Attach the Brake Shoe Retaining Springs

2.2 Turn the lower brake shoe forward and attach a new brake shoe return spring. See **Fig. 5**.

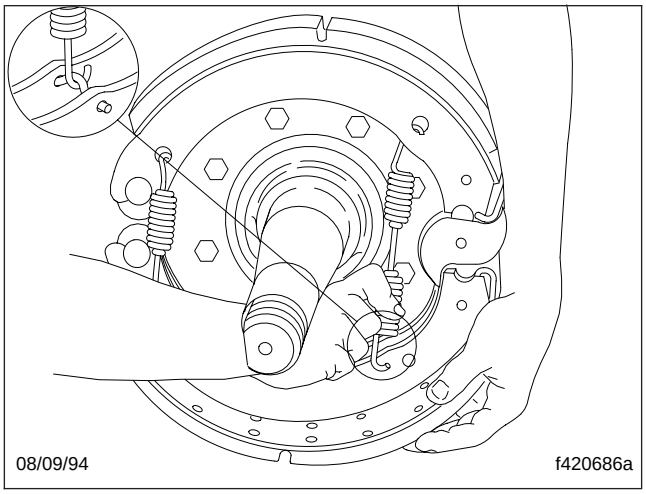
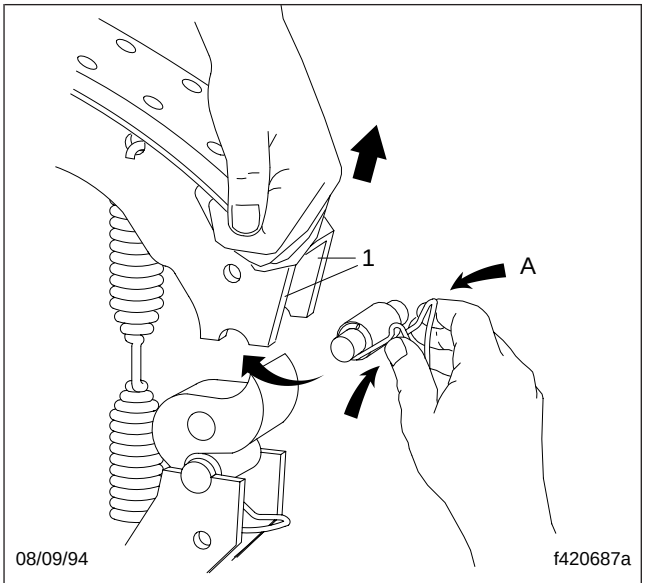


Fig. 5, Attach a New Brake Shoe Return Spring

2.3 Pull each brake shoe away from the cam to allow enough space to install the cam rollers and retainers. Squeeze the ears of

the retainer together to permit the retainer to fit between the brake shoe webs. See **Fig. 6**.



A. Squeeze
1. Web

Fig. 6, Squeeze the Ears of the Retainer

2.4 Push the retainer into the brake shoe until the ears lock in the holes in the shoe webs. See **Fig. 7**.

3. If equipped with 15-inch brakes, install the brake shoes.

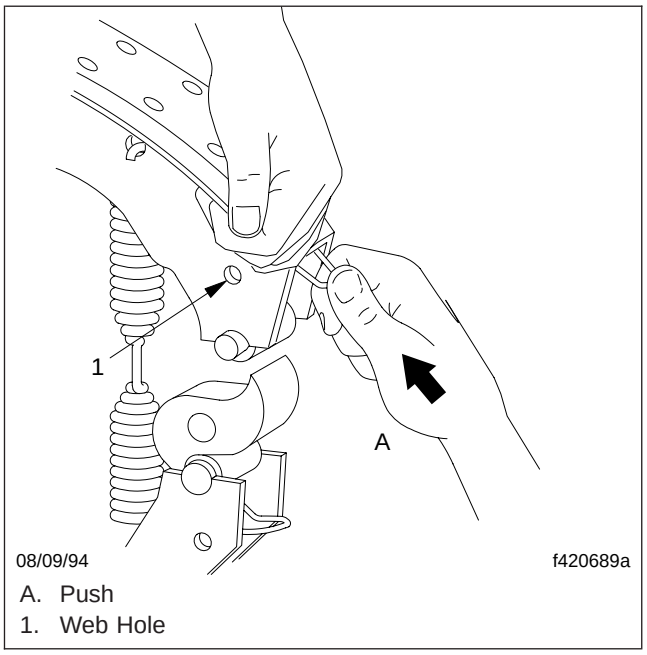
3.1 Install the retainer spring on the shoes and install the shoes on the anchor pins. See **Fig. 8**. Hold the bottom shoe in position and install the return spring.

3.2 Pull each shoe away from the cam to allow enough space, then install the cam rollers.

4. Install the wheels and brake drums. For instructions, refer to **Group 33** or **Group 35** in this manual.

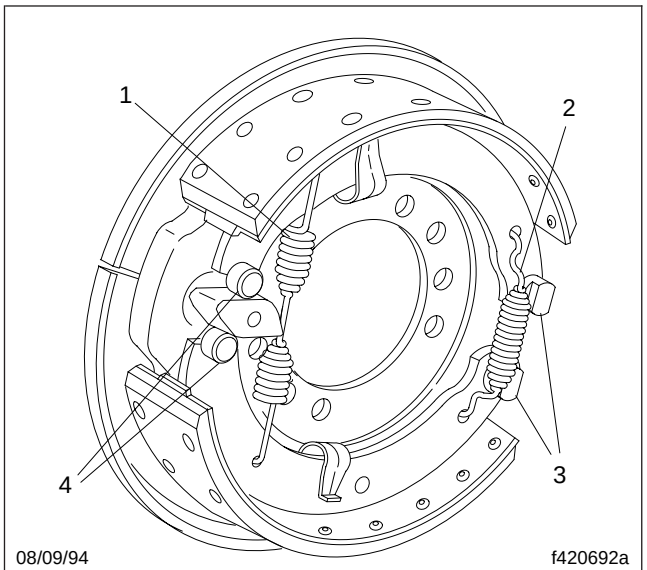
5. Adjust the brakes at the slack adjusters. For instructions, refer to **Subject 125**.

6. Remove the safety stands, lower the vehicle, and remove the chocks from the tires.



A. Push
1. Web Hole

Fig. 7, Push the Retainer into the Brake Shoe



1. Return Spring
2. Retainer Spring
3. Anchor Pins
4. Cam Rollers

Fig. 8, Install the Retainer Spring and the Brake Shoes

Brake Shoe Removal and Installation

⚠ DANGER

DANGER: Don't 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.
   - 7.1 Apply and release the brakes several times to check for air leaks and proper operation of the slack adjusters.
   - 7.2 Do several low speed stops to ensure proper parts replacement and full vehicle control.
   - 7.3 Make ten 40 to 20 mph (60 to 30 km/h) snubs to seat the linings.
   - 7.4 Make ten stops from 20 mph (30 km/h) at 50 percent air pressure.
   - 7.5 Make a full-pressure stop from 20 mph (30 km/h).
   - 7.6 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.

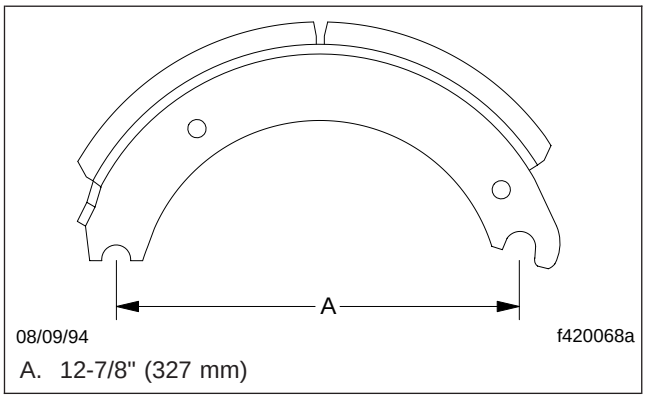
WARNING

WARNING: Before starting the procedure below, read the 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.
   - 2.1 If the linings are grease-or oil-soaked, cracked, or worn to less than 1/4-inch (6.4-mm) thickness at any point, replace them.
   - 2.2 Replace the linings if the lining surface is closer than 1/32 inch (0.8 mm) to any rivet head.

     If bolts are installed, the linings should not be allowed to wear to the point where rivets or bolts may contact the brake drums.
3. Check the shoes for bent or cracked webs or tables, broken welds, loose or out-of-round rivet or bolt holes. Replace the shoes if any of these conditions exist.
4. Check the anchor pin for looseness and the camshaft roller recesses in the shoe webs for visible wear. Replace the shoe if needed.
5. Check the shoe span. Measure the distances between the centerlines of the anchor pin and the camshaft roller pin recesses in the shoe web. If the measurement is more than 12-7/8 inches (327 mm), replace the shoe. See **Fig. 1**.



A. 12-7/8" (327 mm)

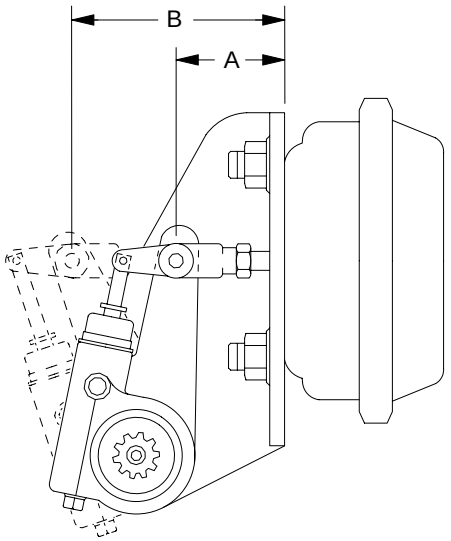
Fig. 1, Measuring the Shoe Span

Adjustment

ROCKWELL AUTOMATIC SLACK ADJUSTER

1. Check the free-stroke.

   1.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.



NOTE: Subtract measurement A from B.

A. Measurement with the brakes released.
B. Measurement with the brakes applied.

Fig. 1, Measuring Initial Free-Stroke

   1.2 Use a pry bar to move the slack adjuster and apply the brakes. Again, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.

   1.3 The difference between the two measurements is the initial free-stroke, and sets the clearance between the linings and the drum.

   1.4 The free-stroke must be 5/8 to 3/4 inch (16 to 19 mm);

   If the free-stroke is correct, go to the next step.

   1.5 If the free-stroke is incorrect, remove the pressure relief capscrew, spring, and pawl assembly from the slack adjuster housing. See **Fig. 2**. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

⚠ CAUTION

CAUTION: Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pawl assembly. If equipped with a pull-pawl assembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

   1.6 Turn the adjusting nut 1/8 turn, as shown in **Fig. 4**. Measure the stroke again, and adjust until it is correct.

2. Check for correct brake chamber stroke.

   2.1 With the brakes fully released, measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**.

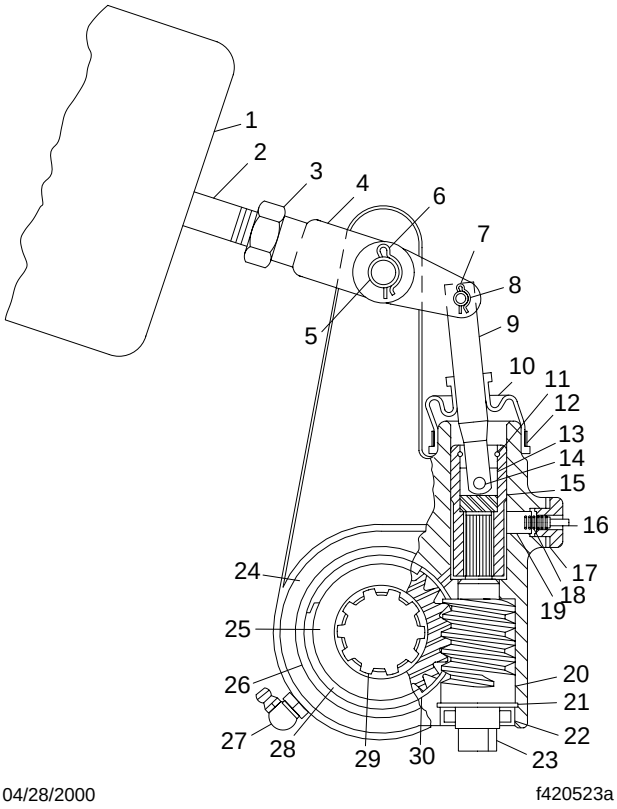
   2.2 Build air pressure to 100 psi (689 kPa). Shut down the engine. Fully apply the brakes, then measure the distance from the bottom of the brake chamber to the center of the large clevis pin. See **Fig. 1**. The difference between the measurements is the brake chamber stroke.

   2.3 The brake chamber stroke must be less than the measurements shown in **Table 1**. If the brake chamber stroke is incorrect, remove the pressure relief capscrew, spring, and pawl assembly from the slack adjuster housing. See **Fig. 2**. If equipped with a pull-pawl assembly, carefully insert a screwdriver and raise the relief cap about 1/8 inch (3.2 mm). See **Fig. 3**.

⚠ CAUTION

CAUTION: Before turning the adjusting nut, remove the pressure relief capscrew, spring, and pawl assembly. If equipped with a pull-pawl assembly, raise the relief cap about 1/8 inch (3.2 mm). Failure to do so could strip the teeth on the pawl.

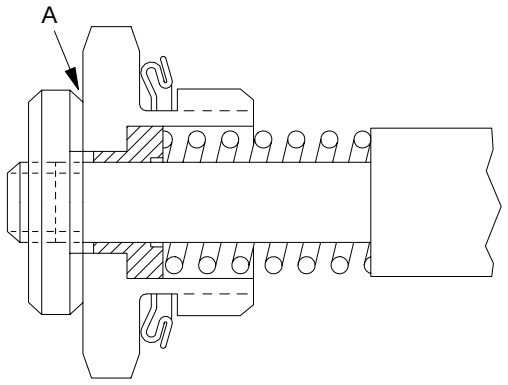
Brake Adjustment



04/28/2000 f420523a

1. Brake Air Chamber
2. Brake Chamber Push Rod
3. Clevis Jam Nut
4. Clevis
5. Clevis Pin (large)
6. Cotter Pin (large)
7. Cotter Pin (small)
8. Clevis Pin (small)
9. Actuator Rod
10. Boot
11. Piston Retaining Ring
12. Boot Retaining Clamp
13. Actuator Piston
14. Roller (Pin)
15. Actuator (Adjusting Screw)
16. Pressure Relief Capscrew (shown 90 degrees out of position)
17. Gasket
18. Pawl Spring
19. Pawl Assembly
20. Worm
21. Worm Retaining Snap Ring
22. Worm Seal
23. Manual (Worm) Adjusting Nut End
24. Slack Adjuster
25. Gear
26. Gear Thrustwasher
27. Grease Fitting
28. Gear Retaining Ring
29. Camshaft Splines
30. Gear-to-Body Seal

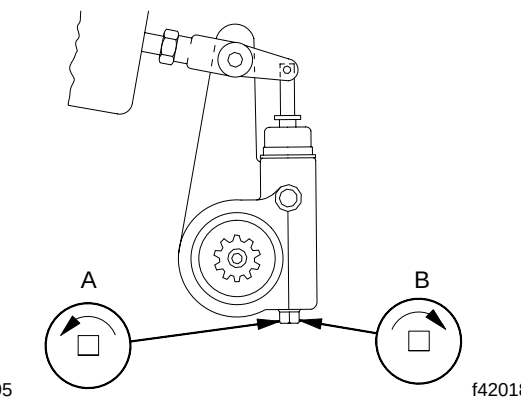
Fig. 2, Rockwell Automatic Slack Adjuster



09/27/94 f420693a

A. Insert screwdriver here.

Fig. 3, Pull-Pawl Assembly (sectional view)



07/05/95 f420181a

A. Shorten the stroke. B. Lengthen the stroke.

Fig. 4, Turn the Adjusting Nut

2.4 Turn the adjusting nut 1/8 turn, as shown in **Fig. 4**. Measure the stroke again, and adjust until correct.

If necessary, replace the slack adjuster. For instructions, see the applicable slack adjuster section in this group.

CAUTION

CAUTION: Don't make the adjusted chamber stroke too short. The free-stroke must not be less than 5/8 to 3/4 inch (16 to 19 mm). If the chamber stroke is too short, the linings can drag and damage the brake.

If the stroke varies or remains greater than the specified range, check the brake components. For instructions, see Subject 140.

2.5 If removed, install the pawl assembly, spring, and the pressure relief capscrew. Tighten the capscrew 15 to 20 lbf·ft (20 to 27 N·m). Or, remove the screwdriver from the pull-pawl assembly (if equipped).

Maximum Adjusted Brake Chamber Stroke	
Chamber Size	**Stroke: inch (mm)**
9, 12	Less than 1-3/8 (35)
16, 20, 24	Less than 1-3/4 (44)
24 long stroke, 30	Less than 2 (51)
36	Less than 2-1/4 (57)

Table 1, Maximum Adjusted Brake Chamber Stroke

WARNING

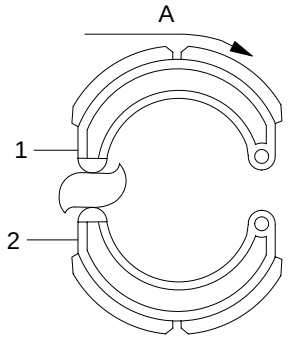
WARNING: Before starting the procedure below, read the information in Safety Precautions, 100. Failure to be aware of the dangers of brake lining dust exposure could result in serious and permanent health damage.

Replacement

IMPORTANT: For the best brake performance, don't mix brake linings between axles. When relining brake shoes, both wheel ends of each axle must have the same linings. On tandem axles, all four wheel ends must also have the same linings. However, it is not necessary for the steering axle brakes to have the same linings as the rear drive axle brakes. Also, when the minimum thickness is reached for any of the brake linings on an axle, reline both brakes on that axle at the same time.

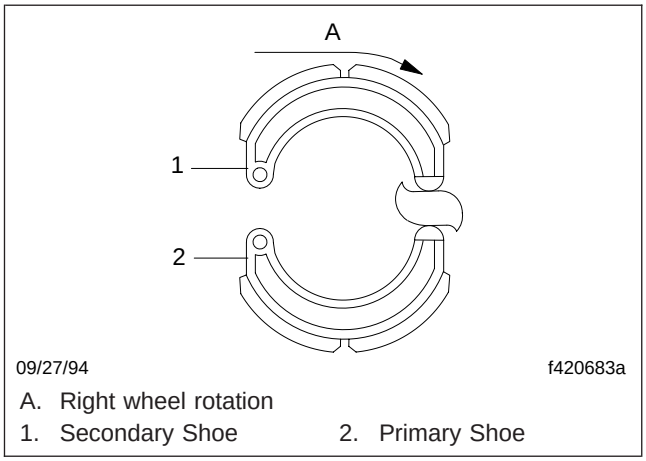
Combination linings with different friction ratings for the primary and secondary shoes are often used. When combination linings are used, install the forward blocks on the primary shoe (following the rotation of the drum, the first shoe after passing the cam or wheel cylinder is the primary shoe).

If the cam is behind the axle, the top shoe is the primary and the lower shoe is the secondary shoe. See Fig. 1. If the cam is in front of the axle, the lower shoe is the primary shoe. See Fig. 2.



A. Right wheel rotation
1. Primary Shoe 2. Secondary Shoe

Fig. 1, Camshaft Behind Axle



A. Right wheel rotation
1. Secondary Shoe 2. Primary Shoe

Fig. 2, Camshaft Ahead of Axle

IMPORTANT: When replacing the linings, check the camshaft end play. Using a dial indicator, measure the up-and-down and side-to-side end play of the camshaft. Replace the bushings if there is more than 0.030 inch (0.8 mm) of movement.

Replacement Using Rivets

With the brake shoe removed, do the following:

1. Using a suitable riveting mandrel, push out the old rivets.

CAUTION

CAUTION: Drilling out rivets or cutting off rivet heads with a chisel can cause the rivet hole to become out-of-round. This could damage the brake shoe.

2. Clean the shoe table. For instructions, refer to Subject 140.
3. Align the brake shoe and lining rivet holes. Using a C-clamp, clamp the lining to the brake shoe.
4. Insert the correct sized rivets into all holes and threads, and temporarily hold them in place with masking tape.

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.

Brake Shoe Lining Replacement

5. Begin riveting at the center of each edge of the shoe and lining, and work toward each end. See **Fig. 3**.

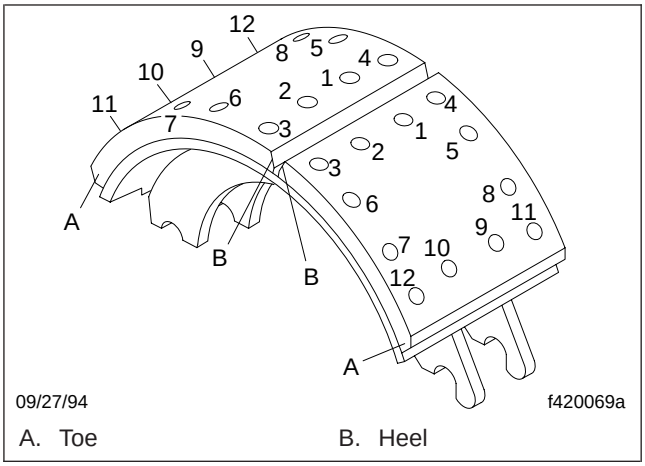


Fig. 3, Rivet or Bolt Attachment Sequence

6. Check for a close fit between the lining and shoe table.

   Try to insert a 0.010-inch (0.25-mm) feeler gauge between the lining and shoe table along the edges. See **Fig. 4**. It should not be possible to insert the feeler gauge anywhere along the edge, except at each end beyond the last row of rivets. See **Fig. 5**. A larger clearance, up to 0.025 inch (0.64 mm), may exist in these areas.

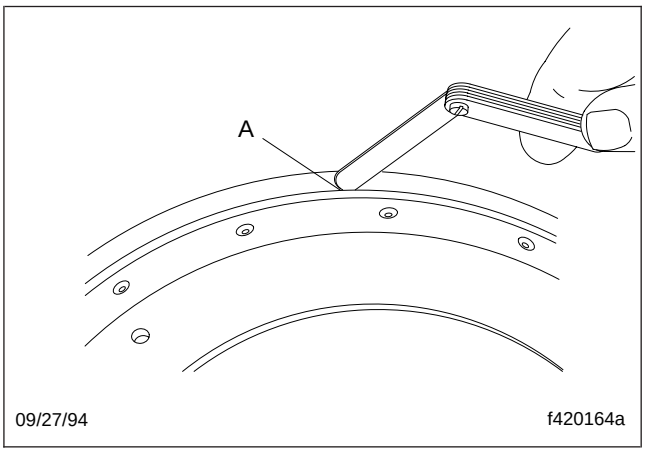


Fig. 4, Insert the Feeler Gauge between the Lining and Shoe Table

7. Circle grind the brake lining to obtain the correct lining-to-drum contact. With the cam in the full-release position, the new brake linings must be ground 0.070 inch (1.8 mm) less than the drum diameter. The cam must be adjusted and the lining ground until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.

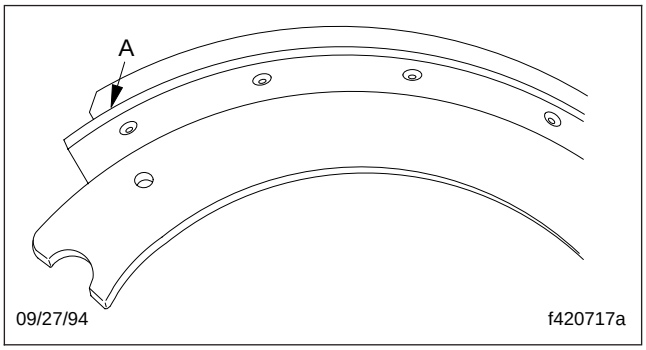


Fig. 5, Area of Feeler Gauge Clearance

Replacement Using Bolts

1. Clean the shoe table. For instructions, refer to **Subject 140**.
2. Align the brake shoe and lining bolt holes. Using a C-clamp, clamp the lining to the brake shoe.
3. Insert the correct sized bolts, and new lockwashers, into all holes and threads. Loosely install the nuts.
4. Tighten the nuts as follows in the sequence shown in **Fig. 3**: on 3/8-inch brass bolts 18 to 23 lbf·ft (24 to 31 N·m); on 1/4-inch brass bolts 80 to 100 lbf·in (900 to 1120 N·cm).
5. Circle grind the brake lining to obtain the correct lining-to-drum contact. With the cam in the full-release position, the new brake linings must be ground 0.070 inch (1.8 mm) less than the drum diameter. The cam must be adjusted and the lining ground until there is an 80 percent lining-to-drum contact, which must be continuous and in the center of the lining.

Brake Components Disassembly and Inspection, Cleaning, and Assembly

Disassembly and Inspection

⚠ WARNING

WARNING: Before starting the procedure below, read the 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. Check the drum for cracks, heat-checks, glazing, grooving, and run-out. See **Fig. 1** and **Fig. 2**. Measure the drum diameter. Replace the drum if it exceeds the maximum diameter stamped on it. Replace cracked drums. Some drums that are glazed, grooved, or out-of-round can be repaired. For detailed instructions, refer to **Group 33** or **Group 35** in this manual.
2. Disconnect the slack adjuster from the push rod clevis. For instructions, refer elsewhere in this group, or to the slack adjuster manufacturer's service information for instructions.
3. With the brake shoes removed, use a dial indicator to measure the up-and-down and side-to-side end play of the camshaft. Replace the bushings if there is more than 0.030 inch (0.8 mm) of movement.
4. Remove the slack adjuster. For instructions, refer elsewhere in this group, or to the manufacturer's service information for instructions.
5. Check the slack adjuster for damage and for binding.
   - 5.1 Check the slack adjuster clevis for cracks or bushing wear. Check the splines for chipped teeth and deformation. Replace as needed.
   - 5.2 Depress the locking sleeve, and turn the adjuster nut with a wrench at least one turn in each direction. If there is binding, or if excessive force is needed to turn the slack adjuster, replace it. For instructions, refer elsewhere in this group

IMPORTANT: If any slack adjuster problem is found, repair or replace the unit, depending on the manufacturer's recommendations.

6. Remove the camshaft by grasping its head and pulling the camshaft outboard.
7. Check the camshaft spline end for cracks, or worn or deformed splines. Replace the camshaft if damaged.
8. Check the camshaft bushing journals for wear or corrosion. Replace the camshaft if it is worn or if roughness is felt in the journal area.
9. 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.
10. Remove the brake chamber stud nuts and lockwashers that attach the brake chamber to the camshaft support bracket.

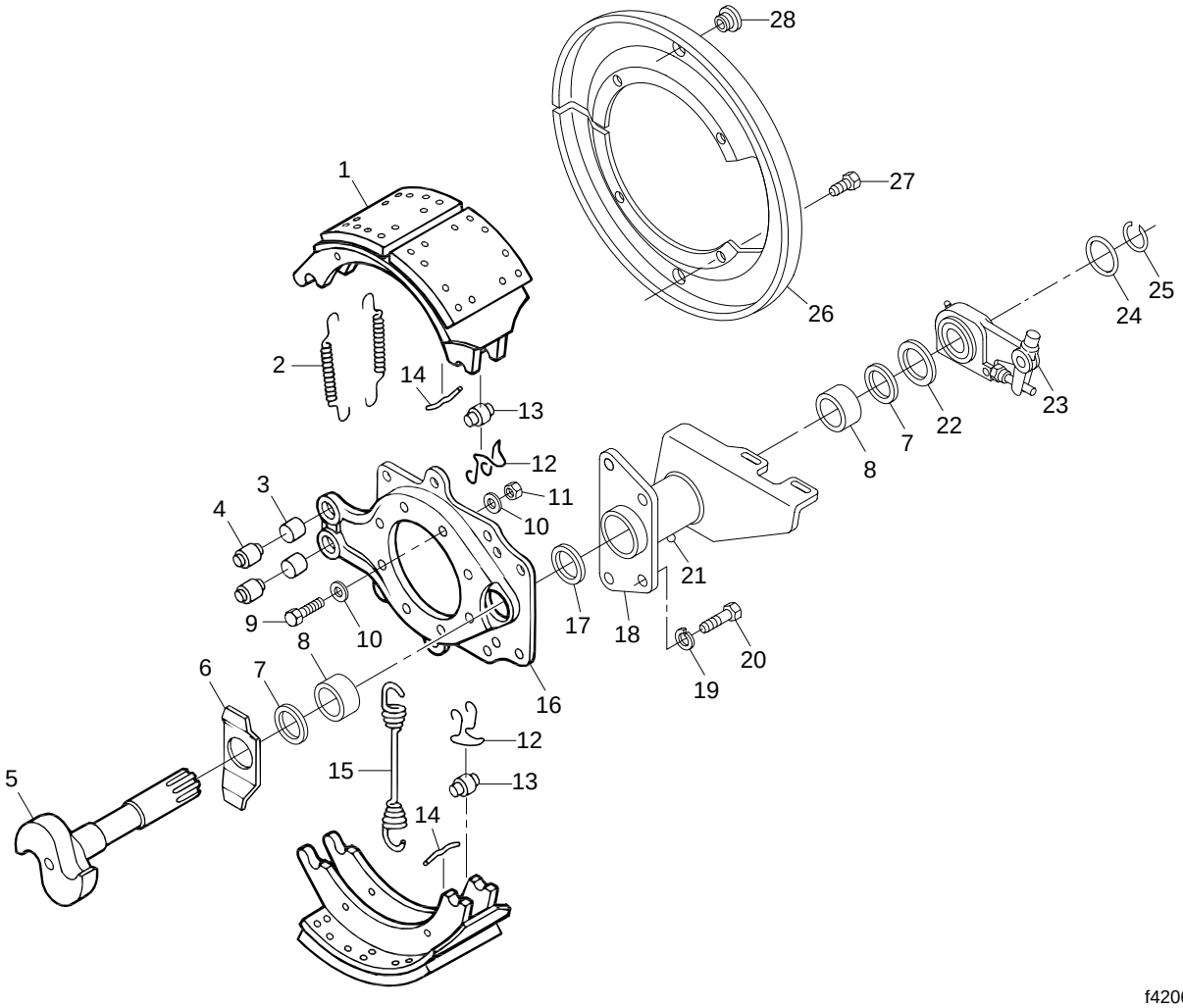
    Check the chamber for a cracked housing, bent push rod, loose clamp ring, loose air fitting, air leaks, or clogged vent holes. Repair or replace brake chamber parts as needed.
11. Remove and inspect the camshaft support bracket. Remove and discard its gasket.

    Check the bracket for a bent, broken or cracked arm, and cracked welds. Replace the bracket if any of these conditions exist.
12. Remove and inspect the old bushing and the grease seal.
    - 12.1 Check the camshaft bushing for wear. The inner surface must be smooth; if rough or abrasive, replace the bushing.
    - 12.2 Inspect the seal. Replace it if the lip is nicked, cut, or distorted.
13. Install the new bushing or seal with a suitable piloted driver.

IMPORTANT: Grease seals are installed in both the bracket and the brake spider so that the seal lip is facing toward the slack adjuster end of the bracket tube. See **Fig. 3**.

14. Remove the spider-to-axle attaching nuts, hardened washers, and bolts. Remove the spider from the axle flange.
15. If equipped, remove the four capscrews that attach the dust shield to the spider; remove the dust shield.
16. Inspect the spider and parts for damage; replace as needed.

Brake Components Disassembly and Inspection, Cleaning, and Assembly



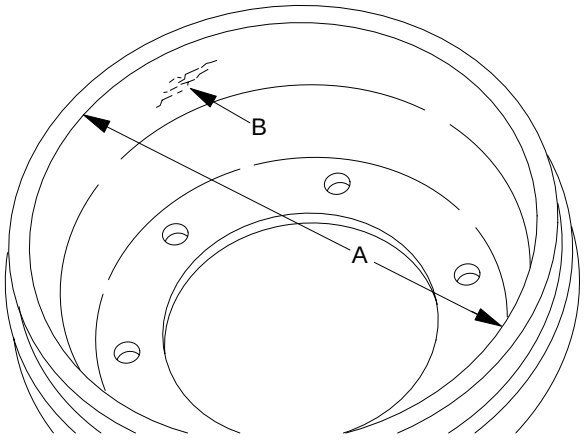
06/23/94 f420691a

NOTE: 16–1/2 inch "Q" Plus Series shown.

1. Brake Shoe and Lining Assembly
2. Brake Shoe Retaining Spring
3. Anchor Pin Bushing
4. Brake Shoe Anchor Pin
5. S-Head Camshaft
6. Camhead Washer
7. Camshaft Grease Seal
8. Camshaft, Spider, and Bracket Bushing
9. Spider Mounting Bolt
10. Hardened Washer
11. Nut
12. Brake Shoe Roller Retainer
13. Brake Shoe Roller
14. Brake Shoe Return Spring Pin
15. Brake Shoe Return Spring
16. Brake Spider
17. Camshaft Support Bracket Gasket
18. Camshaft Support Bracket
19. Bracket Capscrew Washer
20. Camshaft Support Bracket Capscrew
21. Grease Fitting
22. Camshaft Washer
23. Automatic Slack Adjuster Assembly
24. Spacing Washer
25. Camshaft Lockring
26. Dust Shield
27. Dust Shield Capscrew
28. Plug

Fig. 1, Cam-Master Q Plus Series Brakes, Exploded View

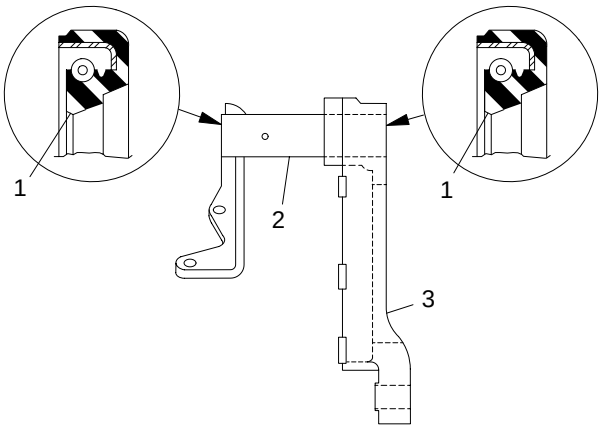
Brake Components Disassembly and Inspection, Cleaning, and Assembly



06/23/94 f420690a

A. Check for diameter and for out-of-round.
B. Check for cracks, heat checks, glazing, and grooves.

Fig. 2, Check the Drum



06/23/94 f420685a

NOTE: The seal lip is facing toward the slack adjuster.

1. Seal Lip
2. Camshaft Support Bracket
3. Brake Spider

Fig. 3, Positioning of Seals on the Camshaft

16.1 Check for cracks at the bolt holes, cam area, and around the anchor pin. Replace if damaged.

16.2 Check the anchor pin. If worn or loose, replace it.

16.3 Check the anchor pin and brake spider bushings for wear. The inner surfaces must be smooth. If any surface is rough or abrasive, replace the part.

16.4 Inspect the seal. Replace it if its lip is nicked, cut, or distorted.

17. Using a suitable piloted driver, install the new bushings and seal.

IMPORTANT: Grease seals are installed in both the bracket and the brake spider so that the seal lip is toward the slack adjuster end of the bracket tube. See **Fig. 3**.

Cleaning

WARNING

WARNING: Before starting the procedure below, read the 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.

After removing the brake parts being serviced, do the following:

1. Wire brush all parts exposed to mud, road dirt, and salt, including the exterior of the drum, spider, brake 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

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.

2. Using an industrial vacuum cleaner with a HEPA filter system, pick up excessive dust accumulation. Wipe the interior of the drums with a damp rag to remove lining dust.
3. Thoroughly clean all remaining brake parts with a damp rag. Wipe dry with a clean, lint-free cloth.

Brake Components Disassembly and Inspection, Cleaning, and Assembly

Assembly

⚠ WARNING

WARNING: Before starting the procedure below, read the 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.

   Position the dust shield against the spider, and install the capscrews. See **Fig. 1** . Tighten the capscrews:

   - 3/8–16 Grade 5—25 to 35 lbf·ft (34 to 47 N·m)
   - 3/8–16 Grade 8—35 to 50 lbf·ft (47 to 68 N·m)

2. Install the spider.

   Place the spider on the axle flange. Using a hardened washer under the bolt head and the nut, install the mounting fasteners. Tighten the bolts in a cross pattern:

   - 1/2–13; 60 to 80 lbf·ft (81 to 108 N·m)
   - 5/8–11 (flanged hexhead capscrew); 160 to 200 lbf·ft (217 to 271 N·m)
   - 5/8–11 (hexhead capscrew); 130 to 160 lbf·ft (176 to 217 N·m)

3. Install the brake chamber and bracket.

   3.1 Place the brake chamber on the mounting bracket with the chamber mounting studs through the bracket holes. Install the hardened flatwashers, lockwashers, and stud nuts. Tighten the nuts:

   - 3/8–16—37 to 50 lbf·ft (47 to 68 N·m)
   - 1/2–13—70 to 100 lbf·ft (95 to 136 N·m)

   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.

   3.2 Place the bracket against the spider, and install the lockwashers and capscrews. Tighten the capscrews:

   - 1/2–13—60 to 80 lbf·ft (81 to 108 N·m)
   - 5/8–11—105 to 145 lbf·ft (142 to 196 N·m)

4. Install the camshaft and parts in the spider; install the slack adjuster.

   4.1 Apply a thin film of chassis grease on the inside of the camshaft bushings and journals. Don't grease the camshaft head area.

   4.2 Apply a thin film of rust preventive grease (Rockwell 0–637, or an equivalent) on the camshaft splines.

   4.3 Carefully slip the camshaft into the spider and the mounting bracket tube.

   4.4 Install the thick camshaft washer on the camshaft.

   4.5 Install the slack adjuster on the camshaft, with the adjuster nut on the side opposite of the brake chamber.

   4.6 Install the outer washers and snap ring.

5. Use a dial indicator to measure the end-play of the camshaft. There should be no more than 0.060 inch (1.5 mm) movement.

6. Pressure lube the camshaft bracket bushings.

   Pump multipurpose chassis grease (NLGI grade 1 or 2) into the chamber bracket until it appears at the slack adjuster end of the bracket. Use care that no grease enters the drum cavity. If grease leaks out under the camhead, the camshaft grease seal is worn or damaged, or is installed backwards.

NOTE: The use of meter-type fittings, having a maximum 40 psi (276 kPa) pressure relief at shutoff, is recommended.

7. Align the appropriate hole in the slack adjuster with the hole in the brake chamber push-rod clevis. For instructions, refer elsewhere in this group or to the manufacturer's service information.

8. Install the brake shoes. For instructions, refer to **Subject 110**.

Specifications

Fastener Torques				
Description	**Grade**	**Size**	**Torque**	
			lbf·in (N·cm)	**lbf·ft (N·m)**
Brake Shoe Lining Nuts	—	3/8"	—	18–23 (24–31)
		1/4"	80–100 (900–1120)	—
Dust Shield Capscrews	5	3/8–16	—	25–35 (34–47)
	8	3/8–16	—	35–50 (47–68)
Spider Mounting Bolts	8	1/2–13	—	60–80 (81–108)
Hexhead Capscrew		5/8–11	—	130–160 (176–217)
Flanged Hexhead Capscrew				160–200 (217–271)
Brake Chamber Mounting Nuts	8	3/8–16	—	37–50 (47–68)
		1/2–13	—	70–100 (95–136)
Brake Chamber Bracket-to-Spider Capscrews	8	1/2–13	—	60–80 (81–108)
		5/8–11	—	105–145 (142–196)

Table 1, Fastener Torques

General Information

The single check valve is installed in an air line to allow air flow in one direction and prevent air flow in the reverse direction. See **Fig. 1** and **Fig. 2**. The check valve is installed in the upstream ends of the primary and secondary brake system air reservoirs to protect brake system air pressure in case the compressor, air pressure regulator or other air delivery component malfunctions.

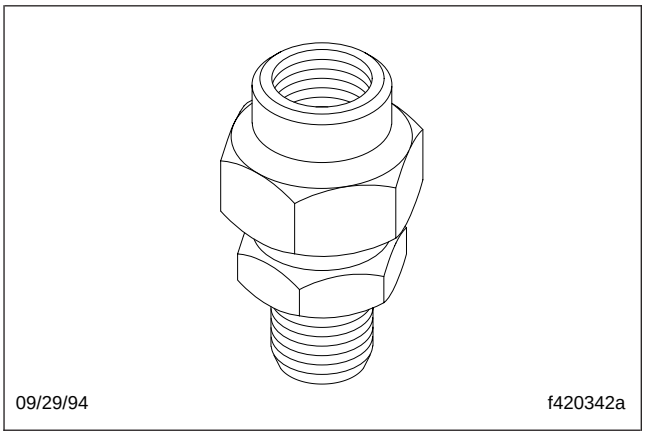


Fig. 1, Single Check Valve, Bendix

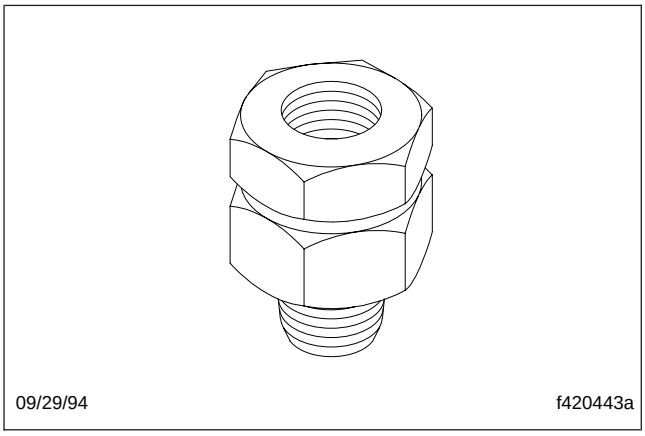


Fig. 2, Single Check Valve, Midland

Principles of Operation

When air in the system moves in the normal direction—from the compressor to the air reservoir—the check valve disk compresses the spring and allows air to pass. See **Fig. 3**. When there is a drop in air pressure on the supply side of the valve, the spring pushes the check valve disk against the valve seat and prevents air from leaving the brake system.

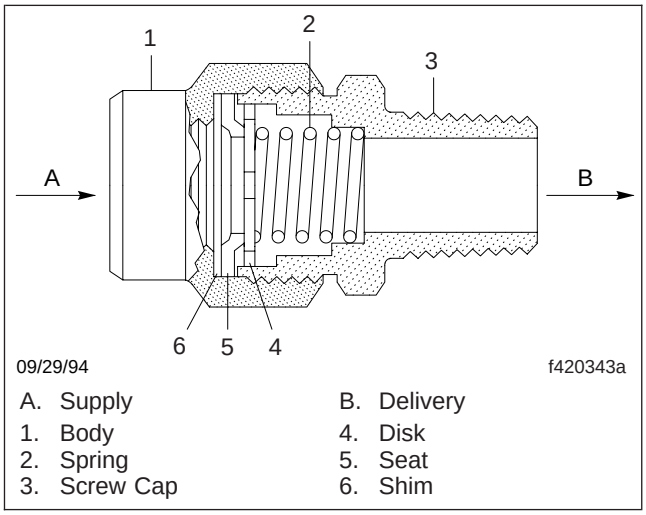


Fig. 3, Cross-Section (Bendix shown)

Safety Precautions

When working on or around air brake systems and components, observe the following precautions:

1. Chock the wheels and stop the engine before working under the vehicle. 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 not correctly disassembled. Use only the correct tools and observe all precautions regarding use of those tools.

Leakage Test

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100** .

After repairing or replacing the single check valve, do the following test:

With the brake air system fully pressurized, drain the air from the supply reservoir (wet tank), and remove the air line from the supply side of the check valve. Coat the open end of the check valve with soap suds. A 1-inch (2.5-cm) or smaller bubble in five seconds is acceptable.

If the check valve is leaking too much, repair or replace it.

IMPORTANT: The Midland check valve is not serviceable. If it leaks or doesn't work, replace it.

Removal

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Chock the tires, then drain the air reservoirs.
2. Remove the supply line from the check valve.
3. Remove the check valve from the air reservoir.

Installation

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

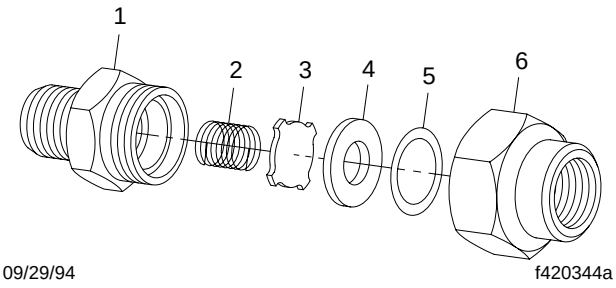
1. Screw the check valve into the supply end of the air reservoir. To ensure the valve is not reversed, the arrow marked on the valve body must point in the direction of air flow.
2. Leak test the check valve following the instructions under **Subject 110**.
3. Connect the supply line to the open end of the check valve.

Disassembly, Cleaning and Inspection, and Assembly (Bendix only)

Disassembly

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Remove the check valve following the instructions under **Subject 120**.
2. Remove the screw cap from the body. See **Fig. 1**.



1. Screw Cap
2. Spring
3. Disk
4. Seat
5. Shim
6. Body

Fig. 1, Check Valve Assembly

3. Remove the shim, seat, disk, and spring.

Cleaning and Inspection

IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Wash all parts of the check valve in cleaning solvent. Dry the parts of the disassembled check valve with compressed air.
2. Inspect the disk for signs of wear or deterioration.
3. Check the spring for cracks, corrosion, or damage.
4. Inspect the body and screw cap for cracks or damage. Replace all worn or damaged parts with new parts.

Assembly

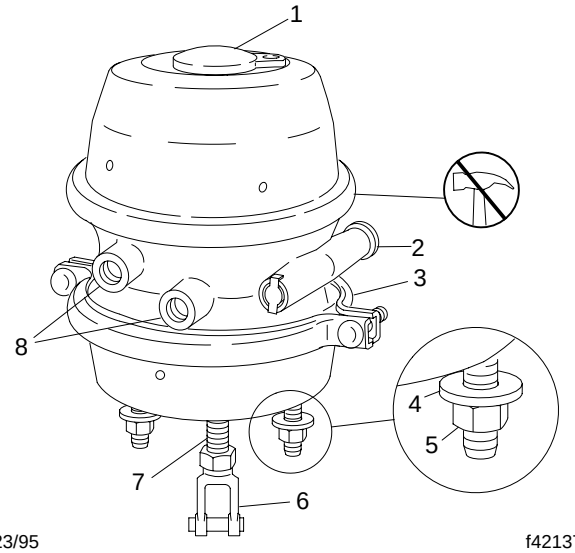
IMPORTANT: Before working on or around air brake systems and components, review **Safety Precautions, 100**.

1. Position the shim, seat, disk, and spring in the body.
2. Screw the screw cap into the body over the other parts. Tighten it securely.
3. Install the check valve following the instructions under **Subject 120**.

DANGER

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: The parking/emergency brake section is factory sealed (no clamp ring) and is a *non-serviceable* unit.



06/23/95 f421371

1. Dust Plug
2. Release Bolt Storage Pocket
3. Service Brake Clamp Ring
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Clevis Assembly
7. Piston Rod
8. Air Inlet Ports

Fig. 1, Brake Chamber

General Information

Anchorlok 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 service brake chamber contains a service return spring, piston rod assembly, and service brake diaphragm.

In the parking/emergency brake section, the adaptor and the parking brake chamber contain a return spring, a push rod assembly, a parking (spring) brake diaphragm, a pressure plate, a power spring, and a detachable release bolt.

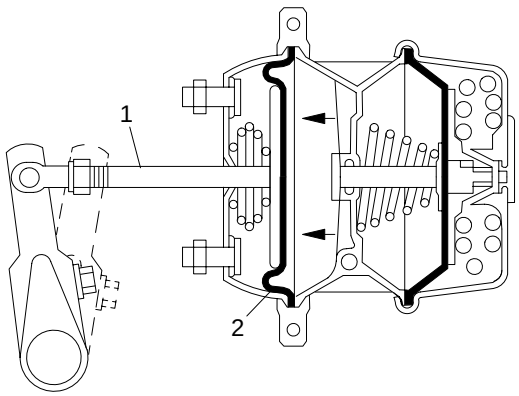
All Anchorlok brake chambers are mounted to the frame using prevailing torque locknuts and hardened flatwashers.

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. For maintenance schedules and procedures, and for inspection of brake chamber parts, refer to the vehicle maintenance manual.

Principles of Operation

SERVICE BRAKES

As the brake pedal is depressed, compressed air enters the service brake chamber through a port. Air pressure acts upon a diaphragm, which forces the piston rod toward the non-pressure chamber, applying a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes. See **Fig. 2**.



06/23/95 f421372

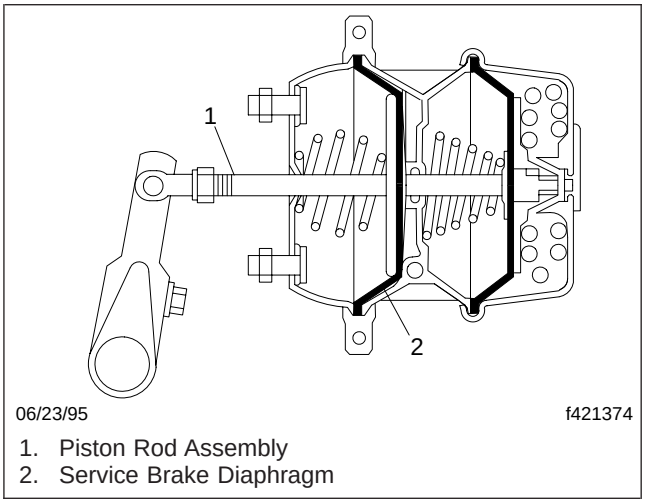
1. Piston Rod Assembly
2. Service Brake Diaphragm

Fig. 2, Service Brakes Applied

Then, when the brake pedal is released see, air is exhausted from the service brake chamber, and the return spring allows the diaphragm, piston rod as-

General Information and Principles of Operation

sembly, and slack adjuster to return to their normal positions, releasing the brakes. See **Fig. 3**.



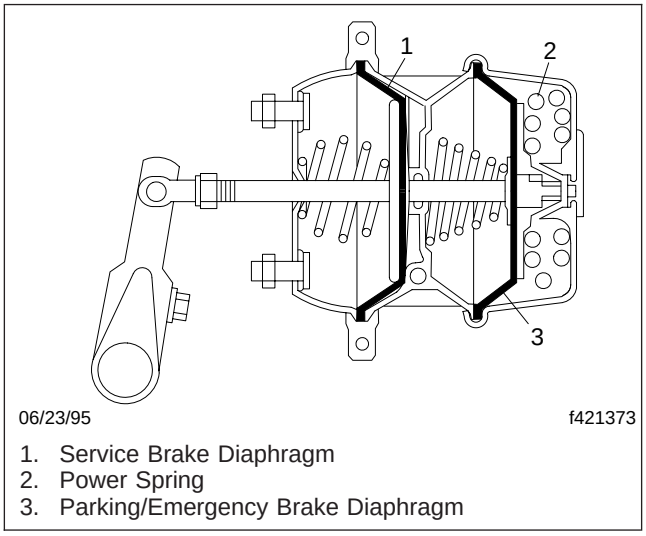
1. Piston Rod Assembly
2. Service Brake Diaphragm

Fig. 3, Service Brakes Released

PARKING/EMERGENCY BRAKES

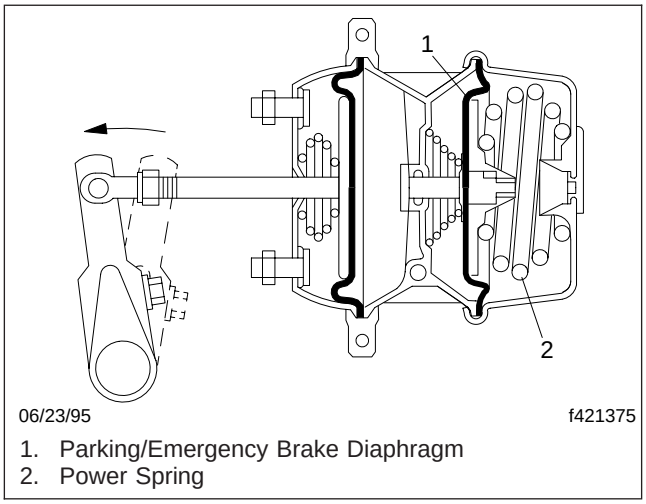
During parking brake release, compressed air enters the parking/emergency brake chamber below the diaphragm, forcing the diaphragm against the pressure plate to compress the power spring and release the parking/emergency brake. See **Fig. 4**. During parking brake application, a control valve in the cab exhausts air from the parking/emergency brake chamber. This allows the power spring to extend and apply the brakes. See **Fig. 5**.

Emergency brake application begins when air pressure in the service brake reservoir drops below about 80 to 85 psi (550 to 585 kPa). Maximum parking brake force is applied when air is entirely exhausted fom the parking/emergency brake chamber.



1. Service Brake Diaphragm
2. Power Spring
3. Parking/Emergency Brake Diaphragm

Fig. 4, Parking/Emergency Brakes Released



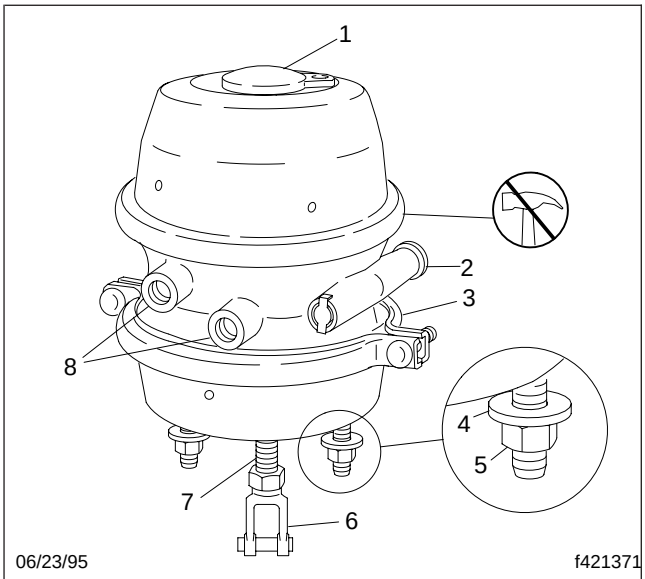
1. Parking/Emergency Brake Diaphragm
2. Power Spring

Fig. 5, Parking/Emergency Brakes Applied

Power Spring Manual Compression and Reset

⚠ DANGER

DANGER: Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. The parking/emergency brake section is not intended to be serviced. See Fig.1. Serious injury or death may result from the sudden release of the power spring.



1. Dust Plug
2. Release Bolt Storage Pocket
3. Service Brake Clamp Ring
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Clevis Assembly
7. Piston Rod
8. Air Inlet Ports

Fig. 1, Brake Chamber

Manual Compression (Parking Brake Release)

1. Chock the tires.
2. Remove the dust plug from the center-hole in the head of the chamber. See **Fig. 2**.

⚠ DANGER

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.

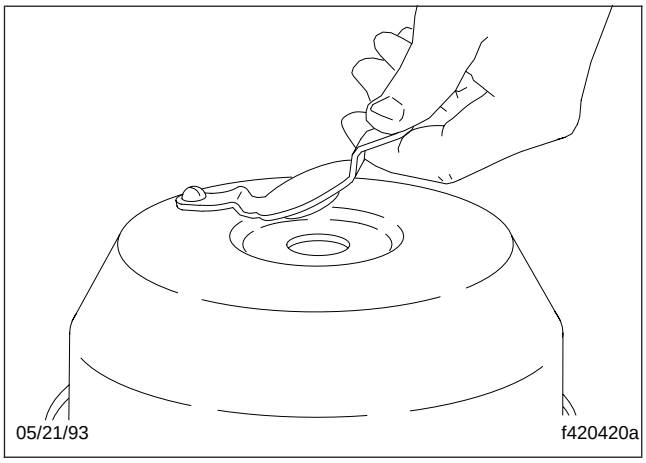


Fig. 2, Remove the Dust Plug

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 Anchorlok installation instructions.

3. Manually release the parking brake (cage the power spring).

   3.1 Using a hand wrench, (*don't use an impact wrench*), unscrew the release nut, and remove the nut, flatwasher, and release bolt from the storage pocket on the side of the chamber. See **Fig. 3**.

   IMPORTANT: If these parts are not stored on the chamber, they must be otherwise obtained or purchased; the parking brake cannot be manually released without them.

   3.2 Insert the release bolt into the center-hole in the chamber head. See **Fig. 4**. Continue to insert the bolt until it bottoms out into the hole in the pressure plate inside the chamber.

   IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged

Power Spring Manual Compression and Reset

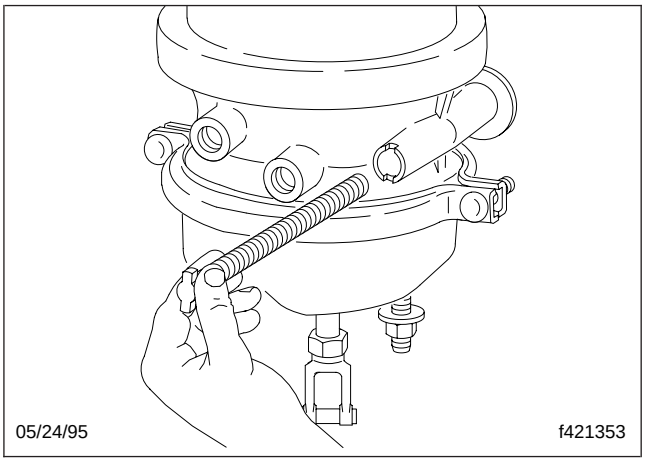


Fig. 3, Remove the Release Bolt

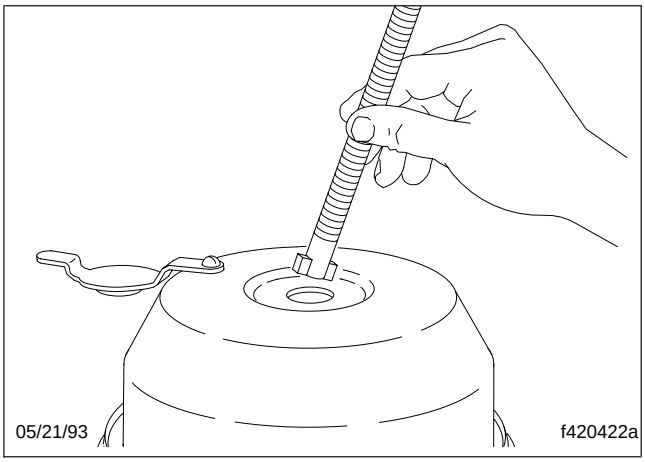


Fig. 4, Insert the Release Bolt

the pressure plate correctly, repeat this step. Repeat it until you are absolutely sure.

3.3 Turn the release bolt one-quarter turn clockwise. Pull to seat the formed end of the release bolt in the recess of the pressure plate.

3.4 Holding the release bolt locked into the pressure plate, install the flatwasher and release nut on the end of the bolt, and turn down the nut against the flatwasher until it is finger-tight. See **Fig. 5**.

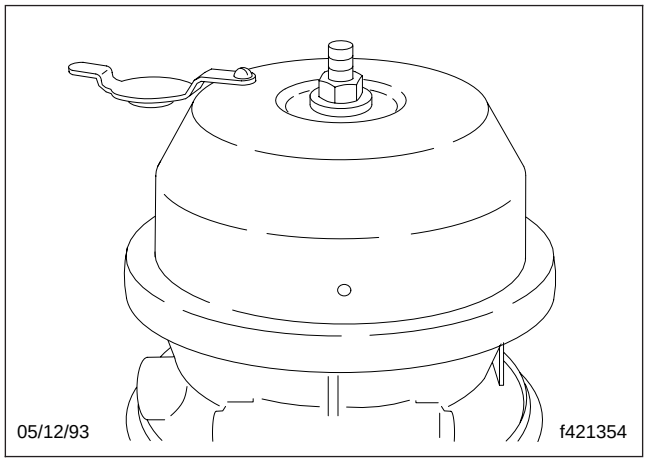


Fig. 5, Flatwasher and Release Nut Installed

⚠ DANGER

DANGER: Exhaust all air pressure before tightening the release nut more than finger-tight. Tightening this nut under pressure can damage the pressure plate and result in sudden release of the power spring, causing death or severe personal injury.

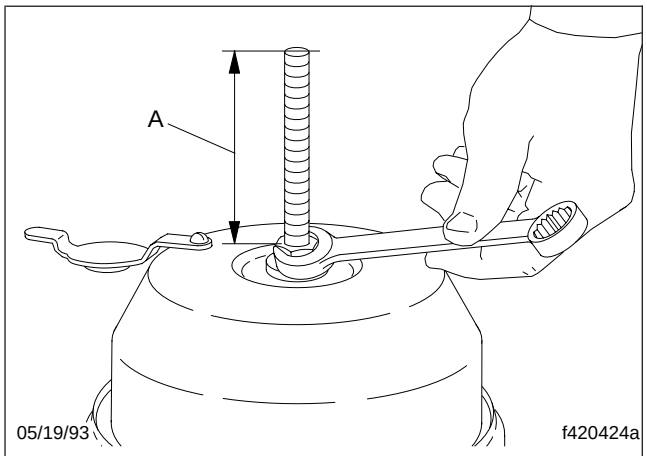
⚠ CAUTION

CAUTION: If equipped with S-cam or disc brakes, don't exceed 35 lbf·ft (47 N·m) torque on the release nut; if equipped with wedge brakes, don't exceed 20 lbf·ft (27 N·m) torque on the release nut.

3.5 Using a hand wrench (*don't use an impact wrench*), turn the release nut clockwise until the power spring is caged. See **Fig. 6**.

The bolt should extend above the nut at least 2.9 inches (74 mm) on 24-inch chambers, or 2.875 inches (73 mm) on 30-inch chambers.

IMPORTANT: Do not exceed these bolt lengths. If the bolt lengths can't be obtained without exceeding the recommended maximum torque values, replace the tandem brake chamber.



A. Measure this distance.

Fig. 6, Turn the Release Nut

Manual Reset (Parking Brake Reset)

1. Uncage the power spring.

CAUTION

CAUTION: Don't use an impact wrench on this nut. Too much torque could damage the pressure plate and prevent manual release of the parking brake.

1.1 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 power spring extends back into the parking/emergency brake chamber.

NOTE: When the power spring is fully extended, force will no longer be felt on the release nut.

1.2 Remove the nut and flatwasher.

1.3 Turn the release bolt one-quarter turn counterclockwise and unlock the bolt from the receptacle in the pressure plate. Remove the release bolt from the center-hole of the chamber.

2. Using a hand wrench, (*don't use an impact wrench*), install the release bolt, flatwasher, and release nut in the storage pocket. Tighten the nut 60 to 96 lbf·in (680 to 1080 N·cm). See **Fig. 7**.

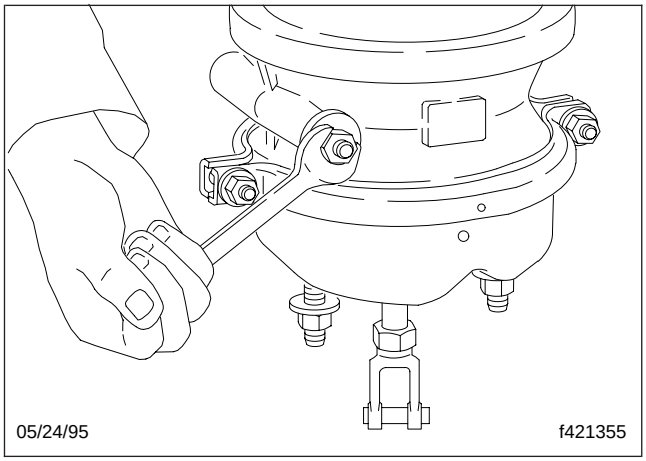


Fig. 7, Tighten the Release Nut

3. Snap the dust plug in place over the center-hole in the chamber head. See **Fig. 8**.

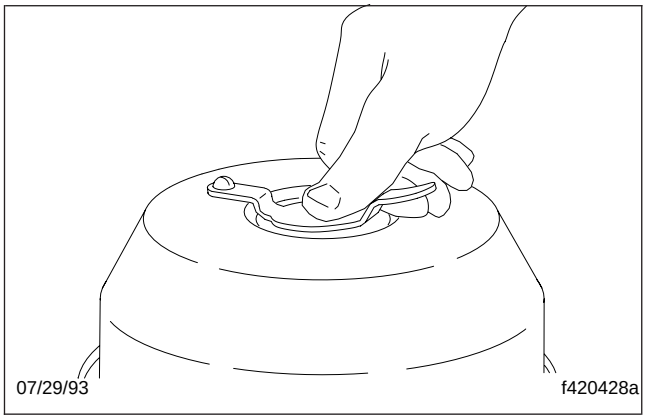


Fig. 8, Snap the Dust Plug in Place

CAUTION

CAUTION: If a dust plug is missing or incorrectly installed, road dirt and debris can adversely affect the operation of the brake chamber. Once inside the chambers, dirt and debris cause the internal parts to deteriorate and shorten their lives.

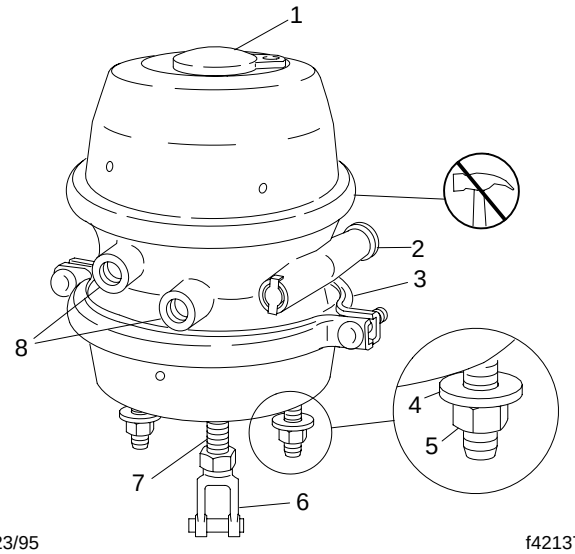
4. Check the plastic dust plug periodically, and replace it with a new one at once if damaged or missing. For intervals, refer to the vehicle maintenance manual.

Power Spring Manual Compression and Reset

5. Remove the chocks from the tires.

DANGER

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.



1. Dust Plug
2. Release Bolt Storage Pocket
3. Service Brake Clamp Ring
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Clevis Assembly
7. Piston Rod
8. Air Inlet Ports

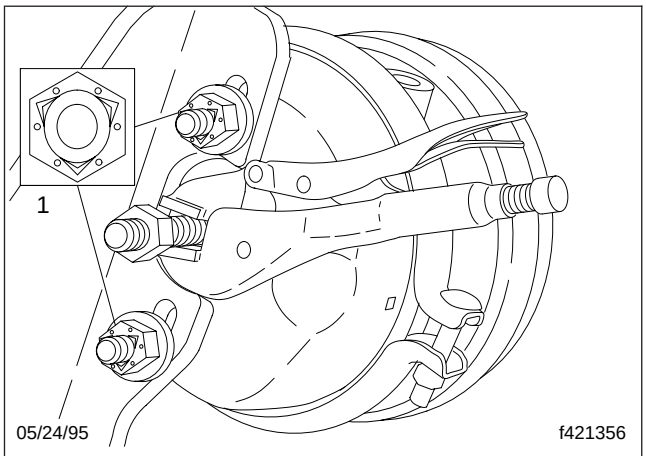
Fig. 1, Brake Chamber

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.

   1.1 Apply the service brakes by actuating the driver's foot brake treadle valve.

   1.2 With the brakes applied, clamp a pair of locking-jaw pliers on the piston rod to lock the rod in place when the air pressure is released. See **Fig. 2**.



1. Prevailing Torque Locknut

Fig. 2, Lock the Piston Rod in Place

WARNING

WARNING: Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in this section (see 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, refer to **Subject 100**.

3. Mark the air lines for later reference. Then carefully disconnect them from the brake chamber.

DANGER

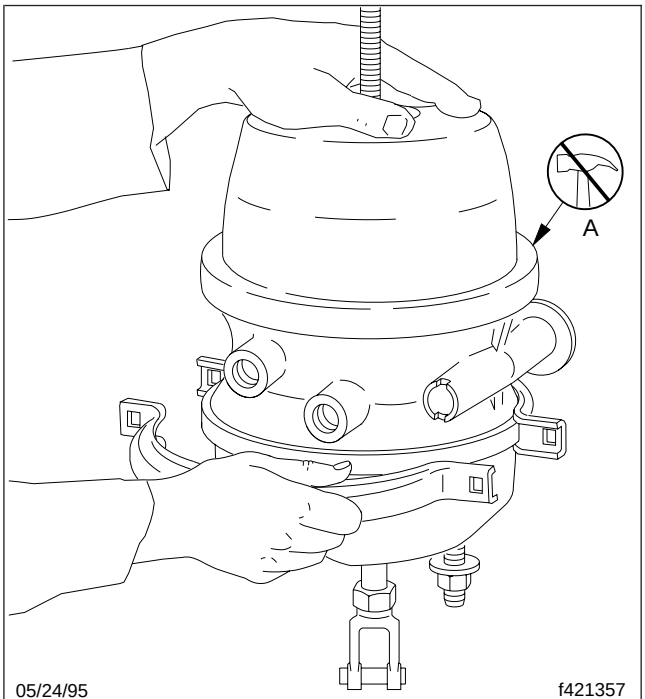
DANGER: Do not attempt to remove the factory-sealed clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

4. Remove the parking brake and adaptor from the service brake section.

   4.1 Using a hand wrench (*don't use an impact wrench*), remove the clamp nuts on the *service* brake clamp ring (*do not disassemble the parking brake section*).

Service Brake Diaphragm Replacement

4.2 While holding the parking brake section securely in place, remove the service clamp ring. Then remove the parking brake section from the service brake non-pressure chamber. See **Fig. 3**.



A. Do not remove the factory-sealed clamp ring.

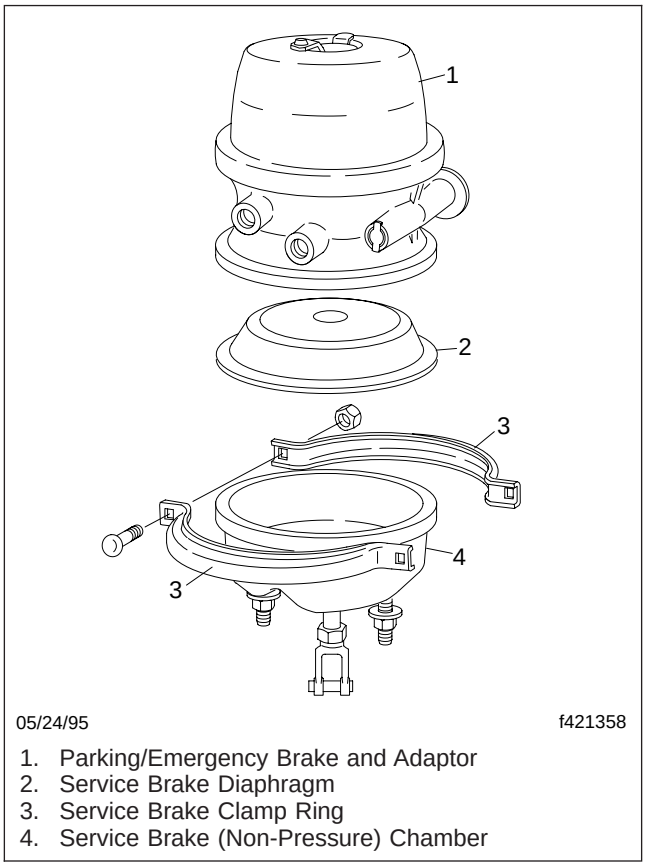
Fig. 3, Remove the Service Clamp Ring

5. Remove the service brake diaphragm from the bottom of the parking brake section.

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. Follow the detailed inspection instructions in the vehicle maintenance manual.

1. Inspect all parts in the service (non-pressure) chamber. Replace any damaged or worn parts.
2. Place the new service brake diaphragm in the bottom recess of the adaptor. See **Fig. 4**.
3. Install the (new, if needed) parking/emergency brake section.



1. Parking/Emergency Brake and Adaptor
2. Service Brake Diaphragm
3. Service Brake Clamp Ring
4. Service Brake (Non-Pressure) Chamber

Fig. 4, Brake Chamber Parts

3.1 If installing a new parking brake section, be sure it is the same size and make as the old one.

3.2 Check that the release bolt is fully extended outward. For instructions, refer to **Subject 100**.

3.3 Install the parking brake section on the service chamber so that all mating parts are aligned straight and the air lines are positioned to mate with the vehicle air supply lines.

4. Install the service brake clamp ring.

4.1 With the service brake clamp ring in place, install the clamp bolts and nuts.

4.2 Using a hand wrench (*don't use an impact wrench*), alternately tighten each clamp nut 18 to 25 lbf·ft (24 to 34 N·m)

while constantly rechecking the alignment of mating parts.

4.3 Lightly tap around the circumference of the service clamp ring with a rubber mallet to ensure full seating of the clamp. If re-alignment is needed, loosen the nuts again, and repeat this step.

5. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).
6. 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).
7. With the parking brake still charged with full line pressure, apply and hold the foot brake treadle valve down to charge the service brake chamber. Remove the locking-jaw pliers from the service piston rod so that the piston returns to a normal position in the chamber.

⚠ DANGER

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.

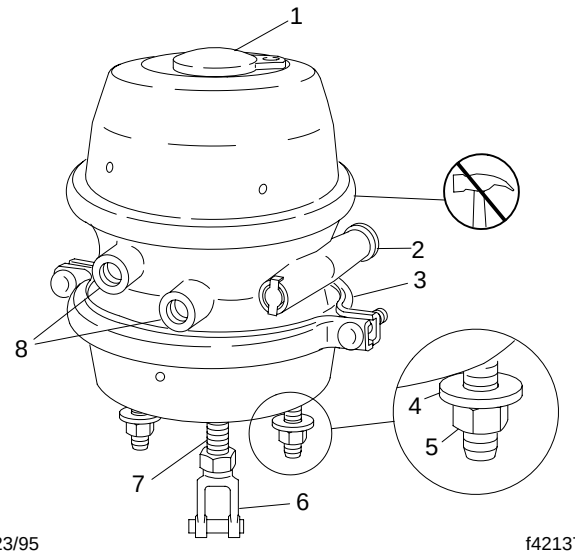
8. Test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, release all air pressure from the chamber, then retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). Anchorlok recommends 18 to 25 lbf·ft (24 to 34 N·m) torque on the clamp hexnuts.
9. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the dust plug in place. For instructions, refer to **Subject 100**.
10. 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 brake adjustment. No brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

Replacement

DANGER

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.



1. Dust Plug
2. Release Bolt Storage Pocket
3. Service Brake Clamp Ring
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Clevis Assembly
7. Piston Rod
8. Air Inlet Ports

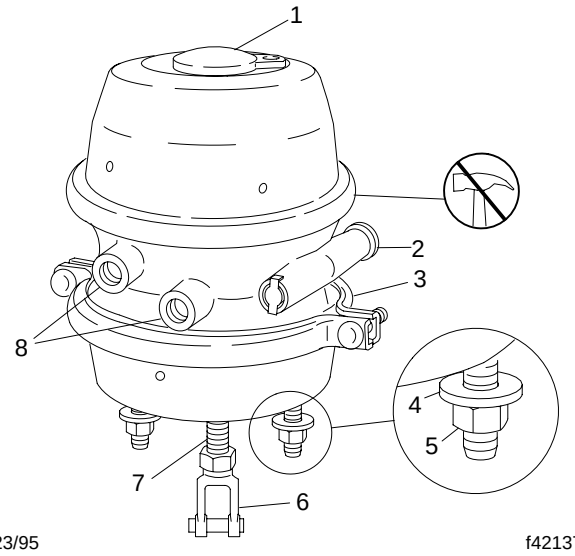
Fig. 1, Brake Chamber

IMPORTANT: The parking/emergency brake section can be replaced as a unit. For instructions, refer to **Subject 110**.

Combination Service and Parking Brake Chamber Removal and Installation

DANGER

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.



1. Dust Plug
2. Release Bolt Storage Pocket
3. Service Brake Clamp Ring
4. Hardened Flatwasher
5. Prevailing Torque Locknut
6. Clevis Assembly
7. Piston Rod
8. Air Inlet Ports

Fig. 1, Brake Chamber

Removal

WARNING

WARNING: Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in this section. See 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, refer to **Subject 100**.
2. Mark the air lines for later reference. Then carefully disconnect them from the brake chambers.
3. Remove the brake chamber from the vehicle.

   3.1 Remove the cotter pin(s) from the clevis pin(s), then remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster.

   NOTE: Automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   3.2 From each mounting stud, remove any installed nuts and washers. Then, cautiously remove the brake chamber from the mounting bracket.

Installation

1. If installing a new brake chamber unit, do the following steps:

   1.1 First, make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 100** and do the applicable steps.

   1.2 Make sure that the piston rod is the same length as the rod on the old unit (measure the rods when *both* chambers are caged).

   1.3 Be sure the new chamber is the same size and make as the brake chamber installed on the other side of the axle.

   1.4 Remove the prevailing torque locknut and hardened flatwasher from each of the mounting studs on the chamber.

2. Clean the face of the mounting bracket, and position the chamber on the bracket. Pay close attention to positioning the chamber air inlet ports for correct alignment to the vehicle air lines.

WARNING

WARNING: Tighten the mounting nuts with a hand wrench, not an impact wrench. An impact wrench could damage the mounting fasteners,

Combination Service and Parking Brake Chamber Removal and Installation

reducing the force of the brakes. This could result in personal injury or property damage.

3. Install one hardened flatwasher and prevailing torque locknut on each mounting stud. Using a hand wrench (*don't use an impact wrench*), tighten the nuts 110 to 150 lbf·ft (149 to 203 N·m). Make sure that the hardened flatwasher is installed between the locknut and the mounting bracket.
4. Check mating and alignment with the vehicle air lines.

⚠ DANGER

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.

4.1 Using a hand wrench (*don't use an impact wrench*), loosen the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

4.2 Reposition the air inlet ports, as needed, to mate with vehicle air supply lines.

Alternately tighten each clamp nut in increments of 18 to 25 lbf·ft (24 to 34 N·m) while constantly rechecking the alignment of mating parts.

If realignment is needed, loosen the nuts again, and repeat this substep.

4.3 Lightly tap around the circumference of the service clamp ring to ensure full seating of the clamp.

5. Connect the slack adjuster. Refer to the applicable slack adjuster section in this group for installation instructions.
6. Inspect the piston rod to be sure it is not binding, and is square with the chamber bottom from zero to full stroke. If there is misalignment, make corrections by loosening the locknuts and repositioning the chamber on the mounting bracket, or by shimming the slack adjuster to the right or left on the camshaft.
7. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).
8. Using the vehicle system air, charge the parking brake with full line pressure, at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).

⚠ DANGER

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: 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, release all air pressure from the chamber, then retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). Anchorlok recommends 18 to 25 lbf·ft (24 to 34 N·m) torque on the clamp hexnuts.

9. With air pressure now exhausted from the service brake chamber, but held on the parking brake, reset the parking brakes by uncaging the power spring, and snap the dust plug in place. For instructions, refer to **Subject 100**.
10. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

IMPORTANT: After replacing any brake chamber, check the piston rod stroke and actuating alignment to ensure correct installation and brake adjustment. No 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, re-

fer to the applicable slack adjuster section in this group.

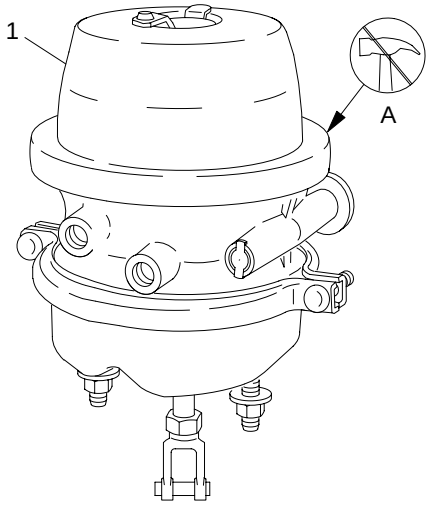
Specifications

Description	Torque	
	lbf·ft (N·m)	lbf·in (N·cm)
Spring Brake Release Bolt Nut: (in storage pocket)	—	60 to 96 (680 to 1080)
(caged—on S-cam or disc brakes)	35 (47)	—
(caged—on wedge brakes)	20 (27)	—
Service Brake Clamp Ring Nut	18 to 25 (24 to 34)	—
Brake Chamber Mounting Stud Locknut	110 to 150 (149 to 203)	—
Air Hose Fitting-to-Chamber	25 (34)	—

Table 1, Torque Values

⚠ DANGER

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

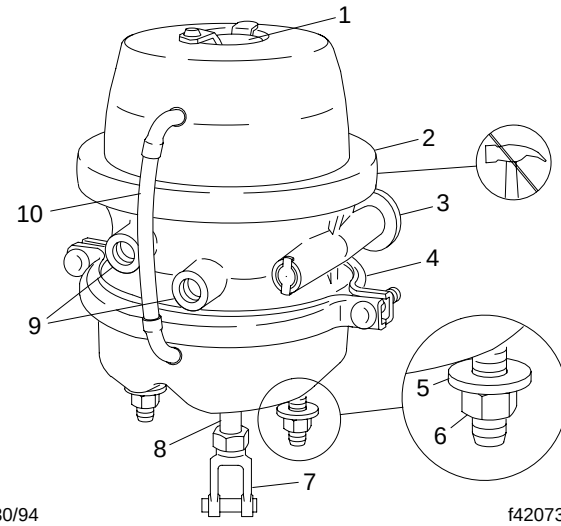
Fig. 1, Brake Chamber

IMPORTANT: 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 chamber consists of a service brake section and a parking/emergency spring brake section. See **Fig. 2**. The service brake section is the smaller section near the clevis assembly.

In the service brake section, the flange case and non-pressure chamber contain a service return spring, piston rod assembly, and service brake diaphragm.



08/30/94 f420730c

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. 2, Model TR-T (TR Series) Brake Chamber

In the parking/emergency brake section, the flange case and the head contain a return spring, a push rod assembly, a parking (spring) brake diaphragm, a piston, a power spring, and a detachable release bolt.

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. 2**.

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. For maintenance schedules and procedures, and for inspection of brake chamber parts, refer to the vehicle maintenance manual.

Principles of Operation

SERVICE BRAKES

As the brake pedal is depressed, compressed air enters the service brake chamber through a port. Air pressure acts upon a diaphragm, which forces the piston rod toward the non-pressure chamber, applying a straight-line force to the slack adjuster, which converts it to a rotational force. This in turn rotates the camshaft and applies the brakes.

Then, when the brake pedal is released, air is exhausted from the service brake chamber, and the return spring allows the diaphragm, piston rod, and slack adjuster to return to their normal positions, releasing the brakes.

PARKING/EMERGENCY BRAKES

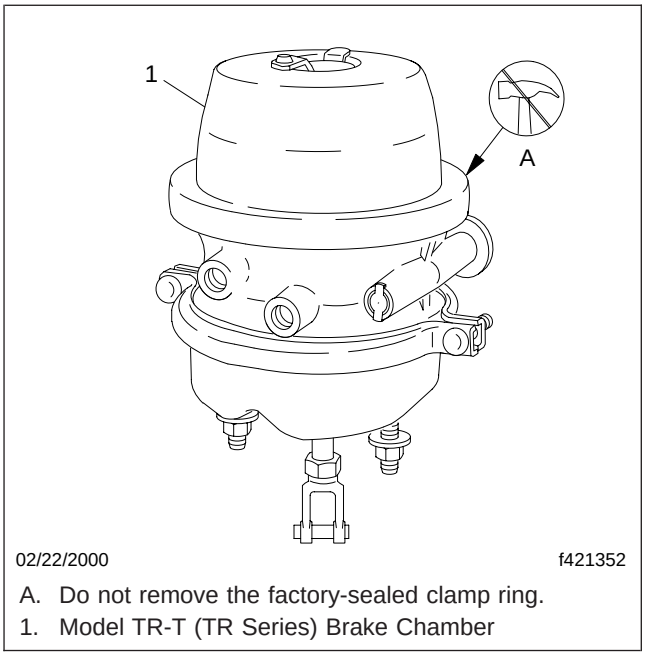
During parking brake release, compressed air enters the parking brake chamber and acts upon the diaphragm and piston, fully compressing the power spring. When the power spring is compressed, the parking brakes are released; the service brakes can then be operated at the brake pedal.

During parking brake application, air is exhausted from the parking brake chamber. The power spring releases, forcing the piston and parking brake diaphragm toward the flange case. The resulting motion on the push rod forces the service brake diaphragm and piston rod outward, applying the brakes.

Power Spring Manual Compression and Reset

⚠ DANGER

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. 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.

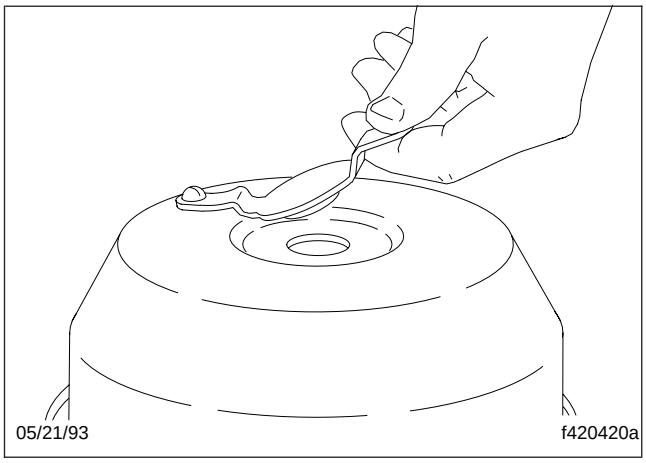


Fig. 2, Remove the End-Cover Cap

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. Manually release the parking brake (cage the power spring).

   3.1 Using a hand wrench (*don't use an impact wrench*), unscrew the release nut, and remove the nut, flatwasher, and release bolt from the storage pocket on the side of the chamber. See **Fig. 3**.

   IMPORTANT: If these parts are not stored on the chamber, they must be otherwise obtained or purchased; the parking brake cannot be manually released without them.

   3.2 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set parking brake in the "release" position).

   3.3 Insert the release bolt into the center-hole in the chamber head. See **Fig. 4**. Insert the bolt until it bottoms out into the hole in the piston inside the chamber.

   IMPORTANT: If you are not absolutely sure that the formed end of the bolt has engaged

Power Spring Manual Compression and Reset

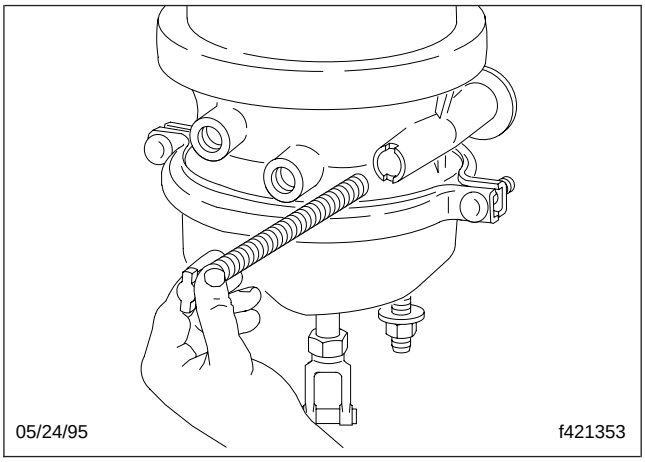


Fig. 3, Remove the Release Bolt

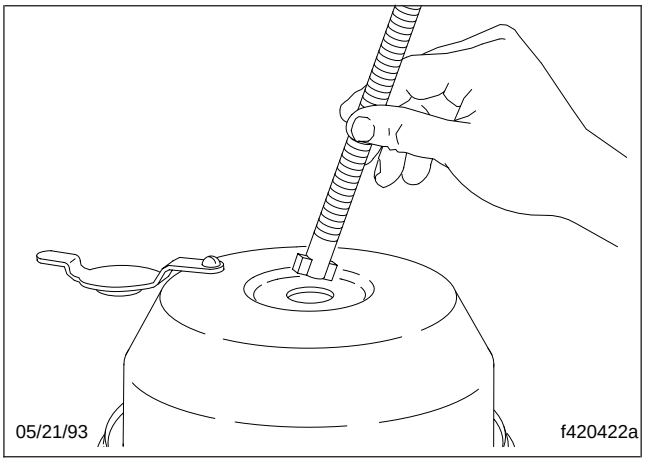


Fig. 4, Insert the Release Bolt

the piston correctly, repeat this step. Repeat it until you are absolutely sure.

3.4 Turn the release bolt one-quarter turn clockwise, and pull the bolt out to lock its formed end into the piston.

IMPORTANT: If the bolt doesn't lock into the piston in less than 1/2-inch (13-mm) outward movement, repeat these steps until you are sure it does lock.

3.5 Then, holding the bolt locked into the piston, install the flatwasher and release nut on the end of the release bolt, and turn down the nut against the flatwasher until it is finger-tight. See **Fig. 5**.

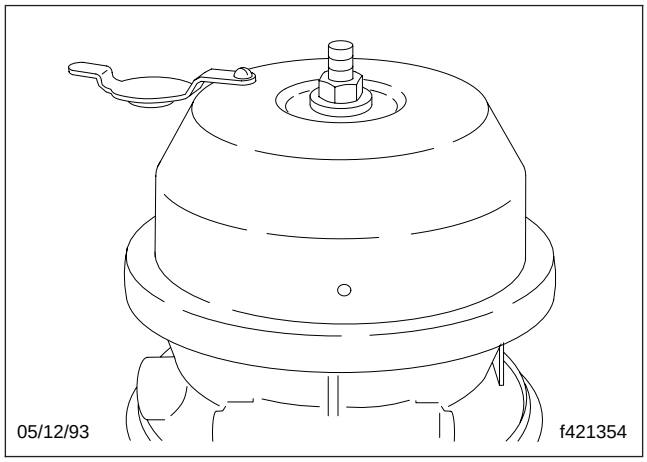
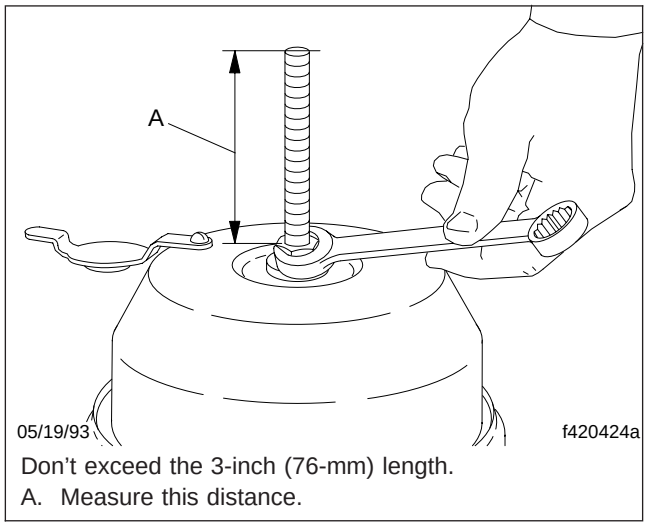


Fig. 5, Flatwasher and Release Nut Installed

⚠ CAUTION

CAUTION: Don't exceed 50 lbf·ft (68 N·m) torque on the release nut; and don't 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.

3.6 Using a hand wrench (*don't use an impact wrench*), turn the release nut clockwise until the bolt extends 3 inches (76 mm) above the nut. See **Fig. 6**.



Don't exceed the 3-inch (76-mm) length.
A. Measure this distance.

Fig. 6, Turn the Release Nut

IMPORTANT: Don't exceed the 3-inch (76-mm) length.

4. Once the power spring has been caged, exhaust the compressed air from the parking brake.

Manual Reset (Parking Brake Reset)

1. Uncage the power spring.
   1.1 Apply at least 90 psi (620 kPa) air pressure to the parking brake inlet port (set parking brake in the "release" position).

CAUTION

CAUTION: Don't exceed 50 lbf·ft (68 N·m) torque on the release nut; and don't 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.

   1.2 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.

   1.3 Remove the nut and flatwasher.

   1.4 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.

2. Using a hand wrench (*don't 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**.

3. Snap the end cover cap in place over the center-hole in the chamber head. **See Fig. 8.**

CAUTION

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.

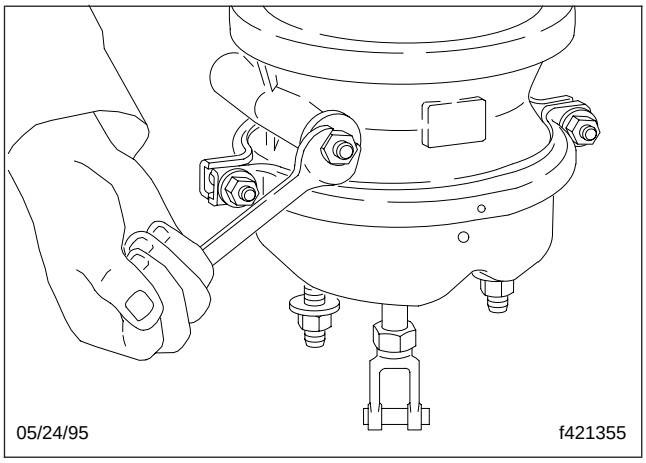


Fig. 7, Tighten the Release Nut

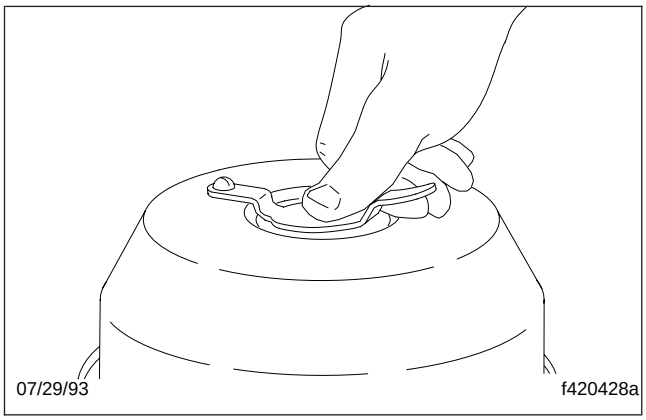


Fig. 8, Snap the End Cover Cap in Place

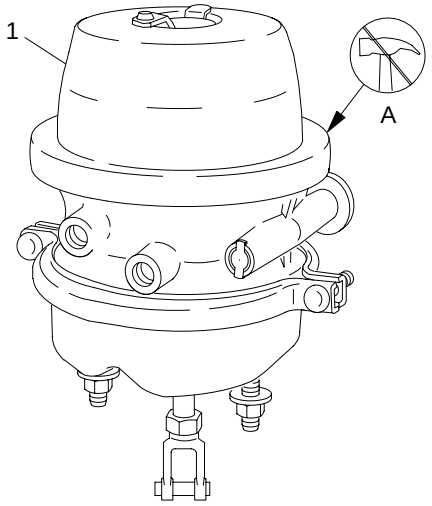
4. Check the plastic end cover cap periodically, and replace it with a new one at once if damaged or missing. For intervals, refer to the vehicle maintenance manual.

5. Remove the chocks from the tires.

Service Brake Diaphragm Replacement

DANGER

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

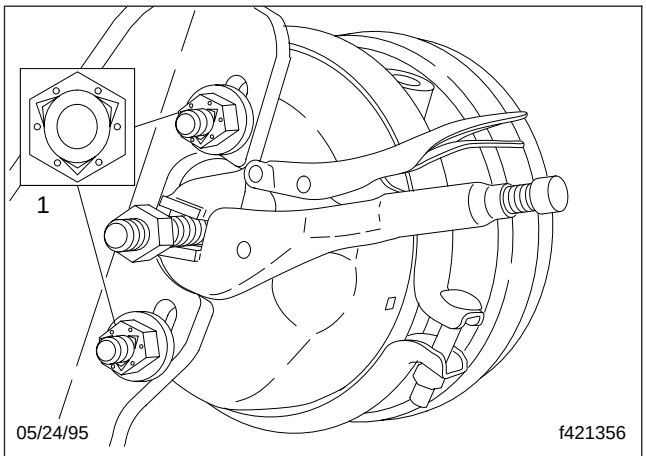
Fig. 1, Brake Chamber

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.

   1.1 Apply the service brakes by actuating the driver's foot brake treadle valve.

   1.2 With the brakes applied, clamp a pair of locking-jaw pliers on the piston rod to lock the rod in place when the air pressure is released. See **Fig. 2**.



1. Prevailing Torque Locknut

Fig. 2, Lock the Piston Rod in Place

WARNING

WARNING: Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in this section. See 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, refer to **Subject 100**.

3. Mark the air lines for later reference. Then 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.

DANGER

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.

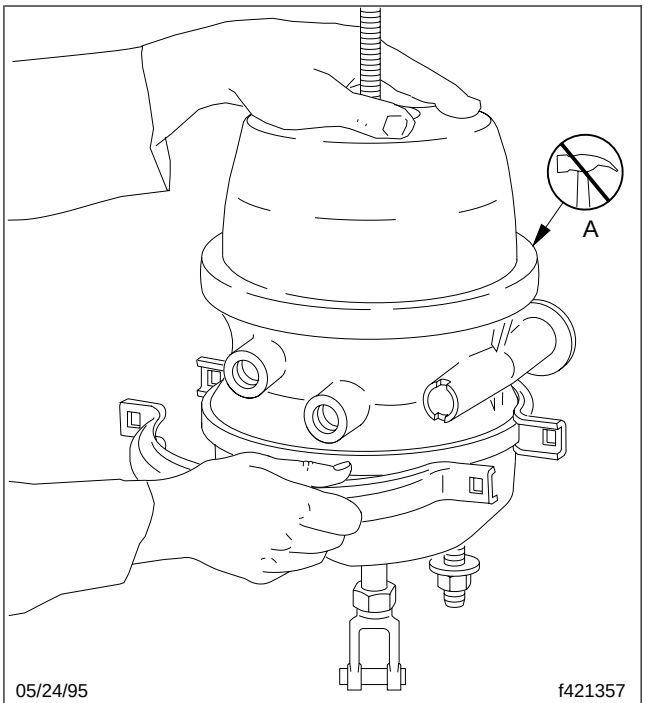
4. Remove the parking brake section from the service brake section.

   4.1 Using a hand wrench (*don't use an impact wrench*), remove the clamp nuts on

Service Brake Diaphragm Replacement

the *service* clamp ring (*do not disassemble the parking brake section*).

4.2 While holding the parking brake section securely in place, remove the service clamp ring. Then remove the parking brake section from the service brake non-pressure chamber. See **Fig. 3**.



A. Do not remove the factory-sealed clamp ring.

Fig. 3, Remove the Service Clamp Ring

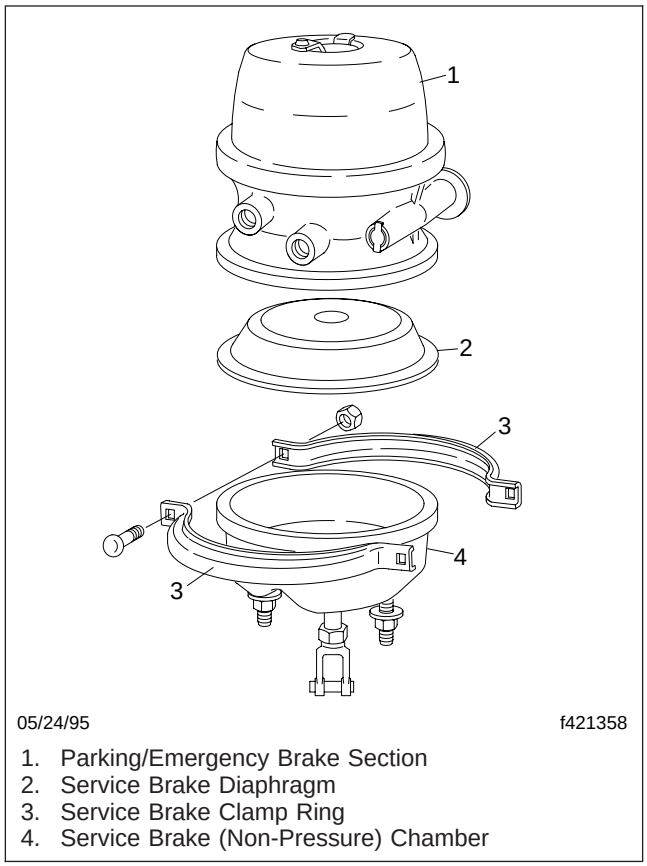
5. Remove the service brake diaphragm from the bottom of the parking brake section.

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. Follow the detailed inspection instructions in the vehicle maintenance manual.

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**.



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

3. Install the (new, if needed) parking/emergency brake section.

   3.1 If installing a new parking brake section, be sure it is the same size and make as the old one.

   3.2 Check that the release bolt is fully extended outward. For instructions, refer to **Subject 100**.

   3.3 Install the parking brake section on the service chamber so that all mating parts are aligned straight and the air lines are positioned to mate with the vehicle air supply lines.

4. Install the service brake clamp ring.

4.1 With the service brake clamp ring in place, install the clamp bolts and nuts.

4.2 Using a hand wrench (*don't 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 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. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

6. 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).

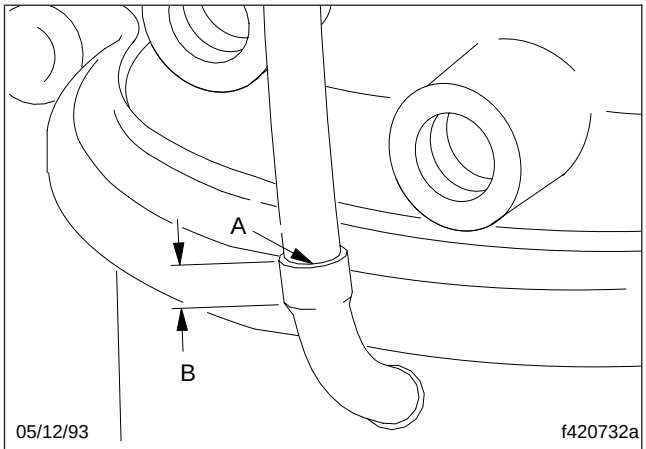
7. With the parking brake still charged with full line pressure, apply and hold the foot brake treadle valve down to charge the service brake chamber. Remove the locking-jaw pliers from the service piston rod so that the piston returns to a normal position in the chamber.

⚠ DANGER

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.

8. 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. 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. Then, apply a high-quality rubber cement to the tube and insert it into the elbow at least 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" (13 mm) minimum engagement.

Fig. 5, Install the External Breather Tube

10. 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, refer to **Subject 100**.

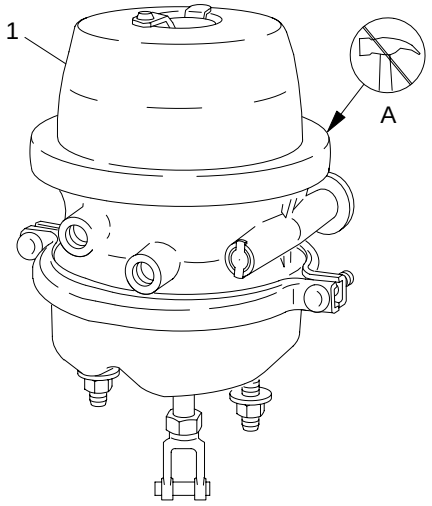
11. Adjust the brakes at the slack adjuster.

IMPORTANT: After replacing any brake chamber components, check the piston rod stroke and actuating alignment to ensure correct installation and brake adjustment. No brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

Replacement

DANGER

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

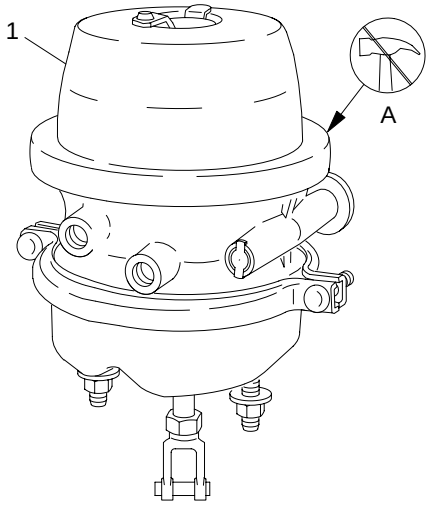
Fig. 1, Brake Chamber

IMPORTANT: The parking/emergency brake section can be replaced as a unit. For instructions, refer to **Subject 110**.

Combination Service and Parking Brake Chamber Removal and Installation

DANGER

DANGER: Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose at any time. See Fig.1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.



02/22/2000 f421352

A. Do not remove the factory-sealed clamp ring.
1. Model TR-T (TR Series) Brake Chamber

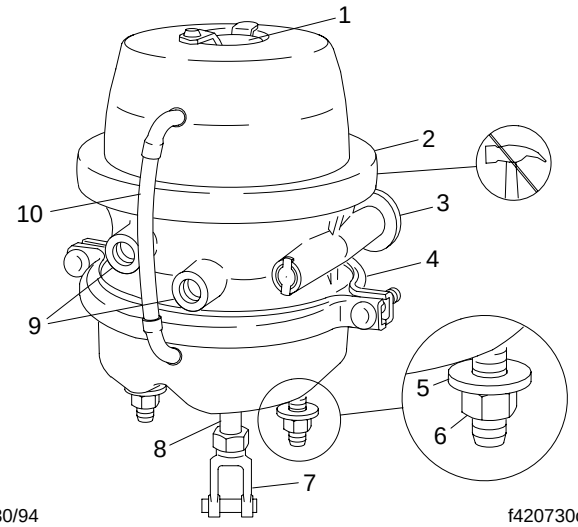
Fig. 1, Brake Chamber

Removal

WARNING

WARNING: Before caging (compressing) the power spring, chock the vehicle tires and read the warnings and instructions in this section. See 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, refer to **Subject 100**.
2. Mark the air lines for later reference. Then carefully disconnect them from the brake chambers. See **Fig. 2**.



08/30/94 f420730c

NOTE: 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. 2, Model TR-T (TR Series) Brake Chamber

3. Remove the brake chamber from the vehicle.

   3.1 Remove the cotter pin(s) from the clevis pin(s), then remove the clevis pin(s) from the clevis. Disconnect the clevis from the slack adjuster.

   NOTE: Gunite and Rockwell automatic slack adjusters have two clevis pins, one large and one small, each locked by a cotter pin.

   3.2 Make sure the parking brake has been released manually (the power spring has been caged). For instructions, refer to **Subject 100**. Also, make sure that the service brake piston is fully retracted (in the brakes "OFF" position). Then, record both of the following dimensions in either

Combination Service and Parking Brake Chamber Removal and Installation

mm or inches, measuring outward from the base of the service brake chamber. See **Fig. 3**:

X dimension: to end of threaded piston rod

Y dimension: to centerline of (large) clevis pin

IMPORTANT: If new chambers are to be attached to manual slack adjusters, the Y dimension is the most critical measurement. When installing the new assembly, its service piston rod must be cut to exactly duplicate this "rod-plus-clevis" length *after* the clevis assembly is installed on the piston rod.

If new chambers are to be attached to automatic slack adjusters, the X dimension is the 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. 4**.

3.3 From each mounting stud, remove any installed nuts and washers. Then, cautiously remove the brake chamber from the mounting bracket.

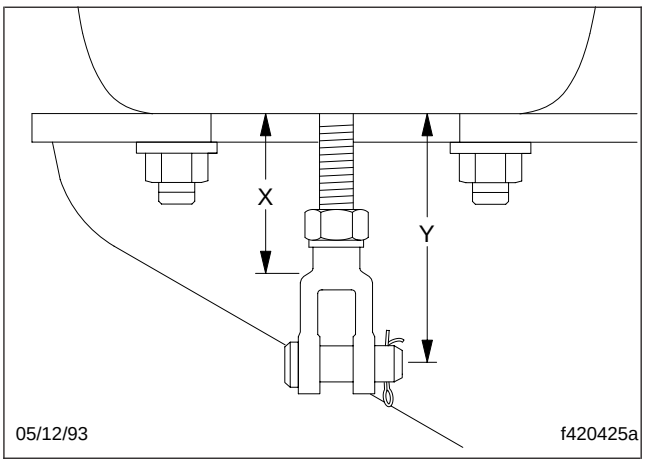


Fig. 3, Measure X and Y

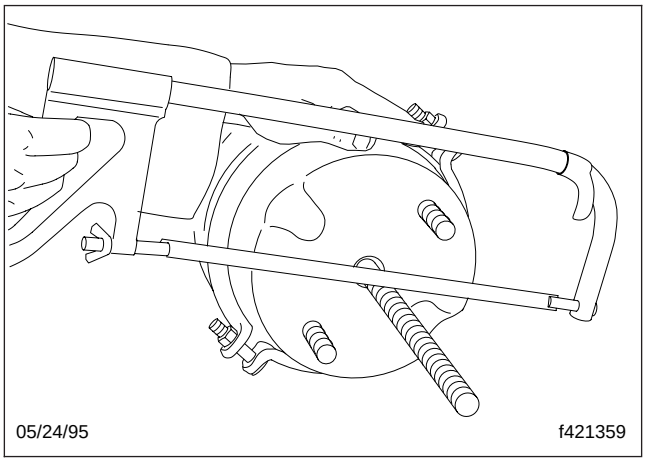


Fig. 4, Cut the Service Piston Rod

Installation

1. If installing a new brake chamber unit, do the following steps: See **Fig. 2**.
   - 1.1 First, make sure the power spring is caged (release bolt fully extended outward). If not, go to **Subject 100** and do the applicable steps.
   - 1.2 Make sure that the piston rod is the same length as the rod on the old unit (measure the rods when *both* chambers are caged).
   - 1.3 Be sure the new chamber is the same size and make as the brake chamber installed on the other side of the axle.
   - 1.4 Remove the prevailing torque locknut and hardened flatwasher from each of the mounting studs on the chamber.
2. Clean the face of the mounting bracket, and install the chamber on the bracket, paying close attention to positioning the chamber air inlet ports for correct alignment to the vehicle air lines.

⚠ WARNING

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.

Combination Service and Parking Brake Chamber Removal and Installation

3. Install one hardened flatwasher and prevailing torque locknut on each mounting stud. Using a hand wrench (*don't use an impact wrench*), tighten the nuts 100 to 115 lbf·ft (136 to 156 N·m). Make sure the flatwasher is installed between the locknut and the mounting bracket.

   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.

⚠ DANGER

DANGER: Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

   4.1 Using a hand wrench (*don't use an impact wrench*), loosen the clamp nuts on the *service* clamp ring (*do not disassemble the parking brake section*).

   4.2 Reposition the air inlet ports, as needed, to mate with vehicle air supply lines.

   Alternately tighten each clamp nut in increments of 60 to 120 lbf·in (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. Refer to the applicable slack adjuster section in this group for installation instructions.

6. Inspect the piston rod to be sure it is working free, not binding, and is square with the chamber bottom within ±3° in any direction from zero to full stroke. If there is misalignment, make corrections by loosening the locknuts and repositioning the chamber on the mounting bracket, or by shimming the slack adjuster to the right or left on the camshaft.

7. Make sure the air hose fittings are free of grease, dirt, and other debris. Then, apply Loctite® 242 sealant, or an equivalent, to the fittings, and install, as referenced earlier. Using a hand wrench (*don't use an impact wrench*), tighten the fittings 25 lbf·ft (34 N·m).

8. Using the vehicle system air, charge the parking brake with full line pressure, at least 100 psi (690 kPa). Using only soapy water (*never any type of oil,* which could deteriorate rubber parts), check for air leaks at the air lines and fittings. If bubbles or leaks appear, tighten the fittings slightly, but not over 25 lbf·ft (34 N·m).

⚠ DANGER

DANGER: Do not attempt to remove the factory-sealed parking brake clamp ring for any purpose at any time. See Fig. 1. The parking/emergency brake section is not intended to be serviced. Serious injury or death may result from the sudden release of the power spring.

IMPORTANT: If the service brake clamp ring was loosened to reposition the air inlet ports, apply air to the parking brake, and then apply and hold the foot brake treadle valve down to charge the service brake chamber. Now test for air leaks around the circumference of the *service* brake clamp ring. If bubbles or leaks appear, firmly tap the circumference of the clamp ring with a rubber mallet, and retighten the clamp nuts until leaks cease (*do not touch the parking brake section*). 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, and snap the end cover cap in place. For instructions, refer to **Subject 100**.

10. Adjust the brakes at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

Combination Service and Parking Brake Chamber Removal and Installation

IMPORTANT: After replacing any brake chamber, check the piston rod stroke and actuating alignment to ensure correct installation and brake adjustment. No brake adjustments, parking brake or service brake, can be made at the chamber and all "stroke" adjustments must be made at the slack adjuster. For instructions, refer to the applicable slack adjuster section in this group.

Specifications

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 Meritor WABCO Antilock Braking System (ABS) is an electronic wheel speed monitoring and control system that works with the standard air brake system. ABS passively monitors vehicle wheel speed at all times, and controls wheel speed during emergency and reduced-traction stops. In normal braking applications, the standard air brake system is in effect.

ABS includes signal-generating tone wheels and sensors located in the wheel hubs of each sensed wheel. The sensors transmit vehicle wheel speed information to an electronic control unit. According to programmed specifications, the control unit signals the appropriate solenoid control valve to increase, reduce, or maintain air pressure supply in the brake chamber. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

ABS CONFIGURATION

The ABS configuration is defined by the number of wheel end sensors and solenoid control valves (modulator valves). On the school bus there is one ABS configuration used with D-version ECUs: **4S/4M** (4 wheel speed sensors, 4 solenoid control valves). See **Fig. 1** and **Fig. 2**. The versions are available with and without traction control. Vehicles with traction control are equipped with full D-Version ECU's; vehicles without traction control are equipped with D-Basic ECU's.

Principles of Operation

The ABS electronic control unit is a digital microcomputer that serves as the information processing and command center for the antilock braking system. See **Fig. 3**. The control unit receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the solenoid control valves. See **Fig. 4**.

ABS MAJOR COMPONENTS

Wheel Speed Sensor

The wheel speed sensors use pulse feedback from tone wheels located in the front and rear axle wheel hubs. When the vehicle is moving, the teeth of the tone wheel cause interruptions in a magnetic field created by the sensor. The interruptions create electrical pulses that are sent by the sensor to the electronic control unit.

Electronic Control Unit (ECU)

The electronic control unit (ECU), located near the circuit breaker panel in the right side of the dash, contains microcomputers to monitor the front and rear control channels. The ECU receives speed sensor pulses and interprets these signals to calculate wheel speed and a vehicle reference speed. If the calculations indicate wheel slip or lockup, the appropriate control circuit signals the solenoid control valve(s) to increase or decrease braking pressure.

The ECU constantly monitors the wheel sensors, solenoid control valves, and the electrical circuitry. After the ignition switch is turned on, the warning light (ABS) indicator light comes on for about three seconds. See **Fig. 5**. After about three seconds, the light goes out only if all of the ABS components are working.

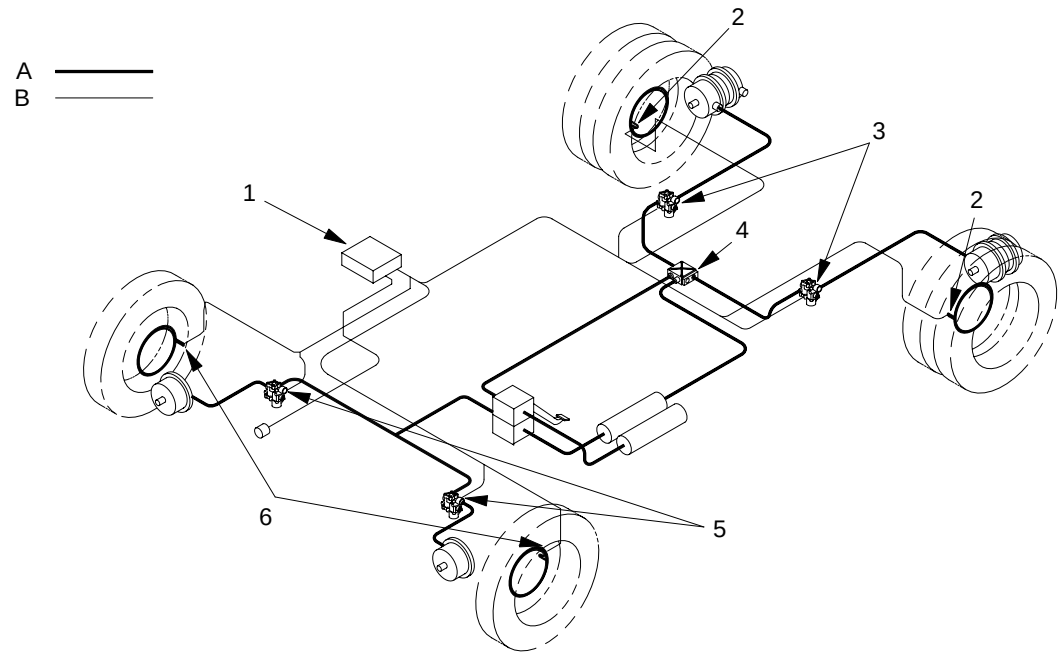
IMPORTANT: If the ABS warning light does not work as described above, repair the ABS system. For fault diagnosis, see **Troubleshooting, 300** for D-Basic ABS or **Troubleshooting, 310** for D-Version ABS.

If, during vehicle operation, there is a component failure in any part of the ABS system (a sensor, solenoid control valve, wiring connection, short circuit, etc.), the warning light (ABS) comes on, and the control circuit where the failure occurred is switched to normal braking action. The remaining control circuit will retain the ABS effect. Even if the ABS system is completely inoperative, normal braking is maintained. An exception would be if the combination solenoid control valve is damaged and inoperative. As these components are an integral part of the air brake system, normal braking may be impaired or inoperative.

Solenoid Control Valve

Solenoid control valves control the air pressure to each affected brake during an ABS function. After the

General Information



01/20/98 f421714

A. Air Lines
B. Electrical Lines

1. Cab-Mounted ECU
2. Wheel Speed Sensors
3. Rear Solenoid Control Valves
4. Relay Valve
5. Front Solenoid Control Valves
6. Wheel Speed Sensors

Fig. 1, D-Basic 4S/4M ABS

ignition is turned on and the ABS light is illuminated, the valves cycle one by one, then together diagonally, as shown in **Fig. 6**.

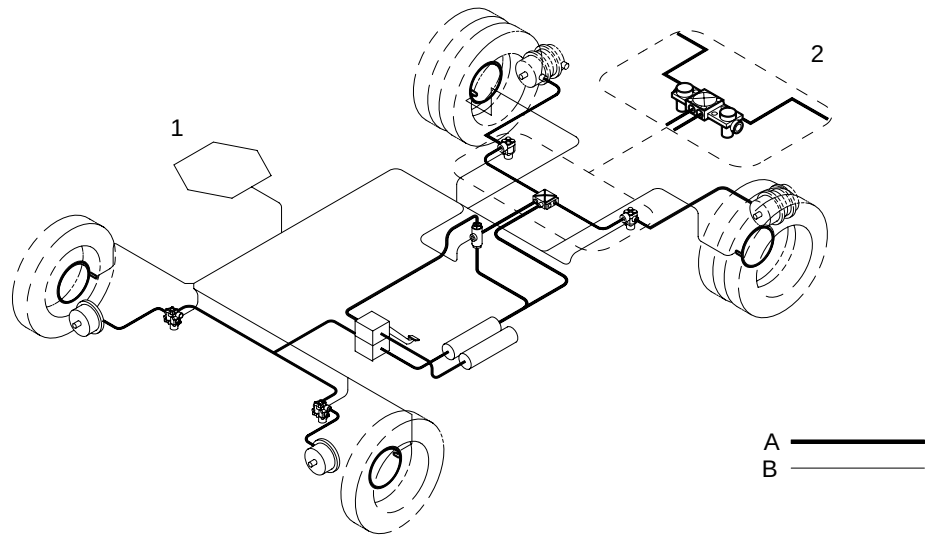
The solenoid control valves for the front axle brakes are attached on each side of the vehicle. The combination solenoid control valve (which includes a relay valve) for the rear axle brakes is attached to the suspension crossmember near the brake chambers. Depending on the signal received from the electronic control unit, the control valve prevents wheel lockup by reducing, maintaining, or increasing brake chamber air pressure. During normal braking applications, compressed air flows freely to the brake chamber through the control valve.

If the electronic control unit signals indicate wheel lockup, air pressure is reduced in the brake chamber. Solenoid valve 1 opens allowing compressed air to enter the inlet chamber and pilot chamber 1. See **Fig. 7**.

At the same time, solenoid valve 1 closes off the exhaust chamber preventing the escape of air from the inlet chamber to atmosphere. Compressed air in the inlet chamber is forced into pilot chamber 1, closing diaphragm valve 1; this prevents air passage to the delivery chamber. Solenoid valve 2 also opens allowing air to vent from pilot chamber 2 through the exhaust port. Complete venting of all air in the delivery chamber occurs as diaphragm valve 2 opens.

As wheel speed increases, the control valve alternately increases, then maintains brake pressure until the proper wheel speed is obtained, or until wheel lockup occurs and the control cycle starts again.

During the pressure increase cycle, both solenoid valves are closed. See **Fig. 8**. Compressed air entering through the inlet chamber forces diaphragm valve 1 open, allowing air to pass through the delivery chamber into the brake chamber. At the same time, pressure within the control valve keeps diaphragm

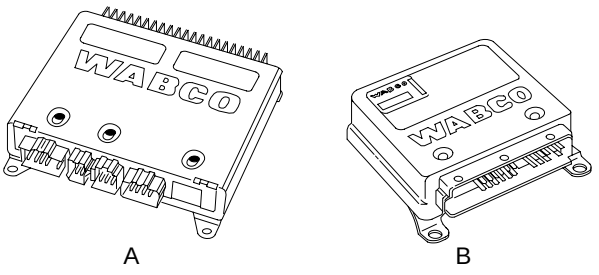


01/20/98 f421716

A. Air Lines
B. Electrical Lines

1. D-Version ECU
2. With Combination Valve Package Installation

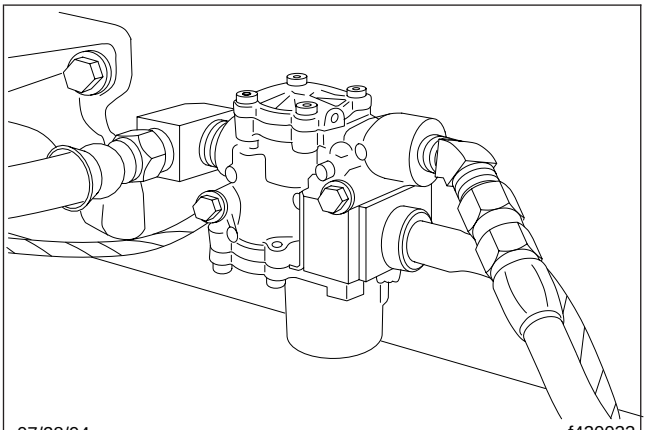
Fig. 2, D-Version 4S/4M ABS/ATC



01/26/98 f421663

A. Full D-Version
B. D-Basic Version

Fig. 3, Cab Mounted WABCO ECU's



07/28/94 f420033

Fig. 4, Solenoid Control Valve, Front Axle Mounting shown

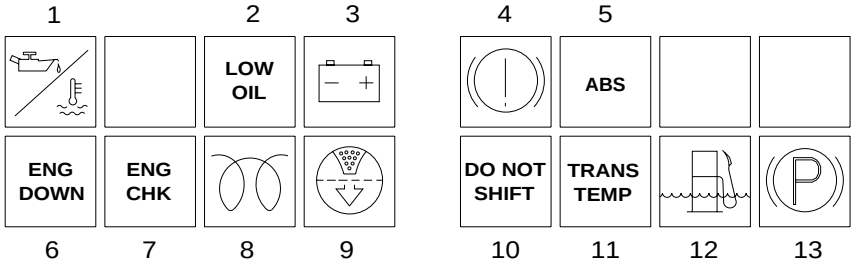
valve 2 closed, preventing air from escaping through the exhaust port.

If maintaining brake air pressure, solenoid valve 1 opens and compressed air passes from the inlet chamber into pilot chamber 1. See **Fig. 9**. Both of the diaphragm valves are forced closed, sealing the delivery chamber and maintaining brake air pressure.

AUTOMATIC TRACTION CONTROL

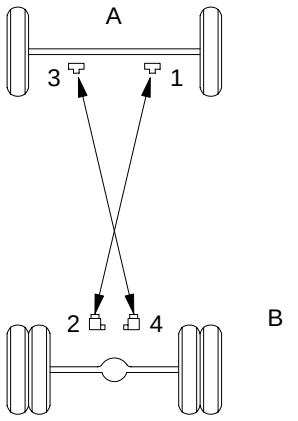
Automatic Traction Control (ATC) is an option available on some ABS-equipped vehicles. It helps improve traction when vehicles are on slippery surfaces

General Information



1. Low Oil Pressure/High Water Temperature Warning
2. Low Oil Level Warning
3. Alternator Warning Light
4. Brake System Warning
5. ABS Warning Light
6. Stop Engine Indicator
7. Engine Check Indicator
8. Cold-Start Manifold Heater Indicator
9. Air Cleaner Restriction Indicator
10. Do-Not-Shift Indicator
11. High Oil Temperature Warning (automatic transmission)
12. Water in Fuel/Water Separator Warning
13. Parking Brake Indicator Light

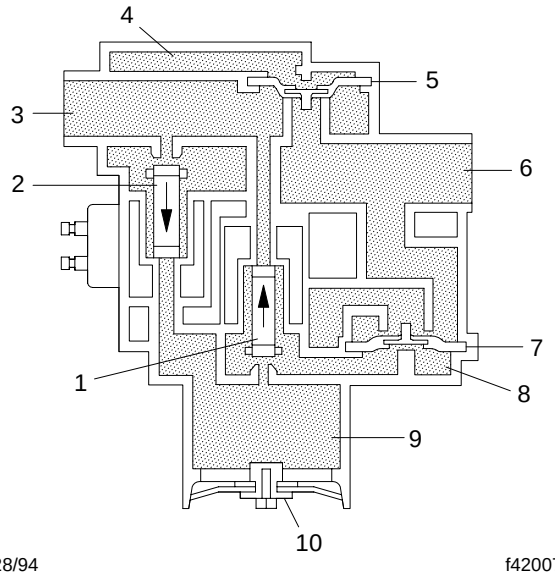
Fig. 5, Warning and Indicator Lights



NOTE: The valves will cycle in 1-2-3-4 order, then diagonally in 1-2 and 3-4 order.

A. Cab
B. Curbside

Fig. 6, Solenoid Control Valve Checking



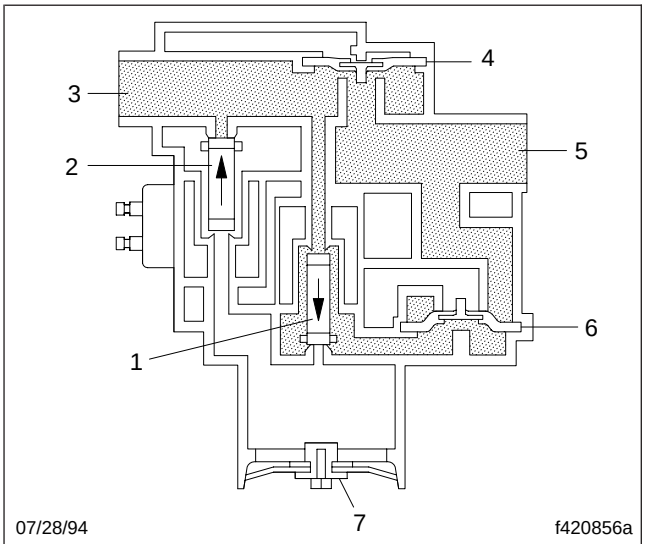
1. Solenoid Valve No. 2
2. Solenoid Valve No. 1
3. Inlet Chamber
4. Pilot Chamber No. 1
5. Diaphragm Valve No. 1
6. Delivery Chamber
7. Diaphragm Valve No. 2
8. Pilot Chamber No. 2
9. Exhaust Chamber
10. Exhaust Port

Fig. 7, Wheel Lockup Cycle

by reducing drive wheel overspin. ATC works automatically in two different ways.

1. If a drive wheel starts to spin, ATC applies air pressure to brake the wheel. This transfers engine torque to the wheels with better traction
2. If all drive wheels spin, ATC reduces engine torque to provide improved traction.

ATC turns itself on and off, drivers do not have to select this feature. If drive wheels spin during acceleration, the ATC indicator lamp comes on, indicating ATC is active. If the lamp goes out when the drive wheels stop spinning. See **Fig. 10**.



1. Solenoid Valve No. 2
2. Solenoid Valve No. 1
3. Inlet Chamber
4. Diaphragm Valve No. 1
5. Delivery Chamber
6. Diaphragm Valve No. 2
7. Exhaust Port

Fig. 8, Pressure Increase Cycle

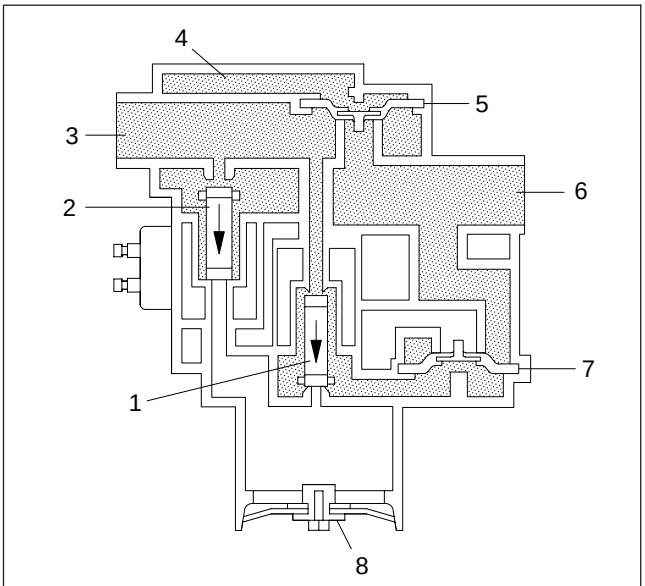
To determine if a vehicle has ATC, look for the ATC valve. It is mounted on the frame or crossmember at the rear of the vehicle. An ATC installation may use an individually mounted valve, or the valve may be part of the ABS valve package. See **Fig. 11**.

NOTE: If ATC is installed, there may be an indicator lamp on the vehicle dash or instrument panel marked ATC, ASR, or WHL SPIN. However, vehicles without ATC may have a wheel spin lamp. In these cases, the wheel spin lamp is a signal, a warning to the driver that the wheels are spinning.

Deep Snow and Mud Switch

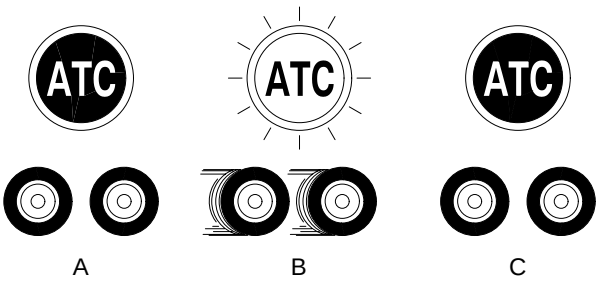
A deep snow and mud option switch is included with ATC. This function increases available traction on extra soft surfaces like slush or mud, or on snow-covered upgrades, by slightly increasing the permissible wheel spin.

Drivers use a deep snow and mud switch to select this feature. When this function is in use, the ATC indicator lamp blinks continuously. **Table 1** shows how the deep snow and mud feature works.



1. Solenoid Valve No. 2
2. Solenoid Valve No. 1
3. Inlet Chamber
4. Pilot Chamber No. 1
5. Diaphragm Valve No. 1
6. Delivery Chamber
7. Diaphragm Valve No. 2
8. Exhaust Port

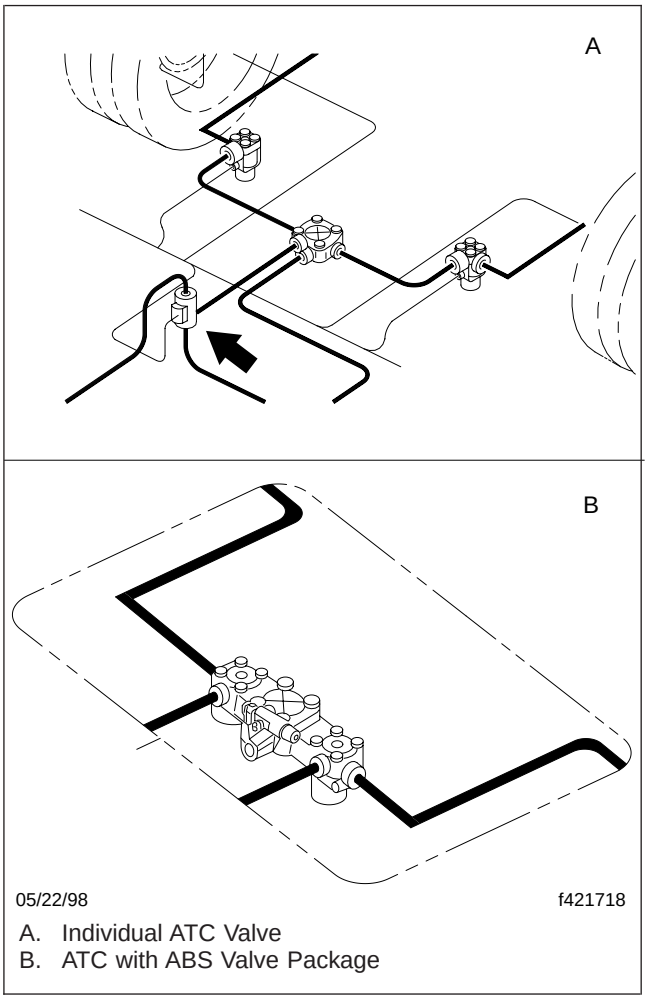
Fig. 9, Maintaining Brake Air Pressure Cycle



A. Normal Vehicle Operation (ATC lamp is off)
B. Excessive Wheel Spin ATC Operational (ATC lamp comes on)
C. Wheels Stop Spinning (ATC lamp goes out)

Fig. 10, ATC Lamp Operation

General Information



A. Individual ATC Valve
B. ATC with ABS Valve Package

Fig. 11, Possible ATC Valve Arrangements

Mud and Snow Switch Function			
Driver Action	System Response	Function	
		Active	Not Active
Press deep snow and mud switch.	ATC lamp blinks continuously	X	
Press switch again.	ATC lamp stops blinking		X

Table 1, Mud and Snow Switch Function

NOTE: Turning off the ignition will also deactivate the deep snow and mud feature.

ATC Components

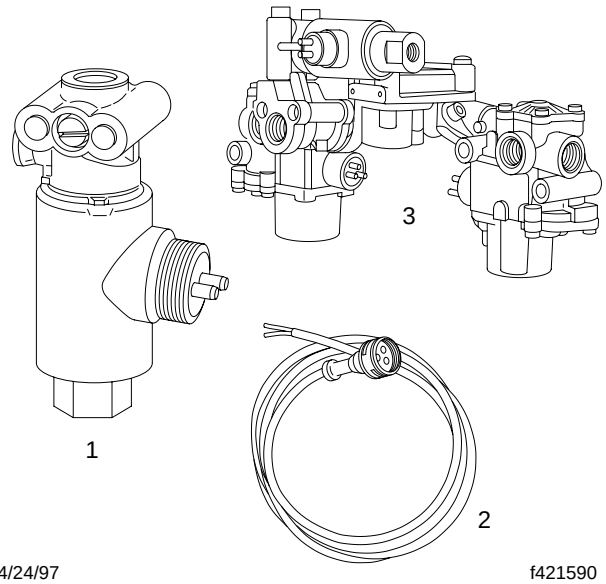
ATC may be used with individual ABS solenoid control valves, or with the ABS valve package.

When installed with individual ABS solenoid control valves, an ATC solenoid valve is mounted on the frame or crossmember, near the rear of the vehicle.

When it is part of the ABS valve package, an ATC valve is attached to the relay valve.

A cable connects the ECU to the ATC valve.

ATC components are illustrated in **Fig. 12**.



1. ATC Valve
2. Cable
3. ABS/ATC Valve Package

Fig. 12, ATC Components

Wheel Speed Sensor Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. Refer to **Group 54** (wiring) in this manual for information on special terminals and connectors, and on ordering tools for them.

FRONT AXLE

1. Chock the rear tires to prevent vehicle movement. Apply the parking brakes.
2. Twist and pull the sensor, to remove it from the steering knuckle. See **Fig. 1**.

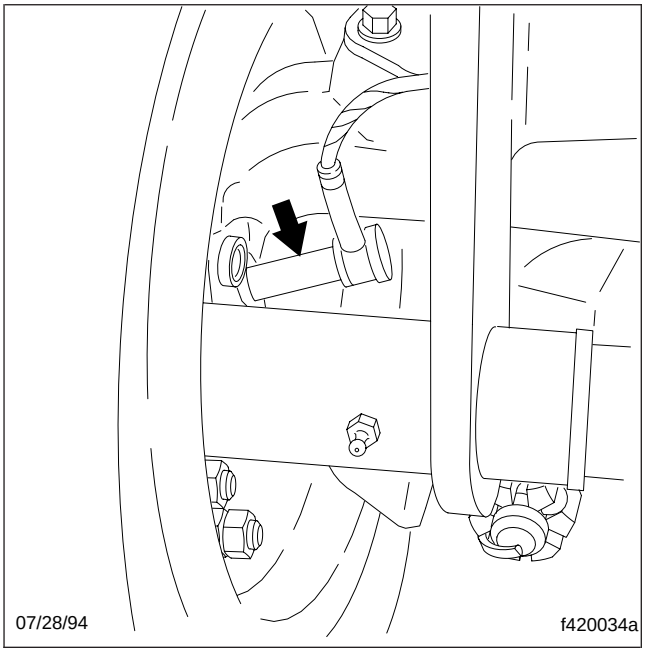


Fig. 1, Remove the Wheel Speed Sensor

3. Remove the sensor cable from the steering knuckle top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the clamping bushing from the steering knuckle.
6. Connect the sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Press the clamping bushing into the brake spider hole until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L, or an equivalent. Press the sensor into the clamping bushing until it is stopped by the tone wheel.
10. Remove the chocks from the rear tires.

REAR AXLE

1. Chock the front tires to prevent vehicle movement. Apply the parking brakes.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Back off the slack adjuster to release the rear axle brake shoes.
4. Remove the wheel and tire assembly from the rear axle. For instructions, refer to **Group 40** in this manual.
5. Remove the brake drum. For instructions, refer to **Group 35** in this manual.
6. Twist and pull the sensor, to remove it from the mounting block in the axle housing.
7. Remove the clamping bushing.
8. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
9. Disconnect the sensor cable from the chassis harness.
10. Connect the sensor cable to the chassis harness.
11. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
12. Press the clamping bushing into the mounting block until it stops.
13. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L, or an equivalent. Using your hand, push the sensor into the clamping bushing until it is stopped by the tone wheel.
14. Install the brake drum on the wheel hub. For instructions, refer to **Group 35** in this manual.

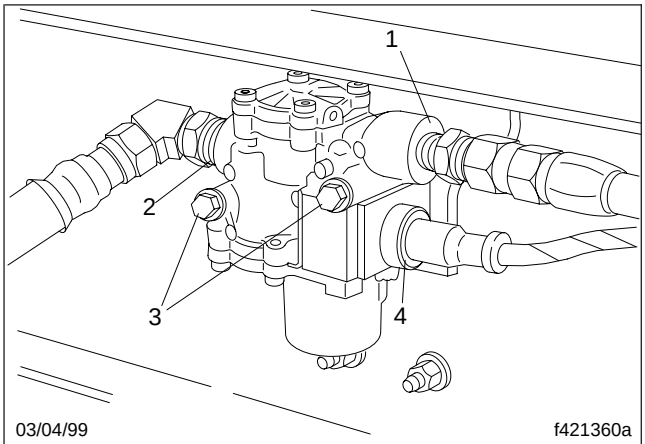
Wheel Speed Sensor Replacement

15. Adjust the rear axle brakes. For instructions, refer to the applicable brake section in this manual.
16. Install the wheel and tire assembly, and tighten the wheel nuts. Use the tightening sequence and torque values listed in **Group 40** in this manual.
17. Remove the safety stands, lower the vehicle, and remove the chocks from the front tires.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** in this manual for information on special terminals and connectors, and on ordering tools for them.

1. Chock the front and rear tires.
2. Release the pressure from the air reservoirs.
3. Disconnect the wiring from the solenoid control valve, or combination solenoid control valve(s). See **Fig. 1** or **Fig. 2**.



03/04/99 f421360a

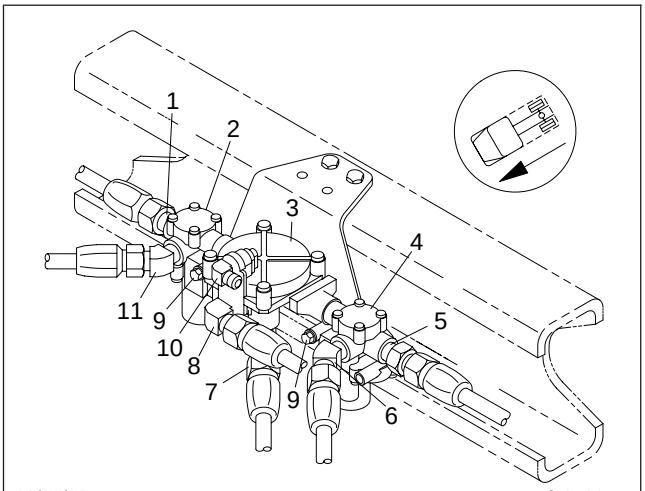
1. Supply Port 1 (from steer axle quick release)
2. Delivery Port 2 (to brake chamber)
3. Mounting Fasteners
4. Electrical Connection

Fig. 1, Solenoid Control Valve

4. Mark the air lines for ease of installation. Disconnect the air lines.
5. Remove the two mounting capscrews, washers, and nuts.
6. Remove the solenoid control valve.

NOTE: The combination solenoid control valve can be disassembled if replacement of the relay valve or one of the solenoid control valves is needed.

7. Install the solenoid valve using the above instructions in reverse order. Tighten the mounting nuts 18 lbf·ft (24 N·m).
8. Remove the chocks from the tires.



03/08/99 f421365a

1. Delivery Port (to right rear brake chamber)
2. Right Modulator Valve
3. Relay Valve
4. Left Modulator Valve
5. Delivery Port (to left rear brake chamber)
6. Delivery Port (to left forward brake chamber)
7. Delivery Port (to park brake quick release valve)
8. Relay Supply Port (from primary air tank)
9. Mounting Fasteners
10. Relay Control Port (from foot valve)
11. Delivery Port (to right forward brake chamber)

Fig. 2, Combination Solenoid Control Valve

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 level ground, set the parking brake, and shut down the engine.

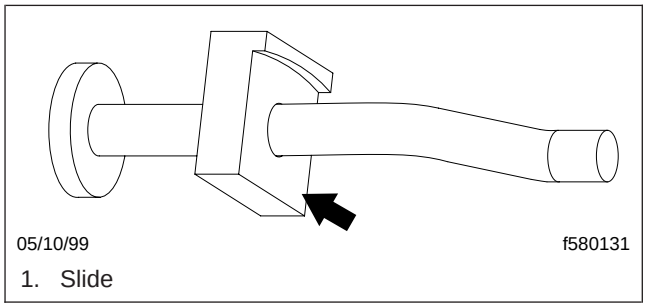


Fig. 1, ABS Sensor Adjustment Tool

2. Chock the front tires.
3. Find the sensor access hole in the rear axle flange.
   - 3.1 View the brake drum and axle from the rear. The ABS sensor wiring harness should be visible passing through a hole in the 12 o'clock position.
   - 3.2 Find the S cam at either the 3 o'clock or 9 o'clock position.
   - 3.3 Just opposite the S cam is the sensor access hole, approximately 3/4 inch (19 mm) diameter.
4. Insert the service tool T11–17556–000 into this hole.
5. Position the slide of the tool on the axle flange to align the tool. See **Fig. 2**.
6. Tap the tool lightly with the palm of your hand. This will ensure the sensor is touching the tone wheel.
7. Remove the tool from the wheel and repeat the procedure on the other rear axle speed sensor.
8. Remove the chocks from the tires.

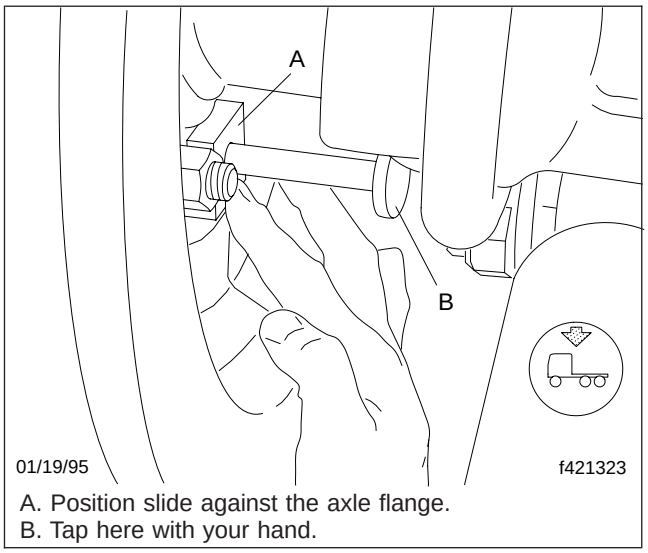


Fig. 2, Position the Tool

Troubleshooting

There are two ABS configurations available for the school bus, D-Basic and D-Full Version ABS. The D-Basic ABS is available for vehicles without Automatic Traction Control (ATC).

This subject includes the following troubleshooting methods for the D-Basic ABS:

- Troubleshooting using blink codes
- Troubleshooting using fault codes

USING BLINK CODES

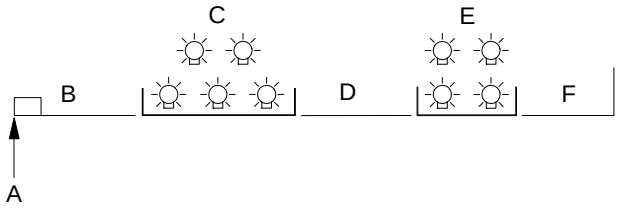
This system has built-in diagnostics to ensure that all components are operating properly. Under normal conditions, the vehicle warning light comes on when the ignition is turned on. After about three seconds these lights should go out if all of the vehicle's ABS components are working. If the light stays on, or comes back on later, a problem within the ABS system has occurred. The vehicle can continue to be driven, but the ABS system could be partially or completely inoperative. To check the type of fault code recorded, stop the vehicle and turn off the engine. Then, turn on the ignition switch, but don't start the engine. If the light is still on, there is an "active" system fault that must be repaired to ensure proper system operation. If the light is not on, a "historical or intermittent" fault (indicating a loose connector or broken wire) has been recorded in the ECU memory.

Fault codes can be diagnosed by either Pro-Link 9000, or Freightliner ServiceLink. MID and SID codes are accessible only through ServiceLink.

NOTE: If troubleshooting the system with the Pro-Link 9000, use the instruction booklet that is supplied with the data cartridge.

Use the ABS CHECK switch (which is located on the ECU) and the ABS warning light operation displayed in **Table 1** to display system faults. With the ignition switch on, depress (for about one second) and release the switch. The ABS light should go out. After a one and one-half second pause, the ABS light will blink the first digit of the two-digit fault code. The number of blinks displaying the first digit will be a number between one and eight. After another one and one-half second pause, the second digit will be displayed. The number of blinks displaying the second digit will be a number between one and six. After a four second pause, the diagnostic code cycle continues to repeat the "active" fault code until it is repaired. If "historical" fault codes exist, the code cycle will display all recorded faults.

For example, after the ABS CHECK switch has been depressed and released, fault code 54 is shown by five flashes, a pause of one and one-half seconds, followed by four flashes. See **Fig. 1**. After a four second pause, the same fault code will continue to repeat, always ending with a four second pause.



A. ABS CHECK switch activated here
B. ABS light goes out
C. 5 flashes
D. 1.5 second pause
E. 4 flashes
F. 4 second pause

Fig. 1, Fault Code 54 shown

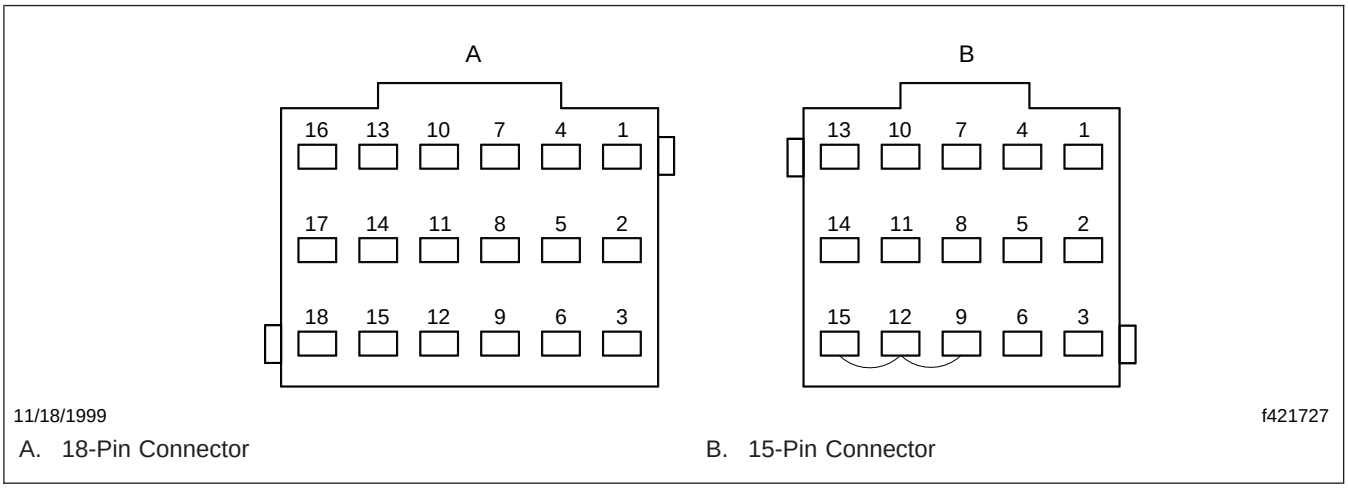
NOTE: When there are no fault codes in the ECU memory, blink code 1-1 is displayed.

Once a fault code has been identified, use a volt/ohmmeter to check the electrical harness at the ECU's pin connectors (there is a 15-pin and 18-pin connector at the ECU, which is located in a panel on the front right side of the firewall). Connect the ohmmeter leads to the applicable pins on each connector. See **Fig. 2**, and **Table 2**, for a description of the circuit wire numbers and their location within the pin connectors.

IMPORTANT: The ignition switch must be off when connecting or disconnecting the ECU.

If the ABS light does not operate correctly after the ignition is turned on (the light doesn't come on at all or doesn't go out after about three seconds), check all related circuit breakers in the electrical panel, and replace if necessary. Check the wiring to the warning lamp. See **Table 3**, and repair or replace the wiring as needed. Make sure that a charged 12-volt battery is available (the ABS system needs at least 11 volts to work).

Troubleshooting for D-Basic ABS



A. 18-Pin Connector

B. 15-Pin Connector

Fig. 2, ECU Pin Connectors

Warning Light Operation		
What You Do	**What Happens**	**What it Means**
Turn the ignition on.	The ABS light comes on momentarily for a bulb check, then goes out.	The system is okay.
	The ABS light does not go out at ignition.	If the light goes out when the vehicle is driven above 4 mph (6 km/h), the system is okay. If the light does not go out at speeds above 4 mph (6 km/h), the ECU senses a fault in the ABS system.

Table 1, Warning Light Operation

Refer to the applicable table in this subject for fault codes, pins to be tested, and the correct volt/ohmmeter readings. Repair or replace the components and/or wiring if the readings are not correct.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

Refer to **Group 54** in this manual for information on special terminals and connectors, and ordering tools for them.

Refer to the applicable wiring diagram in **Specifications 400** when troubleshooting the ABS system. The key switch must be turned on (engine off) to activate the blink codes.

If a fault still can't be repaired, or erased from ECU memory, contact your Meritor District Service Manager, or call Meritor WABCO at 1–800–535–5560.

NOTE: An "active" fault code cannot be erased from ECU memory.

USING FAULT CODES

The first six digits of the fault code indicate the system component or area you need to troubleshoot. To find the component or area that corresponds to a fault code, see **Table 4**. After that, refer to the appropriate table for the troubleshooting procedure.

Circuit Wire Numbers and Descriptions			
Pin Connector	**Pin Number**	**Freightliner Wire Number**	**WABCO Circuit Description**
15-Pin	1	1922–	J1922 Data Link Negative to ECU
	3	1922+	J1922 Data Link Positive to ECU
	4	GND	ECU Ground
	7	376C	ECU Ignition Supply
	8	376A	ECU Positive 12 Volt Supply
	9	GND	ECU Control Ground
	10	1587–	J1587 Data Link Negative to ECU
	11	1587+	J1587 Data Link Positive to ECU
	14	376R	Retarder Interrupt Signal
	15	376L	Vehicle ABS Indicator Light Signal
18-Pin	1	378RFI	Right Front Solenoid Control Valve, In
	2	378LRI	Left Rear Solenoid Control Valve, In
	3	378LFI	Left Front Solenoid Control Valve, In
	4	378RFO	Right Front Solenoid Control Valve, Out
	5	378LRO	Left Rear Solenoid Control Valve, Out
	6	378LFO	Left Front Solenoid Control Valve, Out
	8	378RRI	Right Rear Solenoid Control Valve, In
	9	378RRO	Right Rear Solenoid Control Valve, Out
	10	377RF–	Right Front Sensor, Low
	11	377LR–	Left Rear Sensor, Low
	12	377LF–	Left Front Sensor, Low
	13	377RF+	Right Front Sensor, High
	14	377LR+	Left Rear Sensor, High
	15	377LF+	Left Front Sensor, High
	17	377RR–	Right Rear Sensor, Low
	18	377RR+	Right Rear Sensor, High

Table 2, Circuit Wire Numbers and Descriptions

ABS CHECK Switch and Warning Lamps Wiring Checks				
Wiring Tested	**Test These Pins**	**Volt/Ohmmeter Reading**	**Possible Cause**	**Remedy**
Vehicle Warning (ABS) Light	On the 15-pin connector, pins 9 and 15	2 to 50 ohms (depends on bulb wattage)	Wiring to the light is shorted or open; or the bulb needs replacing.	Repair the wiring, or replace the bulb.

Table 3, Warning Lamp Wiring Checks

Troubleshooting for D-Basic ABS

Fault Codes and Corresponding System Components/Areas		
If the First Six Digits of the Fault Code Are:	**Troubleshoot this Component or Area:**	**See Table:**
136001	Left Front Wheel Sensor	See **Table 5**.
136002	Right Front Wheel Sensor	See **Table 6**.
136003	Left Rear Wheel Sensor	See **Table 7**.
136004	Right Rear Wheel Sensor	See **Table 8**.
136007	Left Front Solenoid Control Valve	See **Table 9**.
136008	Right Front Solenoid Control Valve	See **Table 10**.
136009	Left Rear Solenoid Control Valve	See **Table 11**.
136010	Right Rear Solenoid Control Valve	See **Table 12**.
136013	Retarder	See **Table 13**.
136014	Ground	See **Table 14**.
136023	Warning Light	See **Table 15**.
136249	SAE-J1922 Datalink	See **Table 16**.
136251	Overvoltage	See **Table 17**.
136253	Configuration	See **Table 18**.
136254	Miscellaneous	See **Table 19**.

Table 4, Fault Codes and Corresponding System Components/Areas

Left Front Wheel Sensor Troubleshooting					
Fault Code			**Problem**	**Diagnostic Procedure**	**Blink Code**
MID	**SID**	**FMI**			
136	001	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 12 and 15 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated to 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–2
136	001	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–2
136	001	03	Shorted to power	Measure the potential across pin 12 of the 18-pin connector and ground, and pin 15 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–2
136	001	04	Shorted to ground	Check the continuity between pin 12 and ground, and pin 15 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–2
136	001	05	Open circuit	Check the continuity between pins 12 and 15 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–2
136	001	06	Short circuit	Check the continuity between pins 12 and 15 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–2
136	001	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–2

Left Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	001	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 12 and 15 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–2
136	001	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–2
136	001	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 12 and 15 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–2
136	001	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 12 and 15 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–2
136	001	12	Frequency too high	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–2

Table 5, Left Front Wheel Sensor Troubleshooting

Right Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	002	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 10 and 13 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–1
136	002	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–1
136	002	03	Shorted to power	Measure the potential across pin 10 of the 18-pin connector and ground and pin 13 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–1
136	002	04	Shorted to ground	Check the continuity between pin 10 of the 18-pin connector and ground and pin 13 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–1
136	002	05	Open circuit	Check the continuity between pins 10 and 13 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–1
136	002	06	Short circuit	Check the continuity between pins 10 and 13 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–1
136	002	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–1

Troubleshooting for D-Basic ABS

Right Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	002	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 10 and 13 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–1
136	002	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–1
136	002	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 10 and 13 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–1
136	002	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 10 and 13 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–1
136	002	12	Frequency too high	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–1

Table 6, Right Front Wheel Sensor Troubleshooting

Left Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	003	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 11 and 14 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–4
136	003	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–4
136	003	03	Shorted to power	Measure the potential across pin 11 of the 18 pin-connector and ground, and pin 14 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–4
136	003	04	Shorted to ground	Check the continuity between pin 11 of the 18 pin-connector and ground, and pin 14 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–4
136	003	05	Open circuit	Check the continuity between pins 11 and 14 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–4
136	003	06	Short circuit	Check the continuity between pins 11 and 14 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–4
136	003	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–4

Left Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	003	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 11 and 14 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–4
136	003	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–4
136	003	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 11 and 14 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–4
136	003	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 11 and 14 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–4
136	003	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–4

Table 7, Left Rear Wheel Sensor Troubleshooting

Right Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	004	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 17 and 18 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–3
136	004	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–3
136	004	03	Shorted to power	Measure the potential across pin 17 of the 18 pin-connector and ground, and pin 18 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–3
136	004	04	Shorted to ground	Check the continuity between pin 17 and the 18 pin-connector and ground, and pin 18 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–3
136	004	05	Open circuit	Check the continuity between pins 17 and 18 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–3
136	004	06	Short circuit	Check the continuity between pins 17 and 18 of the 18-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–3
136	004	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–3

Troubleshooting for D-Basic ABS

Right Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	004	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 17 and 18 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–3
136	004	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–3
136	004	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 17 and 18 of the 18-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–3
136	004	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 17 and 18 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–3
136	004	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–3

Table 8, Right Rear Wheel Sensor Troubleshooting

Left Front Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	007	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 3 and 6 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–2
136	007	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 3 and 6 of the 18-pin connector and pin 4 of the 15-pin connector. If the measurement indicates a potential, the valve is shorted to power.	2–2
136	007	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 3 and 6 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–2
136	007	06	Shorted to ground	Disconnect the valve harness. Check continuity between pin 3 of the 18-pin connector and ground, and pin 6 and ground. If continuity exists in either pin, the valve harness is shorted to ground.	2–2

Table 9, Left Front Solenoid Control Valve Troubleshooting

Right Front Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	008	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 and 4 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–1
136	008	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 1 and 4 of the 18-pin connector and pin 4 of the 15-pin connector. If the measurement indicates a potential, the valve is shorted to power.	2–1
136	008	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 and 4 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–1
136	008	06	Shorted to ground	Disconnect the valve harness. Check continuity between pin 1 of the 18-pin connector and ground, and pin 4 and ground. If continuity exists in either pin, the valve harness is shorted to ground.	2–1

Table 10, Right Front Solenoid Control Valve Troubleshooting

Left Rear Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	009	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 2 and 5 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–4
136	009	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 2 and 5 of the 15-pin connector and pin 4 of the 15-pin connector. If the measurement indicates a potential, the valve is shorted to power.	2–4
136	009	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 2 and 5 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–4
136	009	06	Shorted to ground	Disconnect the valve harness. Check continuity between pin 2 of the 18-pin connector and ground, and pin 5 and ground. If continuity exists in either pin, the valve harness is shorted to ground.	2–4

Table 11, Left Rear Solenoid Control Valve Troubleshooting

Troubleshooting for D-Basic ABS

Right Rear Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	010	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 8 and 9 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–3
136	010	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential between pins 8 and 9 of the 18-pin connector and pin 4 of the 15-pin connector. If the measurement indicates a potential, the valve is shorted to power.	2–3
136	010	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pins 8 and 9 of the 18-pin connector and pin 4 of the 15-pin connector. A good measurement should be between 4 and 8 ohms.	2–3
136	010	06	Shorted to ground	Disconnect the valve harness. Check continuity between pin 8 of the 18-pin connector and ground, and pin 9 and ground. If continuity exists in either pin, the valve harness is shorted to ground.	2–3

Table 12, Right Rear Solenoid Control Valve Troubleshooting

Retarder Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	013	03	Shorted to power	Measure the potential between pin 14 on the 15-pin connector and ground. If the measurement indicates a potential, the relay circuit is shorted to power.	7–3
136	013	05	Open circuit	Check continuity of the retarder relay circuit. Replace the wire if continuity does not exist.	7–3
136	013	06	Shorted to ground	Check continuity between pin 14 on the 15-pin connector and ground. If continuity exists, the retarder relay circuit is shorted to ground.	7–3

Table 13, Retarder Troubleshooting

Ground Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	014	04	Low voltage/open circuit	Check the 10A circuit breaker. Check pin 8 in the 15-pin connector for power contact. Check the continuity of the circuit. If continuity does not exist, replace the wire.	8–1

Ground Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	014	07	Valve relay	If fault detection repeats, replace ECU. An internal relay does not open the ECU power supply.	8–3

Table 14, Ground Troubleshooting

Warning Light Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	023	05	Warning Light	Check the bulb and continuity of the warning light circuit. Was the blink code switch activated longer than 16 seconds? If so, cycle the ignition off and on to verify the fault.	7–4

Table 15, Warning Light Troubleshooting

J1922 Datalink Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	249	05	The J1922 datalink has an open circuit	Check the J1922 datalink connections. Check continuity of the datalink wires.	7–1
136	249	06	The J1922 datalink is shorted to ground	Check continuity between pin 1 of the 15-pin connector and ground, and pin 3 and ground. If continuity exists, the J1922 datalink is shorted to ground.	7–1
136	249	10	The J1922 bus is not free	Check other J1922 ECUs for incorrect communication.	7–1

Table 16, J1922 Datalink Troubleshooting

Overvoltage Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	251	03	Overvoltage	Check the alternator output and the battery potential. Supply voltage is too high for more than 5 seconds.	8–2

Table 17, Overvoltage Troubleshooting

Configuration Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	253	02	EEPROM, wheel parameter incorrect	Check parameter setting.	8–4

Troubleshooting for D-Basic ABS

Configuration Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	253	12	EEPROM, checksum	Check the parameter setting. Diagnostic device disconnected during active diagnosis.	8–4

Table 18, Configuration Troubleshooting

Miscellaneous ABS Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	254	02	Internal error	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–3
136	254	05	ABS ECU, no loads	No modulators connected. Fault not memorized.	8–4
136	254	08	Excessive slip/ dynotester	Check the wheel sensor air gaps. One axle was much faster than the other.	7–1
136	254	09	Solenoid Control Valve, activation time	Valve was activated for too long.	2–1
136	254	12	Internal error	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–3

Table 19, Miscellaneous ABS Troubleshooting

Troubleshooting

There are two ABS configurations available for the school bus, D-Basic and the full D-Version ABS. The full D-Version ABS is available for vehicles with Automatic Traction Control (ATC).

This subject includes the following troubleshooting methods for the full D-Version ABS:

- Troubleshooting using the instrument panel blink codes
- Troubleshooting using fault codes

USING THE INSTRUMENT PANEL BLINK CODES

This system has built-in diagnostics to ensure that all components are operating properly. Under normal conditions, the warning light (ABS) and wheel spin light (ATC) come on when the ignition is turned on. After about three seconds these lights should go out if all of the ABS/ATC components are working. If either light stays on, or comes back on later, a problem within the ABS/ATC system has occurred. The vehicle can continue to be driven, but the ABS system could be partially or completely inoperative. To check the type of fault code recorded, stop the vehicle and turn off the engine. Then, turn on the ignition switch, but don't start the engine. If the light is still on, there is an "active" system fault that must be repaired to ensure proper system operation. If the light is not on, a "historical or intermittent" fault (indicating a loose connector or broken wire) has been recorded in the ECU memory.

NOTE: If troubleshooting the system with the Pro-Link 9000, use the instruction booklet that is supplied with the data cartridge.

Use the ABS CHECK switch (which is located on the ECU) and the ABS warning light operation displayed in **Table 1** to display system faults. With the ignition switch on, depress (for about one second) and release the switch. The ABS light should go out. After a one and one-half second pause, the ABS light will blink the first digit of the two-digit fault code. The number of blinks displaying the first digit will be a number between one and eight. After another one and one-half second pause, the second digit will be displayed. The number of blinks displaying the second digit will be a number between one and six. After a four second pause, the diagnostic code cycle continues to repeat the "active" fault code until it is repaired. If "historical" fault codes exist, the code cycle will display all recorded faults.

For example, after the ABS CHECK switch has been depressed and released, fault code 54 is shown by five flashes, a pause of one and one-half seconds, followed by four flashes. See **Fig. 1**. After a four second pause, the same fault code will continue to repeat, always ending with a four second pause.

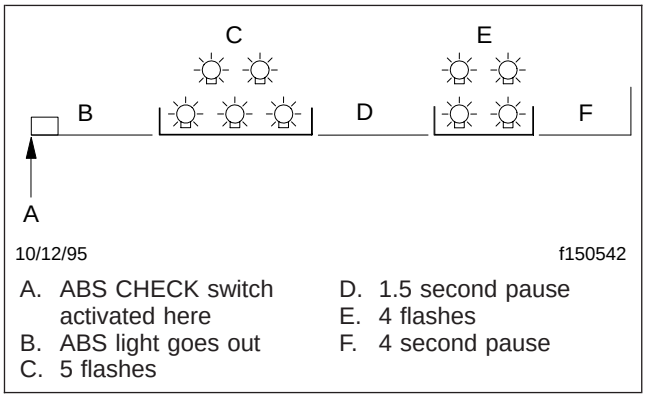


Fig. 1, Fault Code 54 shown

NOTE: When there are no fault codes in the ECU memory, blink code 1-1 is displayed.

Once a fault code has been identified, use a volt/ohmmeter to check the electrical harness at the ECU's pin connectors (there is a 6-pin, 9-pin, 15-pin, and 18-pin connector at the ECU). Connect the ohmmeter leads to the applicable pins on each connector. See **Fig. 2**, and **Table 2**, for a description of the circuit wire numbers and their location within the pin connectors.

IMPORTANT: The ignition switch must be off when connecting or disconnecting the ECU.

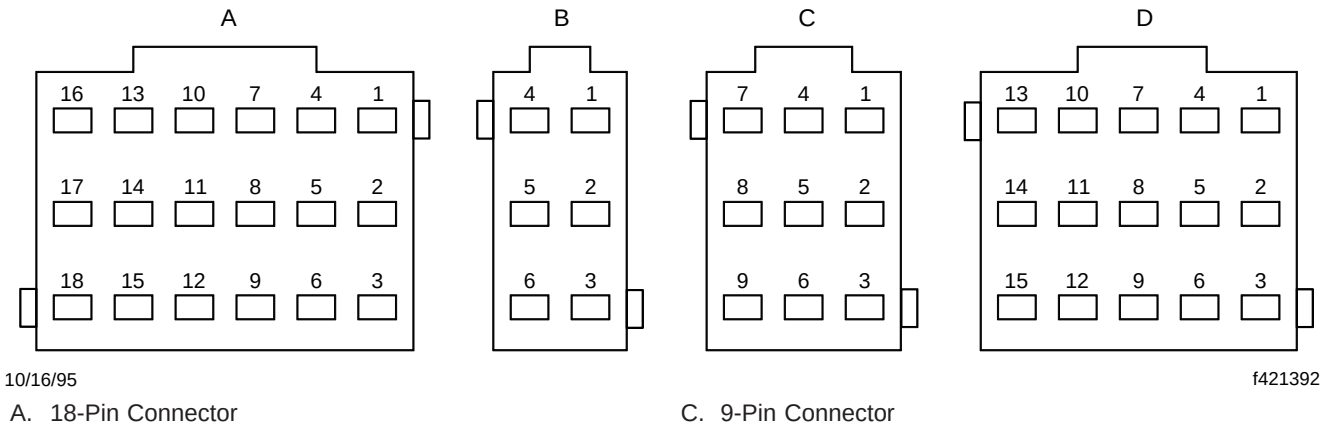
If the ABS or ATC lights do not operate correctly after the ignition is turned on (the lights don't come on at all or they don't go out after about three seconds), check all related circuit breakers in the electrical panel, and replace if necessary. Check the wiring to the ABS CHECK switch and the warning lamps. See **Table 3**, and repair or replace the wiring as needed. Make sure that a charged 12-volt battery is available (the ABS system needs at least 11 volts to work).

Troubleshooting for D-Version ABS

What You Do	What Happens	What it Means
Turn the ignition on.	The ABS light comes on momentarily for a bulb check, then goes out.	The system is okay.
	The ABS light does not go out at ignition.	If the light goes out when the vehicle is driven above 4 mph (6 km/h), the system is okay. If the light does not go out at speeds above 4 mph (6 km/h), the ECU senses a fault in the ABS system.

Table 1, Warning Light Operation

Refer to the applicable table in this section for fault



A. 18-Pin Connector
B. 6-Pin Connector
C. 9-Pin Connector
D. 15-Pin Connector

Fig. 2, ECU Pin Connectors

codes, pins to be tested, and the correct volt/ohmmeter readings. Repair or replace the components and/or wiring if the readings are not correct.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

See **Group 54** in this manual for information on special terminals and connectors, and ordering tools for them.

Refer to the applicable wiring diagram in **Specifications, 400** when troubleshooting the this ABS system. The key switch must be turned on (engine off) to activate the blink codes.

If a fault still can't be repaired, or erased from ECU memory, contact your Meritor District Service Manager, or call Meritor WABCO at 1–800–535–5560.

NOTE: An "active" fault code cannot be erased from ECU memory. "Historical" faults can be erased from ECU memory without being repaired. However, make sure that all "historical" fault codes are recorded because they should be repaired as soon as possible.

Historical fault codes can be erased all at once from the ECU memory. Erase historical fault codes by depressing the ABS CHECK switch for at least three seconds (but less than six seconds). After releasing the switch, the ABS light will go out in one-half second, then there will be a four second pause. After the pause, the ABS light will flash eight times (only if there are no active fault codes–if there are, you will only see the two system flashes), followed by another four second pause. Then, the ABS light will flash two times, another four second pause will follow and the same cycle of two flashes and four-second

pauses will continue until the ignition switch is turned off, then back on.

IMPORTANT: Before performing any vehicle testing on a dynamometer, disable the automatic traction control (if equipped) as follows: Depress the ABS CHECK switch for at least three seconds (but less than six seconds). After releasing the switch, the ABS light will go out in one-half second, a four second pause will occur, then the ABS light will flash two times, a four second pause will follow, and the same cycle of two flashes and four-second pauses will continue until the engine is turned off, then back on. The ATC light will also be on (indicating that ATC is enabled) during this process. Make sure that all "historical" fault codes are recorded because they will be erased when performing this procedure.

USING FAULT CODES

The first six digits of the fault code indicate the system component or area you need to troubleshoot. To find the component or area that corresponds to a fault code, see **Table 4**. After that, refer to the appropriate table for the troubleshooting procedure.

Circuit Wire Numbers and Descriptions			
Pin Connector	**Pin Number**	**Freightliner Wire Number**	**WABCO Circuit Description**
6-Pin	1	378LF0	Left Front Solenoid Control Valve, Out
	2	378LF1	Left Front Solenoid Control Valve, In
	3	378LF–	Left Front Solenoid Control Valve, Ground
	4	377LF+	Left Front Sensor, High
	5	377LF–	Left Front Sensor, Low
9-Pin	4	377RF+	Right Front Sensor, High
	5	377RF–	Right Front Sensor, Low
	7	378RF0	Right Front Solenoid Control Valve, Out
	8	378RF1	Right Front Solenoid Control Valve, In
	9	378RF–	Right Front Solenoid Control Valve, Ground
15-Pin	1	378LR0	Left Rear Solenoid Control Valve, Out
	2	378LR1	Left Rear Solenoid Control Valve, In
	3	378LR–	Left Rear Solenoid Control Valve, Ground
	4	378T–	ATC Valve Return
	5	377LR+	Left Rear Sensor, High
	6	377LR–	Left Rear Sensor, Low
	7	378T+	ATC Valve Supply
	8	377RR+	Right Rear Sensor, High
	9	377RR–	Right Rear Sensor, Low
	10	378RR0	Right Rear Solenoid Valve, Out
	11	378RR1	Right Rear Solenoid Valve, In
	12	378RR–	Right Rear Solenoid Valve, Ground

Troubleshooting for D-Version ABS

Circuit Wire Numbers and Descriptions			
Pin Connector	**Pin Number**	**Freightliner Wire Number**	**WABCO Circuit Description**
18-Pin	1	1922–	J1922 Data Link Negative to ECU
	3	1922+	J1922 Data Link Positive to ECU
	6	376T	ATC Switch (Mud/Snow) Signal
	7	376C	ECU Ignition Supply
	8	376B	ECU #2 Positive 12 Volt Supply
	9	376A	ECU #1 Positive 12 Volt Supply
	10	GND3	ECU Control Ground
	11	GND2	ECU #2 Ground
	12	GND1	ECU #1 Ground
	13	1587–	J1587 Data Link Negative to ECU
	14	1587+	J1587 Data Link Positive to ECU
	16	376S	Wheel Spin Light Signal
	17	376R	Retarder Interrupt Signal
	18	376L	ABS Indicator Light Signal

Table 2, Circuit Wire Numbers and Descriptions

ABS CHECK Switch and Warning Lamps Wiring Checks				
Wiring Tested	**Test These Pins**	**Volt/Ohmmeter Reading**	**Possible Cause**	**Remedy**
Warning (ABS) Light	On the 18-pin connector, pins 7 and 18	2 to 50 ohms (depends on bulb wattage)	Wiring to the light is shorted or open; or the bulb needs replacing.	Repair the wiring, or replace the bulb.
Wheel Spin Light	On the 18-pin connector, pins 7 and 16	2 to 50 ohms (depends on bulb wattage)	Wiring to the light is shorted or open; or the bulb needs replacing.	Repair the wiring, or replace the bulb.
ABS CHECK Switch	On the 18-pin connector, pins 10 and 18 (also, turn on the ABS CHECK switch).	0 to 2 ohms	Wiring to the switch is shorted or open; or the switch needs replacing.	Repair the wiring, or replace the switch.

Table 3, ABS CHECK Switch and Warning Lamps Wiring Checks

If the First Six Digits of the Fault Code Are:	Troubleshoot this Component or Area:	See Table:
136001	Left Front Wheel Sensor	See **Table 5**.
136002	Right Front Wheel Sensor	See **Table 6**.
136003	Left Rear Wheel Sensor	See **Table 7**.
136004	Right Rear Wheel Sensor	See **Table 8**.
136007	Left Front Solenoid Control Valve	See **Table 9**.

If the First Six Digits of the Fault Code Are:	Troubleshoot this Component or Area:	See Table:
136008	Right Front Solenoid Control Valve	See **Table 10**.
136009	Left Rear Solenoid Control Valve	See **Table 11**.
136010	Right Rear Solenoid Control Valve	See **Table 12**.
136011	Left Third Solenoid Control Valve *	See **Table 13**.
136012	Right Third Solenoid Control Valve *	See **Table 14**.
136013	Retarder	See **Table 15**.
136014	Ground (diagonal 1)	See **Table 16**.
136015	Ground (diagonal 2)	See **Table 17**.
136018	ATC Valve	See **Table 18**.
136023	Warning Light	See **Table 19**.
136248	SAE-J1939 Datalink	See **Table 20**.
136249	SAE-J1922 Datalink	See **Table 21**.
136251	Voltage	See **Table 22**.
136253	Configuration	See **Table 23**.
136254	Miscellaneous	See **Table 24**.

* The left or right third solenoid control valve is located on the chassis near the rearmost axle on a 6S/6M configuration.

Table 4, Fault Codes and Corresponding System Components/Areas

Left Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	001	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 6-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–2
136	001	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–2
136	001	03	Shorted to power	Measure the potential across pin 4 and ground and pin 5 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–2
136	001	04	Shorted to ground	Check the continuity between pin 4 and ground and pin 5 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–2
136	001	05	Open circuit	Check the continuity between pins 4 and 5 of the 6-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–2
136	001	06	Short circuit	Check the continuity between pins 4 and 5 of the 6-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–2
136	001	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–2

Troubleshooting for D-Version ABS

Left Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	001	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 6-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–2
136	001	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–2
136	001	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 6-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–2
136	001	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 4 and 5 of the 6-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–2
136	001	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–2

Table 5, Left Front Wheel Sensor Troubleshooting

Right Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	002	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 9-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–1
136	002	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–1
136	002	03	Shorted to power	Measure the potential across pin 4 and ground, and pin 5 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–1
136	002	04	Shorted to ground	Check the continuity between pin 4 and ground, and pin 5 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–1
136	002	05	Open circuit	Check the continuity between pins 4 and 5 of the 9-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–1
136	002	06	Short circuit	Check the continuity between pins 4 and 5 of the 9-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–1
136	002	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–1

Right Front Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	002	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 9-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–1
136	002	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–1
136	002	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 9-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–1
136	002	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 4 and 5 of the 9-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–1
136	002	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–1

Table 6, Right Front Wheel Sensor Troubleshooting

Left Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	003	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–4
136	003	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–4
136	003	03	Shorted to power	Measure the potential across pin 4 and ground, and pin 5 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–4
136	003	04	Shorted to ground	Check the continuity between pin 4 and ground, and pin 5 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–4
136	003	05	Open circuit	Check the continuity between pins 4 and 5 of the 15-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–4
136	003	06	Short circuit	Check the continuity between pins 4 and 5 of the 15-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–4
136	003	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–4

Troubleshooting for D-Version ABS

Left Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	003	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–4
136	003	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–4
136	003	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 4 and 5 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–4
136	003	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 4 and 5 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–4
136	003	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–4

Table 7, Left Rear Wheel Sensor Troubleshooting

Right Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	004	01	Excessive air gap	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 8 and 9 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm. Check for loose wheel bearings and/or excessive hub runout.	3–3
136	004	02	Incorrect tire	Check for correct tire size. Check for correct number of teeth on the tone wheel.	5–3
136	004	03	Shorted to power	Measure the potential across pin 8 and ground, and pin 9 and ground. If the measurement indicates a potential, the sensor is shorted to power.	4–3
136	004	04	Shorted to ground	Check the continuity between pin 8 and ground, and pin 9 and ground. If continuity exists in either pin, the sensor is shorted to ground.	4–3
136	004	05	Open circuit	Check the continuity between pins 8 and 9 of the 15-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–3
136	004	06	Short circuit	Check the continuity between pins 8 and 9 of the 15-pin connector. A good resistance measurement will be between 700 and 3000 ohms.	4–3
136	004	07	Damaged tone wheel	Check the tone wheel for damage such as missing teeth.	6–3

Right Rear Wheel Sensor Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	004	08	Wheel slip	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 8 and 9 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–3
136	004	09	Wires mismatched	Check for a mismatch fault of another sensor and correct the problem in the wiring harness.	5–3
136	004	10	Intermittent signal loss	Adjust the sensor. Verify the adjustment by measuring the voltage across pins 8 and 9 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	3–3
136	004	11	Erratic signal	Check the sensor wiring and connectors for intermittent contact. Check the tone wheel for damage. Verify the signal by measuring the voltage across pins 8 and 9 of the 15-pin connector. A good measurement should be above 0.2 volts AC when the tire is rotated at 30 rpm.	5–3
136	004	12	Frequency incorrect	Check the sensor wiring and connectors for intermittent contact. Check the ECU for an improper fault.	5–3

Table 8, Right Rear Wheel Sensor Troubleshooting

Left Front Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	007	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 6-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–2
136	007	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 1 of the 6-pin connector and pin 3, and between pin 2 and pin 3. If the measurement indicates a potential, the valve is shorted to power.	2–2
136	007	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 6-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–2
136	007	06	Shorted to ground	Check continuity between pin 1 of the 6-pin connector and ground, and pin 2 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–2

Table 9, Left Front Solenoid Control Valve Troubleshooting

Troubleshooting for D-Version ABS

Right Front Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	008	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 7 of the 9-pin connector and pin 9, and between pin 8 and pin 9. A good measurement should be between 4 and 8 ohms.	2–1
136	008	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 7 of the 9-pin connector and pin 9, and between pin 8 and pin 9. If the measurement indicates a potential, the valve is shorted to power.	2–1
136	008	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 7 of the 9-pin connector and pin 9, and between pin 8 and pin 9. A good measurement should be between 4 and 8 ohms.	2–1
136	008	06	Shorted to ground	Check continuity between pin 7 of the 9-pin connector and ground, and pin 8 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–1

Table 10, Right Front Solenoid Control Valve Troubleshooting

Left Rear Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	009	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 15-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–4
136	009	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 1 of the 15-pin connector and pin 3, and between pin 2 and pin 3. If the measurement indicates a potential, the valve is shorted to power.	2–4
136	009	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 15-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–4
136	009	06	Shorted to ground	Check continuity between pin 1 of the 15-pin connector and ground, and pin 2 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–4

Table 11, Left Rear Solenoid Control Valve Troubleshooting

Right Rear Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	010	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 10 of the 15-pin connector and pin 12, and between pin 11 and pin 12. A good measurement should be between 4 and 8 ohms.	2–3
136	010	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 10 of the 15-pin connector and pin 12, and between pin 11 and pin 12. If the measurement indicates a potential, the valve is shorted to power.	2–3
136	010	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 10 of the 15-pin connector and pin 12, and between pin 11 and pin 12. A good measurement should be between 4 and 8 ohms.	2–3
136	010	06	Shorted to ground	Check continuity between pin 10 of the 15-pin connector and ground, and pin 11 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–3

Table 12, Right Rear Solenoid Control Valve Troubleshooting

Left Third Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	011	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 12-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–6
136	011	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 1 of the 12-pin connector and pin 3, and between pin 2 and pin 3. If the measurement indicates a potential, the valve is shorted to power.	2–6
136	011	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 1 of the 12-pin connector and pin 3, and between pin 2 and pin 3. A good measurement should be between 4 and 8 ohms.	2–6
136	011	06	Shorted to ground	Check continuity between pin 1 of the 12-pin connector and ground, and pin 2 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–6

Table 13, Left Third Solenoid Control Valve Troubleshooting

Troubleshooting for D-Version ABS

Right Third Solenoid Control Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	012	01	Open circuit in the inlet and/or outlet solenoid circuits	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 10 of the 12-pin connector and pin 12, and between pin 11 and pin 12. A good measurement should be between 4 and 8 ohms.	2–5
136	012	03	Shorted to power	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Measure the potential across pin 10 of the 12-pin connector and pin 12, and between pin 11 and pin 12. If the measurement indicates a potential, the valve is shorted to power.	2–5
136	012	05	Open circuit	Check the solenoid control valve wiring. Check for damaged wiring in the inlet, outlet and ground circuits. Check the resistance between pin 10 of the 12-pin connector and pin 12, and between pin 11 and pin 12. A good measurement should be between 4 and 8 ohms.	2–5
136	012	06	Shorted to ground	Check continuity between pin 10 of the 12-pin connector and ground, and pin 11 and ground. If continuity exists in either pin, the valve is shorted to ground.	2–5

Table 14, Right Third Solenoid Control Valve Troubleshooting

Retarder Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	013	03	Shorted to power	Measure the potential between pin 17 on the 18-pin connector and ground. If the measurement indicates a potential, the relay circuit is shorted to power.	7–3
136	013	05	Open circuit	Check continuity of the retarder relay circuit 376R. Replace the wire if continuity does not exist.	7–3
136	013	06	Shorted to ground	Check continuity between pin 17 on the 18-pin connector and ground. If continuity exists, the retarder relay circuit is shorted to ground.	7–3

Table 15, Retarder Troubleshooting

Ground (diagonal 1) Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	014	03	Ground, diagonal 2, shorted to power	Measure potential between pin 9 on the 9-pin connector and ground, pin 3 on the 15-pin connector and ground, and pin 3 on the 12-pin connector (if applicable) and ground. If measurements indicate a potential, a solenoid control valve ground is shorted to power.	8–5

Ground (diagonal 1) Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	014	04	Voltage, diagonal 2, low voltage/open circuit	Check the 10A circuit breaker. Check pin 9 in the 18-pin connector for proper contact. Check continuity of the circuit. If continuity does not exist, replace the wire.	8–1
136	014	05	Ground, diagonal 2, open circuit	Check continuity between pins 11 and 12 in the 18-pin connector. If continuity does not exist, replace the wire to pin 12.	8–5
136	014	06	Ground, diagonal 2, short to low	Check continuity between pins 7 and 8 in the 9-pin connector and ground, pins 1 and 2 in the 15-pin connector and ground, and pins 1 and 2 in the 12-pin connector and ground. If continuity exists, a solenoid control valve circuit is shorted to ground.	8–5

Table 16, Ground (diagonal 1) Troubleshooting

Ground (diagonal 2) Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	015	03	Ground, diagonal 1, shorted to power	Measure potential between pin 3 on the 6-pin connector and ground, pin 12 on the 15-pin connector and ground, and pin 12 on the 12-pin connector (if applicable) and ground. If measurements indicate a potential, a solenoid control valve ground is shorted to power.	8–5
136	015	04	Voltage, diagonal 1, low voltage/open circuit	Check the 10A circuit breaker. Check pin 8 in the 18-pin connector for proper contact. Check continuity of the circuit. If continuity does not exist, replace the wire.	8–1
136	015	05	Ground, diagonal 1, open circuit	Check continuity between pins 11 and 12 in the 18-pin connector. If continuity does not exist, replace the wire to pin 11.	8–5
136	015	06	Ground, diagonal 1, short to low	Check continuity between pins 1 and 2 in the 6-pin connector and ground, pins 10 and 11 in the 15-pin connector and ground, and pins 10 and 11 in the 12-pin connector and ground. If continuity exists, a solenoid control valve circuit is shorted to ground.	8–5

Table 17, Ground (diagonal 2) Troubleshooting

ATC Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	018	03	ATC valve, shorted to power	Measure the potential between pin 3 in the 15-pin connector and ground, and pin 7 in the 15-pin connector and ground. If measurements indicate a potential, the ATC valve is shorted to power.	7–2

Troubleshooting for D-Version ABS

ATC Valve Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	018	05	ATC valve, open circuit	Check continuity between pins 4 and 7 in the 15-pin connector. If continuity does not exist replace the wiring. A good measurement will read between 8 and 14 ohms.	7–2
136	018	06	ATC valve, shorted to ground	Check continuity between pins 14 in the 15-pin connector and ground, and pin 7 in the 15-pin connector and ground. If continuity exists, replace the ATC valve wiring.	7–2

Table 18, ATC Valve Troubleshooting

Warning Light Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	023	05	Warning Light	Check the bulb and continuity of the warning light circuit. Was the blink code switch activated longer than 16 seconds? If so, cycle the ignition off and on to verify the fault.	7–4

Table 19, Warning Light Troubleshooting

SAE-J1939 Datalink Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	231	02	J1939 plausibility error	Check the speedometer calibration. Check for tire size mismatch.	7–1
136	231	05	J1939 open circuit	Check J1939 datalink connections. Check for continuity of datalink wires.	7–1
136	231	06	J1939 shorted to ground	Check the continuity between pin 1 and ground, and pin 3 and ground. If continuity exists, the J1939 datalink is shorted to ground.	7–1
136	231	09	J1939 time-out	Check other J1939 ECUs for incorrect communication.	7–1
136	231	12	J1939, internal error	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–3

Table 20, SAE-J1939 Datalink Troubleshooting

J1922 Datalink Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	249	05	The J1922 datalink has an open circuit	Check the J1922 datalink connections. Check continuity of the datalink wires.	7–1
136	249	06	The J1922 datalink is shorted to ground	Check continuity between pin 1 and ground, and pin 3 and ground. If continuity exists, the J1922 datalink is shorted to ground.	7–1

J1922 Datalink Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	249	10	The J1922 bus is not free	Check other J1922 ECUs for incorrect communication.	7–1

Table 21, J1922 Datalink Troubleshooting

Overvoltage Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	251	03	Overvoltage, diagonal 1 or 2	Check the alternator output and the battery potential. Supply voltage is greater than 14 volts for more than 5 seconds.	8–2

Table 22, Overvoltage Troubleshooting

Configuration Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	253	01	ATC configuration	Check the wires responsible for parameter setting.	7–5
136	253	02	EEPROM, wheel parameter incorrect	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–4
136	253	12	EEPROM, checksum	Check the parameter setting. Diagnostic device disconnected during active diagnosis. Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–4

Table 23, Configuration Troubleshooting

Miscellaneous ABS Troubleshooting					
Fault Code			Problem	Diagnostic Procedure	Blink Code
MID	SID	FMI			
136	254	02	Internal error	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–3
136	254	05	ABS ECU, no loads	No modulators connected. Fault not memorized.	8–4
136	254	08	Excessive slip/ dynotester	Check the wheel sensor air gaps.	7–1
136	254	09	Solenoid Control Valve, activation time	Modulator valve was activated for too long.	2–1
136	254	12	Internal error	Cycle the ignition off and on. If the fault detection repeats, replace the ABS electronic control unit.	8–3

Table 24, Miscellaneous ABS Troubleshooting

Wiring Diagrams

Use the following wiring diagrams when you troubleshoot the Meritor D-Basic WABCO ABS system:

- For a full view of the wiring diagram, see **Fig. 1**.
- For detailed views of the wiring diagram, see **Fig. 2** and **Fig. 3**.

Use the following wiring diagrams when you troubleshoot the Meritor D-Version WABCO ABS/ATC system:

- For the power and control wiring diagram, see **Fig. 4**.
- For the sensor and valve wiring diagram, see **Fig. 5**.

Specifications

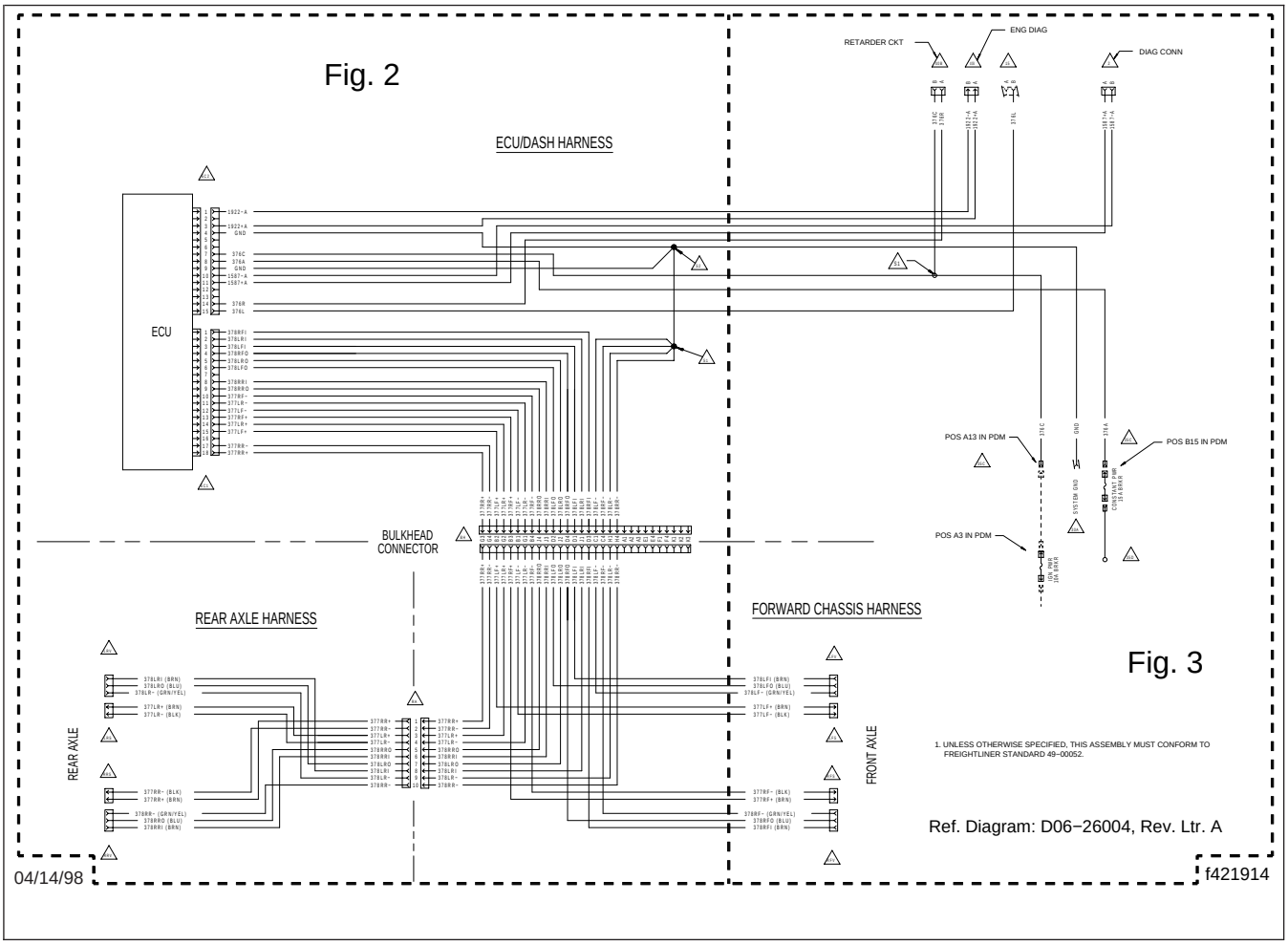


Fig. 1, D-Basic Wiring Diagram (full view)

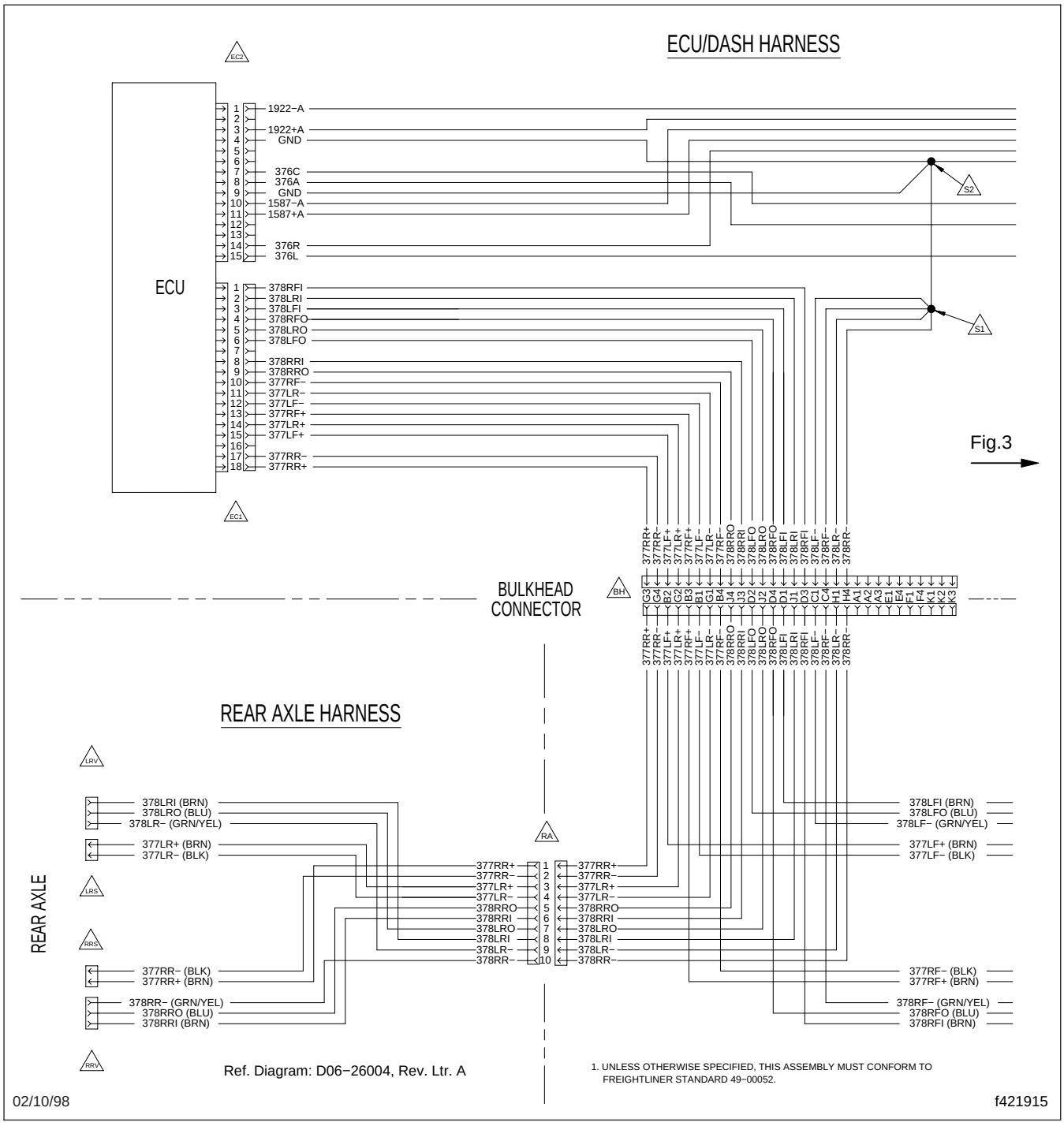


Fig. 2, D-Basic Wiring Diagram (detailed view)

Specifications

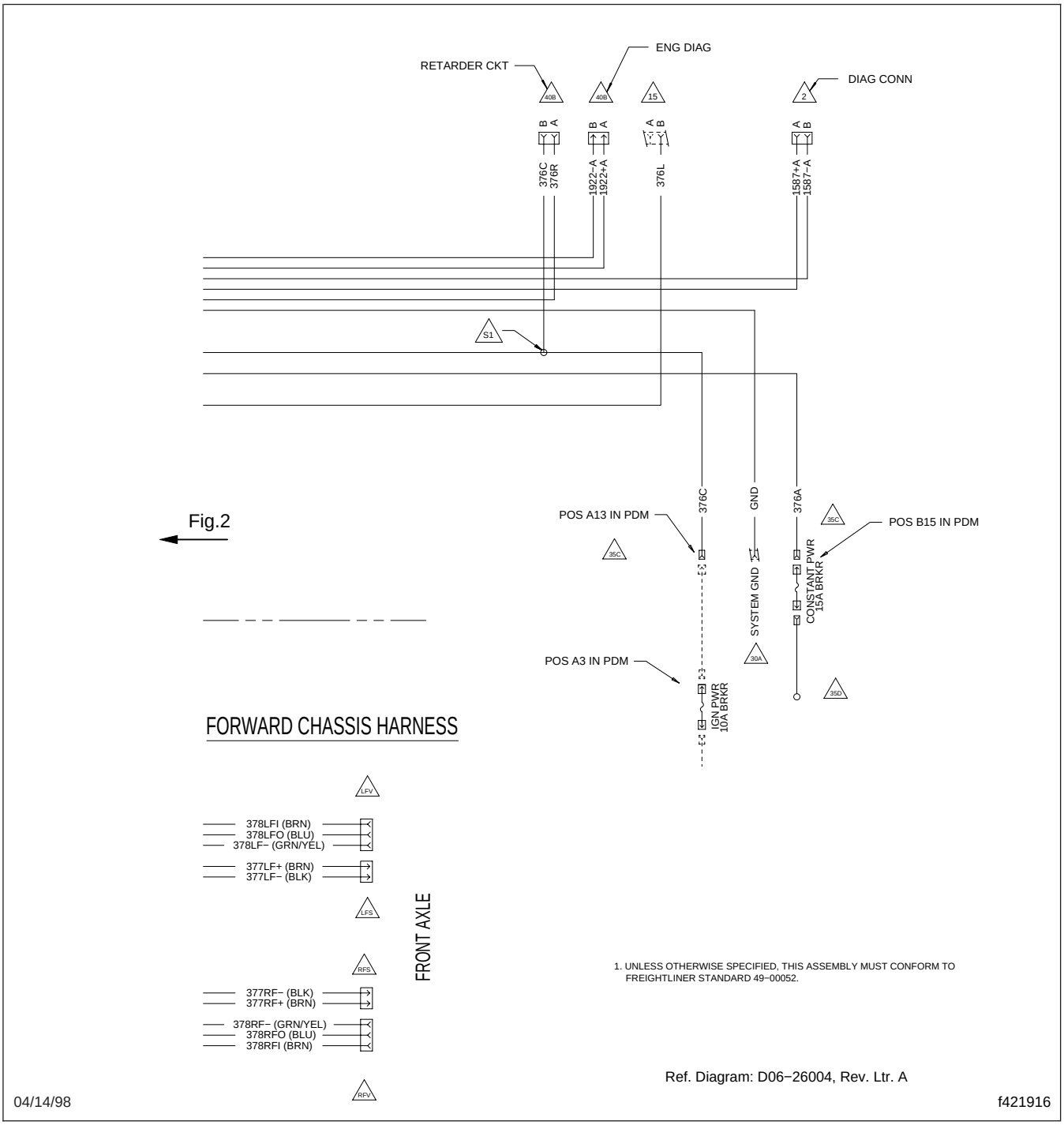


Fig. 3, D-Basic Wiring Diagram (detailed view)

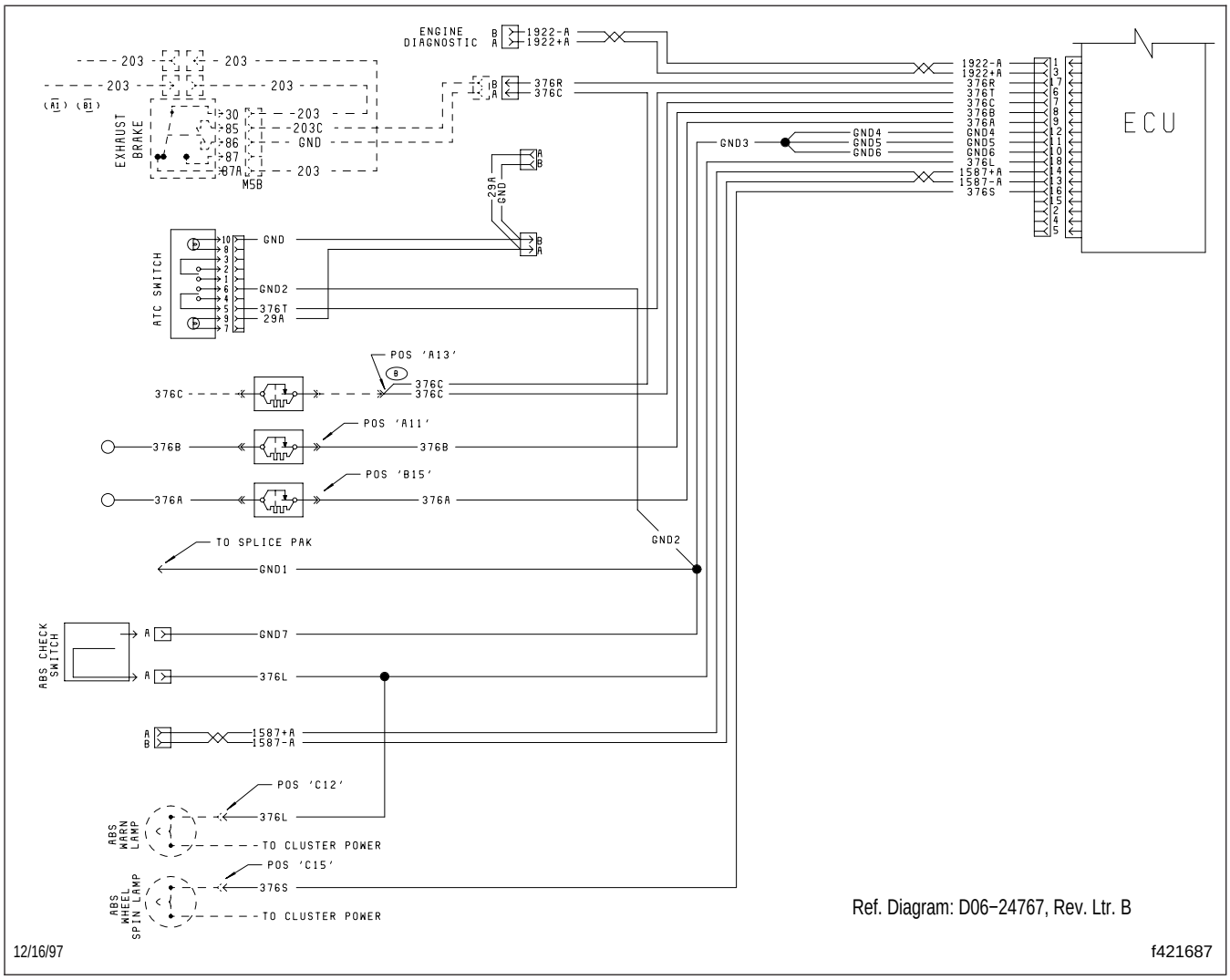


Fig. 4, D-Version Power and Control Wiring Diagram

Specifications

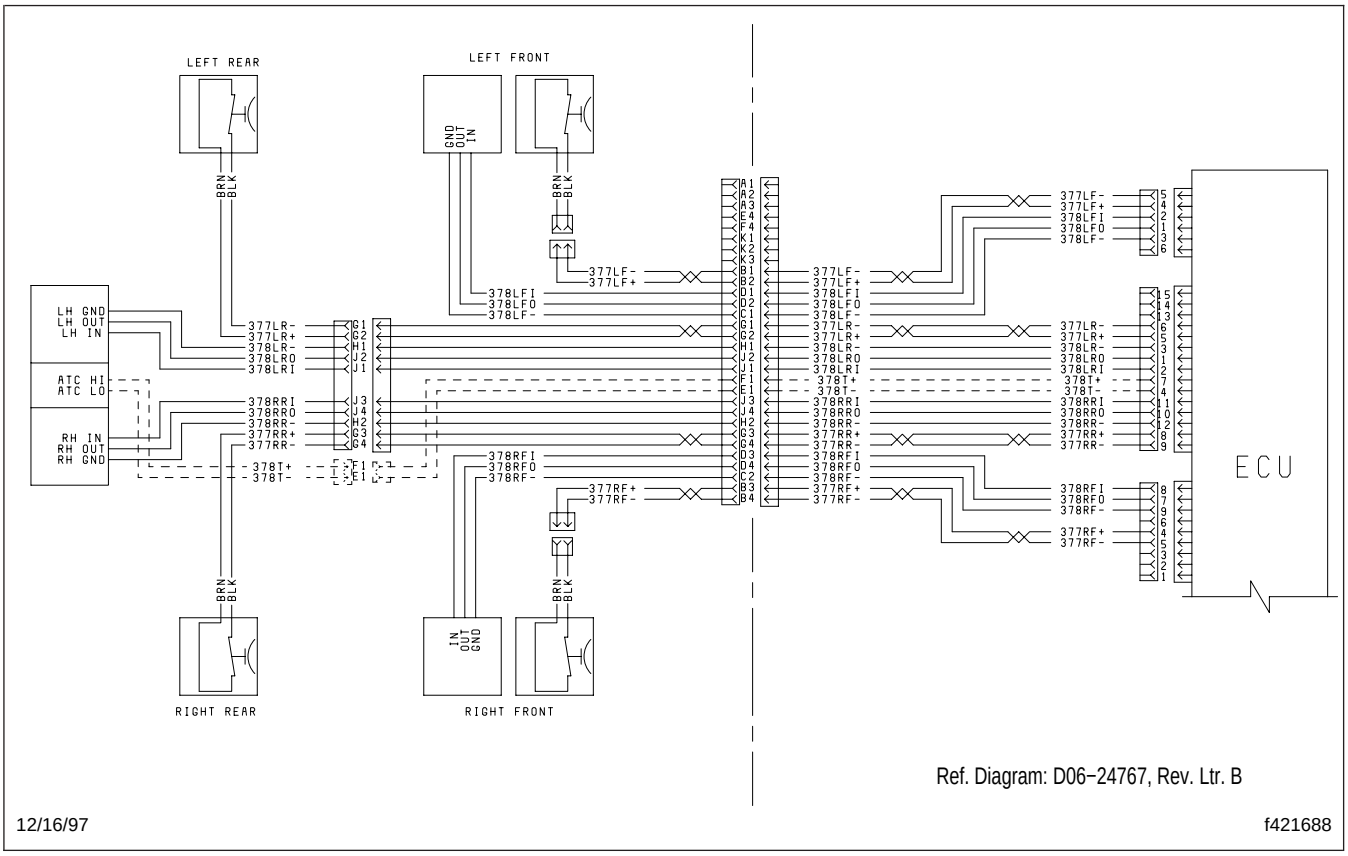


Fig. 5, D-Version Sensor and Valve Wiring Diagram

General Description

The Meritor WABCO Antilock Braking System (ABS) is an electronic wheel speed monitoring and control system that works with the hydraulic brake system. ABS passively monitors vehicle wheel speed at all times, and controls wheel speed during emergency stops. In normal braking applications, the hydraulic brake system is in effect. See **Fig. 1**.

ABS includes signal-generating tone wheels and sensors located in the rotor assembly of each sensed wheel. The sensors transmit vehicle wheel speed information to an electronic control unit. During emergency braking, the control unit signals the brake pressure modulator to reduce, maintain, or increase hydraulic fluid pressure to the brake caliper housing. This prevents front and rear wheel lockup, and enhances steering control during emergency braking situations.

Principles of Operation

The ABS electronic control unit is a digital microcomputer that serves as the information processing and command center for the antilock braking system. See **Fig. 2**. The control unit receives and processes vehicle wheel speed information from the sensors. During emergency brake applications, the control unit regulates the braking force applied to each wheel by sending control signals to the brake pressure modulator. See **Fig. 3**.

ABS MAJOR COMPONENTS

Wheel Speed Sensor

The wheel speed sensors use pulse feedback from tone wheels located in the front and rear axle rotor assemblies. When the vehicle is moving, the teeth of the tone wheel cause changes in the magnetic field created by the sensor. The changes create an AC voltage signal that is sent by the sensor to the electronic control unit.

Electronic Control Unit (ECU)

The electronic control unit (ECU), located on the right-hand side of the frontwall, contains microcomputers to monitor the front and rear control channels. The ECU receives wheel speed signals and interprets these signals to calculate wheel speed and a vehicle reference speed. If the calculations indicate a high degree of wheel slip the ECU signals the brake pressure modulator to adjust braking pressure.

The ECU contains another microcomputer that provides a safety circuit to constantly monitor the wheel sensors, the brake pressure modulator, and the electrical circuitry.

IMPORTANT: After the ignition switch is turned on, the ABS warning light comes on for about three seconds. See **Fig. 4**. After about three seconds, the light goes out only if all of the ABS components are working correctly.

If, during vehicle operation, the safety circuit senses a failure in any part of the ABS system (a sensor, brake pressure modulator, wiring connection, short circuit, etc.), the ABS warning light comes on, and the control circuit where the failure occurred is switched to normal braking action. Even if the ABS system is completely inoperative, normal braking is maintained. See the vehicle driver's manual for complete operating instructions.

Brake Pressure Modulator

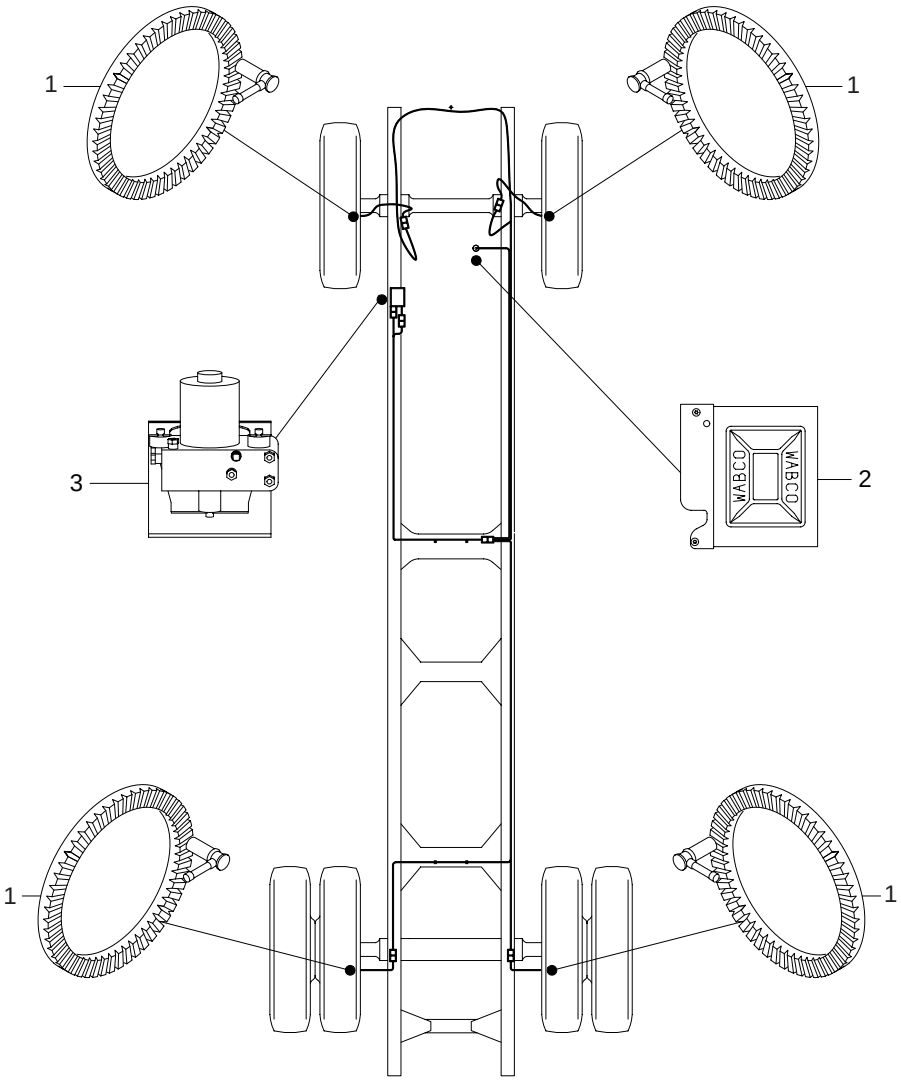
The brake pressure modulator is attached to the inside of the left-side frame rail, under the cowl. Depending on the signal received from the electronic control unit, the modulator prevents wheel lockup by adjusting the hydraulic fluid pressure. During normal braking applications, hydraulic fluid flows freely to the brake caliper housing through the modulator.

Within the modulator are an inlet and outlet control valve for each sensed wheel. If the electronic control unit signals indicate wheel lockup is close to occurring, fluid pressure to the brake caliper of the sensed wheel is reduced. The inlet valve of the sensed wheel closes, preventing fluid delivery to the brake caliper. At the same time, the outlet valve opens, allowing fluid to flow to an accumulator within the module. From the accumulator, a recirculation pump within the module delivers brake fluid back to the master cylinder.

As wheel speed increases, the brake pressure modulator allows increases (inlet valve opens and outlet valve closes), or maintains brake pressure until the proper wheel speed is obtained, or until wheel lockup occurs and the control cycle starts again.

If maintaining brake pressure, both valves are closed, preventing fluid delivery and maintaining fluid pressure.

General Information



10/15/98 f421952

1. Tone Wheel and Sensor
2. Electronic Control Unit
3. Brake Pressure Modulator

Fig. 1, Location of ABS Components, Four-Channel System

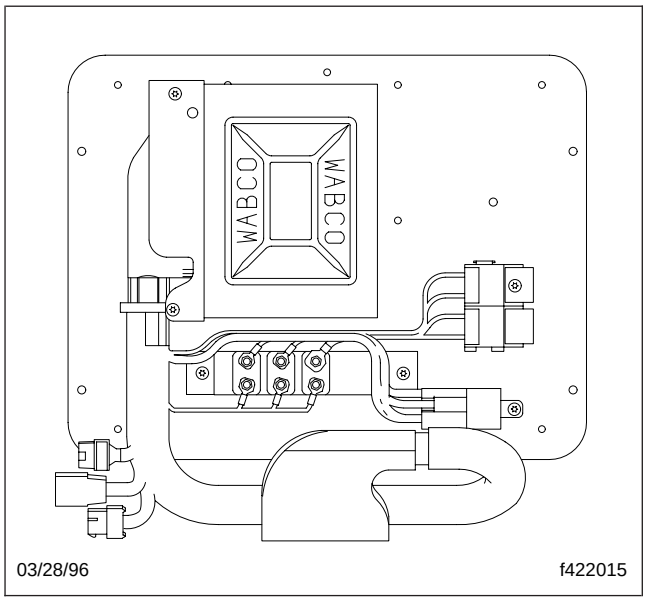


Fig. 2, Electronic Control Unit

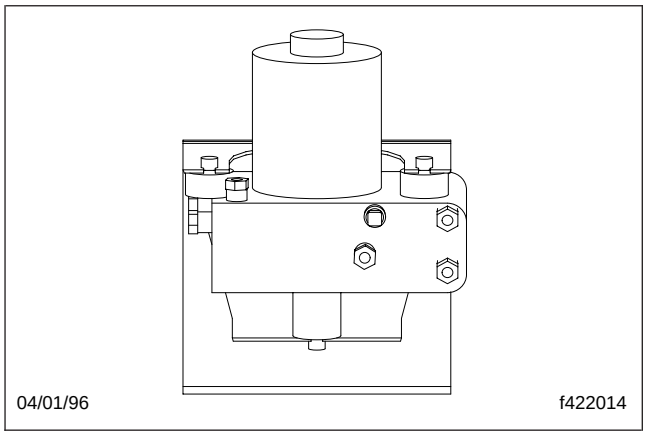
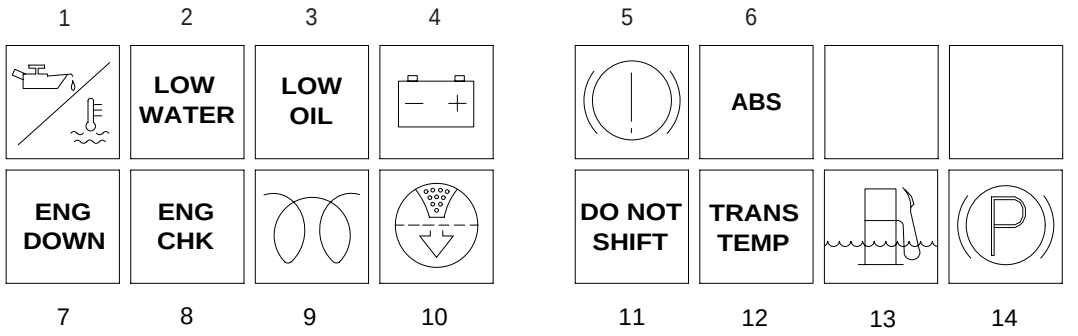


Fig. 3, Brake Pressure Modulator

General Information



06/09/97 f601245a

1. Low Oil Pressure/High Water Temperature Warning
2. Low Water Level Warning
3. Low Oil Level Warning
4. Alternator Warning Light
5. Brake System Warning
6. ABS Warning Light
7. Stop Engine Indicator
8. Engine Check Indicator
9. Cold-Start Manifold Heater Indicator
10. Air Cleaner Restriction Indicator
11. Do-Not-Shift Indicator
12. High Oil Temperature Warning (Automatic Transmission)
13. Water in Fuel/Water Separator Warning
14. Parking Brake Indicator

Fig. 4, Dash Warning and Indicator Lights

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** (wiring) in this manual for information on special terminals and connectors, and on ordering tools for them.

FRONT AXLE

1. Apply the parking brakes. Chock the rear tires.
2. Twist and pull the sensor to remove it from the sensor bracket. See **Fig. 1**.

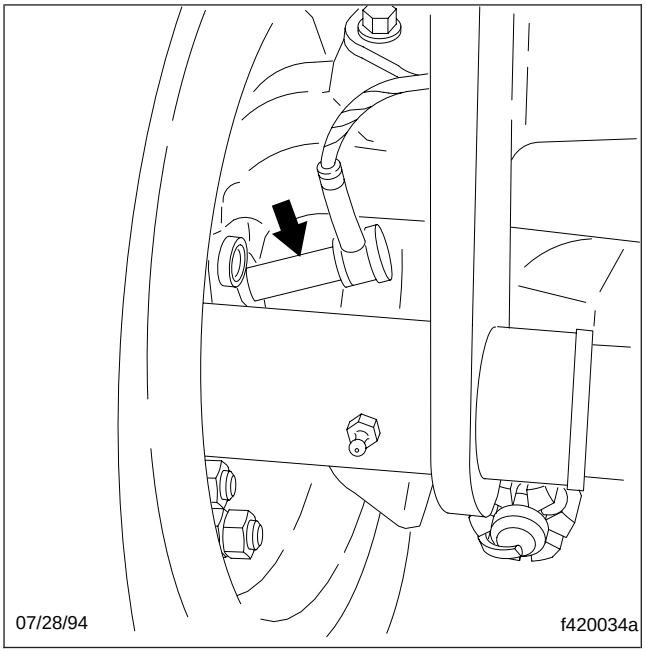


Fig. 1, Remove the Wheel Speed Sensor

3. Remove the sensor cable clip from the steering knuckle top cap.
4. Disconnect the sensor cable from the chassis harness.
5. Remove the clamping bushing from the sensor bracket.
6. Connect the sensor cable to the chassis harness.
7. Attach the sensor cable to the steering knuckle top cap.
8. Press the clamping bushing into the sensor bracket at the brake spider hole until it stops.
9. Coat the sensor with Mobil HP, Valvoline EP 633, Penzoil 707L, or an equivalent lubricant. Press the sensor into the clamping bushing until it is stopped by the tone wheel.
10. Remove the chocks from the rear tires.

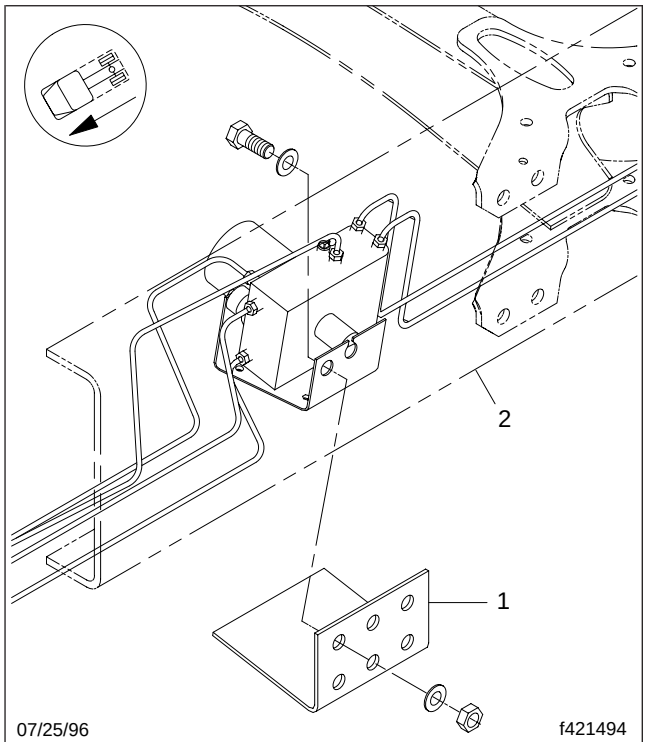
REAR AXLE

1. Apply the parking brakes. Chock the front tires.
2. Raise the rear of the vehicle until the tires clear the ground. Place safety stands under the axle.
3. Twist and pull the sensor to remove it from the mounting block in the axle housing.
4. Remove the clamping bushing.
5. Remove the capscrew that attaches the sensor cable and the hose clamp to the axle tube.
6. Disconnect the sensor cable from the chassis harness.
7. Connect the new sensor cable to the chassis harness.
8. Attach the hose clamp and sensor cable to the axle tube located between the backing plate and the spring plate.
9. Press the clamping bushing into the mounting block until it stops.
10. Coat the sensor with Mobil HP, Valvoline EP633, Penzoil 707L, or an equivalent lubricant. Using your hand, push the sensor into the clamping bushing until it is stopped by the tone wheel.
11. Remove the safety stands, lower the vehicle, and remove the chocks from the front tires.

Replacement

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals. See **Group 54** in this manual for information on special terminals and connectors, and on ordering tools for them.

1. Chock the front and rear tires.
2. Put a container under the modulator to catch leaking brake fluid. See **Fig. 1**.



1. Modulator Mounting Bracket
2. Left Frame Rail

Fig. 1, Brake Pressure Modulator Mounting

3. Disconnect the wiring from the modulator.
4. Mark the brake lines for ease of installation. Disconnect the lines.
5. Remove the mounting capscrews, washers, and nuts that attach the modulator and bracket assembly to the bracket on the frame rail.
6. Remove the modulator and bracket assembly.

IMPORTANT: When replacing the modulator, make sure the new modulator is pre-charged.

7. Install the new modulator using the above instructions in reverse order. Tighten the modulator and bracket assembly mounting nuts 132 lbf·in (1500 N·cm). Tighten the brake line connections 108 lbf·in (1220 N·cm).
8. Bleed the brake system following the instructions in **Subject 120**.

Hydraulic System Bleeding

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 don't use brake fluid containers for any other purpose. Keep brake fluid containers tightly closed to keep new brake fluid clean and dry.

IMPORTANT: Don't let brake fluid touch any painted surfaces, as it will remove the paint. Brake fluid may also damage certain non-metal surfaces. Don't let it get on brake pads or rotors.

PRESSURE BLEEDING, SERVICE BRAKE SYSTEM

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. Apply the parking brake, chock the tires, and tilt the hood.
2. Connect the pressure bleeder to the brake master cylinder reservoir, following the manufacturer's instructions.
   - 2.1 Fill the pressure bleeder with new DOT 3 approved brake fluid, then pressurize it according to the manufacturer's instructions.
   - 2.2 Using the supplied adapter, connect the pressure bleeder to the rear compartment of the master cylinder reservoir.

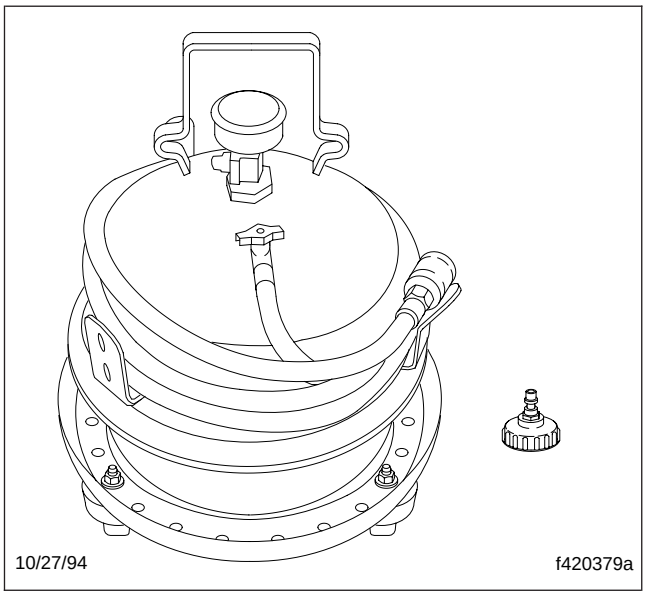


Fig. 1, Pressure Bleeder Kit

3. Bleed the hydraulic connections at the rear wheel calipers, starting on the right side.
   - 3.1 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**.
   - 3.2 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. See **Fig. 2** and **Fig. 3**. Then tighten the fitting firmly.
   - 3.3 Move to the left rear caliper, and repeat steps for bleeding the caliper.
4. Disconnect the pressure bleeder from the rear compartment of the master cylinder reservoir, then connect it to the front compartment of the reservoir.
5. Bleed the front wheel brake calipers, starting at the right side.
   - 5.1 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**.

Hydraulic System Bleeding

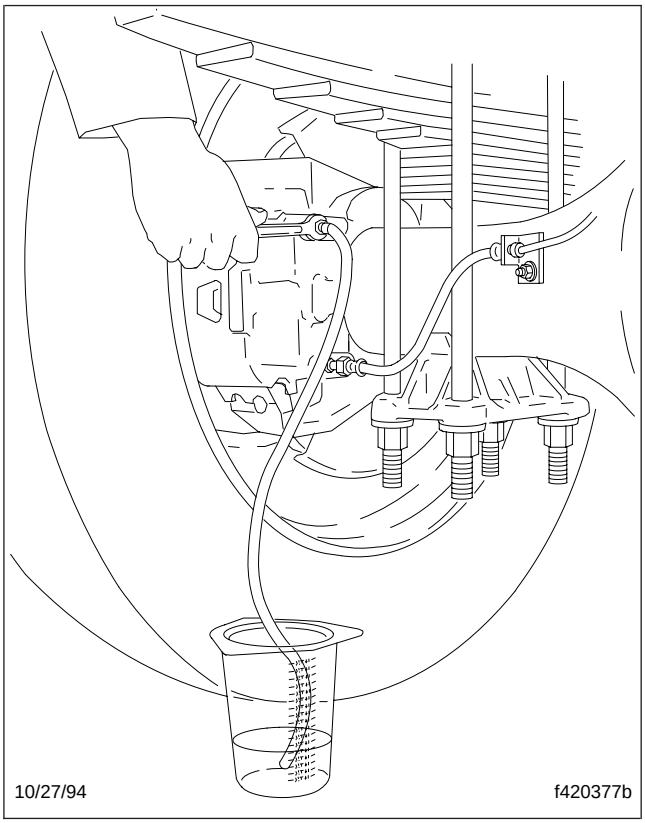
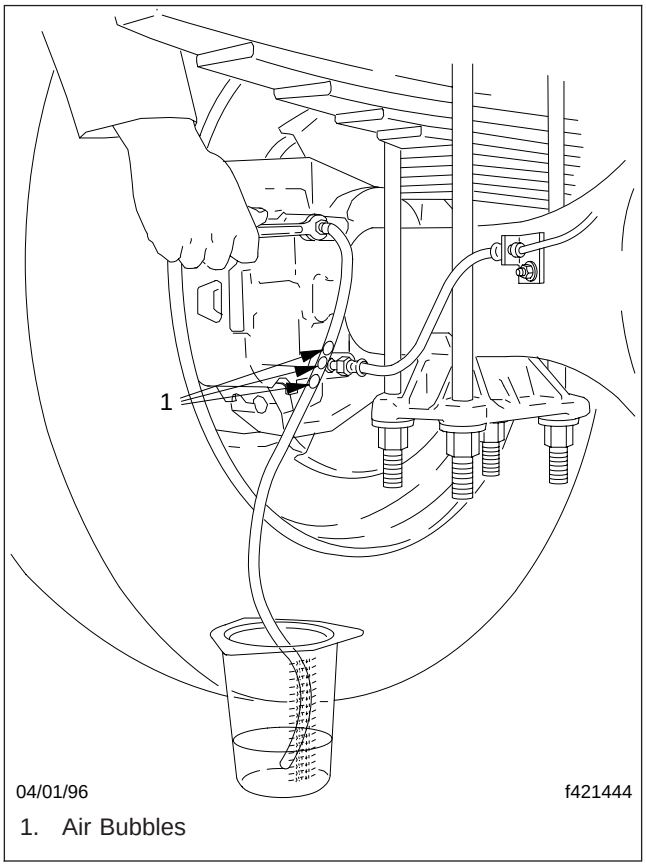


Fig. 2, Bleed the Connections at the Rear Wheel Calipers

5.2 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. See **Fig. 2** and **Fig. 3**. Then tighten the fitting firmly.

5.3 Move to the left front wheel caliper, and repeat the steps for bleeding the caliper.

6. Check the brake fluid level in both compartments of the reservoir. Add new DOT 3 approved brake fluid if needed.
7. 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, go to the troubleshooting subject in **Section 42.09** (Hydraulic Brake System) and find the problem.
8. Lower the hood and remove the chocks.



1. Air Bubbles

Fig. 3, Loosen the Bleeder Fitting

MANUAL BLEEDING, SERVICE BRAKE SYSTEM

If you don't have pressure bleeding equipment, you can use the manual bleeding procedure.

IMPORTANT: Don't 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. Failure to keep the brake reservoir filled could result in more air entering the system, making it impossible to effectively bleed the system.

1. Apply the parking brake, chock the tires, and tilt the hood.
2. Bleed the master cylinder.

2.1 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. 4**. Loosen the fitting about one turn.

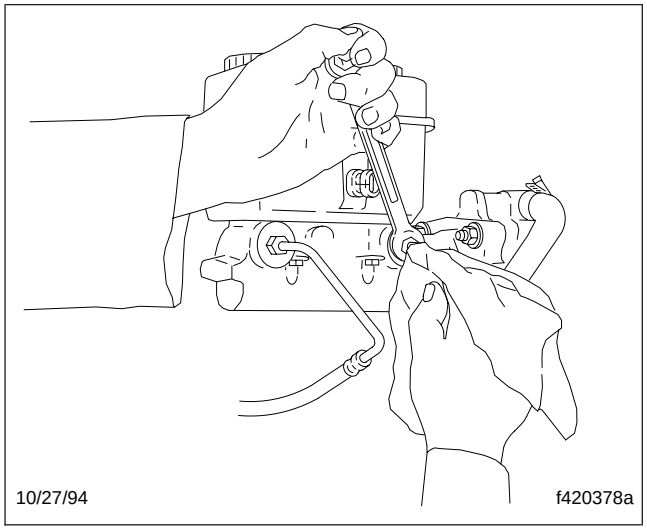


Fig. 4, Loosen the Fitting at the Rear Outlet Port

2.2 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.

2.3 *With the brake pedal held down,* tighten the rear hydraulic line fitting firmly.

IMPORTANT: Don't release the brake pedal until the fitting is tightened, or more air will get into the system.

2.4 Release the brake pedal.

2.5 Loosen the fitting again, and repeat the steps for bleeding as required until no air escapes from the fitting, and the brake pedal feels firm.

2.6 Check the brake fluid level in the rear compartment of the reservoir, then add new DOT 3 approved brake fluid if needed.

2.7 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. 5**. Loosen the fitting about one turn.

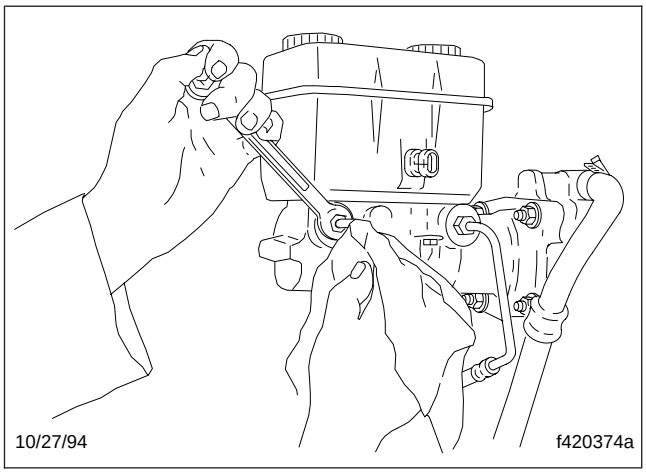


Fig. 5, Loosen the Fitting at the Front Outlet Port

2.8 Repeat the steps as required for the front outlet port.

2.9 Check the brake fluid level in the front compartment of the reservoir. Add new DOT 3 approved brake fluid if needed.

3. Bleed the hydraulic connections at the wheel calipers, starting at the right rear wheel caliper.

3.1 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**.

3.2 Loosen the bleeder fitting about 3/4 turn.

3.3 Have someone slowly push the brake pedal to the floor, then *with the brake pedal depressed,* tighten the bleeder fitting.

IMPORTANT: Make sure the brake pedal stays depressed while you tighten the fitting. If it's released before you tighten the fitting, more air will get into the system.

3.4 Release the brake pedal. Check the fluid in the tube. If there are air bubbles present as shown in **Fig. 3**, repeat the steps as required until the fluid in the tube is completely free of air bubbles, as shown in **Fig. 2**.

3.5 Check the brake fluid level in the reservoir. Add new DOT 3 approved brake fluid if needed.

Hydraulic System Bleeding

3.6 Repeat the steps for bleeding the connections for the left rear caliper, then the right front caliper, and finally for the left front caliper.

4. Lower the hood and remove the chocks.

Using the Instrument Panel Blink Codes

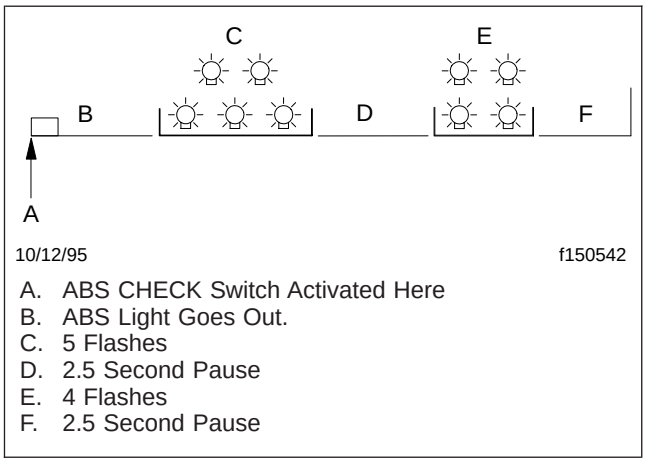
This system has built-in diagnostics to ensure that all components are operating properly. Under normal conditions, the ABS warning light comes on when the ignition is turned on. After about three seconds the light should go out if all of the ABS components are working. If the light stays on, or comes back on later, a problem within the ABS system has occurred. The vehicle can continue to be driven, but the ABS system could be partially or completely inoperative. To check the fault code recorded, stop the vehicle and turn off the engine. Then, turn on the ignition switch, but don't start the engine. If the light is still on, there is an "active" system fault that must be repaired to ensure proper system operation.

Use the ABS CHECK switch (which is located near the circuit breaker panel in the right side of the dash), and the ABS light to display system faults. With the ignition switch on, turn on the ABS CHK switch. The ABS light should go out. After a two and one-half second pause, the ABS light will blink the first digit of the two-digit fault code. The number of blinks displaying the first digit will be a number between one and six. After another two and one-half second pause, the second digit will be displayed. The number of blinks displaying the second digit will be a number between one and fifteen. After a two and one-half second pause, the diagnostic code cycle continues to repeat the fault code until it is repaired.

For example, after the ABS CHECK switch has been turned on, fault code 5–4 is shown by five flashes, a pause of two and one-half seconds, followed by four flashes. See **Fig. 1**. After a two and one-half second pause, the same fault code will continue to repeat, always ending with a two and one-half second pause.

Once a fault code has been identified, use a volt/ohmmeter to check the electrical harness at the ECU's 35-pin connector, which is located just behind the front door. Connect the ohmmeter leads to the applicable pins on each connector. See **Fig. 2** and **Table 1**, for a description of the circuit wire numbers and their location within the pin connectors.

To make testing easier, use the Meritor WABCO test adaptor. See **Fig. 3**.



A. ABS CHECK Switch Activated Here
B. ABS Light Goes Out.
C. 5 Flashes
D. 2.5 Second Pause
E. 4 Flashes
F. 2.5 Second Pause

Fig. 1, Fault Code 5-4 shown

The Meritor WABCO test adaptor is used to service and troubleshoot the Meritor WABCO ABS system. *It can not be used with a vehicle frame-mounted ECU.* A volt ohmmeter (VOM) can determine the condition of the ABS valves, wheel end sensors, and associated wiring. When used with the procedures and blink codes in *Meritor WABCO Maintenance Manual No. 28, Rev. 12/93 (supersedes No. MM 4V)*, it allows you to measure voltages and resistances of components in the system.

The receptacles of the Meritor WABCO test adaptor accept the tips of standard VOM cables. These tips are about 0.080 inch diameter (2 mm). Any good quality digital or analog VOM can be used. A meter with automatic polarity sensing is recommended so you do not have to worry about correct polarity of the meter leads during voltage measurements.

The test adaptor lets you access the 35-pins in the connector that attaches to the Meritor WABCO Electronic Control Unit (ECU). By inserting the probes of a VOM into the proper holes of the adaptor, sensor resistances, solenoid resistances, power, and grounds can be measured and compared to acceptable values. Sensor adjustment and tone ring runout can also be checked using the adaptor.

IMPORTANT: The ignition switch must be off when connecting or disconnecting the ECU.

NOTE: The blink codes are erased from ECU memory as repairs are made. Once a repair has been made, cycle the ignition to ensure the blink code does not reappear. If there are any other outstanding faults, the next blink code will

Troubleshooting

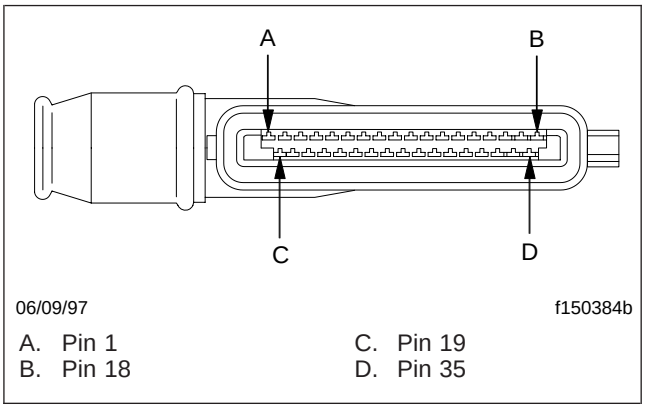


Fig. 2, ECU 35-Pin Connector

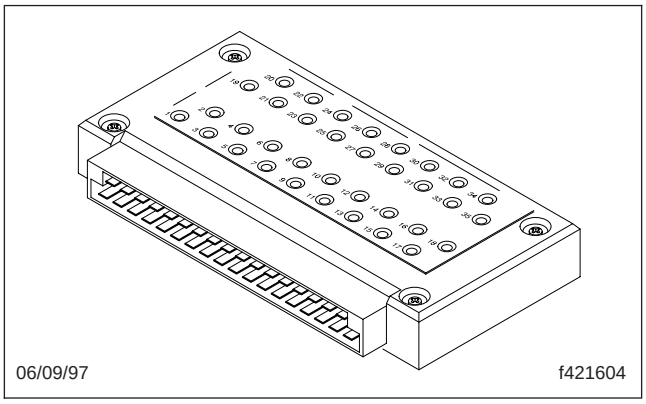


Fig. 3, Test Adaptor

be displayed.

Circuit Wire Numbers and Descriptions		
Pin Number	**Freightliner Wire Number**	**WABCO Circuit Description**
1	X1	ECU Supply/Battery
2	—	—
3	—	—
4	X4	Right Rear Inlet Valve
5	X5	Right Rear Outlet Valve
6	X6	Right Front Inlet Valve
7	X7	Right Front Outlet Valve
8	X8	Valve Relay
9	X9	ECU Ignition Supply
10	X10	Brake Light Input
11	X11	Recirculation Pump Relay
12	—	—
13	X13	Diagnostic Interface
14	X14	Diagnostic Interface/Blink Code Activation
15	X15	Left Front Sensor
16	X16	Right Rear Sensor
17	X17	Right Front Sensor
18	X18	Left Rear Sensor
19	X19	ECU Supply
20	—	—
21	X21	Left Rear Inlet Valve
22	X22	Left Rear Outlet Valve

Circuit Wire Numbers and Descriptions		
Pin Number	**Freightliner Wire Number**	**WABCO Circuit Description**
23	X23	Left Front Inlet Valve
24	X24	Left Front Outlet Valve
25	X25	Brake Light Input
26	X26	ABS Warning Light
27	X27	ECU Ground
28	—	—
29	—	—
30	X30	Recirculation Pump Control
31	X31	Modulator Ground
32	X32	Left Front Sensor
33	X33	Right Rear Sensor
34	X34	Right Front Sensor
35	X35	Left Rear Sensor

Table 1, Circuit Wire Numbers and Descriptions

If the ABS light does not operate correctly after the ignition is turned on (the light doesn't come on at all or it doesn't go out after about three seconds), check all circuit breakers in the control unit panel, and replace if necessary. Check the wiring to the ABS CHECK switch and the warning lamp, and repair or replace the wiring as needed. When checking the warning lamp, do the following:

- Replace the bulb.
- Check voltage potential at the socket.
- Check continuity of the wires to the socket.

When checking the switch, do the following:

- Check the resistance between the terminals while cycling the switch.
- Check the continuity of the wires to the switch.

Make sure that a charged 12-volt battery is available (the ABS system needs at least 11 volts to work).

See **Table 2** through **Table 8** for a listing of all fault codes, pins to be tested, and the correct volt/ohmmeter readings. Repair or replace the components and/or wiring if the readings are not correct.

NOTE: Wire repairs may require the use of special tools for certain connectors and terminals.

See **Group 54** in this manual for information on special terminals and connectors, and ordering tools for them.

WABCO ABS Fault Codes and Tests (2-0 through 2-11)				
Key Switch On to Determine ABS Blink Fault Code		**Key Switch Off to Test System**		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
2–0	Internal electronic control unit fault.	—	—	Replace the electronic control unit.

Troubleshooting

WABCO ABS Fault Codes and Tests (2-0 through 2-11)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	Problem	Begin by Testing These Pins	Volt, Amp, and Ohmmeter Reading	Remedy
2–1	Internal electronic control unit fault.	—	—	Replace the electronic control unit.
2–2	Recirculation pump operates continuously.	—	—	Check the recirculation pump wiring (circuits 11 & 30), the pump relay, and the wiring connections. Repair or replace as needed.
2–3	Recirculation pump does not work.	—	—	Jump pins 9 and 11, and you should hear the pump motor run. Check the recirculation pump wiring, the relay circuit, and the pump connections.
2–4	Recirculation pump motor locked.	9 and 11	0.30 A	Jump pins 9 and 11, and you should hear the pump motor run. Check the recirculation pump wiring, the relay circuit, and the pump connections.
2–6	Stop light switch has failed.	10 and 25	12 DCV	Measure voltage with the brakes applied. Repair the wiring if needed (circuits 10 & 25). Also, make sure that the 35-pin connector is secure at the ECU.
2–7	Continuous power supply to the ECU with ignition off.	9 and 27	0 DCV	With the ignition off, check the valve relay and wiring connections. Repair or replace as needed.
2–8	No voltage to the inlet or outlet valve.	1, 9 and 27	12 V	Check the valve relay, the wiring (circuits 1 & 8), and the wiring connections. Repair or replace as needed.
2–9	Inlet valve supervision time exceeded.	—	—	Check the valves for normal operation. If okay, clear the faults.
2–10	Modulator reference ground interrupted.	31 and ground	0 ohms	Repair or replace wiring (circuit 31) as needed. Check the chassis ground circuit.
2–11	Recirculation pump cycle time is excessive.	—	—	Check the recirculation pump operation. If okay, clear the fault.

Table 2, WABCO ABS Fault Codes and Tests (2-0 through 2-11)

WABCO ABS Fault Codes and Tests (2-12 through 3-5)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
2–12 Right Front (RF) 2–14 Left Front (LF)	Wheel speed signal is erratic.	(RF), pins 17 and 34 * (LF), pins 15 and 32 *	above 0.20 volt AC	A damaged tone wheel, a sensor needs adjustment, or there is excessive hub runout. Repair or replace as needed.
2–13 Left Rear (LR) 2–15 Right Rear (RR)	Wheel speed signal is erratic.	(LR), pins 18 and 35 * (RR), pins 16 and 33 *	above 0.20 volt AC	A damaged tone wheel, a sensor needs adjustment, or there is excessive hub runout. Repair or replace as needed.
3–0 Right Front (RF)	On the steer axle, there is an open circuit in the RF inlet control valve and/or wiring to the modulator connection.	6 and 27	5 to 7.5 ohms 1.6 amps †	Check the inlet control valve wiring (circuit 6). Repair or replace wiring as needed.
3–1 Right Front (RF)	On the steer axle, there is an open circuit in the RF outlet control valve and/or wiring to the modulator connection.	7 and 27	3 to 5 ohms 2.5 amps †	Check the outlet control valve wiring (circuit 7). Repair or replace wiring as needed.
3–2 Left Front (LF)	On the steer axle, there is an open circuit in the LF inlet control valve and/or wiring to the modulator connection.	23 and 27	5 to 7.5 ohms 1.6 amps †	Check the inlet control valve wiring (circuit 23). Repair or replace the wiring as needed.
3–3 Left Front (LF)	On the steer axle, there is an open circuit in the LF outlet control valve and/or wiring to the modulator connection.	24 and 27	3 to 5 ohms 2.5 amps †	Check the outlet control valve wiring (circuit 24). Repair or replace the wiring as needed.
3–4 Right Rear (RR)	On the rear axle, there is an open circuit in the RR inlet control valve and/or wiring to the modulator connection.	4 and 27	5 to 7.5 ohms 1.6 amps †	Check the inlet control valve wiring (circuit 4). Repair or replace the wiring as needed.
3–5 Right Rear (RR)	On the rear axle, there is an open circuit in the RR outlet control valve and/or wiring to the modulator connection.	5 and 27	3 to 5 ohms 2.5 amps †	Check the outlet control valve wiring (circuit 5). Repair or replace the wiring as needed.

* After connecting the volt/ohmmeter test leads, rotate the applicable tire at about 30 rpm (1 revolution every 2 seconds).

† Desired readings are with the battery potential at approximately 12.5 volts.

Table 3, WABCO ABS Fault Codes and Tests (2-12 through 3-5)

Troubleshooting

WABCO ABS Fault Codes and Tests (3-6 through 4-6)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
3–6 Left Rear (LR)	On the rear axle, there is an open circuit in the inlet control valve and/or wiring to the modulator connection.	21 and 27	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 21). Repair or replace the wiring as needed.
3–7 Left Rear (LR)	On the rear axle, there is an open circuit in the outlet control valve and/or wiring to the connection.	22 and 31	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 22). Repair or replace the wiring as needed.
3–8	Open circuit between the ECU and the recirculation pump relays.	22 and 31	—	Jump pins 9 & 11, and if the pump doesn't run, check circuit 11 and the recirculation pump relay.
4–0 Right Front (RF)	On the steer axle, there is a short circuit to ground between the ECU and the RF inlet control valve.	6 and 27	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 6). Repair or replace the wiring as needed.
4–1 Right Front (RF)	On the steer axle, there is a short circuit to ground between the ECU and the RF outlet control valve.	7 and 27	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 7). Repair or replace the wiring as needed.
4–2 Left Front (LF)	On the steer axle, there is a short circuit to ground between the ECU and the LF inlet control valve.	23 and 27	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 23). Repair or replace the wiring as needed.
4–3 Left Front (LF)	On the steer axle, there is a short circuit to ground between the ECU and the LF outlet control valve.	24 and 27	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 24). Repair or replace the wiring as needed.
4–4 Right Rear (RR)	On the rear axle, there is a short circuit to ground between the ECU and the RR inlet control valve.	4 and 27	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 4). Repair or replace the wiring as needed.
4–5 Right Rear (RR)	On the rear axle, there is a short circuit to ground between the ECU and the RR outlet control valve.	5 and 27	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 5). Repair or replace the wiring as needed.
4–6 Left Rear (LR)	On the rear axle, there is a short circuit to ground between the ECU and the LR inlet control valve.	21 and 27	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 21). Repair or replace the wiring as needed.

* Desired readings are with the battery potential at approximately 12.5 volts.

Table 4, WABCO ABS Fault Codes and Tests (3-6 through 4-6)

WABCO ABS Fault Codes and Tests (4-7 through 5-3)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
4–7 Left Rear (LR)	On the rear axle, there is a short circuit to ground between the ECU and the LR outlet control valve.	22 and 27	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 22). Repair or replace the wiring as needed.
4–8	Short circuit to ground between the ECU and the recirculation pump relay.	11, 30 and 27	Open Circuit	Check continuity through the pump to ground. Check the pump connector. Repair or replace wiring as needed.
4–12 Right Front (RF) 4–14 Left Front (LF)	Sensor open circuit.	(RF), pins 17 and 34 † (LF), pins 15 and 32 †	above 0.20 volt AC	Check the sensor wiring. Repair or replace as needed.
4–13 Left Rear (LR) 4–15 Right Rear (RR)	Sensor open circuit.	(LR), pins 18 and 35 † (RR), pins 16 and 33 †	above 0.20 volt AC	Check the sensor wiring. Repair or replace as needed.
5–0 Right Front (RF)	On the steer axle, there is a short circuit to the battery between the ECU and the RF inlet control valve.	6 and 9	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 6). Repair or replace the wiring as needed
5–1 Right Front (RF)	On the steer axle, there is a short circuit to the battery between the ECU and the RF outlet control valve.	7 and 9	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 7). Repair or replace the wiring as needed.
5–2 Left Front (LF)	On the steer axle, there is a short circuit to the battery between the ECU and the LF inlet control valve.	23 and 9	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 23). Repair or replace the wiring as needed.
5–3 Left Front (LF)	On the steer axle, there is a short circuit to the battery between the ECU and the LF outlet control valve.	24 and 9	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 24). Repair or replace the wiring as needed.

* Desired readings are with the battery potential at approximately 12.5 volts.

† After connecting the volt/ohmmeter test leads, rotate the applicable tire at about 30 rpm (1 revolution every 2 seconds).

Table 5, WABCO ABS Fault Codes and Tests (4-7 through 5-3)

Troubleshooting

WABCO ABS Fault Codes and Tests (5-4 through 6-0)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
5–4 Right Rear (RR)	On the rear axle, there is a short circuit to the battery between the ECU and the RR inlet control valve.	4 and 9	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 4). Repair or replace the wiring as needed.
5–5 Right Rear (RR)	On the rear axle, there is a short circuit to the battery between the ECU and the RR outlet control valve.	5 and 9	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 5). Repair or replace the wiring as needed.
5–6 Left Rear (LR)	On the rear axle, there is a short circuit to the battery between the ECU and the LR inlet control valve.	21 and 9	5 to 7.5 ohms 1.6 amps *	Check the inlet control valve wiring (circuit 21). Repair or replace the wiring as needed.
5–7 Left Rear (LR)	On the rear axle, there is a short circuit to the battery between the ECU and the LR outlet control valve.	22 and 9	3 to 5 ohms 2.5 amps *	Check the outlet control valve wiring (circuit 22). Repair or replace the wiring as needed.
5–8	Short circuit to battery between the ECU and the recirculation pump relay.	30 and 11	Open Circuit	Repair or replace wiring as needed. Check the pump ground connection.
5–12 Right Front (RF) 5–14 Left Front (LF)	Wheel speed signal is erratic.	pins 17 and 34 pins 15 and 32	Above 0.2 volts AC	An incorrect or damaged tone wheel. Replace the tone wheel and rotor if needed. Also, check the tire sizes for possible mismatch, and check for correct wheel bearing adjustment.
5–13 Left Rear (LR) 5–15 Right Rear (RR)	Wheel speed signal is erratic.	pins 18 and 35 pins 16 and 33	Above 0.2 volts AC	An incorrect or damaged tone wheel. Replace the tone wheel and rotor if needed. Also, check the tire sizes for possible mismatch, and check for correct wheel bearing adjustment.
6–0 Right Front (RF)	On the steer axle, there is a short circuit in the RF inlet control valve wiring to other wiring.	4, 5, 6, 7, 21, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 6 and the other control valve circuits. Replace the modulator if the short is located within the valve.

* Desired readings are with the battery potential at approximately 12.5 volts.

Table 6, WABCO ABS Fault Codes and Tests (5-4 through 6-0)

WABCO ABS Fault Codes and Tests (6-1 through 6-8)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	Problem	Begin by Testing These Pins	Volt, Amp, and Ohmmeter Reading	Remedy
6–1 Right Front (RF)	On the steer axle, there is a short circuit in the RF outlet control valve wiring to other wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 7 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–2 Left Front (LF)	On the steer axle, there is a short circuit in the LF inlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 23 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–3 Left Front (LF)	On the steer axle, there is a short circuit in the LF outlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 24 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–4 Right Rear (RR)	On the rear axle, there is a short circuit in the RR inlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 4 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–5 Right Rear (RR)	On the rear axle, there is a short circuit in the RR outlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 5 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–6 Left Rear (LR)	On the rear axle, there is a short circuit in the LR inlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 21 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–7 Left Rear (LR)	On the rear axle, there is a short circuit in the LR outlet control valve wiring to other valve wiring.	4, 5, 6, 7, 21, 22, 23, and 24	Open circuit	Repair or replace the wiring if continuity exists between circuit 22 and the other control valve circuits. Replace the modulator if the short is located within the valve.
6–8	Short circuit to the battery between a solenoid valve and recirculation pump relay.	11 and 27	0 ohms	Check the 35-pin connector and the ECU.

Table 7, WABCO ABS Fault Codes and Tests (6-1 through 6-8)

Troubleshooting

WABCO ABS Fault Codes and Tests (6-12 through 6-15)				
Key Switch On to Determine ABS Blink Fault Code		Key Switch Off to Test System		
WABCO Fault Code	**Problem**	**Begin by Testing These Pins**	**Volt, Amp, and Ohmmeter Reading**	**Remedy**
6–12 Right Front (RF) 6–14 Left Front (LF)	Wheel speed signal is missing.	pins 17 and 34 pins 15 and 32	Above 0.2 volts AC	The gap is too large, adjust the sensor.
6–13 Left Rear (LR) 6–15 Right Rear (RR)	Wheel speed signal is missing.	pins 18 and 35 pins 16 and 33	Above 0.2 volts AC	The gap is too large, adjust the sensor.

Table 8, WABCO ABS Fault Codes and Tests (6-12 through 6-15)

See the wiring diagram in **Specifications 400** when troubleshooting the ABS system. The key switch must be turned on (engine off) to activate the blink codes.

If a fault still can't be repaired, or erased from ECU memory, contact your Meritor District Service Manager, or call Meritor WABCO at 1–800–535–5560.

ERASING A FAULT FROM THE ECU MEMORY

NOTE: An existing fault cannot be erased until it has been corrected.

Meritor WABCO recommends that you erase all faults from the ECU memory after they have been noted and corrected.

Faults can only be erased one at a time. A fault is erased from the ECU memory by doing the following:

1. Turn the blink code switch on.
2. Wait until the blink code light stops flashing.
3. Turn the ignition off, then on.

See **Fig. 1** for a full view of the wiring diagram for troubleshooting 4S/4M ABS systems using instrument panel blink codes. See **Fig. 2** for a plumbing diagram of the hydraulic ABS system.

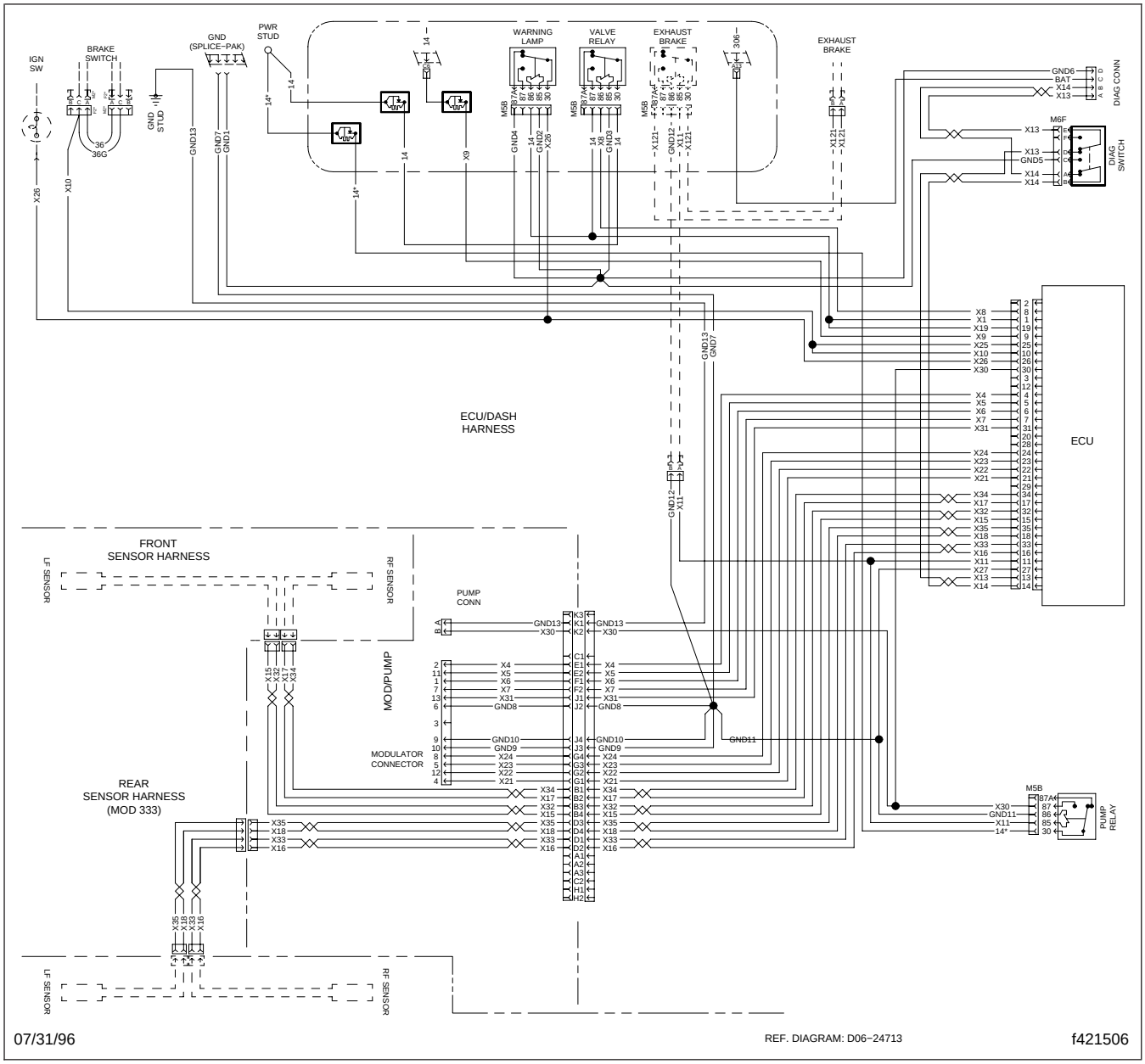
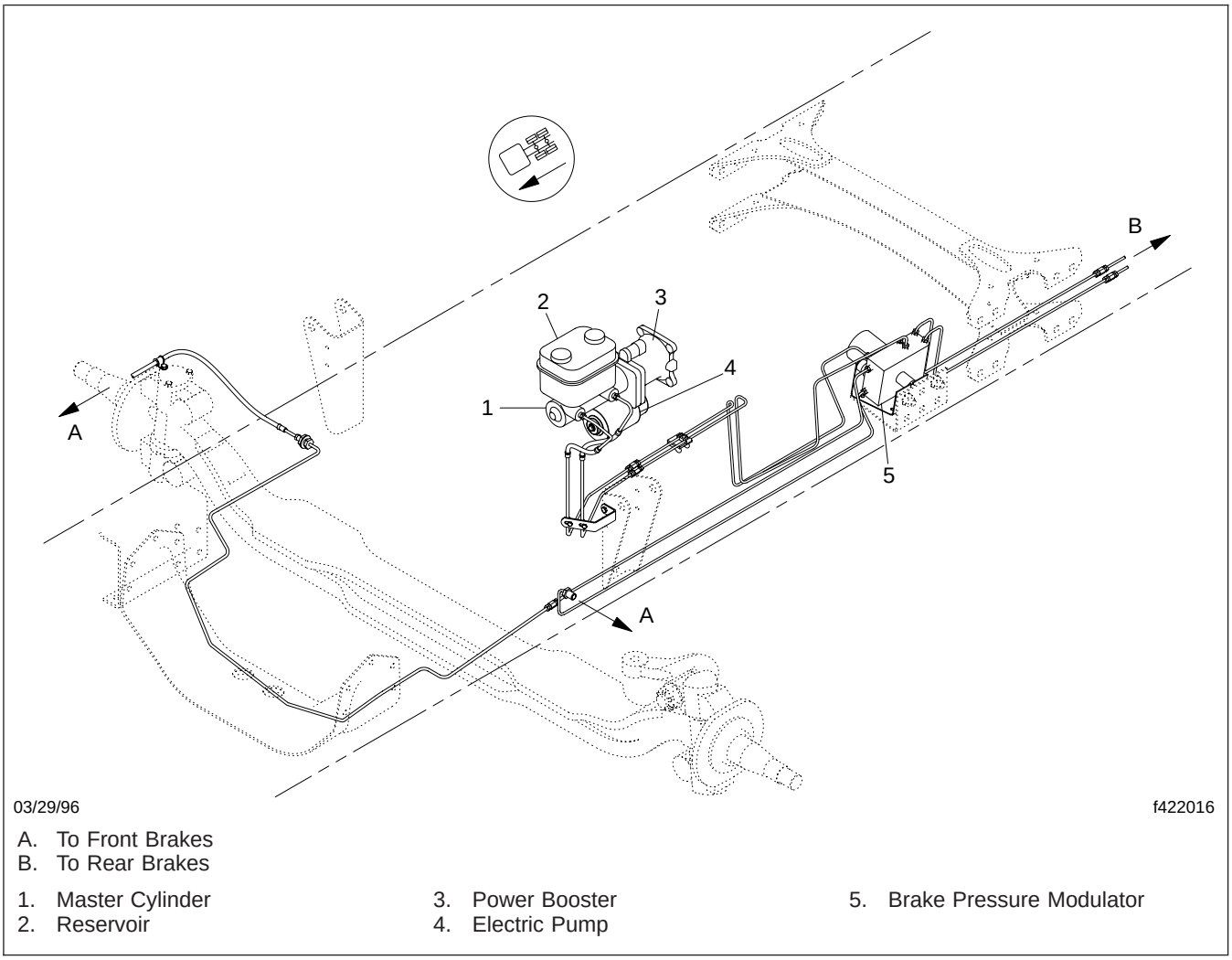


Fig. 1, Chassis Wiring Diagram for Troubleshooting 4S/4M ABS Systems

Specifications



A. To Front Brakes
B. To Rear Brakes

1. Master Cylinder
2. Reservoir
3. Power Booster
4. Electric Pump
5. Brake Pressure Modulator

Fig. 2, Hydraulic ABS Plumbing

General Description

The Luk-Automotive Hydraulics (formerly Vickers) LF 73 power steering pump supplies power steering fluid for the operation of the power steering gear.

The pump is mounted on the driver's side of the engine, at the rear of the gear case, or the air compressor. See **Fig. 1**. It is powered by an adaptor gear in the engine.

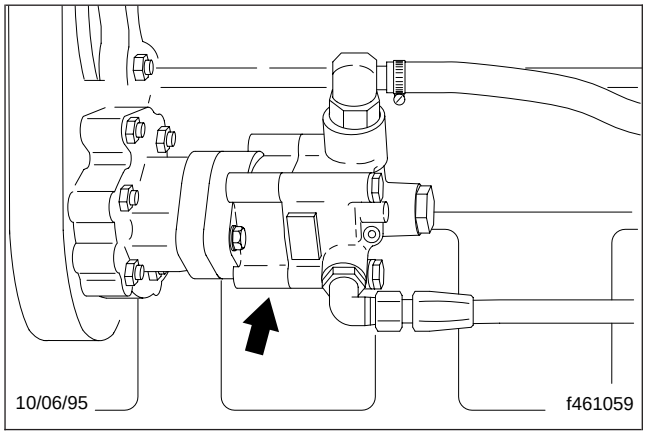


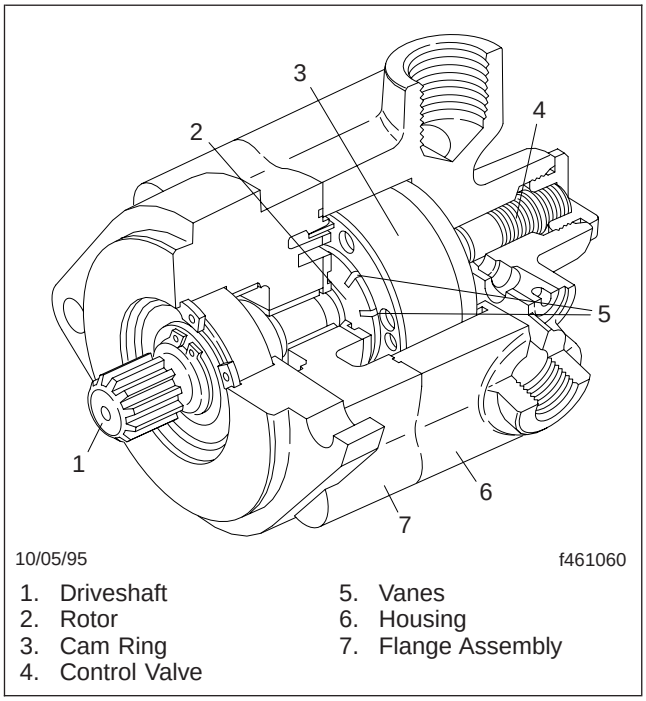
Fig. 1, Pump Mounting (at the rear of the gear case)

The main parts of the power steering pump are the housing, driveshaft, cam ring, rotor, vanes, and control valve. See **Fig. 2**.

Principles of Operation

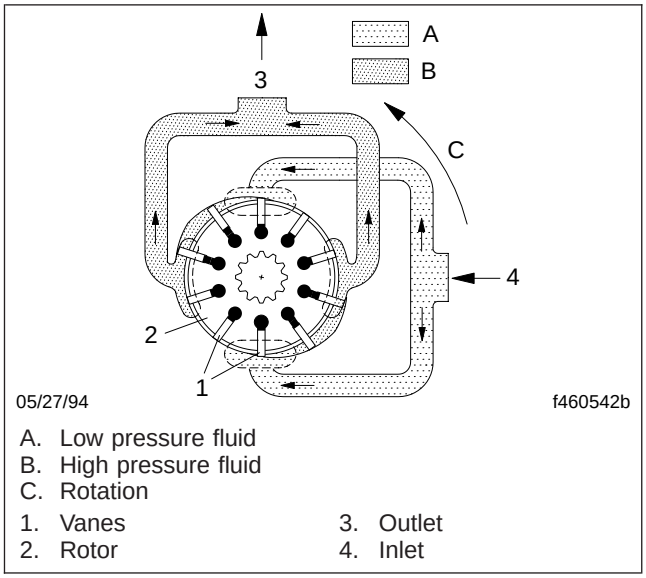
The driveshaft, powered by the adaptor gear in the engine gear case, turns the rotor, which is inside the cam ring. As the rotor turns, centrifugal force pushes the vanes out toward the surface of the cam ring. As fluid enters the cam ring through the inlet port, the rotor vanes force it out through the outlet port, and into the system. The fluid operates the steering gear. Eventually the fluid returns to the power steering reservoir, and then back to the power steering pump. See **Fig. 3**.

If the system pressure gets too high, a poppet inside the control valve is forced off its seat, shunting fluid into a relief passage connected to the inlet port. The fluid then recirculates inside the pump instead of going to the outlet port. When the system pressure drops to the correct level, the poppet seats, closing off the relief passage to the inlet port. The fluid flow returns to normal, flowing from the inlet port to the outlet port and then into the power steering system.



1. Driveshaft
2. Rotor
3. Cam Ring
4. Control Valve
5. Vanes
6. Housing
7. Flange Assembly

Fig. 2, Pump Components



A. Low pressure fluid
B. High pressure fluid
C. Rotation

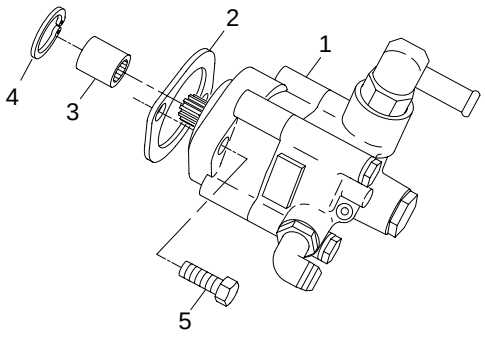
1. Vanes
2. Rotor
3. Outlet
4. Inlet

Fig. 3, Pump Fluid Flow Diagram

Removal

1. Apply the parking brakes, chock the tires, then tilt the hood.
2. Clean all outside dirt from around the fittings and hose connections.
3. Put a container under the inlet port of the pump, then disconnect the fitting. Plug the hose to keep out dirt and to prevent fluid from leaking.

   Repeat this step at the pump outlet port.
4. Remove the mounting capscrews that attach the pump to the air compressor or the engine accessory drive mounting flange. See **Fig. 1**. Slide the pump out of the shaft coupling or sleeve, and remove the pump from the engine.



08/28/2002 f461061b

1. Pump
2. Gasket
3. Coupling
4. Coupling Clip
5. Capscrew

Fig. 1, Cummins and Caterpillar Pump Mounting

Installation

1. Using engine oil, lightly lubricate a new gasket and the pump shaft.
2. Install the new gasket on the pump mounting flange, then place the pump on the air compressor or the engine's accessory drive mounting. See **Fig. 1**. Turn the pump or shaft as needed to mesh the shaft with the shaft coupling or sleeve. Seat the pilot of the pump mounting flange in the accessory drive mounting (or in the air compressor mounting), without applying unneccessary force. Install the mounting capscrews. Tighten the capscrews 32 to 37 lbf·ft (43 to 50 N·m).
3. Connect the hoses to the pump inlet and outlet ports.
4. Check the fluid level of the power steering reservoir and add fluid if neccessary. Start the engine and let it idle for two minutes. Do not turn the steering wheel; doing so can cause air to enter the system.

   Turn off the engine, and check the fluid level in the reservoir.
5. Start the engine again. To remove air from the system, steer the vehicle from full-left to full-right several times.

   Add fluid as necessary to the full line on the reservoir dipstick.
6. If the steering gear doesn't have a manual bleed screw, turn the steering wheel from full-lock to full-lock two or three times with the engine running at idle. Repeat this step, and add fluid as neccessary until there are no bubbles in the reservoir.

   If the steering gear is equipped with a manual bleed screw, turn the steering wheel from full-lock to full-lock two or three times with the engine running at idle. Then loosen the manual bleed screw about one turn and look for clear fluid or fluid mixed with bubbles at the threaded area of the bleed screw. Repeat this step and add fluid as necessary until only clear fluid shows. Tighten the manual bleed screw 27 to 33 lbf·in (300 to 360 N·cm). Refill the reservoir to the full line on the dipstick if necessary.
7. Lower the hood, then remove the chocks from the tires.

Steering Pump Shaft Seal Replacement

CAUTION

CAUTION: Be careful when working on the pump housing; it is aluminum, and can be easily damaged. When putting it in a vise, pad the vise jaws; tighten the vise just enough to hold the pump.

Replacement

WARNING

WARNING: Wear safety goggles or glasses when disassembling the power steering pump. Some of the parts are held in place by springs or snap rings, which can release with considerable force, possibly causing injury.

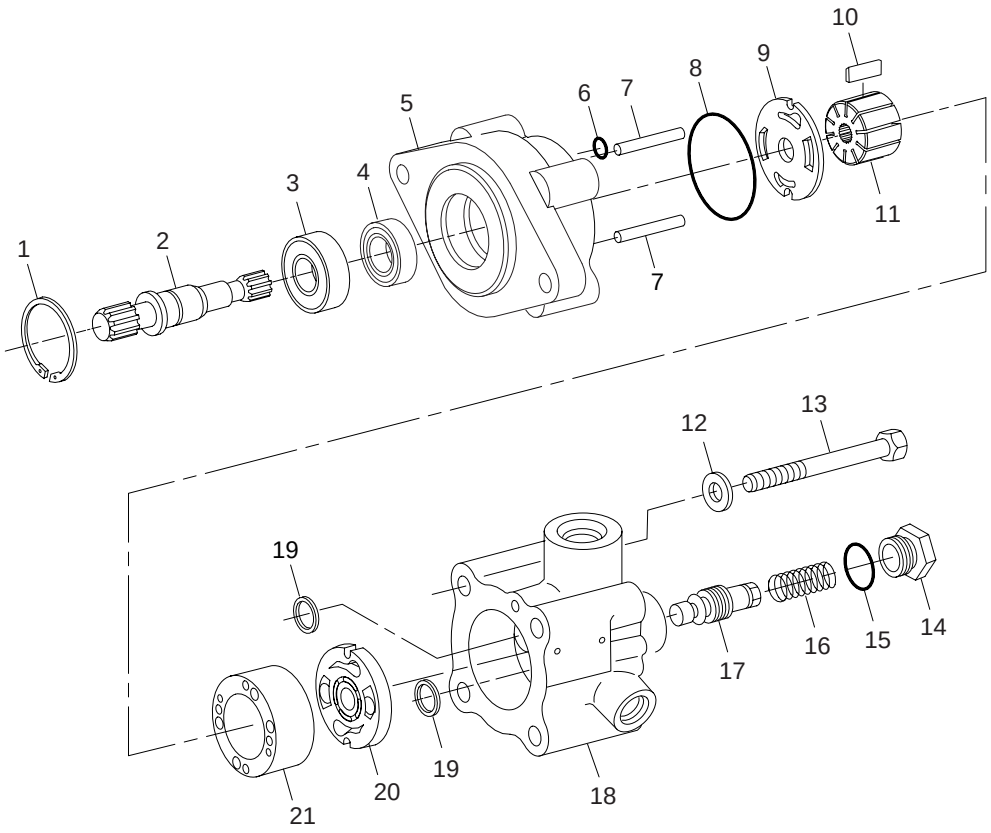
NOTE: The shaft seal kit contains a replacement seal for LF and VT series pumps. The seal for the LF-series pump is smaller.

1. Remove the power steering pump from the engine, following the instructions under **Subject 100**. See **Fig. 1**.
2. Carefully remove the end plug (There is a spring underneath it) from the pump body. Remove the spring, then, slide out the control valve, as shown in **Fig. 2**. Be careful not to scratch the control valve.
3. Remove and discard the O-ring from the plug.
4. Put the pump housing in a padded vise, then remove the four screws holding the housing and the flange assembly together. See **Fig. 3**.
5. Remove and discard the combination O-rings/ back-up rings from the pump housing. See **Fig. 4**.
6. Remove the pressure plate, guide pins, cam ring, rotor, vanes, and wear plate as a unit and set aside.
7. Remove and discard the small and large O-rings from the flange assembly. See **Fig. 5**.
8. Remove the snap ring holding the shaft seal in place. Discard the snap ring. See **Fig. 6**.
9. Put the flange assembly in a vise with the inner end of the shaft pointing up. Carefully tap out the driveshaft. See **Fig.7**.
10. Remove and discard the shaft seal.
11. Clean all the parts, using a solvent compatible with the power steering fluid. Then, using filtered compressed air, dry all the parts.
12. Coat all the parts with clean power steering fluid. See the power steering fluid table in **Specifications, 400**.
13. Place the spacer over the outer (drive) end of the shaft with the cupped side of the spacer facing the inner end of the shaft.
14. Using power steering fluid, lubricate the new shaft seal. Carefully place the seal over the outer (drive) end of the shaft, up against the spacer. The lettered side of the seal should be visible.

NOTE: To correctly install the driveshaft seal, it is necessary to make a suitable driver from tubular stock. See **Fig. 8** for the applicable dimensions.

15. Using a suitable driver, install the shaft seal into the bore in the flange assembly. Make sure the spring side of the seal faces the flange. See **Fig. 9**. Seat the seal firmly against the shoulder in the bore.
16. Install the small snap ring in its groove on the driveshaft, with the sharp edge facing toward the bushing.
17. Put the flange assembly in a padded vise with the drive end of the shaft pointing up. Install a new large O-ring in the flange assembly.
18. Install a new small O-ring in the flange assembly.
19. Install the pressure plate, guide pins, cam ring, rotor, vanes, and wear plate as a unit. Make sure that the two guide pins are seated in the flange assembly.
20. Using power steering fluid, lubricate the new combination O-ring/back-up rings. Install the rings in the pump housing with the black side facing the housing, and the white-plastic side exposed.
21. Install the pump housing over the flange assembly, lining up the mounting holes.
22. Install the four hexbolts and washers in the pump housing. Tighten them in a cross pattern 29 to 37 lbf·ft (40 to 50 N·m).

Steering Pump Shaft Seal Replacement



10/16/95 f461063

1. Snap Ring
2. Driveshaft
3. Driveshaft Bushing
4. Shaft Seal
5. Flange Assembly
6. Small O-Ring
7. Guide Pin
8. Large O-Ring
9. Wear Plate
10. Vane
11. Rotor
12. Washer (4 qty.)
13. Hexbolt (4 qty.)
14. End Plug
15. End Plug O-Ring
16. Spring
17. Control Valve
18. Pump Housing
19. Combination O-Ring/Back-up Ring
20. Pressure Plate
21. Cam Ring

Fig. 1, Steering Pump Assembly

23. Install the control valve in the pump housing.

CAUTION

CAUTION: Make sure you install the control valve correctly in its bore. If it's installed backwards, the power steering pump won't work, and will quickly overheat, which could cause severe damage to the pump.

23.1 Lubricate the control valve with power steering fluid, then install it—with the hex-plug end up—into the bore in the pump housing. See the power steering fluid table in **Specifications, 400**. See **Fig. 10**.

23.2 Install the spring over the hex-plug end of the control valve.

23.3 Install a new O-ring on the end plug, then install the end plug. Tighten it 33 to 40 lbf·ft (45 to 55 N·m).

24. Turn the shaft by hand; it should turn smoothly and without binding.

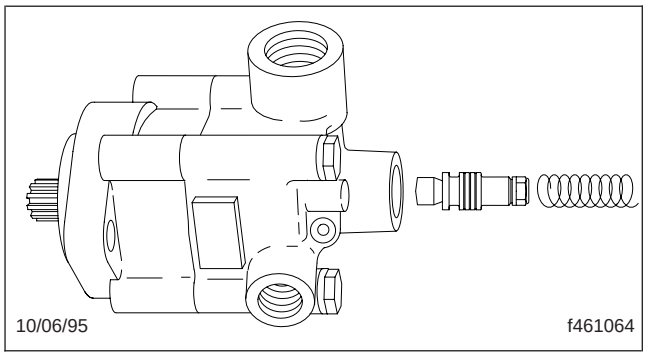


Fig. 2, Slide Out the Control Valve

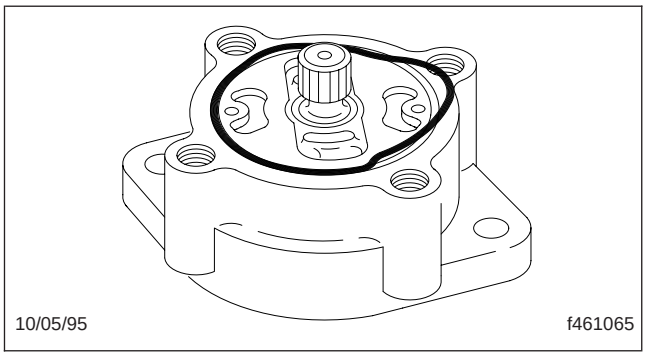


Fig. 5, Remove the Large O-Ring

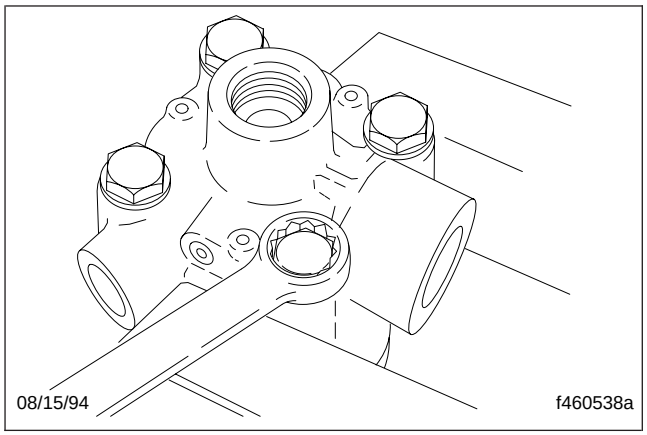


Fig. 3, Remove the Screws

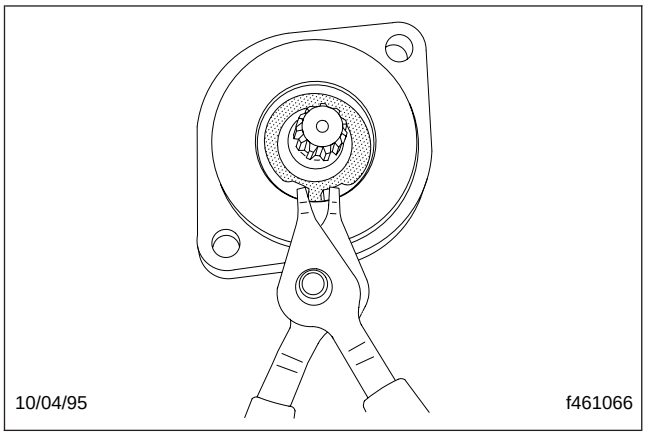


Fig. 6, Remove the Snap Ring

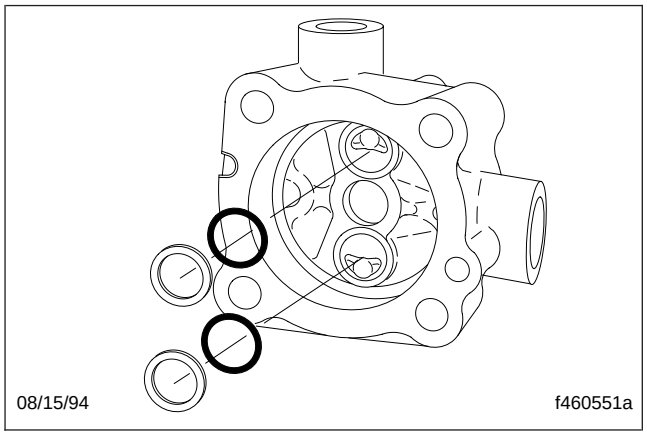


Fig. 4, Remove the Two Combination O-Ring/Back-Up Rings

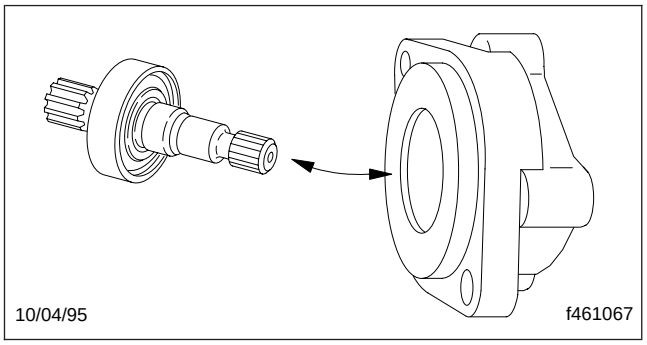
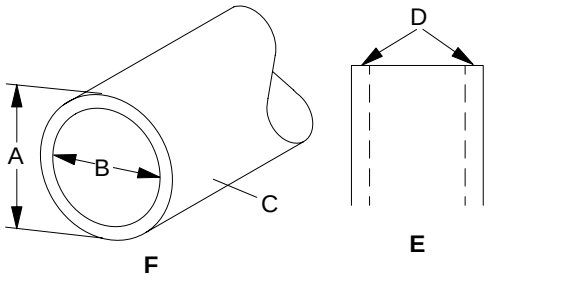


Fig. 7, Tap Out the Driveshaft

25. Install the power steering pump on the engine. For instructions, refer to **Subject 100**.

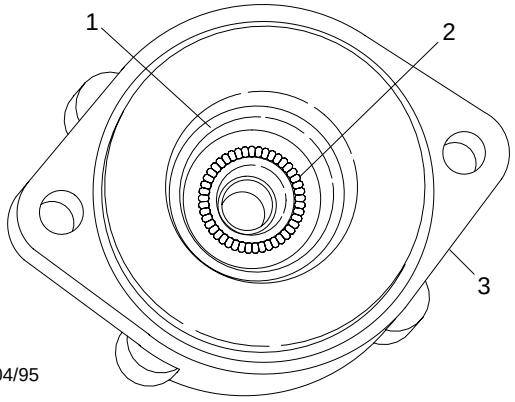
Steering Pump Shaft Seal Replacement



05/10/95 f460546a

A. Slightly smaller than the o.d. of the shaft seal.
B. Slightly larger than the o.d. of the driveshaft.
C. To be made of tubular stock.
D. The ends must be square.
E. Side View
F. Front View

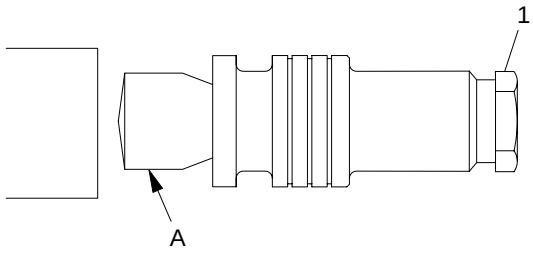
Fig. 8, Shaft Seal Installation Tool



10/04/95 f461068

1. Shaft Seal
2. Garter Spring
3. Flange

Fig. 9, Install the Shaft Seal



08/15/94 f460544a

A. Insert this end first.
1. Hex Plug

Fig. 10, Install the Control Valve

Problem—The Power Steering Pump Doesn't Deliver Fluid

Problem—The Power Steering Pump Doesn't Deliver Fluid	
Possible Cause	**Remedy**
The pump driveshaft is broken, or not engaging.	Replace the pump.
The control valve is stuck open.	Remove the pump. Carefully remove the end plug. Check and see if the control valve is binding in the housing. If it is binding, remove the control valve. If the valve feels gritty, replace it. If not, clean it in a solvent. Install the control valve, then check for any binding in the bore. If the control valve continues to bind, replace it.
Incorrect power steering fluid is used.	Check for the type of fluid used. If it's incorrect, drain, flush, and fill the system with power steering fluid. See the power steering fluid table in **Specifications, 400**.
The pump intake port is blocked.	Drain and flush the system. Fill the system with clean power steering fluid. See the power steering fluid table in **Specifications, 400**.
The air vent in the power steering reservoir is clogged, or the filter is dirty.	Remove the filter cap from the reservoir, then clean the air slot. Check the filter and replace it if needed.
A power steering hose is kinked or blocked.	Repair or replace the hose.

Problem—The Power Steering Pump Is Making Noise

Problem—The Power Steering Pump Is Making Noise	
Possible Cause	**Remedy**
The intake line or filter is plugged.	Drain the system. Clear the intake line if needed, then check the filter. Replace it if needed. Fill the system. See the power steering fluid table in **Specifications, 400**.
There is an air leak at the pump connections, the fittings, the reservoir connections, or the shaft seal.	Check all the connections by pouring power steering fluid over them, then listen for a reduction in sound. Tighten all the connections as needed. If the problem persists, remove the pump, then disassemble it and replace the shaft seal.

Specifications

Steering Gear and Lubricant Type	Recommended Lubricant	
Ross Power Steering Gears With Automatic Transmission Fluid Installed *	Dexron II®	
Ross Power Steering Gears With Heavy-Duty Engine Oil Installed *	Union	10W–40
	Texaco	10W–40
	Chevron	10W–40
	Mobil Super	10W–40
	Union	15W–40
	Shell Rotella	T30W

* Do not mix engine oil with automatic transmission fluid (ATF). Use the same lubricant for parts as is used in the power steering system. Refer to the text in this group for a detailed warning statement.

Table 1, Power Steering Fluid

Description	Torque lbf·ft (N·m)
Pump Mounting Bolts	32–37 (43–50)
Pump Housing-to-Flange Assembly Hexbolts	29–37 (40–50)
Pump End-Plug	33–40 (45–55)
Pump Inlet Connection	26 (35)
Pump Outlet Connection	22 (30)

Table 2, Fastener Torques

General Description

The drag link is nonadjustable, with non-removable socket ball studs at both ends. See **Fig. 1**.

The drag link connects the pitman arm to the front axle steering arm. The socket ball studs, one located at each end, rotate to allow for changing angles between the pitman arm and steering arm as the vehicle is steered and the suspension articulates.

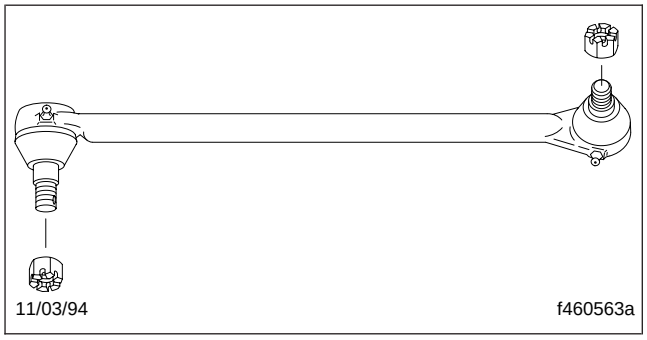


Fig. 1, Nonadjustable Drag Link

Removal

1. Before removing the drag link. If ball stud wear or looseness is suspected, check for wear of the ball studs. Refer to **Subject 110** for instructions.
2. 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.
3. Apply the parking brakes, and chock the rear tires.
4. Release the hood latches, and tilt the hood.
5. Remove the drag link from the vehicle.

    5.1 At both ends of the drag link, remove the cotter pins and loosen the nuts on the socket ball studs. See **Fig. 1** and **Fig. 2**. Be sure the nuts are loosened far enough to allow use of a ball stud removal tool.

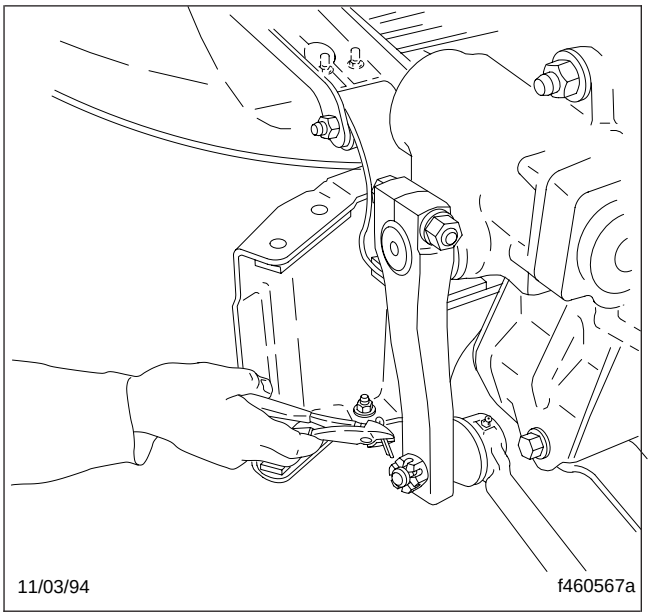


Fig. 1, Remove the Cotter Pin

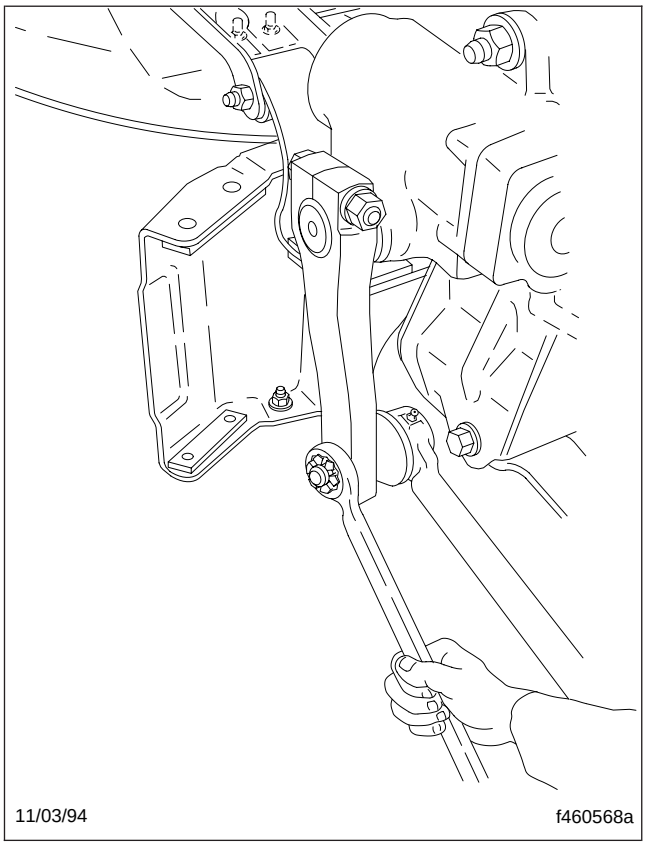


Fig. 2, Loosen the Nut

5.2 Using a ball stud removal tool, loosen the drag link from the pitman arm and the axle steering arm. See **Fig. 3**, **Fig. 4**, and **Fig. 5.**

5.3 Remove the nuts and drag link.

IMPORTANT: Do not steer the gear with the linkage removed; unintended setting of the automatic poppets may result.

Installation

1. Before installing the drag link, check for damage or wear. Replace parts as needed.

    1.1 Check the ball stud covers or dust caps for extreme wear, cuts, or other damage; replace the covers (seals) if needed.

    1.2 Inspect the socket ball studs, ball stud nuts, drag link rod, and grease fittings for

Removal and Installation

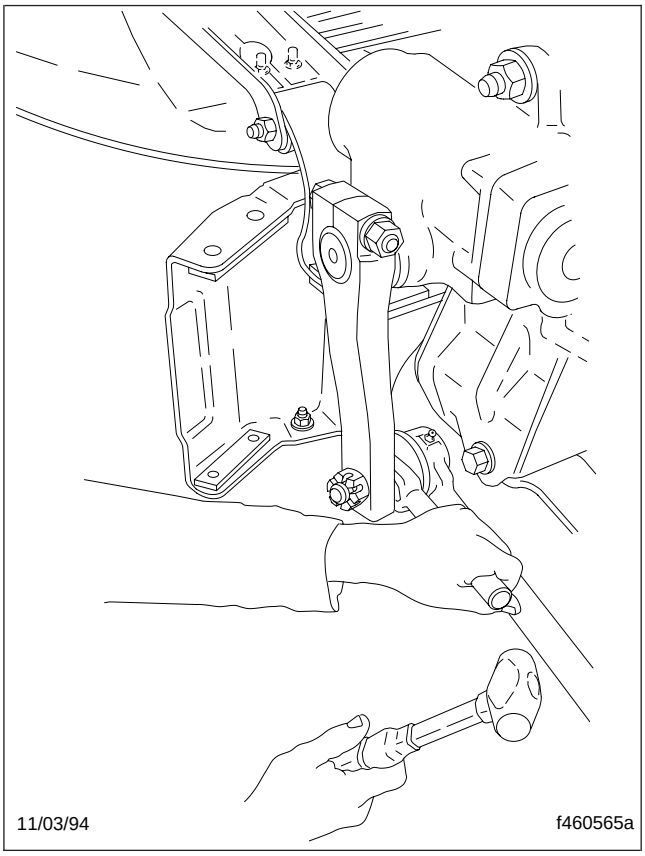


Fig. 3, Loosen the Drag Link from the Pitman Arm

wear or damage. Replace the components as needed.

2. Install the drag link.

   2.1 When installing the drag link, if needed, slightly turn the steering wheel to change the distance between the pitman arm and the steering arm.

   2.2 Tighten the ball stud nuts as follows:

   - 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).

   2.3 If required, continue tightening each nut until a slot on the nut aligns with the hole in the ball stud. *Don't back off the nut when locating the cotter pin hole.*

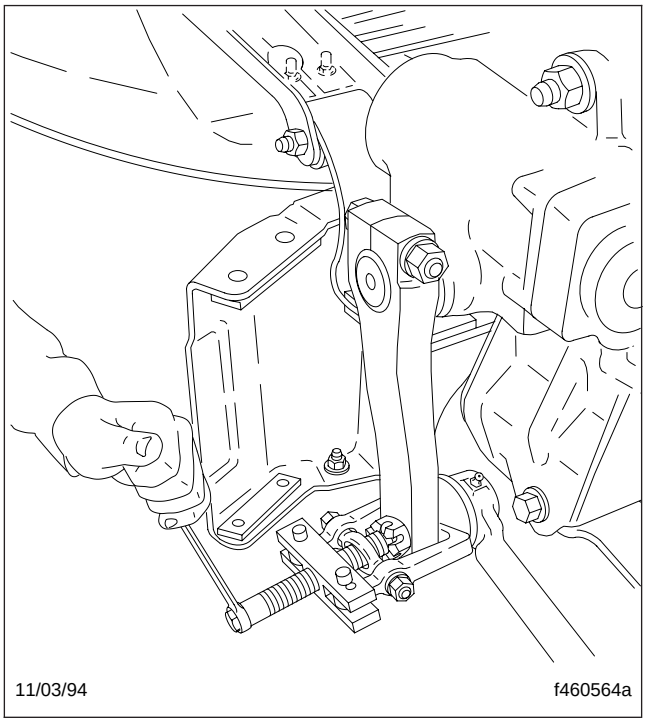


Fig. 4, Position the Ball Stud Removal Tool

   2.4 Install new cotter pins through the ball studs and nuts, and lock the cotter pins in place.

⚠ WARNING

WARNING: Failure to install and lock new cotter pins in the ball studs and nuts could result in disengagement of the parts and loss of steering control. This could cause serious personal injury.

3. Wipe the dirt from the grease fittings. Apply chassis grease until the old grease is forced out.
4. Lower the hood, and fasten the hood latches.
5. Align the steering wheel spokes. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 6**. If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.

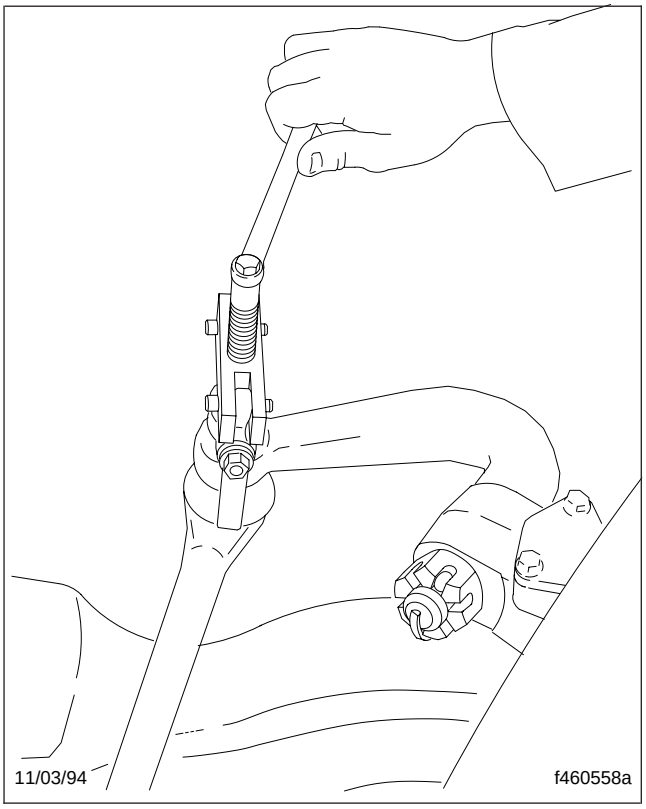


Fig. 5, Remove the Drag Link from the Steering Arm

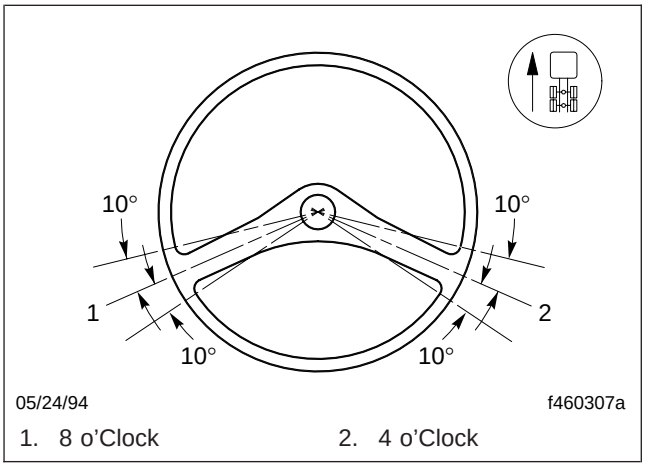


Fig. 6, Steering Wheel Alignment

Testing

Check for wear of the drag link ball stud end, and nut tightness as follows:

Have someone gently turn the steering wheel back and forth; check for looseness between the ball stud end, and both the pitman arm and steering arm. Also check for looseness of the ball stud nut.

If the ball stud *end* is loose, replace the drag link. If the ball stud *nut* is loose, replace the nut and cotter key. Tighten the ball stud nut as follows:

- 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).

Grasp the drag link near the pitman arm end, push and pull laterally to check for axial looseness in the ball stud end. If there is looseness, replace the drag link. For instructions, refer to **Subject 100**. If there is 1/8 inch (3 mm) looseness or more, do not drive the vehicle until the drag link is replaced.

Grasp the drag link near the steering arm end. Push and pull vertically to check for axial looseness in the ball stud end. If there is looseness, replace the drag link. For instructions, refer to **Subject 100**. If there is 1/8 inch (3 mm) looseness or more, do not drive the vehicle until the drag link is replaced.

Grease the drag link until the old grease is purged.

Specifications

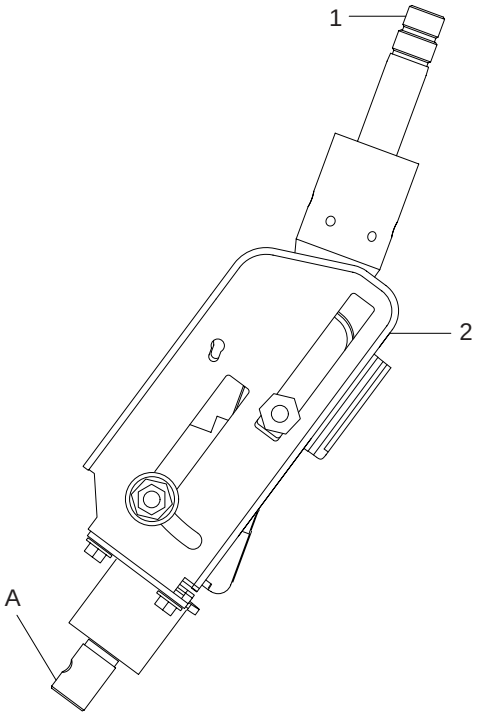
Nut Size	Torque lbf·ft (N·m)
3/4–16	90–170 (122–230)
7/8–14	160–300 (217–407)

Table 1, Torque Values

General Information

The tilt function of the tilt steering column is controlled by a foot-operated release valve or pedal. See **Fig. 1**, **Fig. 2** and **Fig. 3**. See Chapter 2 of the *School Bus Chassis Operator's Manual* for operating instructions.

At the upper end of the tilt steering column assembly are threads to accept a wheel nut, and tapered external serrations to match the internal serrations of the steering wheel hub. At the lower end, the shaft is serrated to connect with the steering driveline upper end yoke.

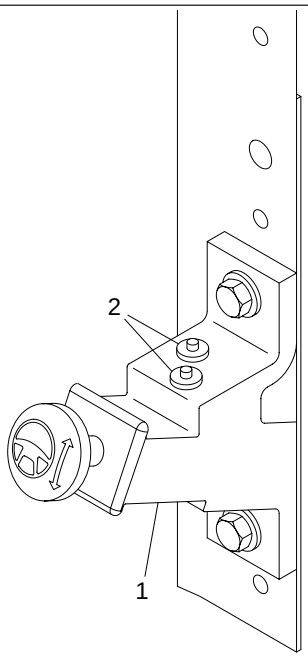


08/11/95 f461044

A. Steering driveline upper end yoke attaches here
1. Tilt Steering Column Shaft
2. Tilt Column Assembly

Fig. 1, Tilt Steering Column Assembly

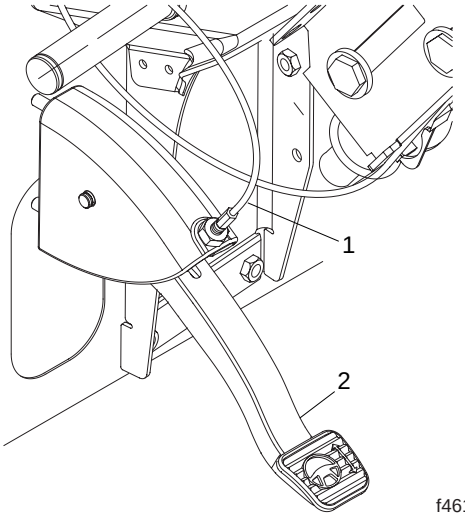
NOTE: On some vehicles, a two-piece upper steering column cover may be present. See **Fig. 4**.



08/30/96 f461115

1. Column Release Valve
2. Air Line Connection

Fig. 2, Tilt Column Release Valve

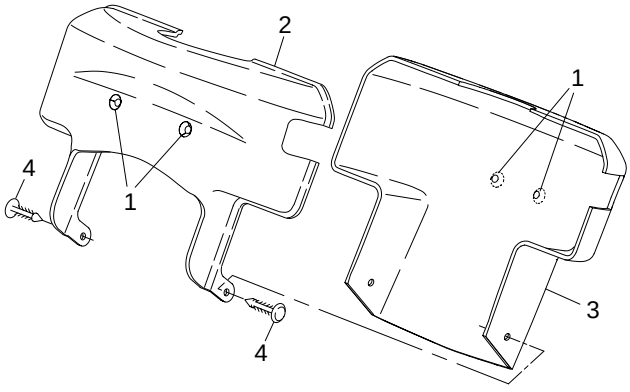


07/31/97 f461233

1. Release Cable
2. Tilt Column Release Pedal

Fig. 3, Tilt Column Release Pedal

General Information



07/06/2000 f461788

1. Allen-Head Screw Locations
2. Cover (upper half)
3. Cover (lower half)
4. Plastic Fastener

Fig. 4, Two-Piece Upper Steering Column Cover

Steering Wheel Removal and Installation

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. Apply the parking brake and chock the tires.
3. Disconnect the batteries at the negative terminal.
4. Using a small screwdriver, carefully pry out the horn button. Disconnect the two wires from it. See **Fig. 1**.

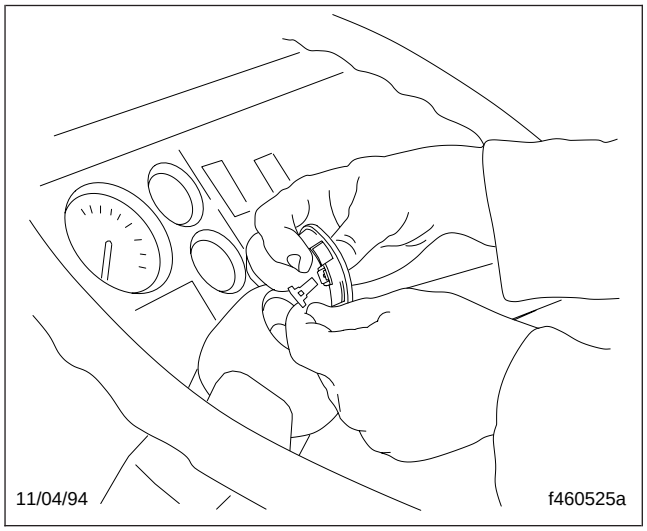


Fig. 1, Pry out the Horn Button

5. Using a deep socket to avoid damaging the wires, remove the steering wheel nut. See **Fig. 2**.
6. Using a steering wheel puller, remove the steering wheel from the steering column. See **Fig. 3**.

IMPORTANT: When you set the steering wheel aside, be careful not to damage the turn signal self-cancelling pin on the underside of the wheel. See **Fig. 4**.

Installation

1. Make sure the front tires are pointed straight ahead and the steering gear is centered.

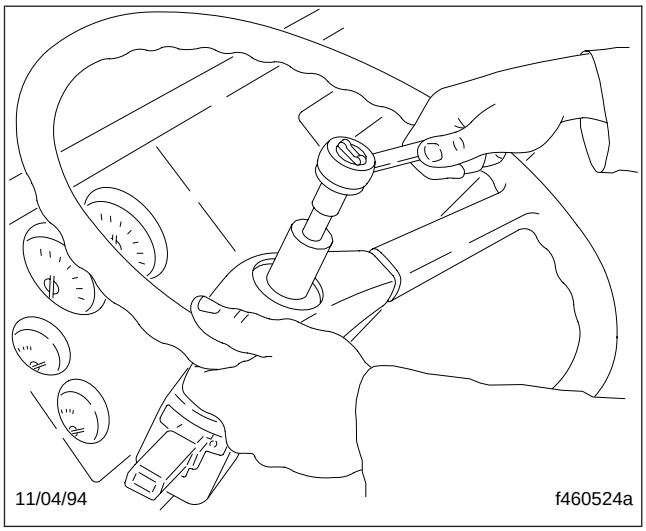


Fig. 2, Remove the Steering Wheel Nut

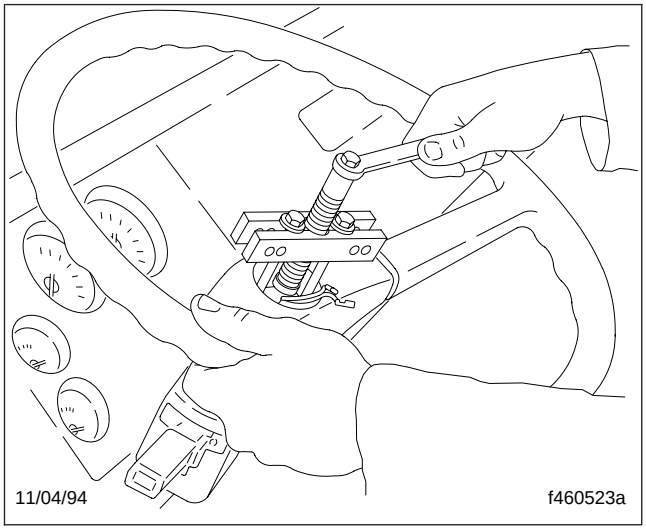


Fig. 3, Remove the Steering Wheel from the Column

2. Put the steering wheel on the steering column so that the spokes are within 10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 5**.
3. Thread the two horn wires through the steering wheel nut, then install the nut. Tighten it 60 lbf·ft (81 N·m).
4. Connect the two wires to the horn button. Pack the horn wires with dielectric grease.

NOTE: The horn wires may be connected to either terminal.

Steering Wheel Removal and Installation

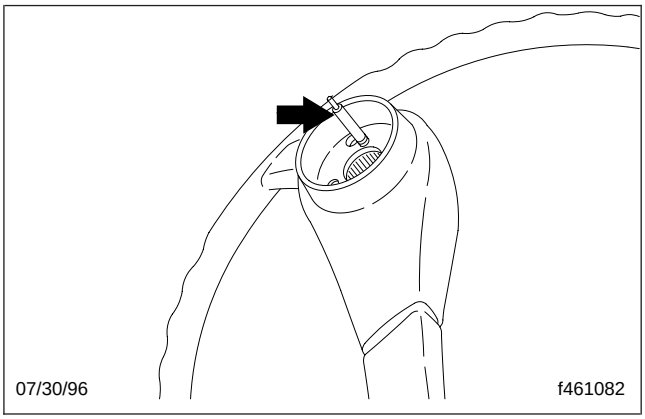


Fig. 4, Turn Signal Self-Cancelling Pin

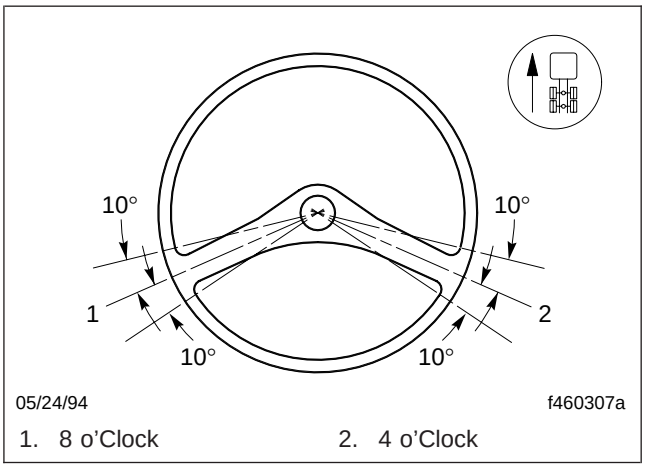


Fig. 5, Center the Steering Wheel

5. Install the horn button in the steering wheel hub so the logo on it is aligned with the steering wheel spokes. See **Fig. 6**.

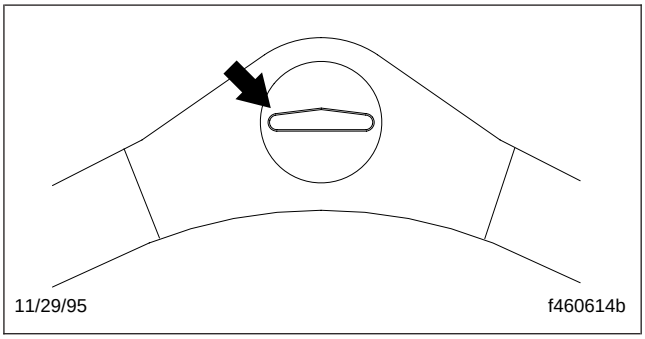
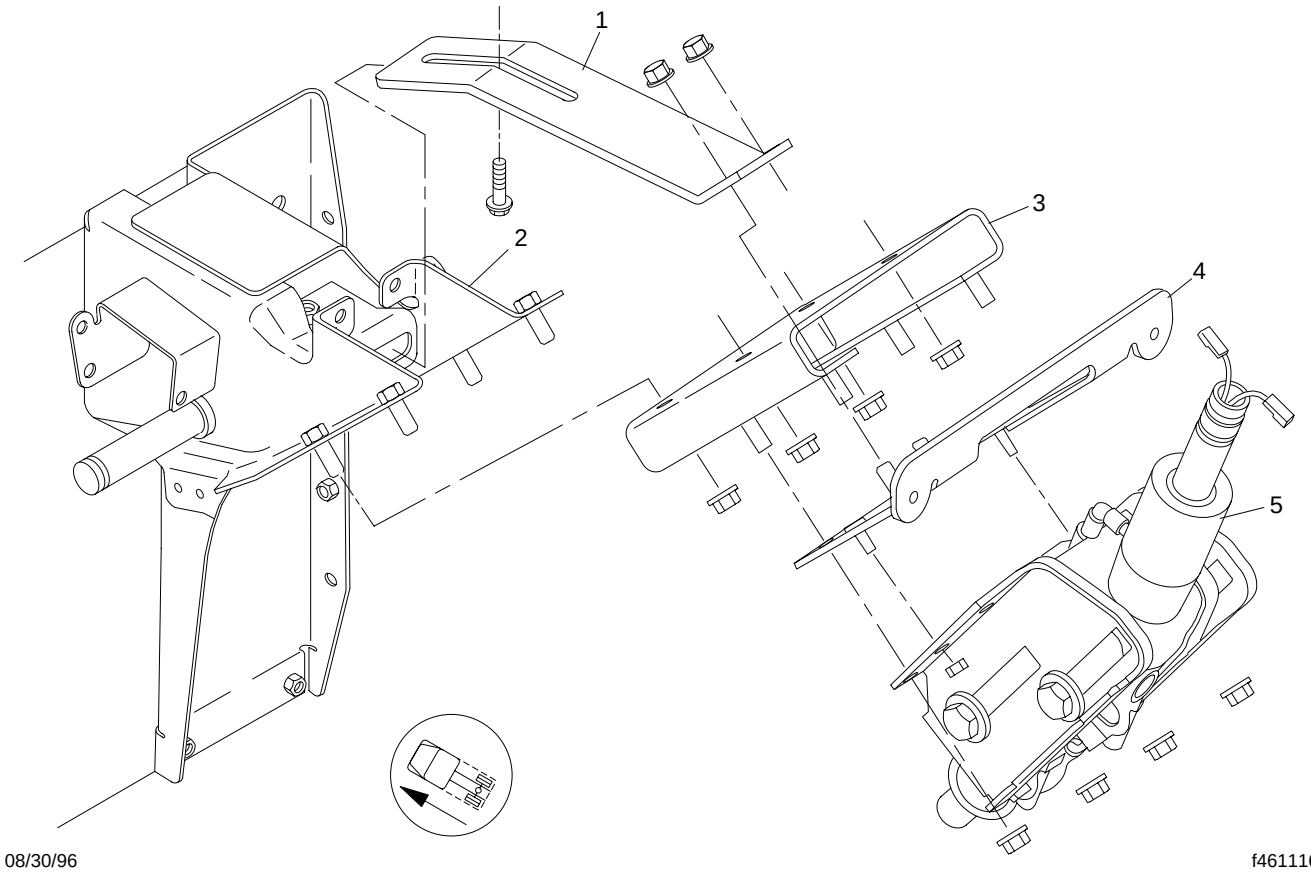


Fig. 6, Align the Logo

6. Take the vehicle for a test drive to make sure the steering wheel is on correctly. If it isn't, remove it and install it again.

Removal

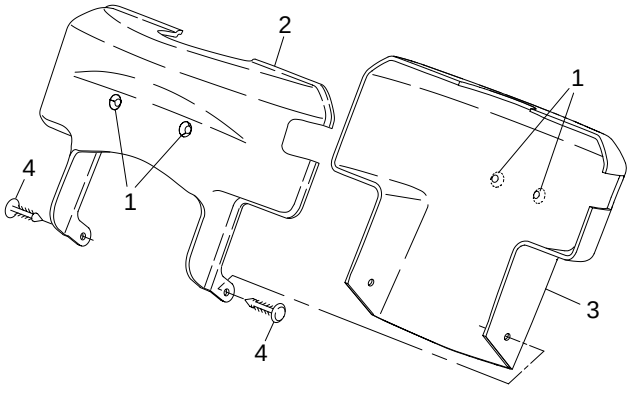


1. Steering Column Support Bracket
2. Steering Column Mounting Bracket
3. Steering Column Spacer
4. Instrument Cluster Mounting Plate
5. Steering Column Assembly

Fig. 1, Tilt Steering Column Mounting

1. Position 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 this procedure.
2. Shut down the engine, set the parking brake, and chock the tires.
3. Depress the column adjustment valve knob and allow the column to move to the neutral (center) position. See **Fig. 1**.
4. On vehicles equipped with a two-piece upper steering column cover, remove the steering column cover. See **Fig. 2**.
   - 4.1 Remove the two allen-head screws securing the upper half of the cover to the steering column assembly.

Steering Column Removal and Installation



07/06/2000 f461788

1. Allen-Head Screw Locations
2. Cover (upper half)
3. Cover (lower half)
4. Plastic Fastener

Fig. 2, Two-Piece Upper Steering Column Cover

4.2 Remove the two allen-head screws securing the lower half of the cover to the steering column assembly.

4.3 Carefully remove the two plastic fasteners attaching the lower front ends of the cover-halves to each other.

4.4 Remove the two-piece steering column cover from the steering column assembly.

5. Remove the plastic cover from the turn signal switch on the left side of the steering column.
6. Remove the two allen-head screws that attach the turn signal switch to the steering column, then swing the turn signal switch up and out of the way.
7. Disconnect the horn wire.
8. Remove and discard the pinch bolt and nut from the steering driveline yoke.
9. Disconnect the steering column from the steering driveline U-joint yoke. If the yoke is marked with red paint, it is secured with adhesive. Heat the base of the yoke with a torch, until the adhesive bond begins to weaken at 300°F (149°C).
10. Disconnect the air line from the steering column.
11. Remove the capscrew that secures the column support bracket on the mounting bracket assembly.
12. Remove the four flanged hexnuts that attach the steering column to the steering column spacer.
13. Remove the steering column, support bracket, and cluster mounting plate as an assembly.
14. If replacing the column, remove the cluster mounting plate and the support bracket. Also, remove the steering wheel. For instructions on steering wheel removal, see **Subject 100**.

Installation

1. Install the steering wheel. For instructions, see **Subject 100**.
2. If removed, install the cluster mounting plate (and support bracket) on the steering column. Tighten the nuts 96 to 120 lbf·in (1080 to 1360 N·cm). See **Fig. 1**.
3. Position the steering column assembly on the steering column mounting bracket. Loosely install the four flanged hexnuts.
4. Install the capscrew that secures the column support bracket on the mounting bracket assembly. Tighten the capscrew 23 to 29 lbf·ft (31 to 39 N·m). Then, tighten the four hexnuts 23 to 29 lbf·ft (31 to 39 N·m).
5. Connect the air line to the steering column.
6. Clean the end of the column shaft with a clean dry cloth.
7. Using a wire brush and Loctite® Safety Solvent, or an equivalent, clean the serrations of the end yoke and the shaft.

IMPORTANT: If Loctite Safety Solvent is not available, use clean solvents, such as trichloroethylene, trichloroethane, perchloroethylene, MEK, acetone, or alcohol. *Do not use* kerosene, gasoline, naptha, fuel oil, Varsol, or Stoddard solvents.

8. Apply Locquic® General Purpose Primer T to the serrated portion of the steering column shaft. Let it dry five minutes.
9. Apply a bead of Loctite RC680 adhesive to the serrations inside the base of the upper end yoke.

IMPORTANT: Curing of the adhesive will begin immediately after installation of the end yoke on

the column shaft; the pinch-bolt nut must be torqued within four minutes. If not, disassemble the parts, clean them, and treat them again. Allow the assembled parts to cure for 30 minutes before applying steering load pressures.

Slide the upper end yoke onto the column shaft, then install a new end yoke pinch bolt. Before installing the pinch-bolt nut, make sure that the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a new pinch-bolt nut, and tighten 37 lbf·ft (50 N·m).

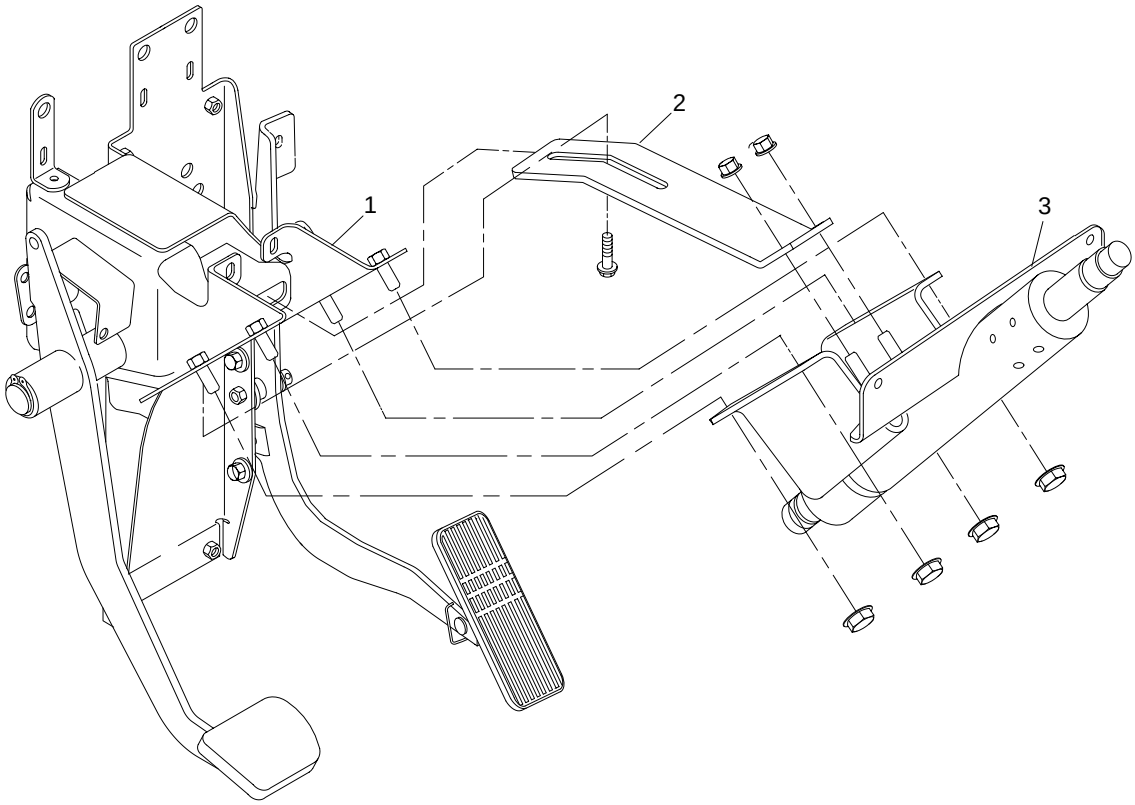
10. Apply torque seal OGP F900WHITE to the exposed pinch bolt threads and to the locknut. To show that adhesive has been applied, mark the end of the steering column shaft with red paint.
11. Connect the horn wire.
12. Install the turn signal switch on the left side of the steering column. Install and tighten the allen-head screws firmly. Install the plastic cover.
13. On vehicles equipped with a two-piece upper steering column cover, install the steering column cover.
    - 13.1 Place the steering column cover halves in position around the steering column assembly.
    - 13.2 Join the upper and the lower halves together at the front and install the plastic fasteners (removed previously).
    - 13.3 Install two allen-head mounting screws in the upper half of the cover and tighten them securely.
    - 13.4 Install two allen-head mounting screws in the lower half of the cover and tighten them securely.
14. Remove the chocks from the tires.
15. Test drive the vehicle and ensure that the steering column assembly operates smoothly; if not, repeat the service operations.

Specifications

Torque Values			
Description	**Size**	**Torque**	
		lbf·in (N·cm)	**lbf·ft (N·m)**
Steering Column Mounting Hexnuts	—	—	23–29 (31–39)
Steering Column-to-Cluster Mounting Plate Hexnuts	—	23–120 (1080–1360)	—
Column Support Bracket Mounting Capscrew	—	—	23–29 (31–39)
Upper End Yoke Pinch Bolt	3/18–16	—	37 (50)
	3/18–24	—	44 (60)
	7/16–20	—	55 (75)
Steering Wheel Nut	—	—	60 (81)

Table 1, Torque Values

General Information



1. Steering Column Bracket Assembly
2. Steering Column Support Bracket
3. Fixed Steering Column

Fig. 1, Steering Column Assembly Installation

The steering wheel is cushion-rimmed, with a button for the electric horn mounted in the center of the wheel hub.

A turn signal switch attaches to the steering column just below the steering wheel.

Major parts of the steering column assembly are a jacket (tube), bearing assemblies (staked in place in the top and bottom of the jacket), a steering column shaft, and wiring and contact assemblies for the electric horn. See **Fig. 1**. At the upper end of the steering column shaft are threads to accept a wheel nut, and straight external serrations to match the internal serrations of the steering wheel hub. The lower end has straight external serrations to match the internal serrations of the steering driveline upper end-yoke. The steering column assembly is attached to the dash steering column bracket with four fasteners that are hidden by the steering column cover. A lower steering column cover extends from the under-dash cover to the floor. The steering column assembly is not repairable; if any steering column parts are damaged or badly worn, the steering column assembly must be replaced.

Steering Wheel Removal and Installation

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. Apply the parking brake and chock the tires.
3. Disconnect the batteries at the negative terminal.
4. Using a small screwdriver, carefully pry out the horn button. Disconnect the two wires from it. See **Fig. 1**.

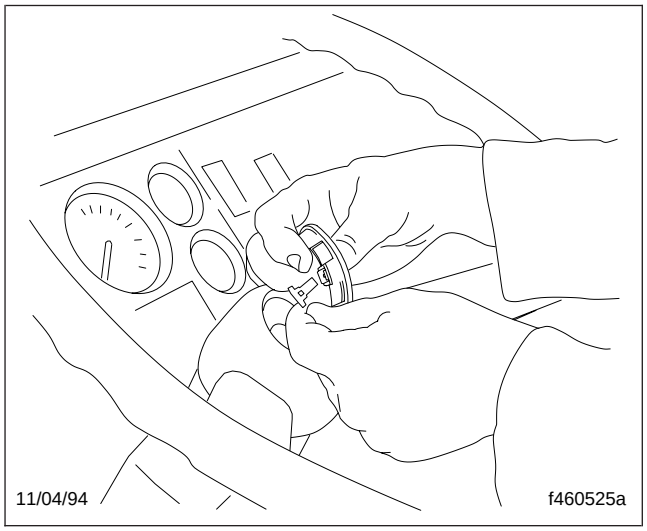


Fig. 1, Pry out the Horn Button

5. Using a deep socket to avoid damaging the wires, remove the steering wheel nut. See **Fig. 2**.
6. Using a steering wheel puller, remove the steering wheel from the steering column. See **Fig. 3**.

IMPORTANT: When you set the steering wheel aside, be careful not to damage the turn signal self-cancelling pin on the underside of the wheel. See **Fig. 4**.

Installation

1. Make sure the front tires are pointed straight ahead and the steering gear is centered.

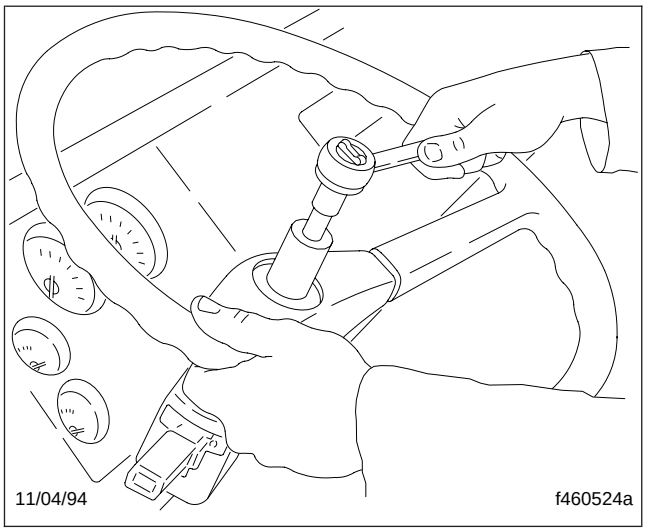


Fig. 2, Remove the Steering Wheel Nut

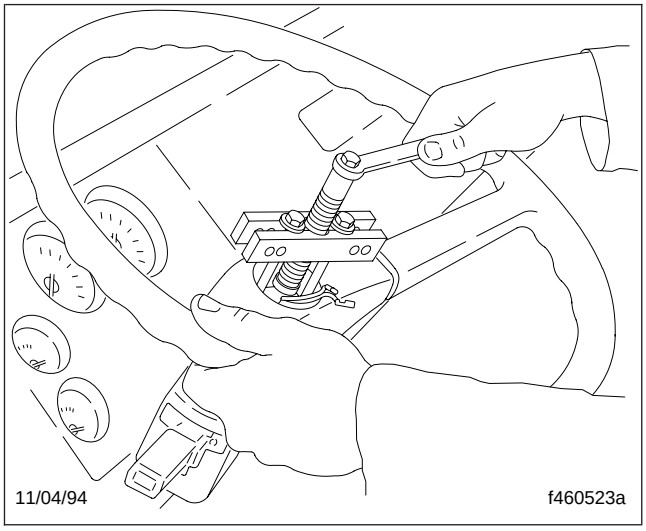


Fig. 3, Remove the Steering Wheel from the Column

2. Put the steering wheel on the steering column so that the spokes are within 10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 5**.
3. Thread the two horn wires through the steering wheel nut, then install the nut. Tighten it 60 lbf·ft (81 N·m).
4. Connect the two wires to the horn button. Pack the horn wires with dielectric grease.

NOTE: The horn wires may be connected to either terminal.

Steering Wheel Removal and Installation

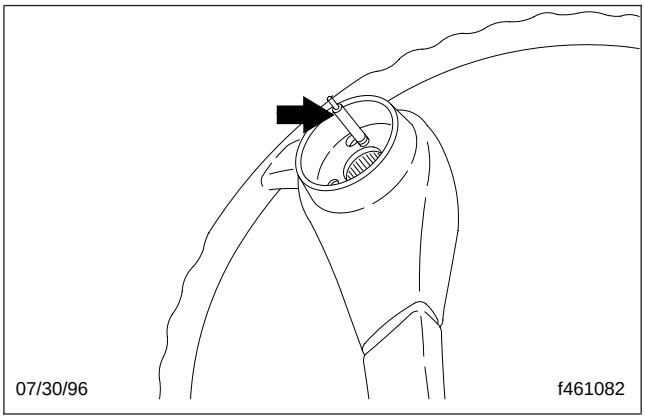


Fig. 4, Turn Signal Self-Cancelling Pin

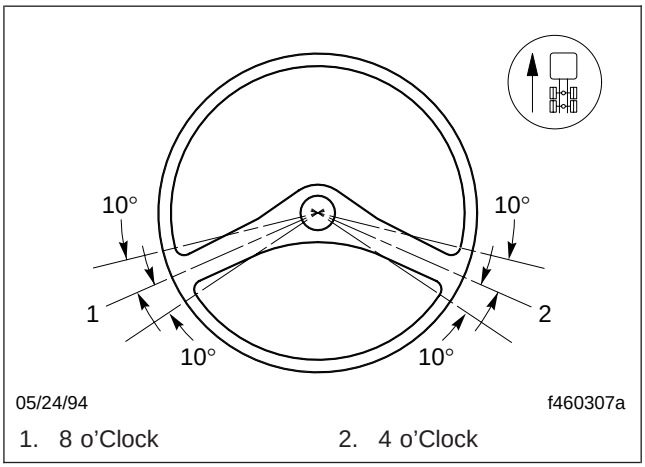


Fig. 5, Center the Steering Wheel

5. Install the horn button in the steering wheel hub so the logo on it is aligned with the steering wheel spokes. See **Fig. 6**.

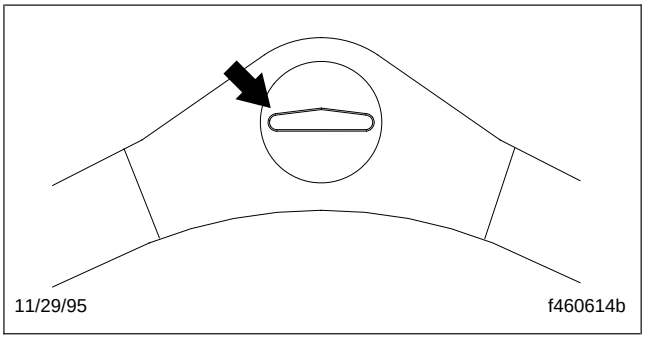
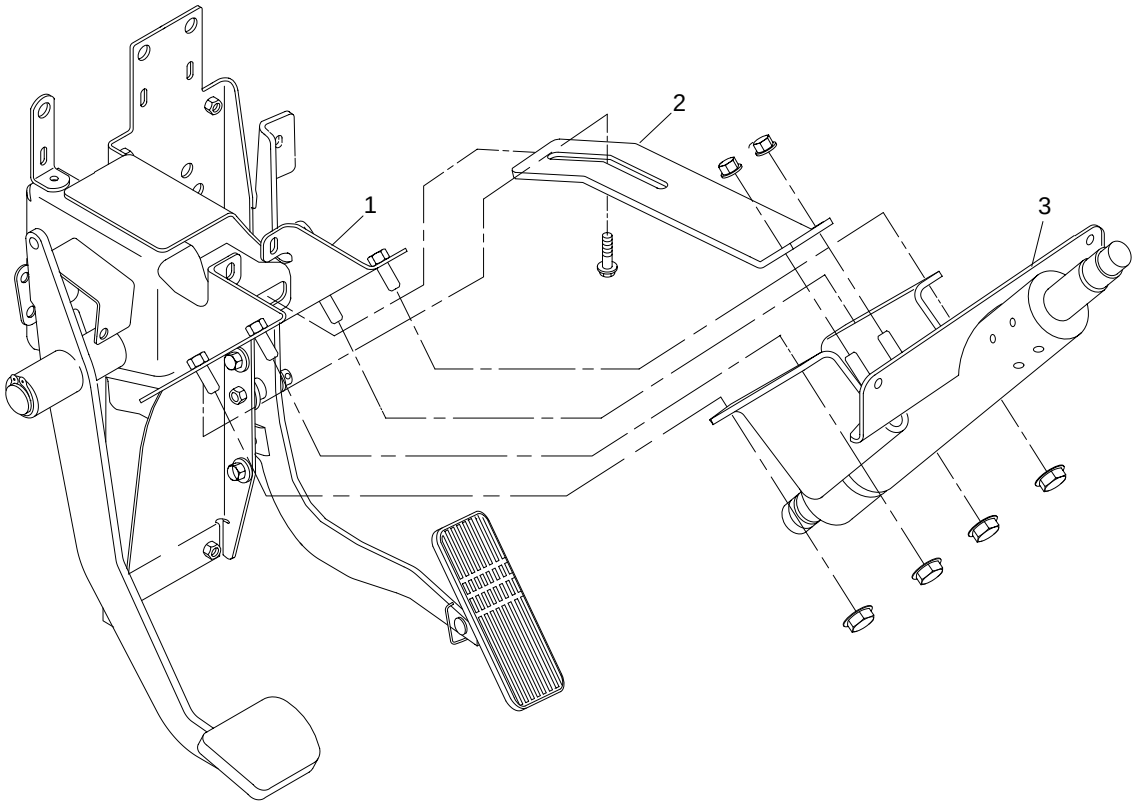


Fig. 6, Align the Logo

6. Take the vehicle for a test drive to make sure the steering wheel is on correctly. If it isn't, remove it and install it again.

Steering Column Assembly Removal and Installation

Removal



1. Steering Column Bracket Assembly
2. Steering Column Support Bracket
3. Fixed Steering Column

Fig. 1, Steering Column Assembly Installation

1. Park the vehicle on a level surface. Make sure the front tires are pointing forward. Apply the parking brakes. Shut down the engine. Chock the tires.

IMPORTANT: Once the vehicle is parked, do not turn the steering wheel at any time during the following procedures.

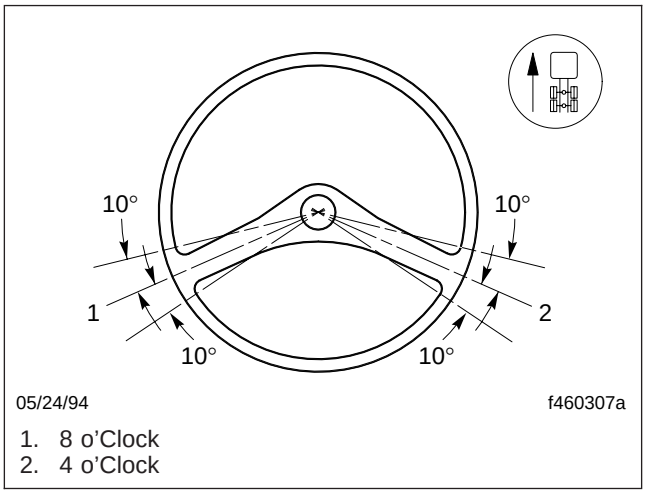
2. Disconnect the batteries.
3. Remove the pinch-bolt nut and pinch bolt from the upper end yoke. Discard the nut and the bolt. See **Fig. 1**.
4. Remove the two screws that attach the turn signal switch mounting bracket. Remove the turn signal switch mounting assembly from the steering column. Disconnect the wiring connector from the turn signal switch.
5. Remove the upper end yoke from the steering column shaft.
6. Remove the capscrew that secures the steering column support bracket.
7. Remove the nuts that attach the steering column to the mounting bracket.
8. Remove the steering column assembly from the vehicle. Remove the support bracket from the column if necessary.

Steering Column Assembly Removal and Installation

Installation

1. Install the support bracket on the column (if removed). Tighten the capscrews 26 lbf·ft (35 N·m). Insert the support bracket into the mounting bracket assembly and loosely install the capscrew.
2. Position the steering column on the steering column mounting bracket. Tighten the nuts 26 lbf·ft (35 N·m). Tighten the support bracket capscrew 26 lbf·ft (35 N·m).
3. Wipe the end of the column shaft with a clean, dry cloth.
4. Slide the upper end yoke onto the column shaft. Install a new end yoke pinch bolt. Before installing the pinch-bolt nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install and tighten a new pinch-bolt nut. For the proper torque, see **Specifications, 400**.
5. Apply torque seal OGP F900WHITE to the exposed pinch-bolt threads and to the locknut.
6. Place the turn signal switch mounting assembly on the steering column. Align the switch so that it is pointed directly to the left. Install and firmly tighten the mounting screws. Connect the turn signal harness connector.
7. Insert the horn ground wire through the bracket.
8. Check the position of the steering wheel when the front tires are pointing forward. The steering wheel should be within ±10 degrees of center as shown in **Fig. 2**.

   If necessary, remove the steering wheel and reposition it. For instructions, see **Subject 100**.
9. Connect the batteries.
10. Remove the chocks from the tires.
11. Test drive the vehicle and make sure the steering column assembly operates smoothly. If it does not operate smoothly, repeat the service operations.



1. 8 o'Clock
2. 4 o'Clock

Fig. 2, Steering Wheel Centered

Specifications

Torque Values		
Description	**Size**	**Torque lbf·ft (N·m)**
Steering Wheel Retaining Nut	—	60 (81)
Steering Column Mounting Bracket Nuts	—	26 (35)
Steering Driveline Upper End Yoke Pinch Bolt	3/18–16	37 (50)
	3/18–24	44 (60)
	7/16–20	55 (75)

Table 1, Torque Values

General Description

The Ross TAS40, TAS55, and TAS65 integral power steering gears use pressurized hydraulic fluid to help the driver turn the front wheels. All three models mount on the left frame rail, and all operate in the same way.

The difference between the three gears is size. The TAS40 can be installed on vehicles with front axle capacities up to 9000 lb (4086 kg). The TAS55 is for vehicles with front axle capacities up to 12,000 lb (5448 kg), and the TAS65 is for front axle capacities up to 14,300 lb (6500 kg).

All three gears use more pressurized fluid when the driver turns the steering wheel quickly than when the driver turns the steering wheel slowly, but the minimum amount of power steering fluid is different for each model. With the driver turning the steering wheel 1-1/2 turns per second, the TAS40 needs at least 2.2 gpm of fluid per minute (8.3 liters). At the same turning speed, the TAS55 needs 2.6 gpm (9.8 Lpm), and the TAS65 needs 3.0 gpm (11.4 Lpm).

⚠ CAUTION

Never steam clean or high-pressure wash the steering gear. Internal damage to gear seals and ultimately the steering gear can result.

Principles of Operation

When the driver turns the steering wheel, that force travels down through the steering driveline to the steering gear input shaft. See **Fig. 1**. The input shaft turns the worm shaft which moves the rack piston forward or backward in the gear housing by means of a series of recirculating balls in the spiral channels of the worm shaft. See **Fig. 2**.

Grooves in the rack piston mesh with teeth in the sector shaft, and as the piston slides back and forth, it turns the sector shaft. See **Fig. 2**. The sector shaft swings the pitman arm. See **Fig. 1**. The pitman arm pulls or pushes the drag link, and the drag link moves the axle steering arm, steering the vehicle.

Pressurized power steering fluid helps the worm shaft slide the rack piston forward or backward in the gear housing.

The input shaft is not connected directly to the worm shaft. Instead, a thin bar, the torsion bar, holds the input shaft to the worm shaft. See **Fig. 2**. The outside end of the torsion bar is fastened to the input shaft, and the inside end is fastened to the worm shaft; thus, the force of the driver turning the steering wheel travels from the input shaft to the worm shaft through the torsion bar.

With the force of the driver alone, the front axle would be difficult to steer. The weight on the front wheels, the friction of the tires against the road, and the inertia of the vehicle traveling in its current direction all combine to hold the sector shaft and the rack piston in place.

To overcome this resistance, the steering gear has a valve for directing pressurized hydraulic fluid either in front of the rack piston or behind it, thus using the fluid to push the rack piston in the direction the worm shaft is trying to slide it.

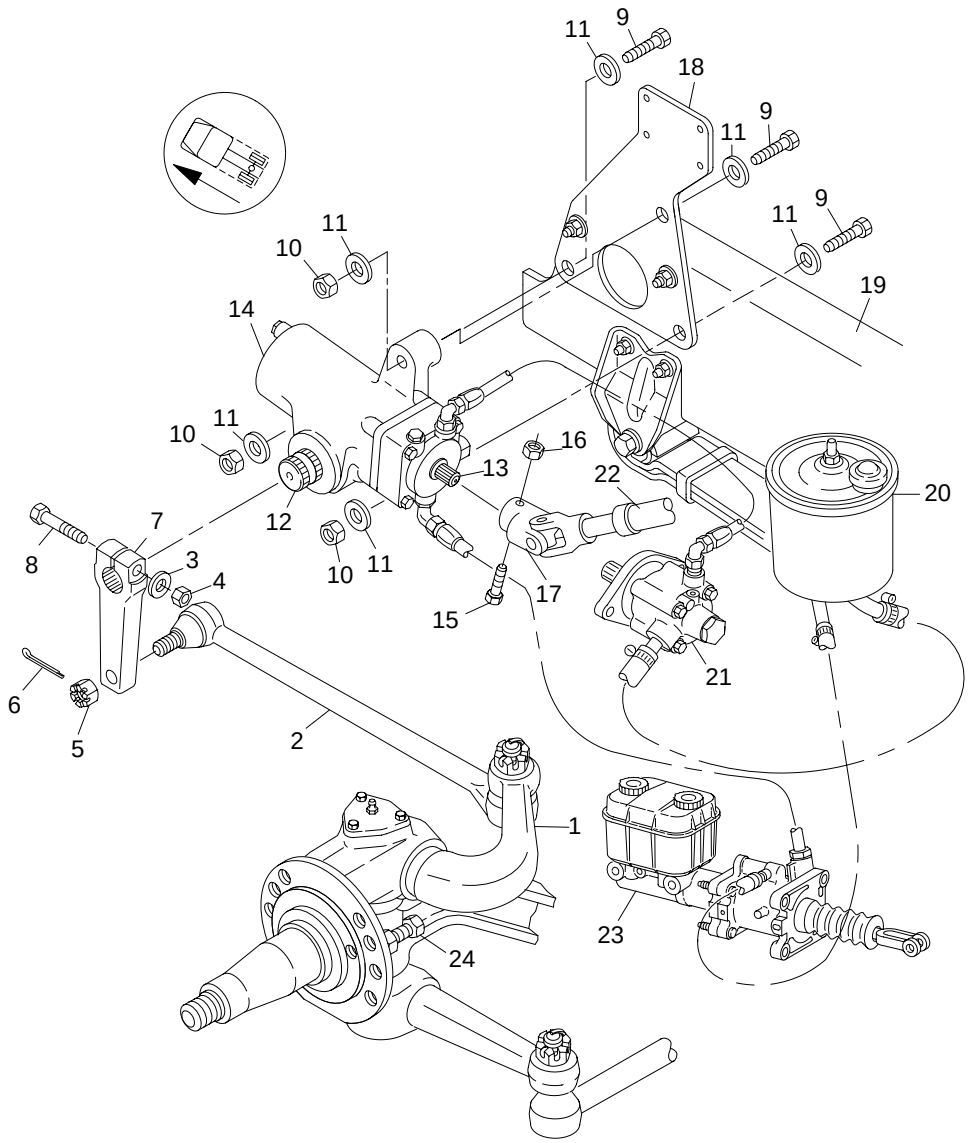
The torsion bar controls the hydraulic fluid. As the driver turns the steering wheel to turn the input shaft, and the front wheels resist turning and hold the rack piston and worm shaft in place, the torsion bar connecting the input shaft and worm shaft twists slightly. That twisting aligns holes in the hydraulic control valve with channels that carry hydraulic fluid. See **Fig. 2**. Depending on the direction the driver turns the steering wheel—the direction the torsion bar twists—the valve aligns the channels to direct hydraulic fluid in front of the rack piston or behind it. The fluid provides the extra force the worm shaft needs to overcome the resistance from the front wheels, and the worm shaft can then slide the rack piston in the gear housing.

The rack piston slides, and turns the sector shaft. The sector shaft swings the pitman arm. The pitman arm pulls or pushes the drag link. The drag link moves the axle steering arm, and the front wheels turn.

As the front wheels reach the axle stop—the farthest the wheels can turn in that direction—a poppet (unloading valve) in the rack piston trips to prevent steering gear damage. The tripped poppet reduces steering fluid pressure, heat generated by the power steering fluid pump, and outside forces from acting on the steering linkage. See **Fig. 2**.

The hydraulic fluid around the rack piston also prevents road shocks from moving the steering wheel. When the vehicle hits an obstacle, the shock travels up through the front tires and the steering linkage to the steering gear. There, the sector shaft would

General Description and Principles of Operation

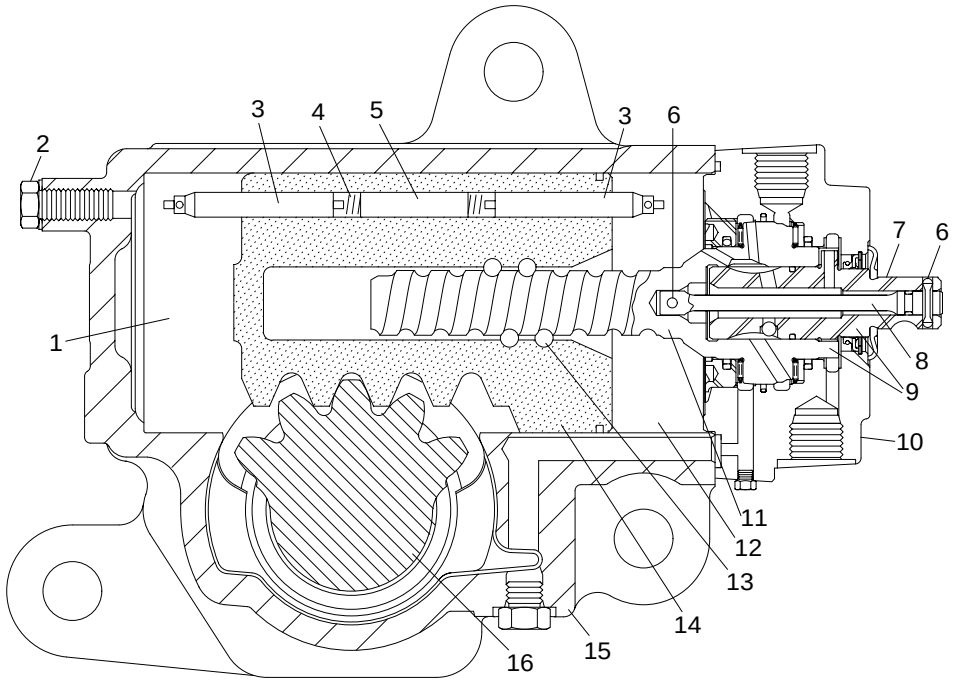


10/31/96 f460591a

1. Axle Steering Arm
2. Drag Link
3. Pitman Arm Washer
4. Pitman Arm Pinch-Bolt Nut
5. Castle Nut
6. Cotter Pin
7. Pitman Arm
8. Pitman Arm Pinch Bolt
9. Mounting Capscrew
10. Locknut
11. Hardened Washer
12. Sector (Output) Shaft
13. Input Shaft
14. Steering Gear
15. Lower End Yoke Pinch Bolt
16. Lower End Yoke Pinch-Bolt Nut
17. Lower End Yoke
18. Steering Gear Mounting Plate
19. Left Frame Rail
20. Power Steering Reservoir
21. Power Steering Pump
22. Steering Driveline
23. Brake Booster
24. Axle Stop

Fig. 1, Ross TAS40/55/65 Steering Gear Installation (chassis with hydraulic brakes)

transmit the shock to the rack piston, but the power steering fluid helps to hold the piston in place and dampen the shock before it can move up the worm shaft to the steering driveline and the steering wheel.



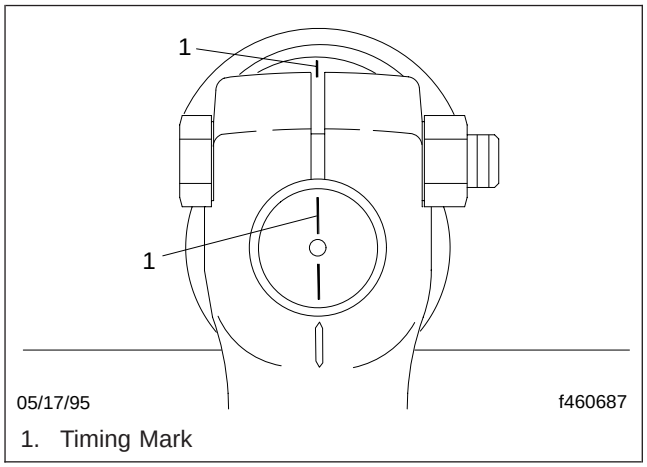
10/31/96 f460581a

1. Lower Cylinder Cavity
2. Poppet Fixed Stopscrew
3. Poppet Assembly
4. Poppet Spring
5. Push Tube
6. Pin
7. Input Shaft
8. Torsion Bar
9. Control Valve
10. Valve Housing
11. Worm Shaft
12. Upper Cylinder Cavity
13. Ball (recirculating)
14. Rack Piston
15. Gear Housing
16. Sector Shaft

Fig. 2, Steering Gear Section View

Sector (Output) Shaft Adjustment

1. Position the sector shaft at its center of travel by turning the steering wheel until the alignment mark on the sector shaft is at a right angle to the input shaft centerline, and in line with the timing mark on the end of the housing trunnion. See **Fig. 1**.



1. Timing Mark

Fig. 1, Sector (Output) Shaft Adjustment

2. Disconnect the drag link from the pitman arm. Don't turn the input-shaft/valve/worm assembly more than 1-1/2 turns in either direction from its center of travel while the drag link is disconnected from the pitman arm. Turning the input shaft more than 1-1/2 turns from center will cause misadjustment of the automatic poppets. This may require the installation of a service poppet adjustment tool to manually reset the poppets.
3. With the sector shaft in the center position, grasp the pitman arm and gently try to move it back and forth. Finger-tip force is adequate to detect lash (free-play) of a loose sector shaft. See **Fig. 2**. There should be no movement of the input shaft or sector shaft. Loosen the sector shaft adjusting screw jam nut. See **Fig. 3**. If no lash was detected, turn the shaft adjusting screw counterclockwise until lash is detected.
4. To adjust, move the adjusting screw clockwise until no lash is felt at the pitman arm. Use no more than 10 lbf·ft (14 N·m) of torque. Slowly turn the adjusting screw clockwise an additional one-eighth turn. Hold the adjusting screw in place and tighten the jam nut 40 to 45 lbf·ft (54 to 61 N·m).
5. Again, check the pitman arm for lash. Turn the steering wheel one-quarter turn each side of center. No lash should be felt. If lash exists, readjust the sector shaft.
6. Connect the drag link to the pitman arm. For instructions, refer elsewhere in this group.

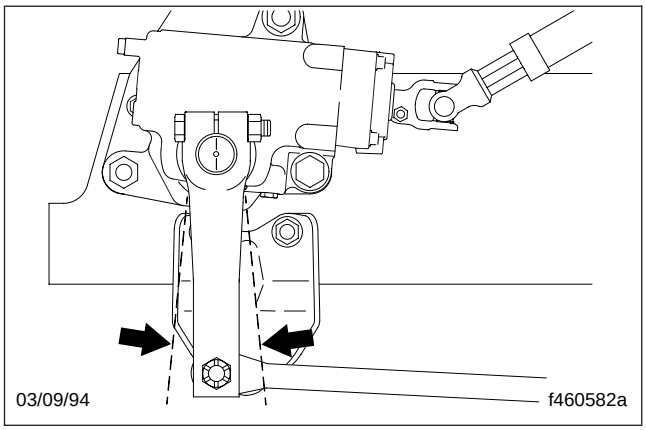


Fig. 2, Check the Sector Shaft for Free-Play

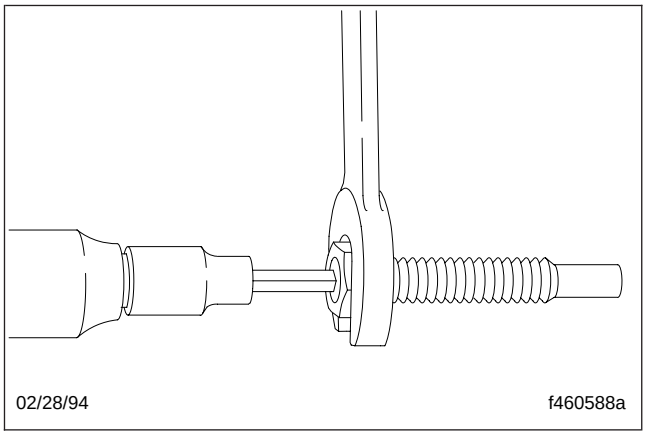


Fig. 3, Screw In the Poppet Adjusting Screw

Poppet Valves Adjustment

TAS40, TAS55, and TAS65 steering gears have automatic poppet valves that reset themselves if the axle stops are reset for increased steering travel. However, if the axle stops are reset for *decreased* steering travel, the poppet valves must be reset manually,

In-Vehicle Adjustments

through the use of a special service poppet adjusting screw and sealing jam nut kit, unless they were reset for automatic adjustment while the steering gear was disassembled.

Use the following procedure for manually resetting the poppet valves:

1. Verify correct axle stop adjustment. For instructions, refer to **Group 33** of this manual.

IMPORTANT: The axle stops must be set so that there are at least 1-3/4 steering wheel turns from a straight-ahead position to both a full-left and a full-right turn; otherwise the poppet valves will not work.

2. If both axle stops were set for increased travel, the steering gear poppets have reset automatically and gear adjustments are complete. No further action is required.

   If either axle stop was set for decreased travel, the steering gear poppets must be set manually; continue with the following steps.

3. Install the steering gear manual poppet adjusting screw.

   3.1 Screw the special poppet adjusting screw (from Ross kit number 021407–X1) into the non-sealing end of the sealing jam nut, until the drive end of the screw is flush with the nut. See **Fig. 3**.

   3.2 With the vehicle unloaded, the engine off, and the front wheels in the straight-ahead position, remove and discard the poppet fixed stopscrew and washer from the lower end of the steering gear housing. See **Fig. 4**.

   NOTE: With the wheels straight ahead, and the timing marks on the sector shaft and gear housing aligned as shown in **Fig. 1**, the steering gear is centered.

   3.3 Using an allen wrench turn the adjusting screw and nut without rotating the nut, into the steering gear housing until the nut is firmly against the housing. See **Fig. 5**. Tighten the nut 33 to 37 lbf·ft (45 to 50 N·m).

   NOTE: It may be necessary to move the sector shaft slightly from the "straight-ahead position" to assemble the service adjusting screw as instructed and then return it to "straight ahead."

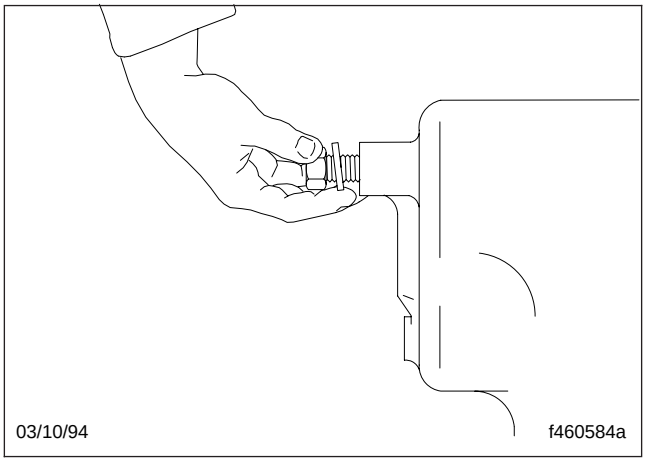


Fig. 4, Remove the Poppet Fixed Stopscrew and Washer

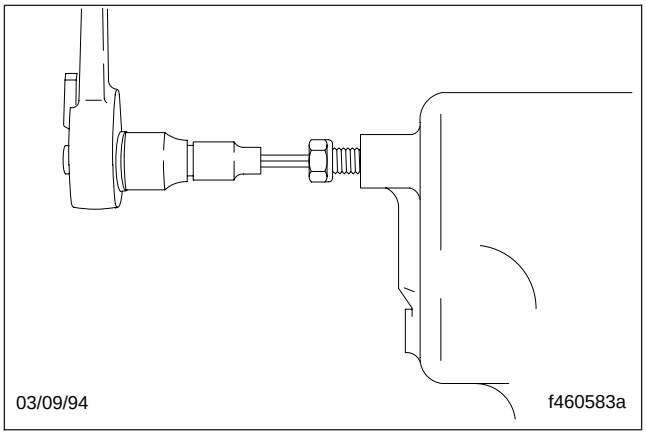


Fig. 5, Turn the Adjusting Screw

4. Adjust the poppets manually.

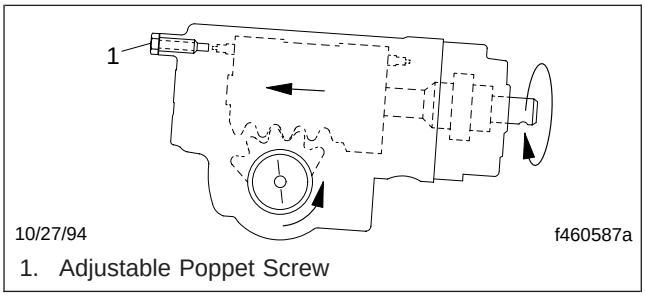
   4.1 Check the fluid level and fill the power steering reservoir with Dexron II type ATF if required.

   4.2 Make sure the engine is off.

   4.3 Place a jack under the center of the front axle, and raise the steer tires off the ground.

   4.4 Turn the steering wheel to the right until the axle stopscrew contacts the axle stop, or the end of the gear travel is reached.

This pushes out the left-hand turn poppet to prepare it for setting. See **Fig. 6.**



1. Adjustable Poppet Screw

Fig. 6, Preparing the Poppet for Setting

4.5 Turn the steering wheel to the left until the left-hand stop makes contact. This sets the left-turn poppet. Release the steering wheel, and do not steer again until the adjusting screw has been backed out and the sealing nut tightened.

4.6 Loosen the sealing nut on the gear housing, and back out the adjusting screw until it is 1 to 1-1/16 inches (25 to 27 mm) beyond the sealing nut. See **Fig. 7**. Tighten the sealing nut 33 to 37 lbf·ft (45 to 50 N·m).

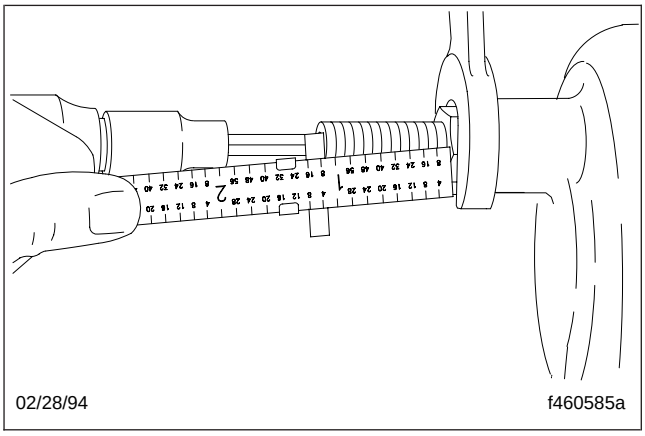


Fig. 7, Back Out the Adjusting Screw and Measure

IMPORTANT: Make sure the adjusting screw does not protrude more than 1-1/16 inches (25 to 27 mm) beyond the sealing nut.

4.7 Have someone turn the steering wheel all the way to the right, and hold in place when the axle stops are contacted.

4.8 With the steering wheel held in place, loosen the sealing nut one turn, and while holding the sealing nut, turn the adjusting screw using an allen wrench. Don't force the screw. Use one or two fingers and turn the allen wrench until it comes to a stop. When this happens contact has been made with the poppet seat; *don't turn it any further*. Back out the screw 3-1/4 turns. Have the steering wheel released at this time.

4.9 While holding the adjusting screw in place, tighten the sealing nut firmly against the gear housing. See **Fig. 8**. Tighten it 33 to 37 lbf·ft (45 to 50 N·m).

Check the adjusting screw. If it extends more than 1-1/16 inches (25 to 27 mm) from the sealing nut, loosen the sealing nut, and turn the adjusting screw in as needed. Tighten the sealing nut 33 to 37 lbf·ft (45 to 50 N·m). See **Fig. 7** and **Fig. 8**.

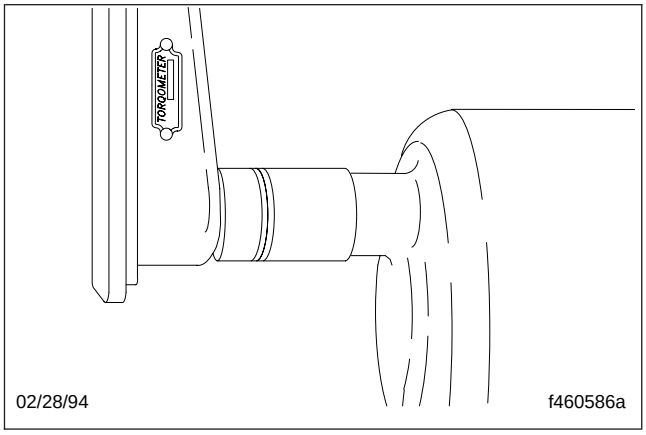


Fig. 8, Tightening the Sealing Nut

⚠ WARNING

If the adjusting screw protrudes more than 1-1/16 inches (25 to 27 mm) from the sealing nut, the screw could fall out of the steering gear, resulting in loss of power steering. This could cause an accident resulting in serious personal injury or property damage.

IMPORTANT: Once the poppet adjusting screw and sealing nut are in place and the

In-Vehicle Adjustments

poppet valves have been manually adjusted, the adjustment procedure must be repeated if steering travel is either increased or decreased in the future.

Removal

IMPORTANT: Before removing the steering gear, see **Troubleshooting and Diagnostic Checks, 300** to identify the problem.

1. Verify correct axle stop adjustment. For instructions, see **Group 33**. Ensuring correct axle stop adjustment now will eliminate the possibility of resetting steering gear poppet valves after the gear is reinstalled. See **Fig. 1**.
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. Apply the parking brakes and chock the tires.
3. Clean all outside dirt from around the fittings and hose connections.
4. Drain the power steering system. Disconnect all hydraulic lines from the gear, marking the lines for later assembly reference. Seal the lines and the fittings to keep out dirt.
5. Disconnect the pitman arm from the steering gear sector shaft.
   - 5.1 Remove the pinch bolt, washer, and nut from the pitman arm. Discard the nut.
   - 5.2 Remove the pitman arm using a suitable puller, and swing the pitman arm and drag link out of the way.
6. Disconnect the steering driveline from the steering gear input shaft.
   - 6.1 Remove the pinch-bolt nut and pinch bolt from the steering driveline lower end yoke.

CAUTION

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   - 6.2 Remove the lower end yoke from the input shaft.
7. Clean the entire assembly before removing the gear.

IMPORTANT: The TAS40 steering gear weighs 40 lb (18 kg) dry, the TAS55 weighs 60 lb (27 kg) dry, and the TAS65 weighs 80 lb (36 kg) dry. Use care when removing, lifting, and carrying the steering gear, to avoid injury.

8. Remove the fasteners that attach the steering gear to the frame rail. Remove the steering gear.

Installation

IMPORTANT: The TAS40 steering gear weighs 40 lb (18 kg) dry, the TAS55 weighs 60 lb (27 kg) dry, and the TAS65 weighs 80 lb (36 kg) dry. Use care when removing, lifting, and carrying the steering gear, to avoid injury.

1. Install the steering gear and fasteners as shown in **Fig. 2**.

   Tighten the fasteners to the torque shown in **Table 1**.
2. If not previously done, center the steering gear. The sector (output) shaft alignment mark must be at a right angle to the steering gear input shaft centerline. Make sure the steering gear remains centralized as the service work continues.

Description	Size	Torque: lbf·ft (N·m)
Steering Gear Mounting Locknut	7/8–14	278–352 (377–477)

Table 1, Torque Values

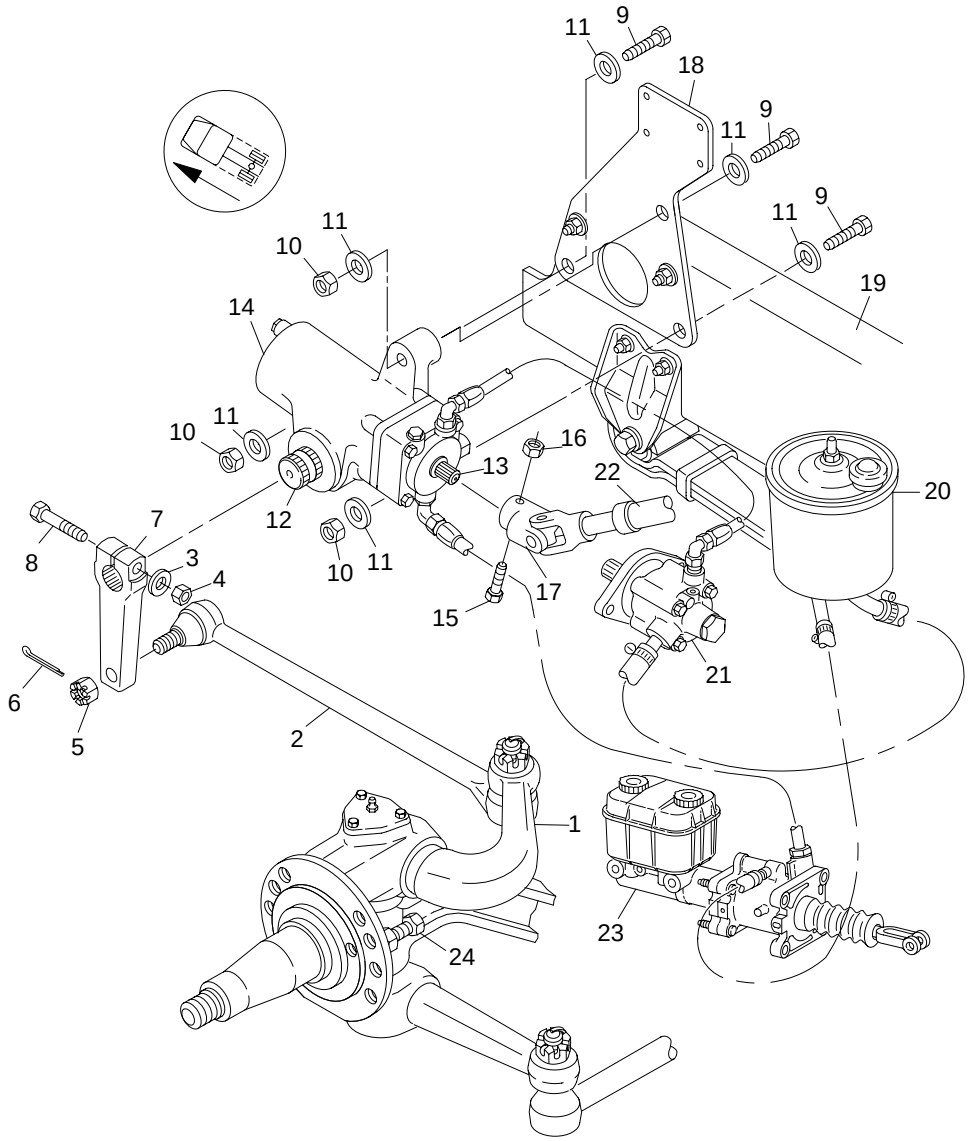
3. Install the pitman arm.
   - 3.1 Position the pitman arm on the steering gear, aligning the timing mark as shown in **Fig. 3**.

WARNING

Never leave a chisel wedged in the pitman arm slot. When using a chisel to spread the slot in the pitman arm, maintain a firm grip on the chisel at all times. Otherwise the chisel may fly loose, which could cause an injury.

NOTE: The pitman arm may not fit over the splines on the sector shaft without spreading the slot in the arm. Use a ball-peen hammer to drive a chisel into the slot. Hold the chisel in place. Install the pitman arm on the sector shaft. Remove the chisel from the slot.

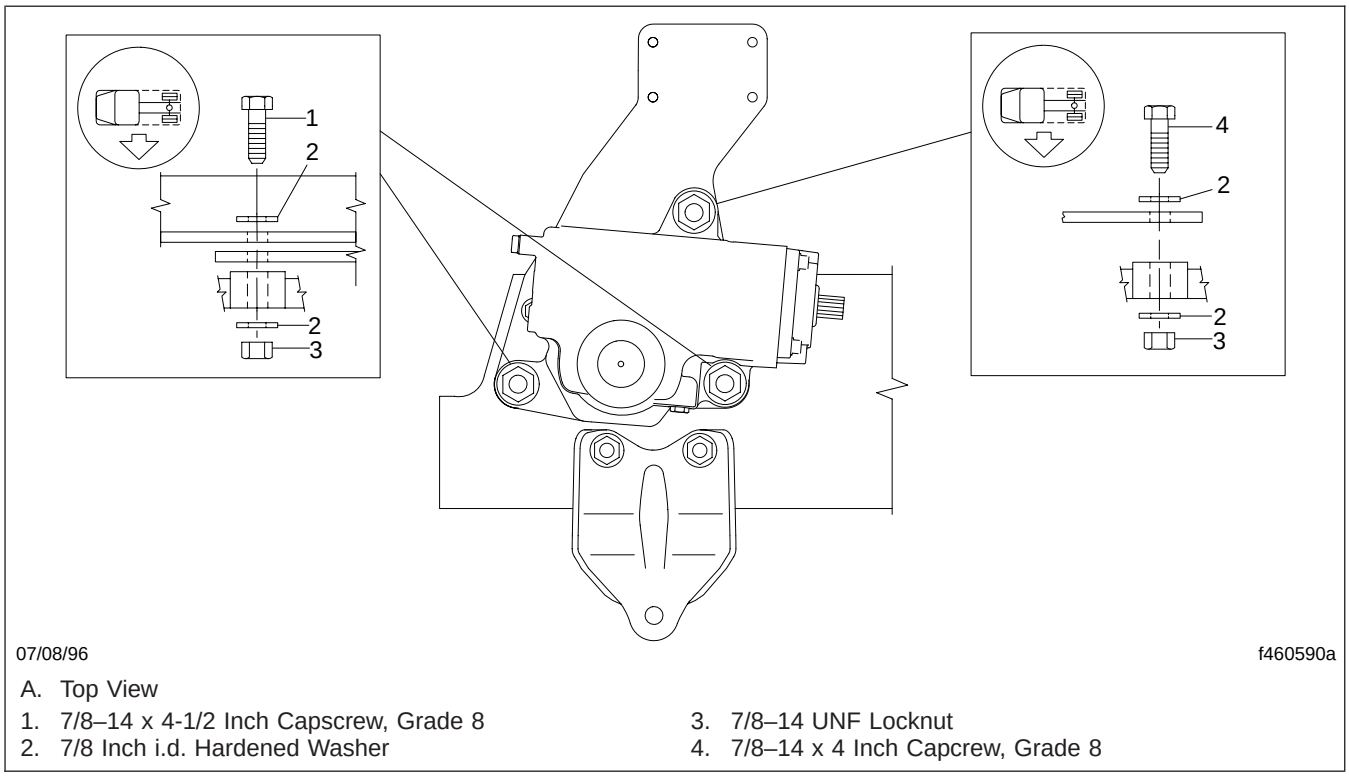
Steering Gear Removal and Installation



10/31/96 f460591a

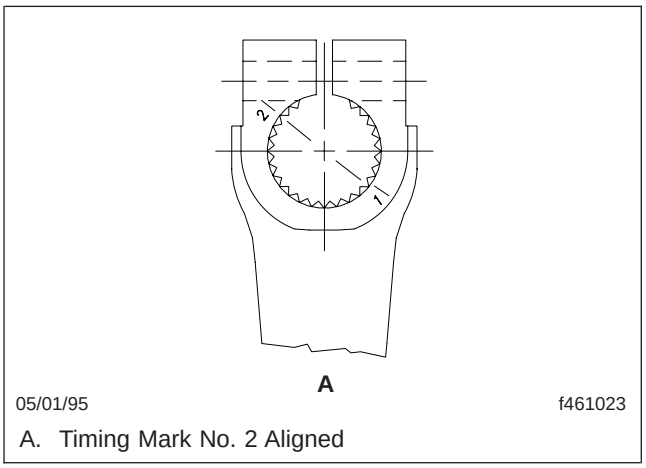
1. Axle Steering Arm
2. Drag Link
3. Pitman Arm Washer
4. Pitman Arm Pinch-Bolt Nut
5. Castle Nut
6. Cotter Pin
7. Pitman Arm
8. Pitman Arm Pinch Bolt
9. Mounting Capscrew
10. Locknut
11. Hardened Washer
12. Sector (Output) Shaft
13. Input Shaft
14. Steering Gear
15. Lower End Yoke Pinch Bolt
16. Lower End Yoke Pinch-Bolt Nut
17. Lower End Yoke
18. Steering Gear Mounting Plate
19. Left Frame Rail
20. Power Steering Reservoir
21. Power Steering Pump
22. Steering Driveline
23. Brake Booster
24. Axle Stop

Fig. 1, Ross TAS40/55/65 Steering Gear Installation (chassis with hydraulic brakes)



A. Top View
1. 7/8–14 x 4-1/2 Inch Capscrew, Grade 8
2. 7/8 Inch i.d. Hardened Washer
3. 7/8–14 UNF Locknut
4. 7/8–14 x 4 Inch Capcrew, Grade 8

Fig. 2, Steering Gear Installation, TAS40/55/65



A. Timing Mark No. 2 Aligned

Fig. 3, Typical Pitman Arm and Timing

3.2 Install the pitman arm pinch bolt, washer, and a new nut. Tighten the locknut as shown in **Table 2**.

Description	Size	Torque: lbf·ft (N·m)
Pinch-Bolt Locknut	5/8–14	120–140 (163–190)
	3/4–16	215–245 (292–332)

Table 2, Pinch-Bolt Locknut Torque Values

3.3 Apply white Torque Seal® F-900 to the exposed threads and the locknut.

4. Connect the steering driveline to the steering gear input shaft.

4.1 Clean the steering gear input shaft and the inside of the driveline yoke.

4.2 Apply a thin film of grease to the yoke spline.

4.3 Slide the yoke onto the input shaft, and install a new yoke pinch bolt and a new pinch-bolt locknut. Tighten the pinch-bolt nut 55 to 65 lbf·ft (75 to 88 N·m).

4.4 Apply white Torque Seal F-900 to the exposed pinch-bolt threads and the locknut.

Steering Gear Removal and Installation

5. Connect the hydraulic lines.
   - 5.1 If they were removed, attach the hydraulic line elbow fittings to the steering gear. Tighten the fittings 38 lbf·ft (51 N·m). Tighten the pressure line fitting jam nut 41 lbf·ft (56 N·m).
   - 5.2 Remove the plugs from the hydraulic lines. Connect the lines to the steering gear as previously marked. Tighten the nut on each fitting finger-tight. Then, use a wrench to tighten the nut until there is firm resistance. Tighten one-sixth turn more.
6. Fill and bleed the steering system.

   IMPORTANT: Do not turn the steering wheel until instructed. Doing so can cause air to enter the system, which can make it more difficult and time-consuming to bleed air from the system.
   - 6.1 Fill the power steering reservoir with Dexron II type ATF until nearly full. Crank the starter for 10 seconds without allowing the engine to start; if the engine does start, shut it down immediately. Check and fill the reservoir as needed. Repeat this procedure three times, each time checking and filling the reservoir.
   - 6.2 Start the engine and let it idle for two minutes. Shut down the engine, and check the fluid level in the reservoir.
   - 6.3 Start the engine again. Steer the vehicle from full-left to full-right, several times. As necessary, add fluid to the full line on the reservoir dipstick.

   IMPORTANT: If the poppet adjuster seat and sleeve assemblies were not set for automatic adjustment during assembly of the steering gear, AND if the axle stops have been adjusted for *decreased* steering travel or the steering gear is installed on a different vehicle, the poppets must be set manually, following the procedure under **Subject 100**.
7. Go to **Subject 140** and do the checks as instructed.
8. Test drive the vehicle, or take a ride with the driver.

Check the steering wheel spoke position. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 4**. If not, remove the steering wheel and install it in the correct position. For instructions, see the applicable section in this group.

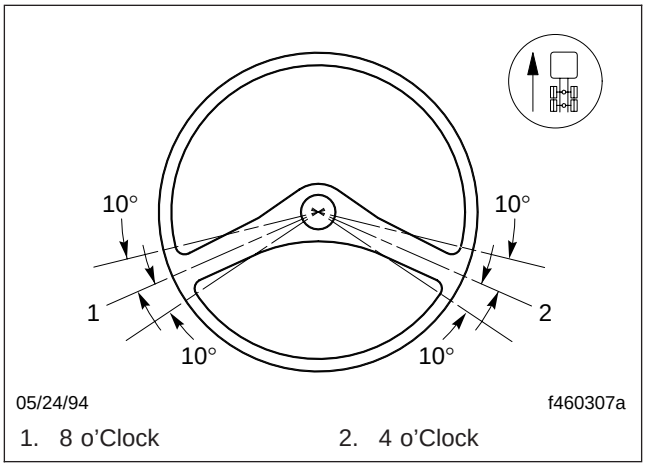


Fig. 4, Steering Wheel Centered

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

Disassembly

⚠ WARNING

All steering mechanisms are safety items. Because of this, follow the instructions in this subject exactly. Failure to do so may result in loss of steering, which could cause an accident resulting in personal injury or property damage.

Be sure that required tools are available before beginning the service procedures described here. See the special tools table in **Specifications, 400.** The special tools required for disassembly and assembly of the steering gear components are available from the Kent-Moore Tool Division, or an affiliated dealer.

IMPORTANT: When the sector shaft is disconnected from the vehicle steering linkage, don't allow the input shaft to move more than 1-1/2 turns from the straight-ahead position. If the input shaft moves more than 1-1/2 turns, the initial setting of the poppet valves will be changed.

Make sure that the steering gear is placed on a clean surface. Clean and dry the gear before disassembly. As the gear is disassembled, clean all parts in a clean, petroleum-based solvent, and blow them dry only.

Never steam clean or high-pressure wash the hydraulic steering components. Do not force or abuse closely fitted parts. Doing so could cause damage to steering system parts.

Keep each part separate to avoid nicks and burrs. Discard all seals, O-rings, and gaskets, and replace them with new parts. **See Fig. 1**.

1. Place the steering gear in a vise so that the output shaft is horizontal. Clamp the gear at the mounting flange.
2. Put a basin under the hydraulic ports, and remove both hydraulic port plugs from the gear.
3. Using a 3/4-inch or 11/16-inch socket wrench, turn the input shaft so that the timing mark on the end of the sector shaft is lined up with the timing mark on the end of the housing trunnion. See **Fig. 2**.
4. Using a small screwdriver, remove and discard the water seal from the housing trunnion. See **Fig. 3** . Remove any dirt, paint, or corrosion from the sector shaft with a piece of fine emery cloth. See **Fig. 4**.
5. Tape the splines and the bolt groove of the sector shaft, using one layer of masking tape. See **Fig. 5**.
6. Using a 3/4-inch socket, remove the jam nut from the sector shaft adjusting screw. See **Fig. 6**.
7. Put a container under the side cover to catch any drainage, then remove the six special bolts from the side cover. See **Fig. 7**.

IMPORTANT: These special bolts are equipped with either an integral ring or washer on the underside of the head. See **Fig. 8**. If replacing one or more bolts, use bolts of the *same special type and length as those that were removed*. Do not use a substitute. Don't mix different types of bolts.

8. Remove the side cover and the sector shaft assembly, as a unit, from the steering gear housing. See **Fig. 9**. If necessary, start the removal by tapping the end of the sector shaft with a rubber or wooden mallet.

   Remove and discard the side cover gasket.
9. Using a screwdriver, screw the sector shaft adjusting screw into the side cover. See **Fig. 10**.
10. Remove the sector shaft from the side cover.
11. Remove the side-cover seal:

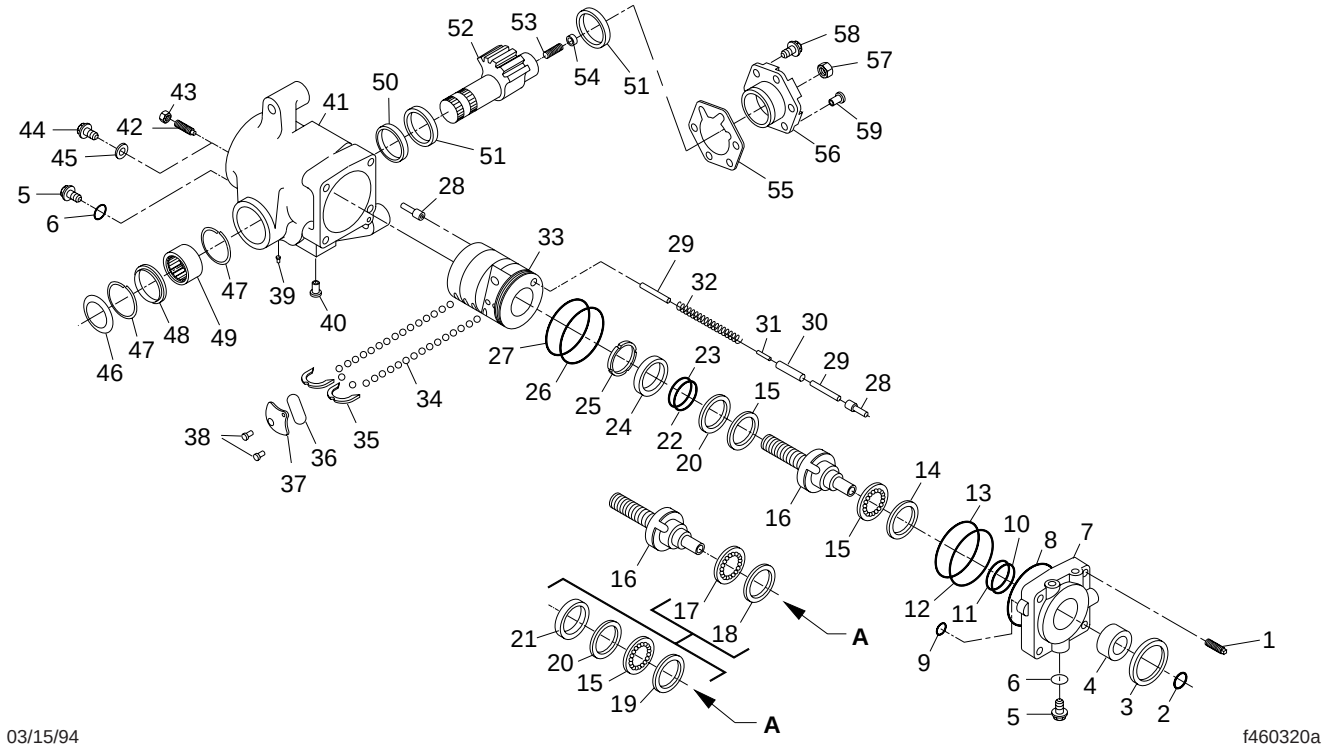
    IMPORTANT: Be careful when you are removing the side-cover seal, or you may damage the side-cover bore, the *"DU"* bushing (on a TAS65 gear).

    11.1 Screw a 3-inch, 1/2-20 bolt into the hole in the side cover where the sector shaft adjusting screw was.

    Make sure the bolt is in far enough so that it will support a rolling head (ladyfoot) type pry bar. See **Fig. 11**.

    11.2 With the pry bar supported by the bolt end, pry up the side-cover seal, and remove it. Discard the side-cover seal, and remove the 3-inch bolt from the side cover.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



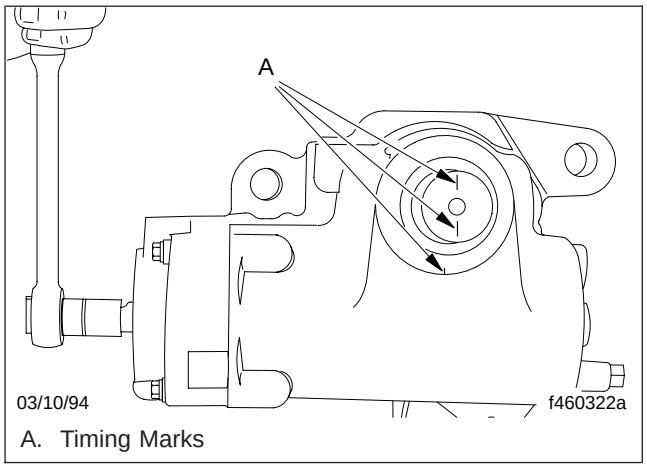
NOTE: The side cover for TAS65 steering gears contains a bushing.

A. Alternate Construction

1. Bolts, Valve Housing (4 qty.)
2. Dirt-and-Water Seal
3. Retaining Ring
4. Seal
5. Auxiliary Port Plug (2 qty.)
6. O-Ring, Auxiliary Port Plug (2 qty.)
7. Valve Housing and Ball Plug Assembly
8. Seal Ring, Large
9. Seal Ring, Small
10. O-Ring
11. Seal Ring
12. O-Ring, Valve Housing
13. Seal Ring
14. Thrustwasher, Thick
15. Roller Thrust Bearing (1 or 2 qty.)
16. Input-Shaft/Valve/Worm Assembly
17. Ball Bearing Assembly (Valve/Worm)
18. Ball Bearing Race
19. Thrustwasher, Thick
20. Thrustwasher, Thin
21. Spacer Sleeve
22. Seal Ring
23. O-Ring
24. Bearing Adjuster
25. Adjuster Locknut
26. Seal Ring, Rack Piston
27. O-Ring (Backup)
28. Poppet Adjuster Seat and Sleeve Assembly (2 qty.)
29. Poppet (2 qty.)
30. Push Tube
31. Spacer Rod
32. Poppet Spring
33. Rack Piston
34. Steel Balls
35. Ball Return Guide Halves (2 qty.)
36. Seal, Ball Return Guide Cap
37. Ball Return Guide Cap
38. Torx Screws (2 qty.)
39. Grease Fitting
40. Plug, Auto-Bleed
41. Gear Housing
42. Service Poppet Adjusting Screw
43. Service Sealing Jam Nut
44. Fixed Stopscrew, Poppet
45. Washer, Stopscrew
46. Dirt-and-Water Seal (Trunnion)
47. Retaining Ring (2 qty.)
48. Dirt Seal
49. Roller Bearing
50. Washer (Spacer)
51. Seal, Output (2 qty.)
52. Sector Shaft
53. Adjusting Screw, Shaft
54. Retainer, Adjusting Screw
55. Gasket, Side Cover
56. Side Cover and Bushing/Bearing Assembly
57. Jam Nut
58. Special Bolts, Side Cover (6 qty.)
59. Vent Plug, Side Cover

Fig. 1, Steering Gear Components

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



A. Timing Marks

Fig. 2, Line Up the Timing Marks

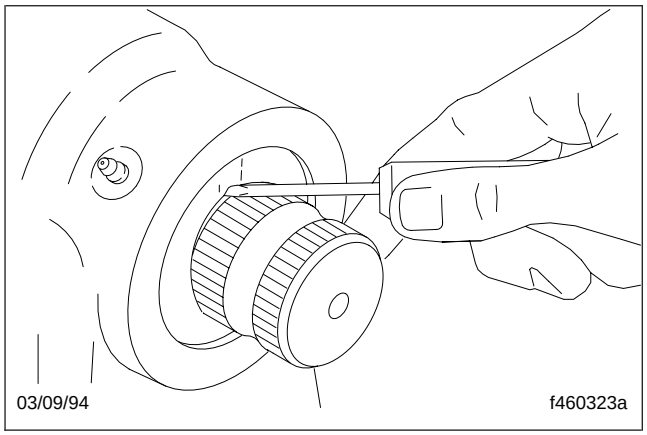


Fig. 3, Remove the Water Seal

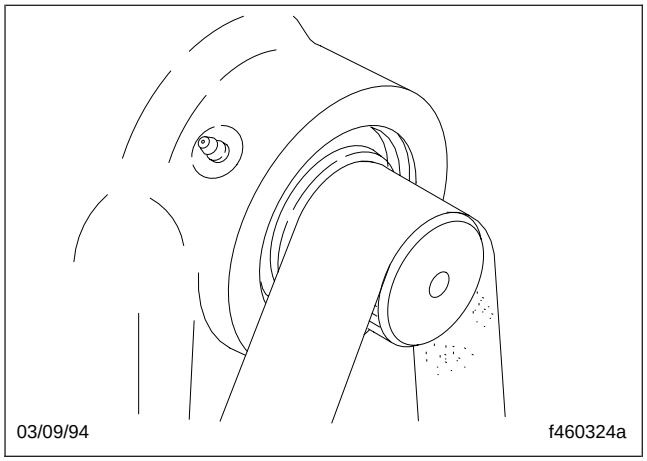


Fig. 4, Remove Dirt, Paint, or Corrosion

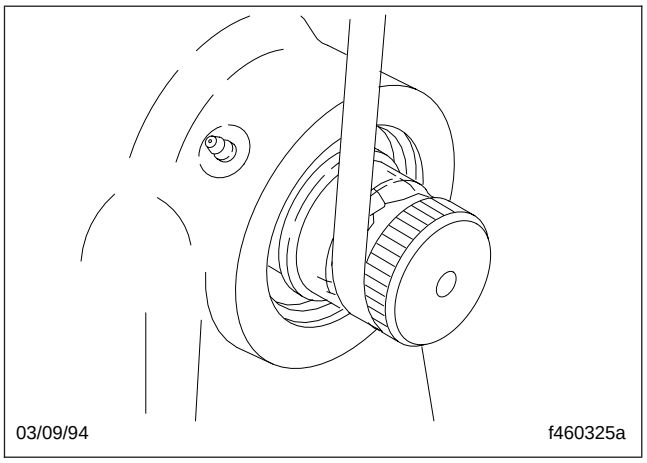


Fig. 5, Tape the Splines

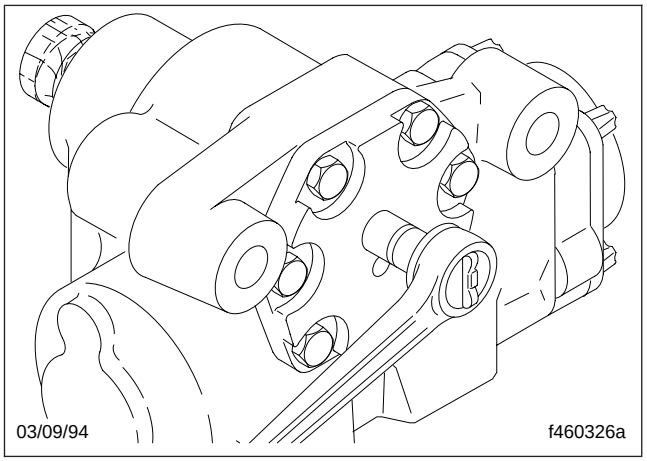


Fig. 6, Remove the Jam Nut

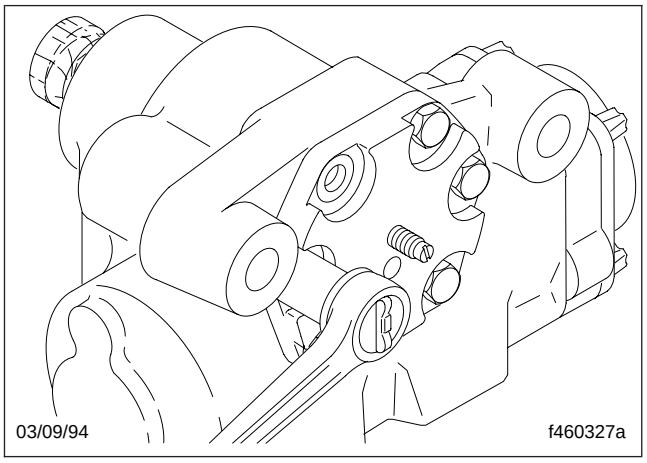


Fig. 7, Remove the Special Bolts

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

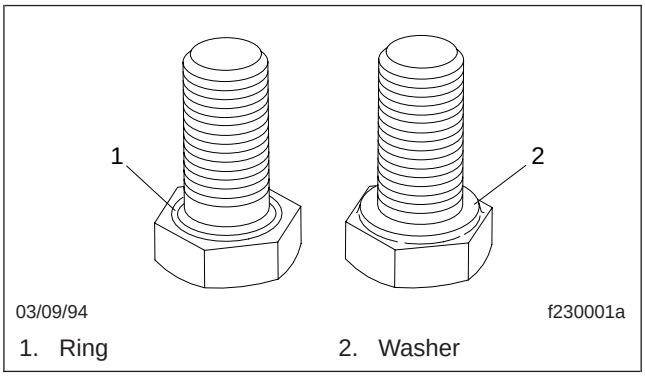


Fig. 8, Integral Ring and Washer

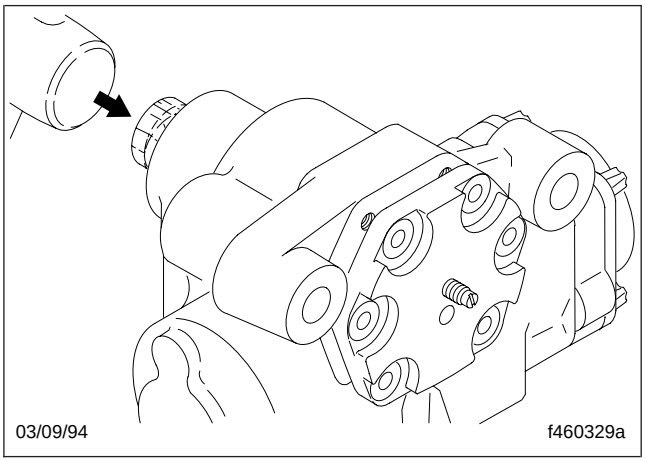


Fig. 9, Remove the Side Cover and Sector Shaft

12. Remove and discard the vent plug from the side cover.
13. Put the sector shaft in a padded vise, and using a chisel, unstake the adjusting-screw retainer. See **Fig. 12**. Unscrew the retainer, remove it from the sector shaft, then remove the adjusting screw. Discard the retainer.
14. Remove and discard the dirt-and-water seal from the input shaft. Clean the exposed part of the input shaft, using a fine grade emery cloth. See **Fig. 13**.
15. Using an E-16 Torx® socket wrench, remove the four valve housing bolts. See **Fig. 14**.
16. Remove the valve housing from the main gear housing, together with the worm shaft and rack piston assembly. See **Fig. 15**. Set the assembly on a clean bench.

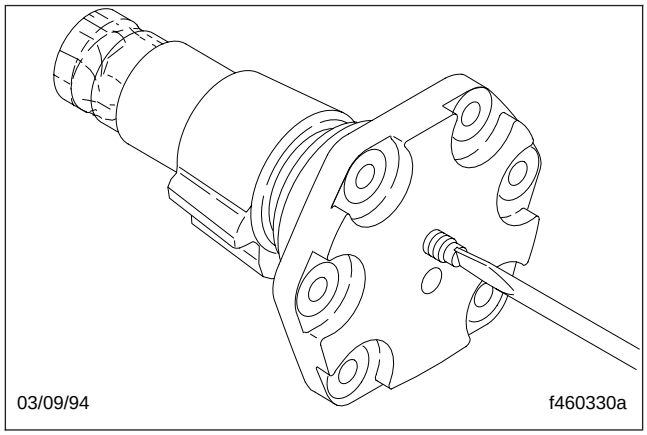


Fig. 10, Screw the Sector Shaft Adjusting Screw into the Side Cover

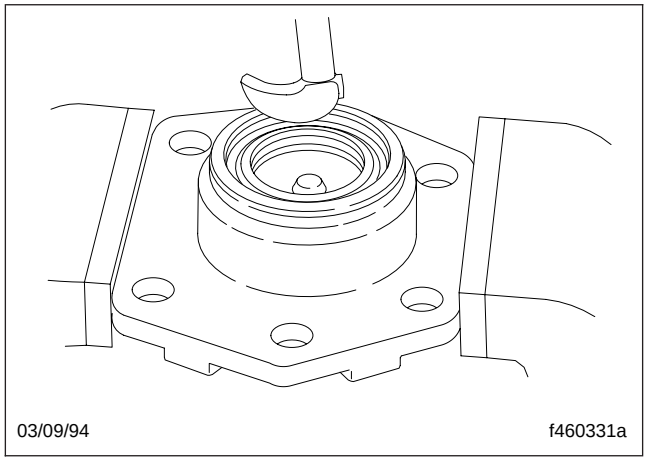


Fig. 11, Check the Bolt for Support

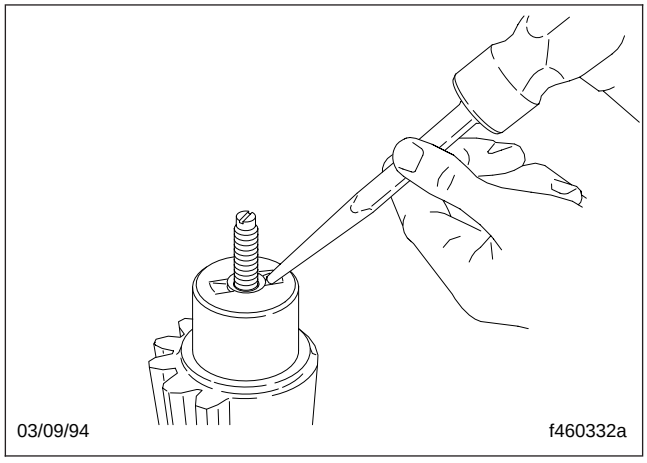


Fig. 12, Unstake the Adjusting-Screw Retainer

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

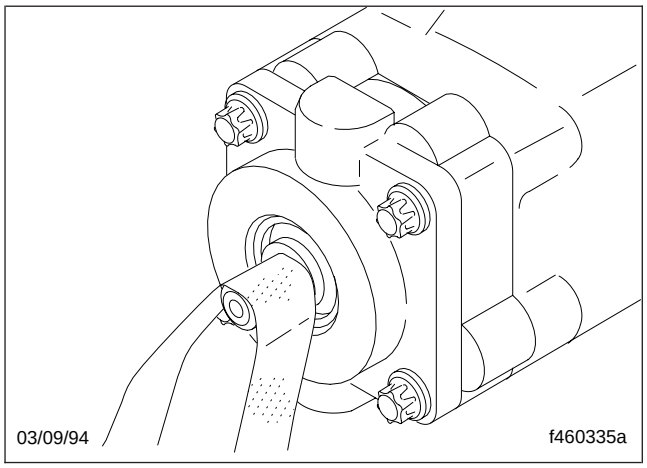


Fig. 13, Clean the Input Shaft with Emery Cloth

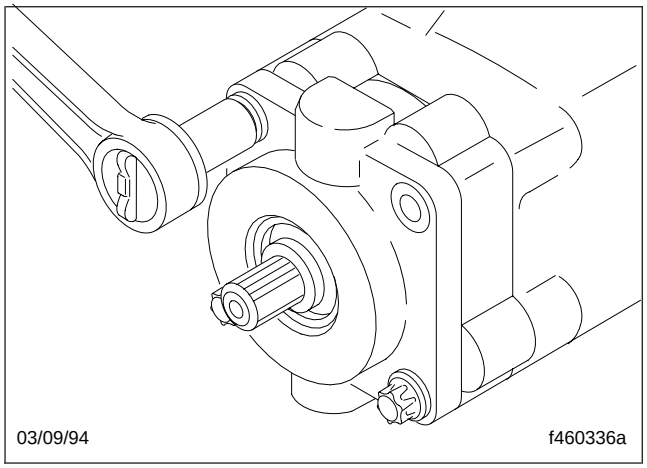


Fig. 14, Remove the Valve Housing Bolts

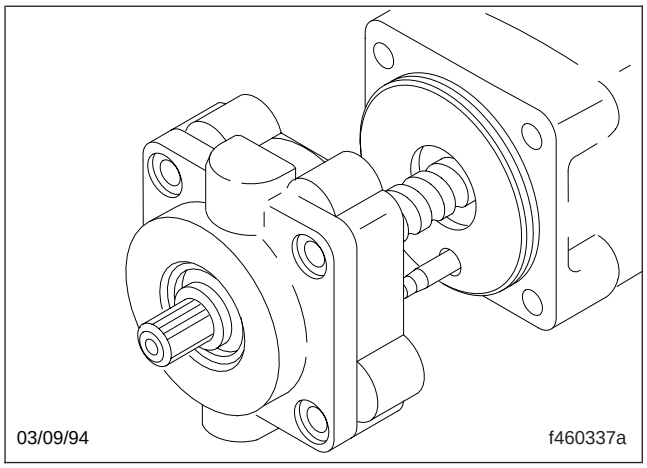


Fig. 15, Remove the Valve Housing

NOTE: It may be easier to remove the rack piston from the gear housing if the Teflon® ring on the rack piston is cut first. See **Fig. 16**.

17. Remove and discard the seal rings from the valve housing.

IMPORTANT: If you are not going to remove, reset, or replace the poppet valves on the steering gear, make sure that the setting for them isn't accidentally changed. Mark the gear, identifying the vehicle from which it was removed, and note that the poppet valve adjustments are for that particular vehicle.

18. Using a 5/32-inch allen socket (or a T-30 Torx wrench), remove the two sealing screws holding the ball return guide cap to the rack piston. See **Fig. 17**. Remove the cap and its seal. See **Fig. 18**. Discard the two screws and the seal.

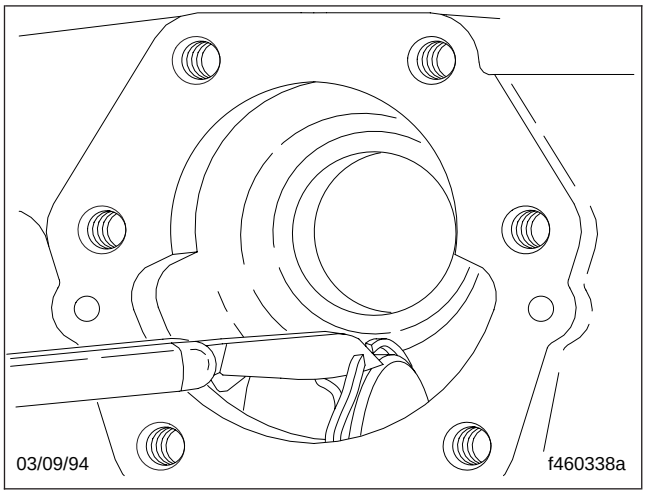


Fig. 16, Cut the Teflon Ring

19. Remove the ball return guide halves from the rack piston by carefully prying up on them with a screwdriver. See **Fig. 19**.

20. Remove the 29 (TAS40), 31 (TAS55), or 32 (TAS65) steel balls from the rack piston by turning the worm shaft until all of them are out. See **Fig. 20**. *Do not lose any of these balls, or you will have to replace the entire set.*

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

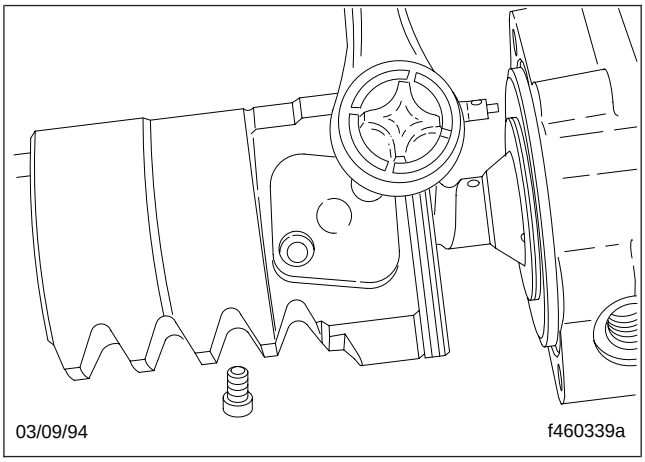


Fig. 17, Remove the Two Sealing Screws

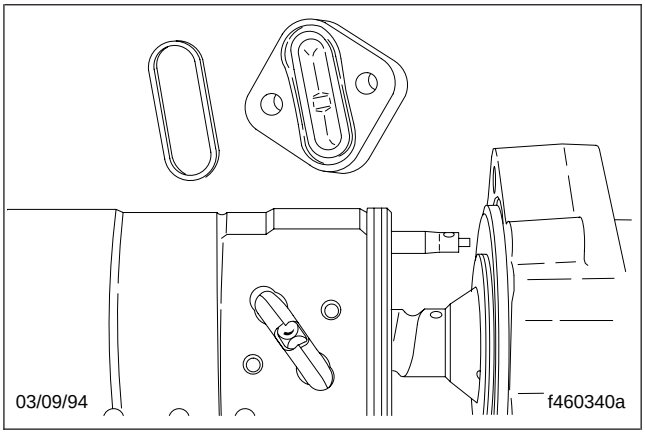


Fig. 18, Remove the Cap and Seal

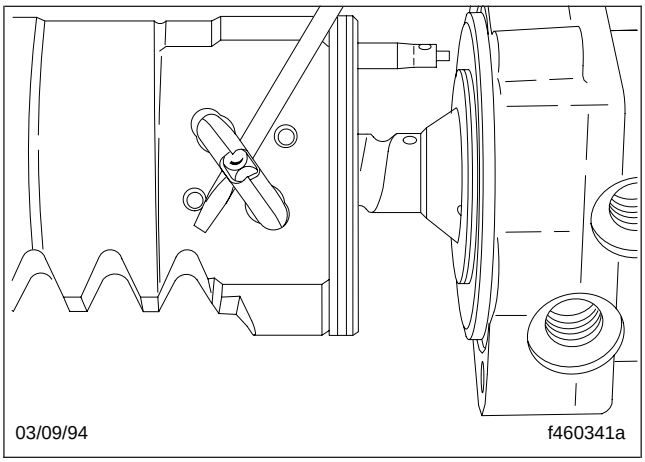


Fig. 19, Remove the Ball Return Guide Halves

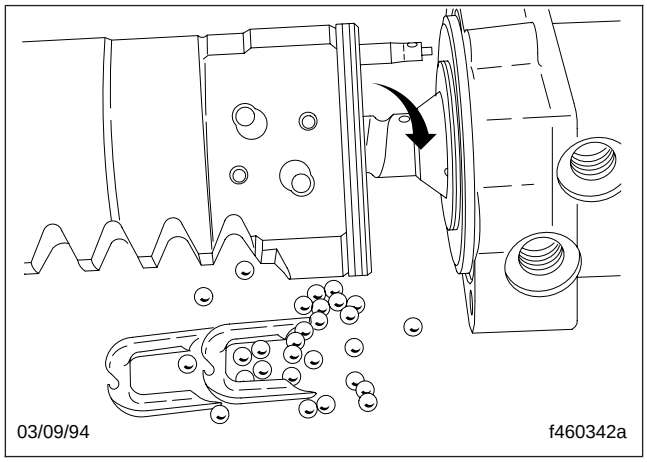


Fig. 20, Remove the Steel Balls

WARNING

Never mix different sets of steel balls. To do so may cause a loss of steering control, which could cause an accident resulting in serious injury or property damage.

21. Remove the worm shaft and valve housing assembly from the rack piston. See **Fig. 21**.

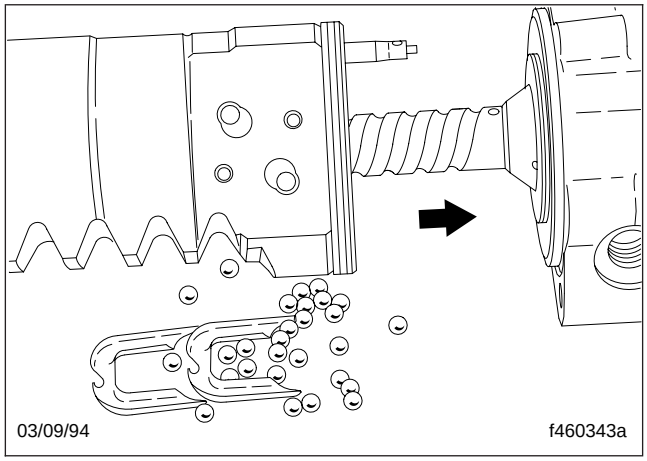


Fig. 21, Remove the Worm Shaft and Valve Housing Assembly

22. If not already done, cut and remove the Teflon seal ring and the O-ring from the rack piston. See **Fig. 22**.

23. Remove the poppet valve assemblies:

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

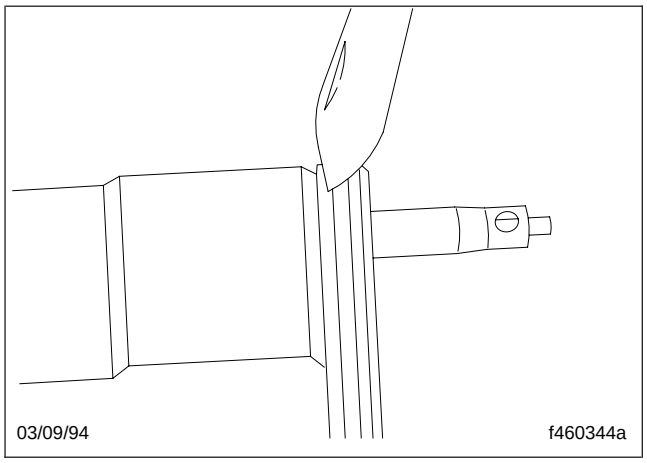


Fig. 22, Cut the Teflon Seal Ring

⚠ CAUTION

The poppet valve assemblies are installed with Loctite®. Be careful when removing them, and use only special tool J36452 or J38713. Failure to do so may damage the rack piston, which would require replacing the rack piston, steel ball kit, and the poppet valve assemblies.

IMPORTANT: Don't use special tool J38713 on a rack piston that doesn't have a counterbore in the hole for the seat and sleeve assembly.

23.1 Put the rack piston in a padded vise.

23.2 Slide the special tool J36452 or J38713 over the poppet adjuster seat. See **Fig. 23**. Turn the tool so that its prongs fit into the slot on the threaded adjustment sleeve. Hit the end of the tool firmly four or five times with a 16 oz. hammer to loosen the Loctite. See **Fig. 24**.

23.3 Using a breaker bar, unscrew the adjuster seat and sleeve assemblies from the rack piston.

23.4 Remove both poppets, and the spring, spacer rod, and push tube. See **Fig. 25**.

23.5 Repeat the previous steps for the other poppet adjuster seat and sleeve assembly.

24. If it's necessary to disassemble the valve housing, do the following:

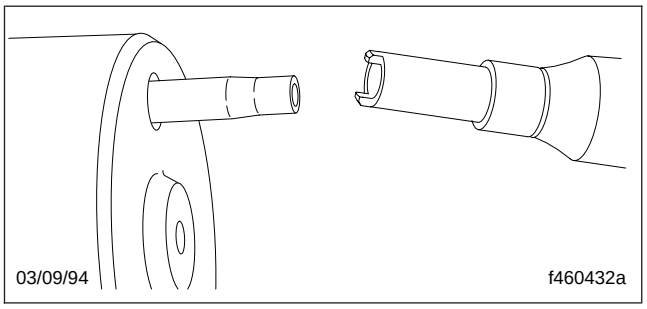


Fig. 23, Slide the Special Tool Over the Poppet Adjuster Seat

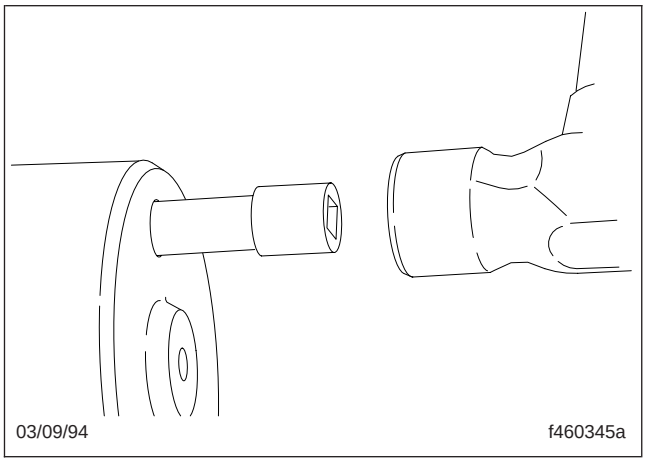


Fig. 24, Hit the End of the Tool with a Hammer

IMPORTANT: Don't disassemble the valve housing unless you find signs of extreme heat, internal leakage, bearing damage or roughness, or if worm shaft preload adjustment is necessary.

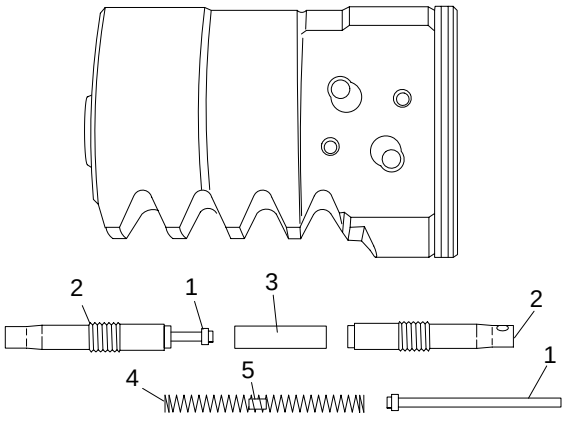
24.1 Put the worm shaft and valve housing assembly into a padded vise, with the worm shaft in a vertical position, as shown in **Fig. 26**.

24.2 Using a punch, unstake the adjuster locknut. See **Fig. 26**.

24.3 Using special tools J37464 and J37070, unscrew the adjuster locknut, then the bearing adjuster from the valve housing. See **Fig. 27**.

NOTE: The bearing adjuster has either two slots (new-style), or two drill points (old-style) on its face. Special tool J37070 can be used for re-

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



1. Poppet
2. Adjuster Seat and Sleeve Assembly
3. Push Tube
4. Poppet Spring
5. Nylon Spacer Rod (inside poppet spring)

Fig. 25, Remove the Poppets, Spring, Spacer Rod, and Push Tube

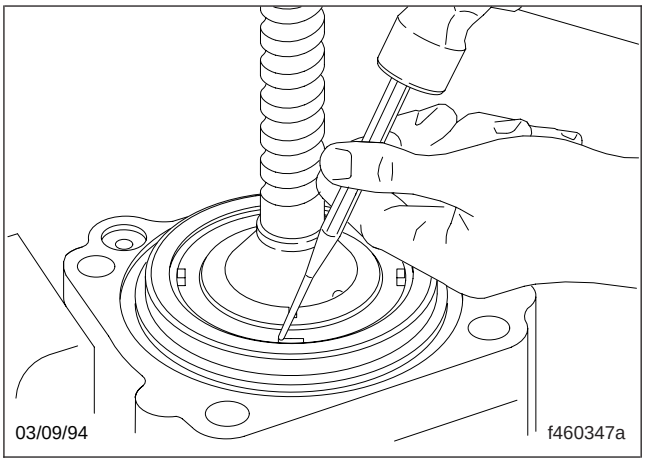


Fig. 26, Unstake the Adjuster Locknut

moving and installing either style of bearing adjuster. See **Fig. 27**.

25. Remove and discard the seal ring and the O-ring from the bearing adjuster. See **Fig. 28**.
26. Remove the thin washer, thrust bearing, input shaft, rotary valve, and worm shaft assembly from the valve housing. See **Fig. 29**.

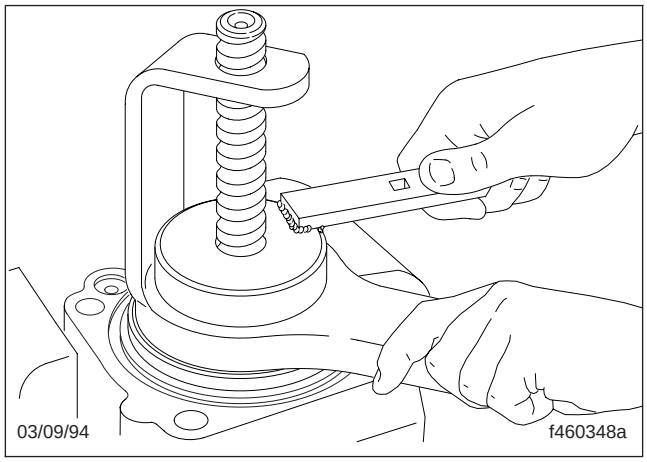


Fig. 27, Unscrew the Adjuster Locknut and Bearing Adjuster

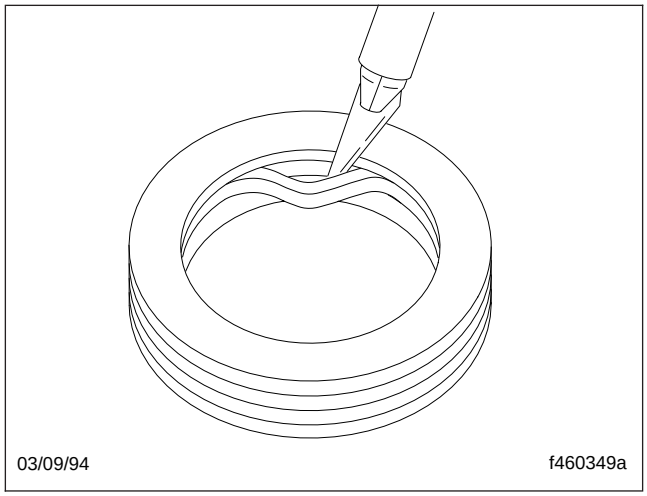


Fig. 28, Remove the Seal Ring and O-Ring

IMPORTANT: Don't disassemble the input shaft or worm shaft assembly any further. These aren't serviceable.

27. Depending on how the gear is equipped, do one of the following (A, B, or C):

    A. Remove the roller thrust bearing assembly and the thick thrustwasher from the valve housing. See **Fig. 30**.

    B. Remove the spacer sleeve, thin thrustwasher, roller thrust bearing assembly, and the thick thrustwasher from the valve housing. See **Fig. 31**.

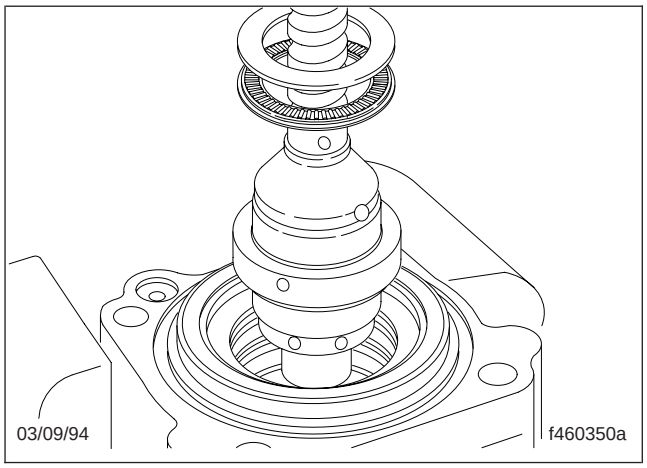


Fig. 29, Remove the Thin Washer, Thrust Bearing, Input Shaft, Rotary Valve, and Worm Shaft Assembly

C. Remove the ball bearing assembly and ball race from the valve housing. See **Fig. 32**.

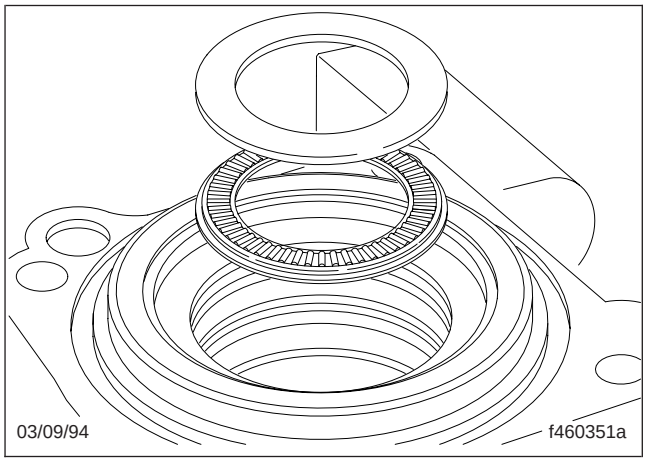


Fig. 30, Remove the Roller Thrust Bearing and Thick Thrustwasher

⚠ WARNING

If a ball bearing assembly is present, do not continue servicing the steering gear. Contact a Freightliner district service manager for instructions on returning the steering gear to the manufacturer. Under no circumstances is this steering gear to be serviced further, or installed on a vehicle. To do so could cause an accident resulting in property damage or serious personal injury.

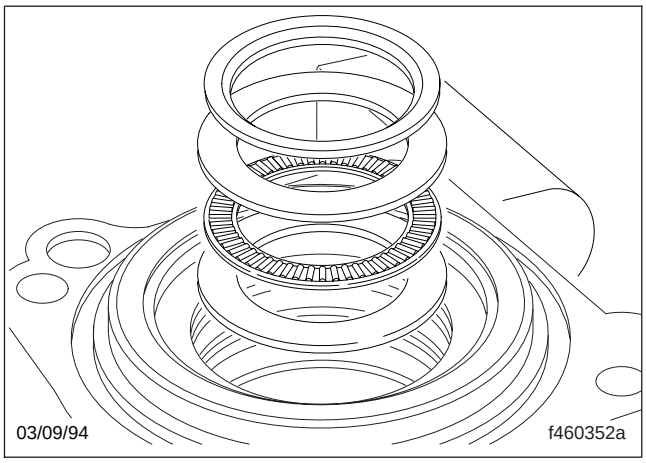


Fig. 31, Remove the Spacer Sleeve, Thin Thrustwasher, Roller Thrust Bearing Assembly, and the Thick Thrustwasher

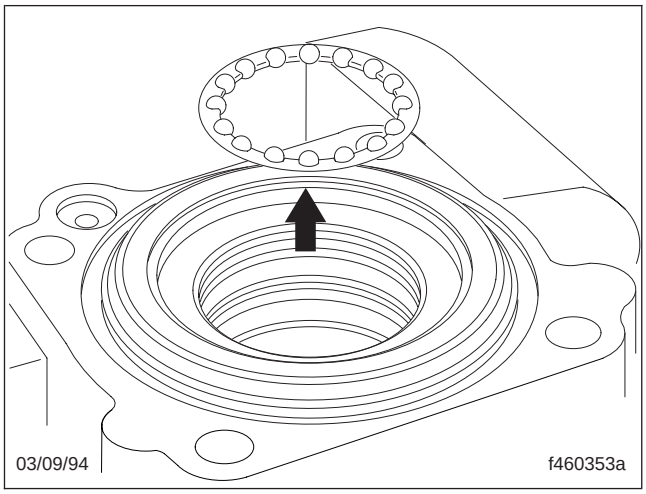


Fig. 32, Remove the Ball Bearing Assembly and the Ball Race

28. Using a small knife, a probe, or a pick, remove and discard the seal rings and O-rings from the valve housing. See **Fig. 33**.

⚠ CAUTION

In the next step, be careful when removing the retaining ring and seal from the valve housing, or you may damage the seal bore. If this happens, you will have to replace the gear housing.

29. Turn the valve housing over, and remove the retaining ring. See **Fig. 34**. Using a 1-1/8 inch

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

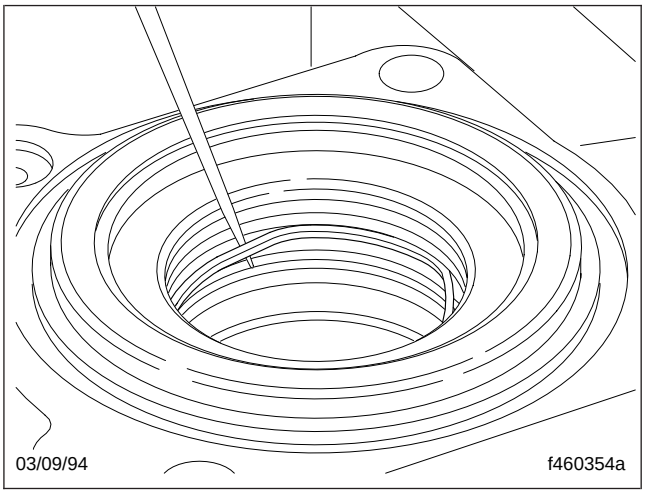


Fig. 33, Remove and Discard the Seal Rings and O-rings from the Valve Housing.

socket, tap out the seal from the valve housing. See **Fig. 35**. Discard the seal.

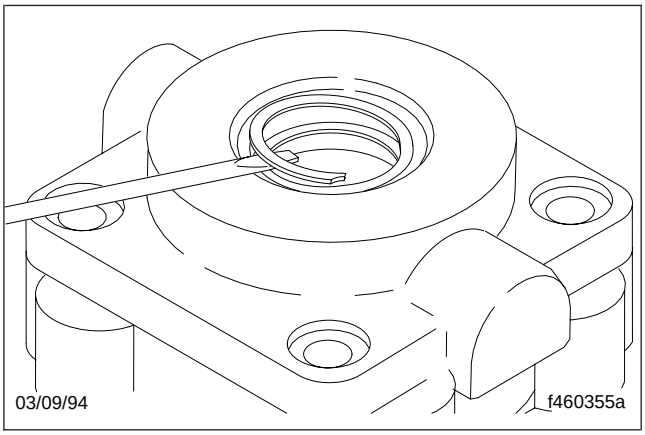


Fig. 34, Remove the Retaining Ring

30. If replacing either of the auxiliary port plugs, remove them. Be sure to remove and discard the O-rings.
31. The steering gear is equipped with either a poppet fixed stopscrew, or an adjusting screw and sealing nut. See **Fig. 36**.

    If the poppet fixed stopscrew needs replacement, remove it, using a 5/8-inch socket wrench, or an E–14 Torx wrench.

    If the adjusting screw and sealing nut need replacement, remove them, using a 7/32-inch allen wrench and a 3/4-inch socket wrench.

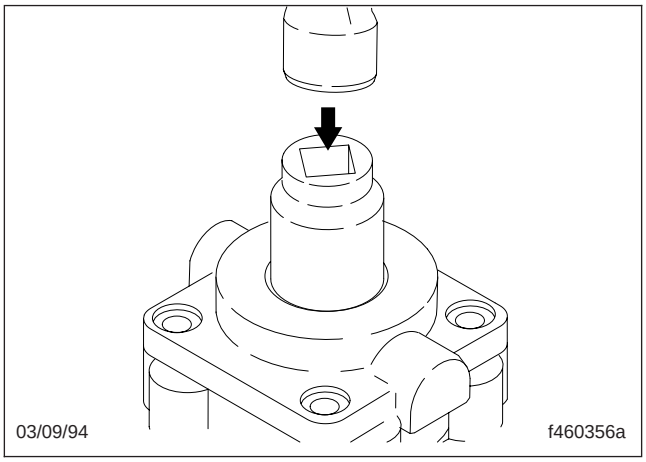
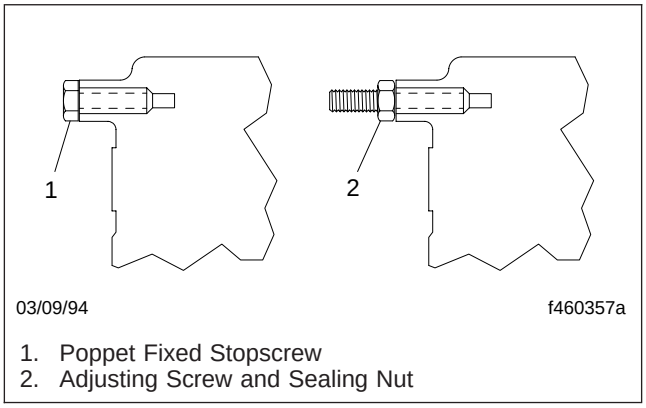


Fig. 35, Tap out the Seal from the Valve Housing



1. Poppet Fixed Stopscrew
2. Adjusting Screw and Sealing Nut

Fig. 36, Gear Equipped with a Poppet Fixed Stopscrew and Adjusting Screw and Sealing Nut

32. Remove the retaining ring from the output end of the housing trunnion. See **Fig. 37**.
33. Remove and discard the dirt seal. See **Fig. 38**.
34. Insert a screwdriver into the gear housing, and carefully push the seal and the spacer washer out of the other end of the bearing bore. See **Fig. 39**. Be careful not to damage the sealing area of the bore. Discard the seal.
35. If replacing the roller bearing in the housing, remove it, using special tool J37071. Press the roller bearing out of the trunnion end of the housing, from the side of the bore where the side cover was attached. See **Fig. 40**.
36. If replacing the retaining ring, remove it through the trunnion end, opposite the end where the

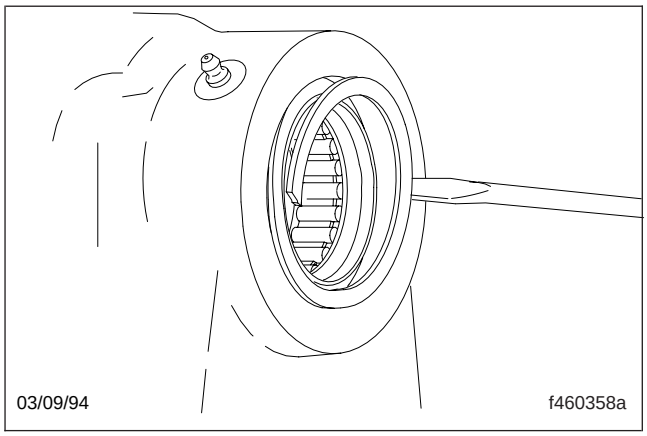


Fig. 37, Remove the Retaining Ring

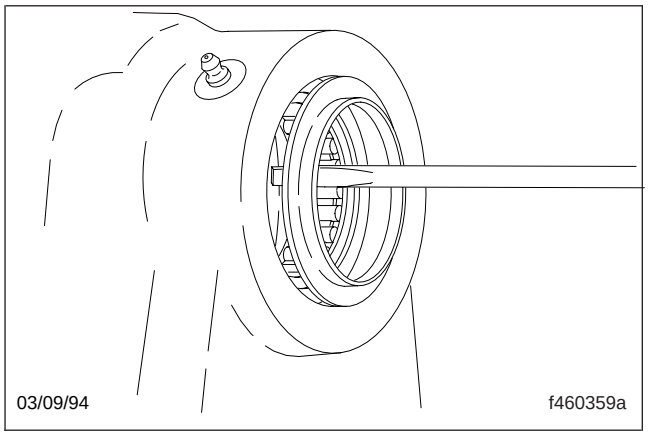


Fig. 38, Remove the Dirt Seal

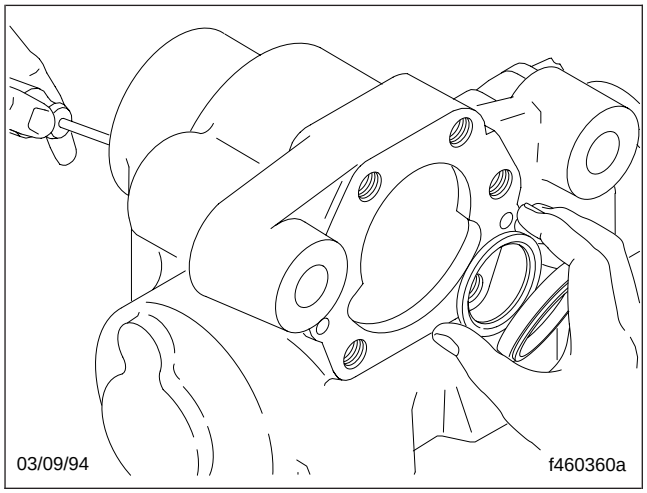


Fig. 39, Push the Seal and the Spacer Washer

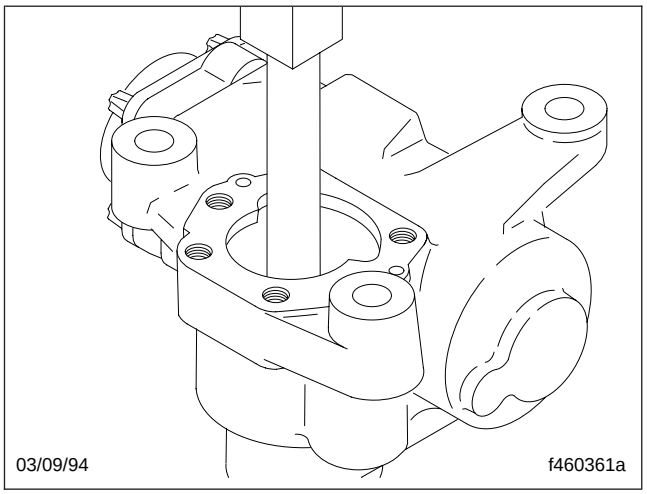


Fig. 40, Press out the Roller Bearing

side cover was attached. See **Fig. 41**. Be careful not to damage the pressure seal bore area.

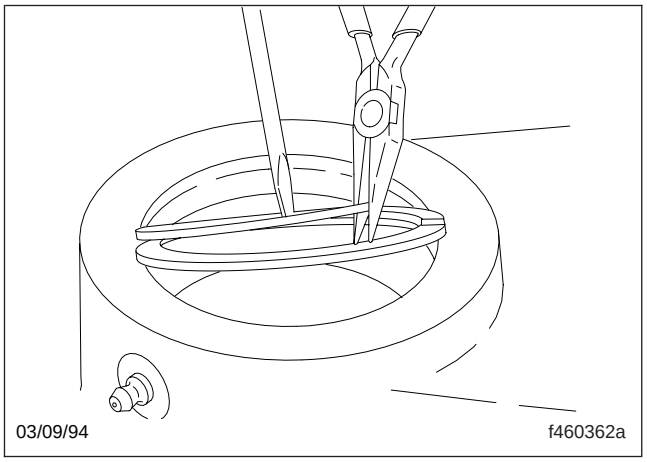


Fig. 41, Remove the Retaining Ring

Inspection

All sealing surfaces and seal cavities must be free of nicks and corrosion. If any part is nicked or corroded where sealing occurs, the part must be replaced to ensure proper sealing.

Wash all parts in a clean petroleum-based solvent. Blow them dry with air.

1. Inspect the rack piston teeth for cracks and wear. See **Fig. 42**. If a step can be detected by running your fingernail horizontally across the teeth

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

surfaces, the rack piston, the sector shaft, and the set of steel balls must be replaced.

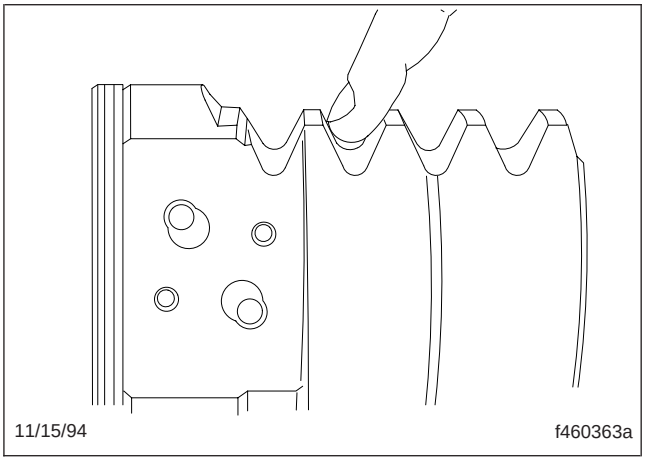


Fig. 42, Inspect the Rack Piston Teeth

2. Inspect the rack piston internal ball-track grooves for brinelling (dents) or spalling (flaking). See **Fig. 43**. If either condition exists, replace the following parts: the rack piston; the valve/worm shaft assembly, and the set of steel balls.

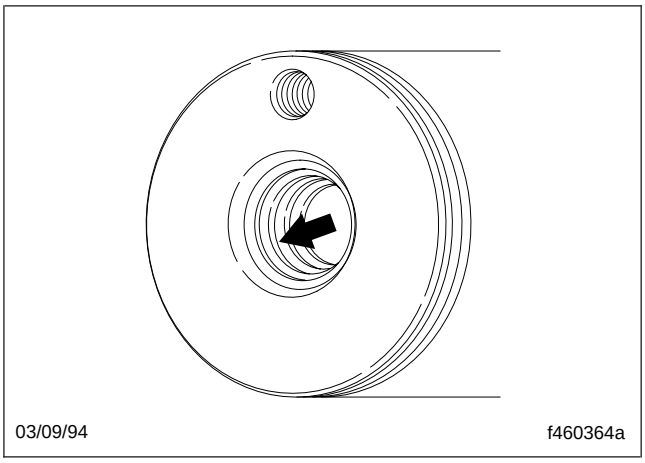


Fig. 43, Inspect the Rack Piston Internal Ball-Track Grooves

3. Inspect the worm shaft ball-track grooves for brinelling or spalling. See **Fig. 44**. If either condition exists, replace the following parts: the worm/input shaft assembly; the rack piston; and the set of steel balls. Inspect the upper shaft-seal area, near the input shaft serrations, for nicks. Run your fingernail across the sealing surface to detect steps. See **Fig. 45**.

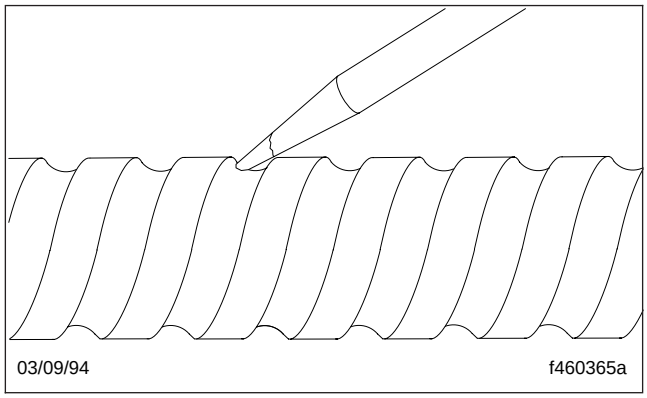


Fig. 44, Inspect the Worm Shaft Ball-Track Grooves

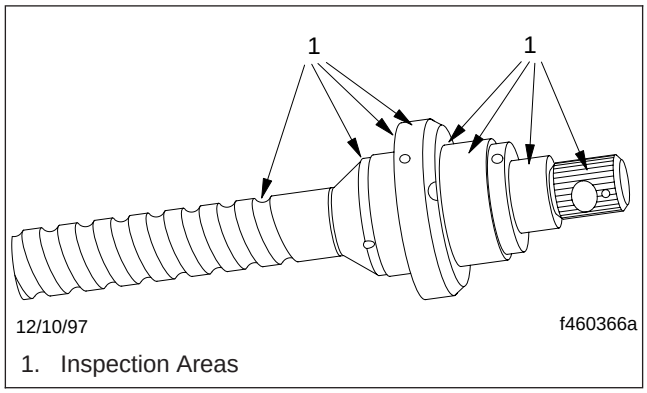


Fig. 45, Inspect the Upper Shaft-Seal Area

4. Inspect the housing cylinder bore. See **Fig. 46**. Minor scoring marks running lengthwise through the bore are normal, and should not be compared to the scoring that might be found in the cylinder bores of an inter-nal combustion engine. Replace the housing only if it has been tested for internal leakage, and it is determined that the scoring is the cause of internal leakage greater than 1 gpm (3.8 Lpm). For test procedures, refer to **Section 46.07, Subject 300.**

NOTE: In evaluating this test, make sure that internal leakage of more than 1 gpm (3.8 Lpm) can be attributed only to the housing, and not to the seals in the worm shaft, rack piston, and valve assembly.

5. Inspect the housing faces for nicks that would prevent proper sealing. See **Fig. 47.** Replace the gear housing if these nicks cannot be easily removed with a fine-toothed flat file, without changing the dimensional characteristics.

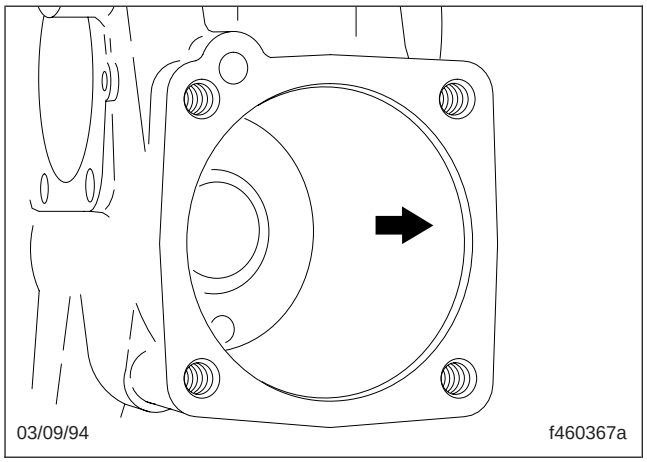


Fig. 46, Inspect the Housing Cylinder Bore

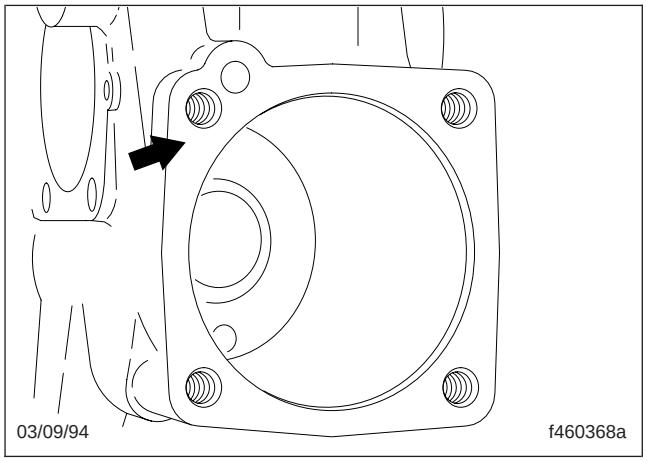


Fig. 47, Inspect the Housing Faces for Nicks

6. Inspect the housing roller bearing for brinelling or spalling. See **Fig. 48**. If either condition exists, replace the housing bearing. Inspect the side cover bushing. If the clearance between the bushing and the sector shaft is more than 0.008 inch (0.20 mm), replace the side cover and bushing assembly. See **Fig. 49**.
7. Inspect the sector shaft bearing sealing areas for brinelling or spalling. See **Fig. 50**. Run your fingernail across these areas to detect steps. Also, inspect for cracks. If any of these conditions exist, replace the sector shaft.
8. Check the sector shaft assembly for damaged adjusting screw threads. See **Fig. 1**. Make sure the staked retainer is locked in place and has no cracks. The adjusting screw must turn by hand with no end play (lash). If the adjusting screw is damaged, replace it and its retainer.

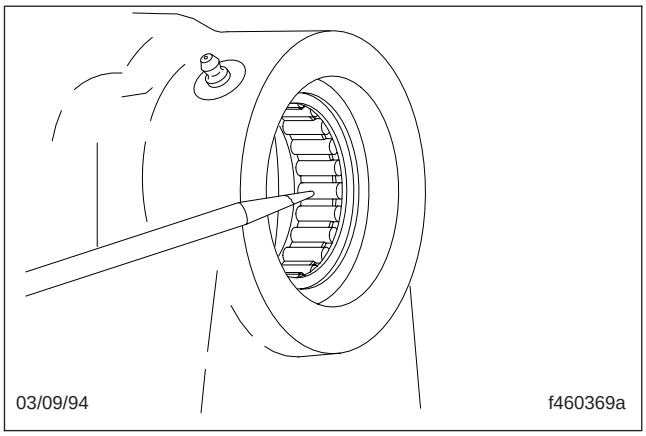


Fig. 48, Inspect the Housing Roller Bearing

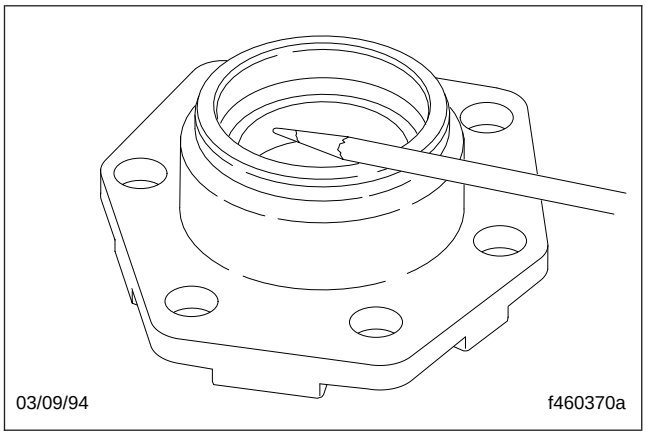
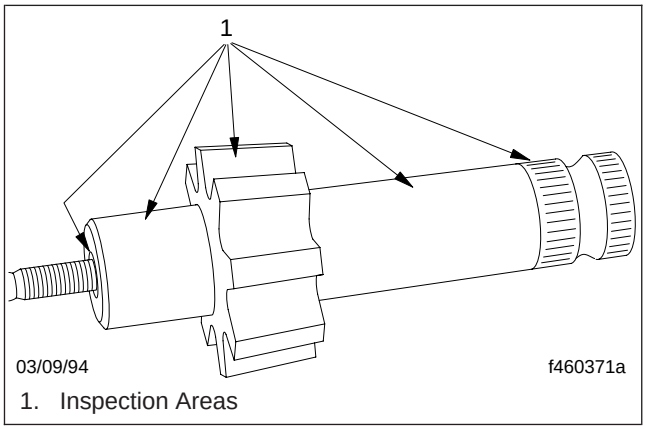


Fig. 49, Inspect the Side Cover Bushing



1. Inspection Areas

Fig. 50, Inspect the Sector Shaft Bearing Sealing Areas

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

9. Inspect the thrust bearing rollers for any deterioration. Inspect the thrustwashers for brinelling, spalling, or cracks. See **Fig. 51** or **Fig. 52**. Replace any part if these conditions are detected.

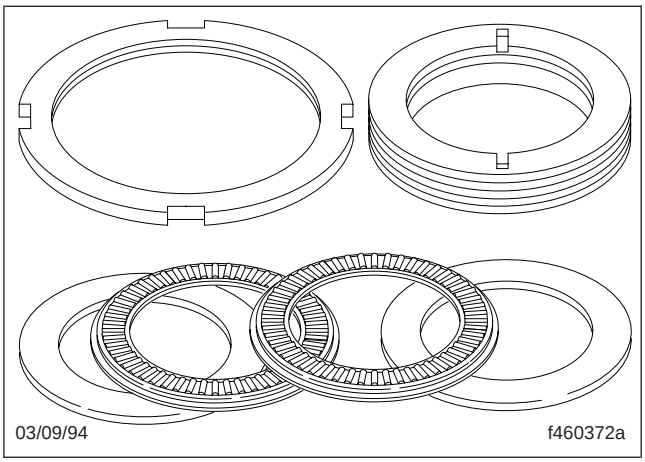


Fig. 51, Inspect the Thrust Bearing Rollers for Deterioration

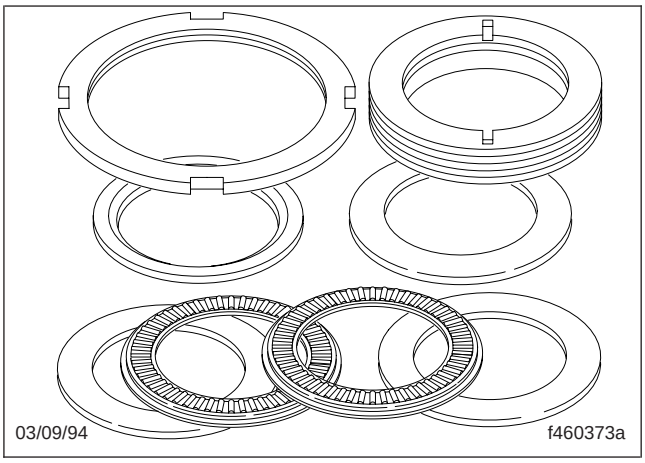


Fig. 52, Inspect the Thrustwashers for Brinelling, Spalling, or Cracks.

Assembly

IMPORTANT: Be sure that required tools are available before beginning the service procedures described here. See the special tools table in **Specifications, 400.** The special tools required for disassembly and assembly of the steering gear components are available from the Kent-Moore Tool Division, or an affiliated dealer.

After inspection, clean all parts again in clean petroleum-based solvent, and blow them dry with air.

All seals, seal rings, and gaskets, must be replaced with new ones each time the gear is disassembled. Individual seals, seal rings, and gaskets, as well as complete seal kits are available from Freightliner parts distributors. See **Fig. 1**.

1. If installing a new roller bearing into the gear housing:

   1.1 Put the gear housing on its side, with the trunnion end of the bore facing up, as shown in **Fig. 53**.

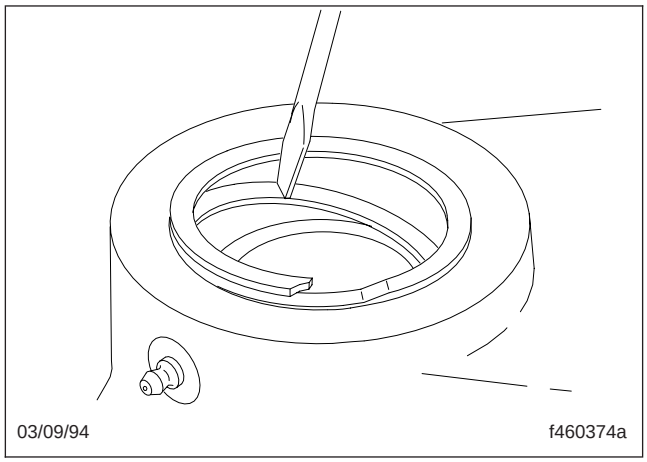


Fig. 53, Put the Gear Housing on its Side

   1.2 Install the retaining ring in the groove closest to the side-cover end of the bore. See **Fig. 53**. Then lubricate the bore.

   1.3 Place the new roller bearing on the housing bore, with the lettered side of the bearing shell facing up.

⚠ CAUTION

When using special tool J37705 (TAS40), or J37071 (TAS55/65) to install the roller bearing, be sure to use the *installation* side of the tool, or you may damage the new roller bearing.

   1.4 Using the installation end of the special tool, press the roller bearing into the housing, until it seats against the retaining ring. See **Fig. 54**.

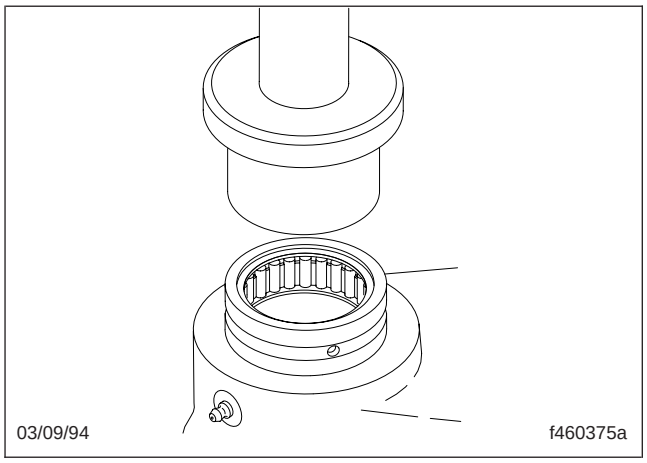


Fig. 54, Press the Roller Bearing into the Housing

2. Put the gear housing on its side, with the side-cover end of the bore facing up, as shown in **Fig. 55**.

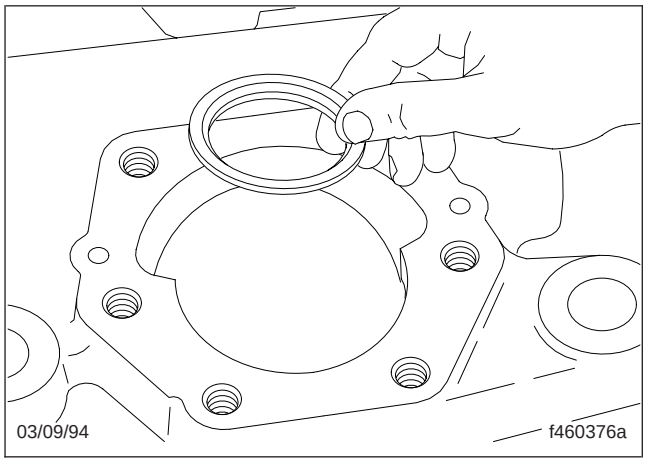


Fig. 55, Put the Gear Housing on its Side (with the side-cover end of the bore facing up)

3. Install the washer in the bore, with the small diameter end of it facing the roller bearing retaining ring. See **Fig. 55**.
4. Put the new seal on special tool J37705 (TAS40), or J37071 (TAS/5565) so that the lip of the seal with the garter spring is toward the shoulder of the tool. See **Fig. 56**.
5. From the side-cover end of the bore, press the new seal onto the washer (and the roller bearing below it) with a force of 100 to 800 lb (45 to 363 kg).

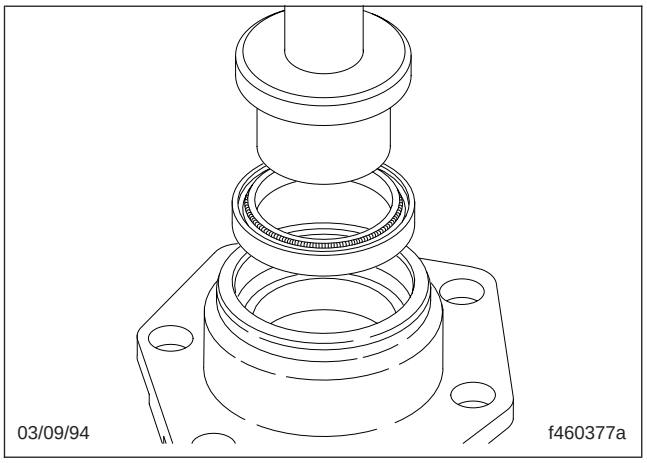


Fig. 56, Put the New Seal on Special Tool J37705 (TAS40), or J37071 (TAS/5565)

6. Turn the gear housing over so that the trunnion end of the bore is up, and install the new dirt seal against the roller bearing, with the lip facing up. See **Fig. 57**.

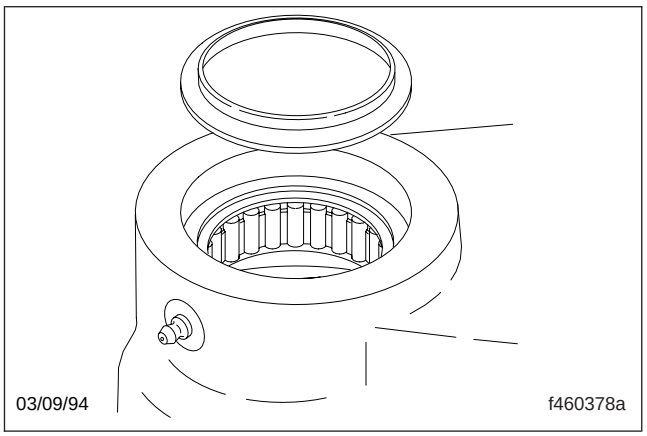


Fig. 57, Install the New Dirt Seal

7. Install the second retaining ring, seating it firmly into the groove in the bore. See **Fig. 58**.
8. Pack the area between the dirt seal and the pressure seal (including the roller bearing) with Mobil Temp® 1 grease, or equivalent. See **Fig. 59**.

⚠ CAUTION

In the next step, when putting the valve housing in a vise, be careful not to clamp against the threaded port hole or the relief-valve hole sealing

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

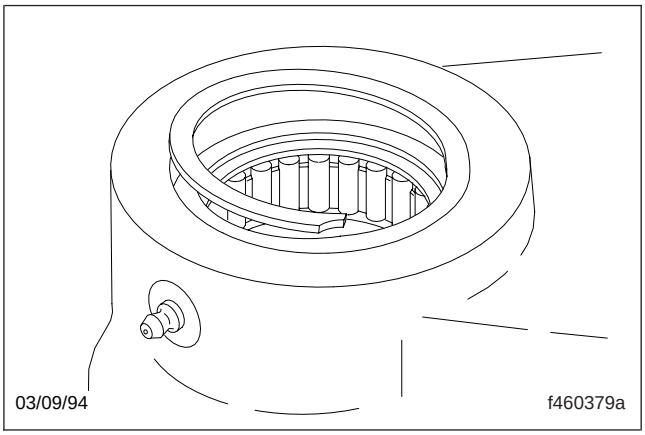


Fig. 58, Install the Second Retaining Ring

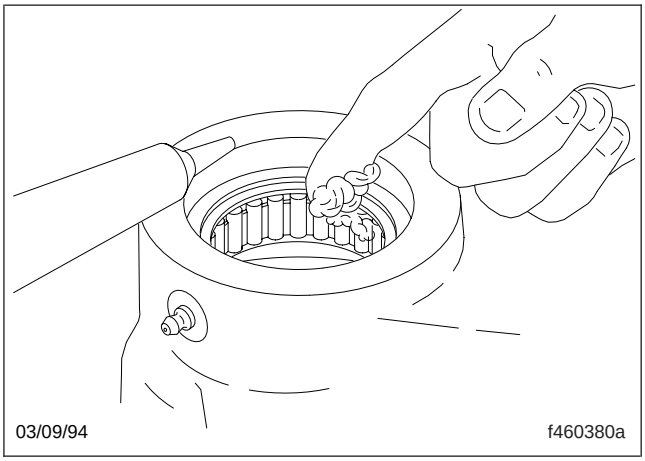


Fig. 59, Pack the Area between the Dirt Seal and the Pressure Seal with Grease

faces. To do so may damage these surfaces, which would require the replacement of the valve housing.

9. Put the valve housing in a vise so the input/worm shaft can be installed with the worm shaft up.
10. Lubricate and install a new O-ring in the valve housing. See **Fig. 60**.
11. Lubricate a new large diameter O-ring and a new seal ring, then install them in the valve housing. See **Fig. 61**.
12. See **Fig. 1**. Depending on how the steering gear is equipped, do one of the following (A or B):

    A. Install the roller thrust bearing and the thick thrustwasher on the input shaft thrust face. See **Fig. 62**. Then install a new seal ring onto the input shaft, and against the thick thrustwasher. See **Fig. 1**.

    B. Install the spacer sleeve (the side with the curved edge down), thin thrustwasher, roller thrust bearing, and thick thrustwasher on the input shaft thrust face. See **Fig. 63**. Then install a new seal ring onto the input shaft, and against the thick thrustwasher. See **Fig. 1**.

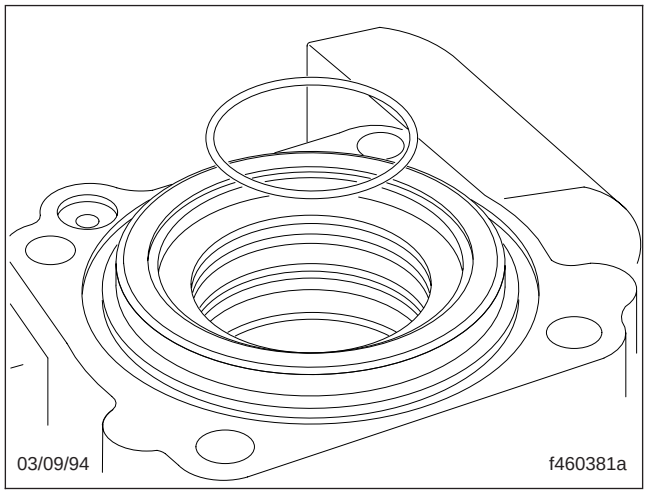


Fig. 60, Lubricate and Install a New O-Ring

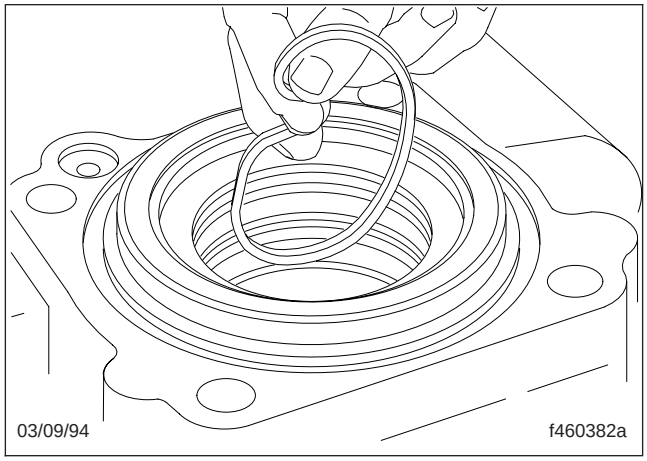


Fig. 61, Lubricate and Install a New Large Diameter O-Ring and a New Seal Ring

IMPORTANT: If you have replaced the input-shaft/valve/worm assembly with a new assembly, don't install the existing spacer sleeve or the

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

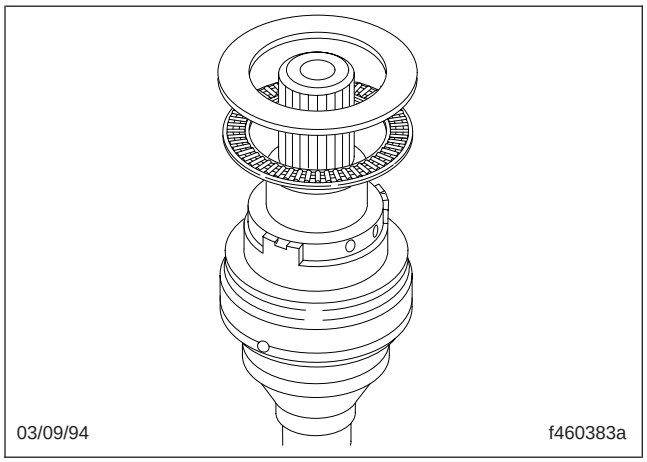


Fig. 62, Install the Roller Thrust Bearing and the Thick Thrustwasher

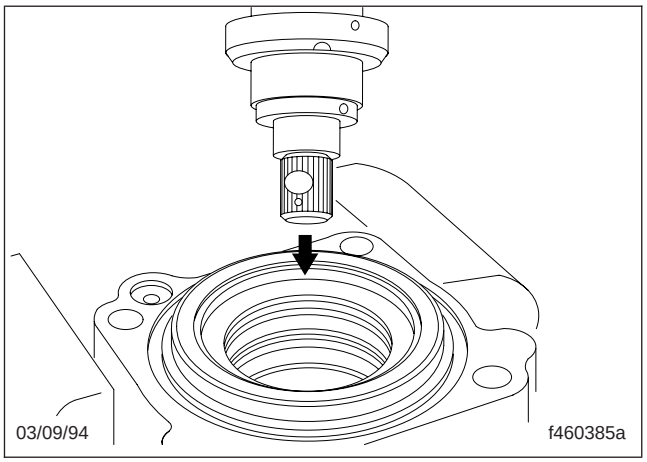


Fig. 64, Lubricate, then Install the Input-Shaft/Valve/ Worm Assembly

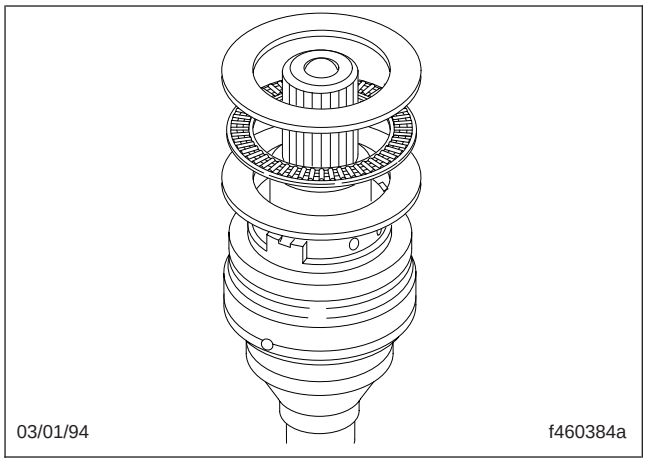


Fig. 63, Install the Spacer Sleeve, Thin Thrustwasher, Roller Thrust Bearing, and Thick Thrustwasher

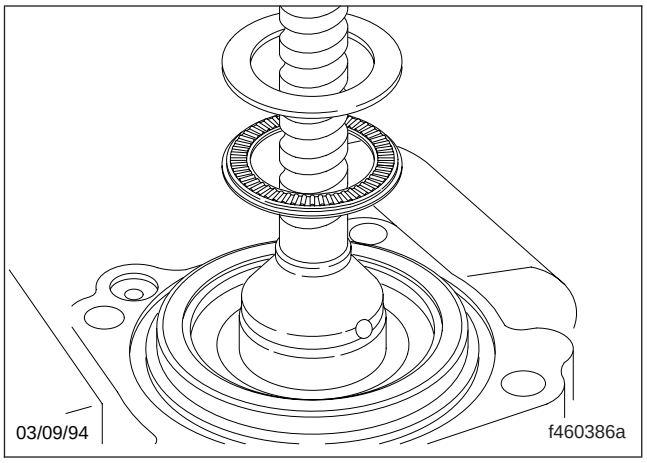


Fig. 65, Lubricate, then Install a Second Thrust Bearing and Thin Washer

thin washer. They are not needed with a new input-shaft/valve/worm assembly.

13. Lubricate, then install the input-shaft/valve/worm assembly in the valve housing, seating it firmly. See **Fig. 64**.
14. Lubricate, then install a second thrust bearing and thin washer over the worm shaft. See **Fig. 65**.
15. Lubricate the new O-ring and seal ring. See **Fig. 1**. Install the O-ring, then the seal ring in the groove of the bearing adjuster. See **Fig. 66**.
16. Making sure the bearing adjuster threads are clean and free of any stake burrs, lubricate, then install the bearing adjuster over the worm shaft, and into the valve housing.

    Using a torque wrench and bearing adjuster tool J37070, tighten the valve adjuster 11 to 15 lbf·ft (15 to 20 N·m), then back it off 1/4 to 1/2 turn. See **Fig. 67**.
17. Turn the valve housing over in the vise so that the worm shaft is facing down.
18. Using an inch-pound torque wrench, check the torque needed to turn the input shaft 360 degrees clockwise and counterclockwise. Tighten the bearing adjuster so that the torque needed to turn the input shaft is increased by 5 to 10 lbf·in (60 to 120 N·cm). See **Fig. 68**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

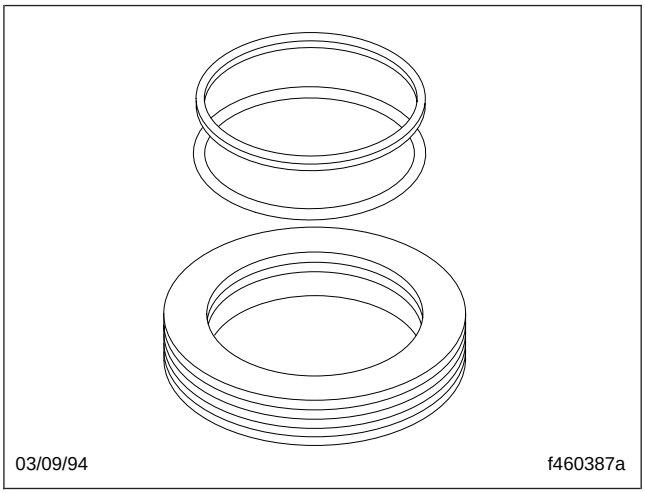


Fig. 66, Lubricate the New O-Ring and Seal Ring

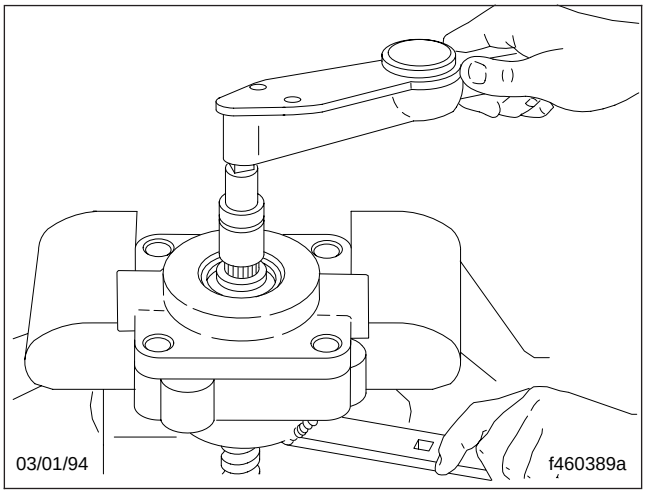


Fig. 68, Check the Torque

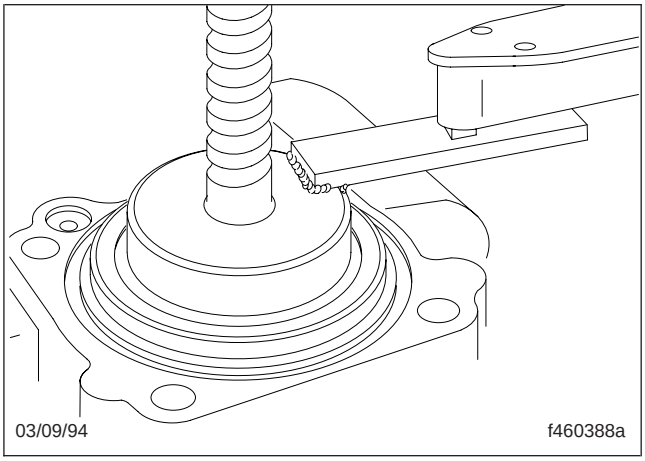


Fig. 67, install the Bearing Adjuster over the Worm Shaft

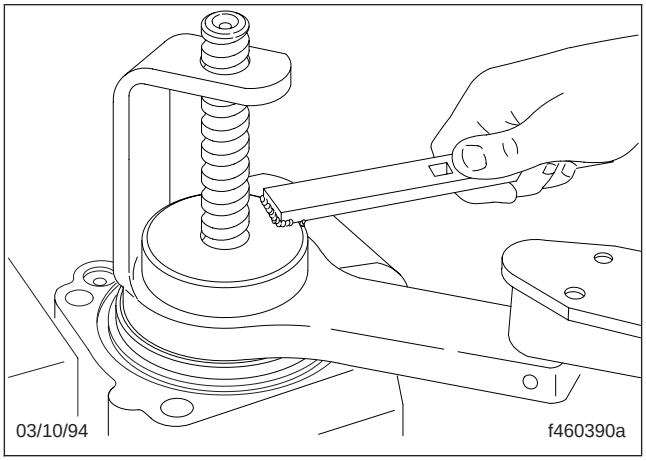


Fig. 69, Install the Locknut on the Bearing Adjuster

19. Turn the valve housing over in the vise again, so that the worm shaft is facing up.
20. Oil and install the locknut on the bearing adjuster, and using special tools J37070 and J37464, tighten the locknut 101 to 122 lbf·ft (137 to 165 N·m), while holding the bearing adjuster. See **Fig. 69**.
21. Check the torque needed to turn the input shaft again. If the torque isn't the same as it was previously, remove the locknut from the bearing adjuster, and repeat the previous steps beginning with turning the valve housing over in the vise so that the worm shaft is facing down.
22. Using a punch, stake the locknut to the valve housing at two opposite slots in the locknut. Stake each slot in the most clockwise corner, as shown in **Fig. 70**.
23. Stake the locknut to the bearing adjuster at two places 180 degrees apart. See **Fig. 70**. Don't use a spot that was staked before.
24. Check the torque needed to turn the input shaft. If the torque isn't the same as it was previously, unstake the locknut and the bearing adjuster, and repeat the previous steps beginning with turning the valve housing over in the vise so that the worm shaft is facing down.

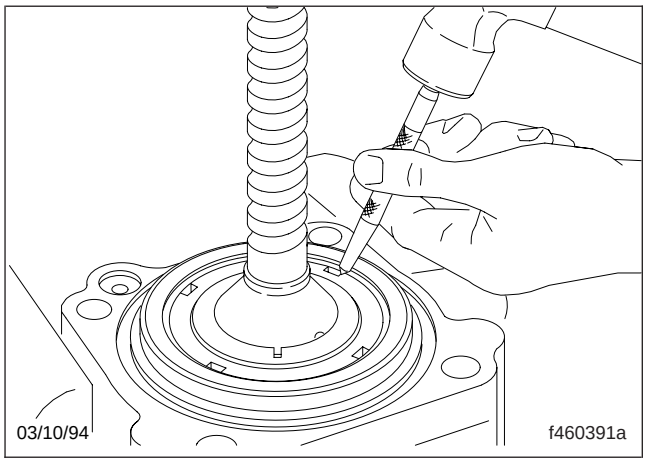


Fig. 70, Stake the Locknut to the Valve Housing and the Bearing Adjuster

NOTE: The torque needed to turn the input shaft must not be more than 22 lbf·in (240 N·cm).

25. Oil the new grease seal rings, and install them in the valve housing. See **Fig. 71**.

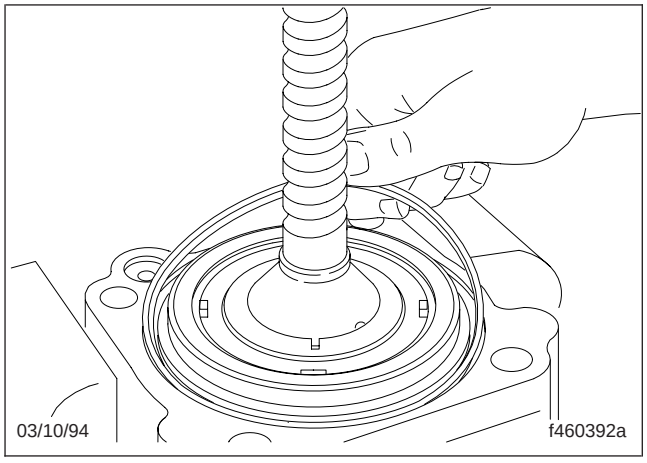


Fig. 71, Install the New Grease Seal Rings

26. If you are installing the removed automatic poppet adjuster seats and sleeve assemblies, reset them as follows:

    IMPORTANT: Make sure the poppet adjuster seat and sleeve assemblies and the threaded holes in the rack piston are free of Loctite.

    26.1 Turn the poppet adjuster seat and sleeve assembly so that it is in the *opposite* direction in which it was installed, and loosely screw it into the threaded hole in the rack piston. See **Fig. 72**.

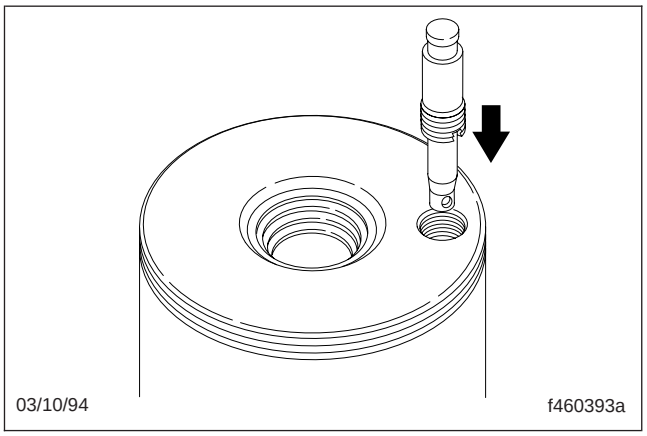


Fig. 72, Screw the Poppet Adjuster Seat and Sleeve Assembly into the Rack Piston

    26.2 Press the adjuster seat into the adjuster sleeve with a force of 500 to 2500 lb (227 to 1134 kg), until the shoulder on the seat bottoms on the sleeve. See **Fig. 73** and **Fig. 74**.

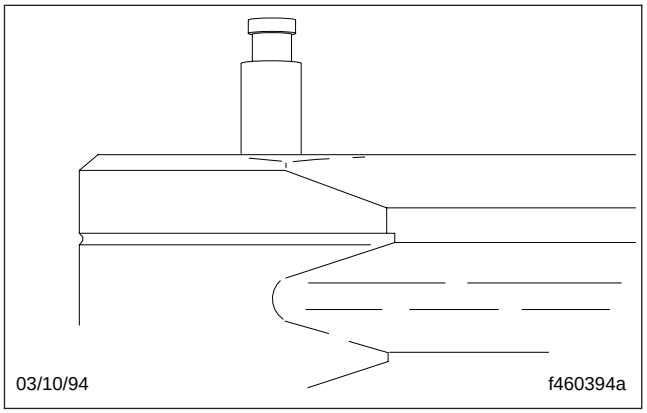


Fig. 73, Adjuster Seat/Adjuster Sleeve in the Rack Piston

    26.3 Remove the adjuster seat and sleeve assembly from the rack piston.

    26.4 Repeat the previous steps as needed for the other poppet adjuster seat and sleeve assembly.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

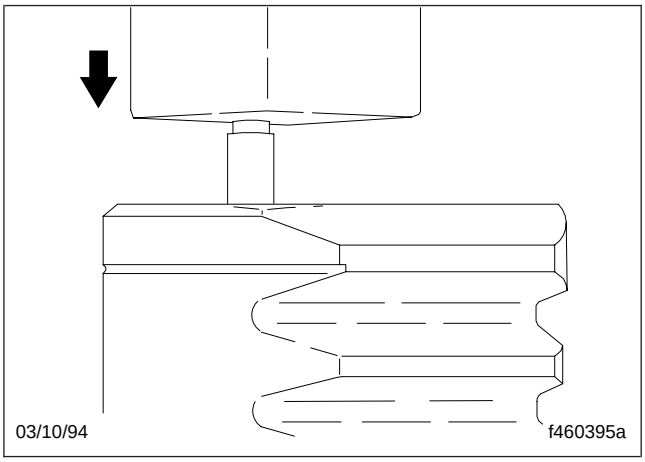


Fig. 74, Press the Adjuster Seat into the Adjuster Sleeve

27. Install a new backup O-ring and new Teflon seal ring on the rack piston. See **Fig. 75**. Do not stretch them any more than necessary when installing them.

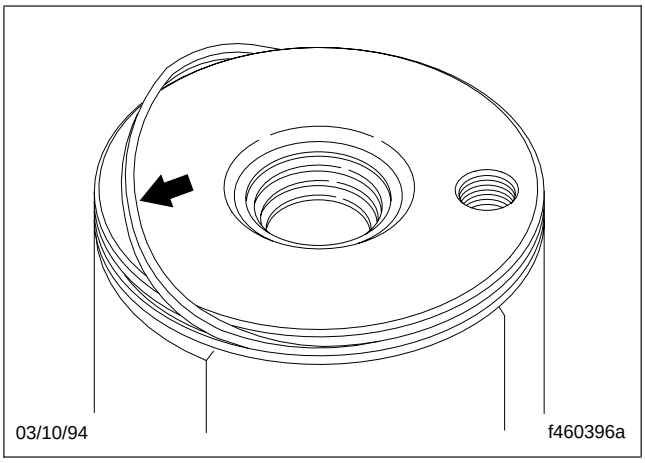


Fig. 75, Install a new Backup O-Ring and new Teflon Seal Ring

⚠ CAUTION

When doing the next step, be careful not to get any Loctite or Locquic on the adjuster seat itself. If this happens, the automatic poppets will not adjust correctly.

NOTE: If you are installing new poppet adjuster seat and sleeve assemblies, they may already have Dri-Loc® 200 on them; if so, more Loctite isn't needed.

28. Apply Locquic primer "T" to the threaded poppet holes in the rack piston, and to the threads on the poppet adjuster seat and sleeve assemblies. Let dry for ten minutes, then apply Loctite RC680 to the same threads. See **Fig. 76**.

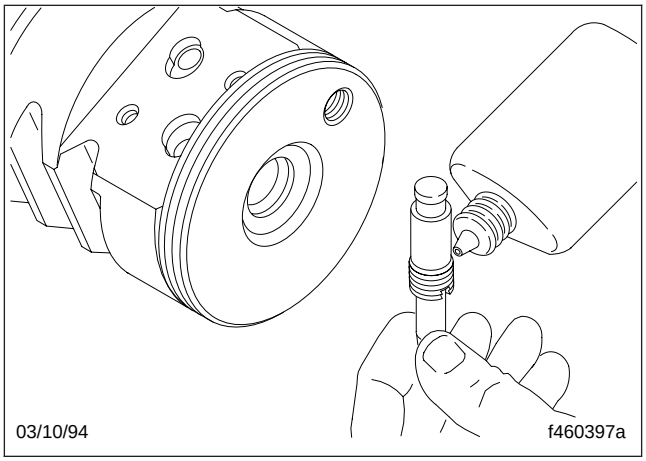


Fig. 76, Apply Locquic Primer T

29. Place the rack piston in a padded vise, and install a poppet adjuster seat and sleeve assembly, slotted end out, into the threaded hole at one end of the rack piston. See **Fig. 77**.

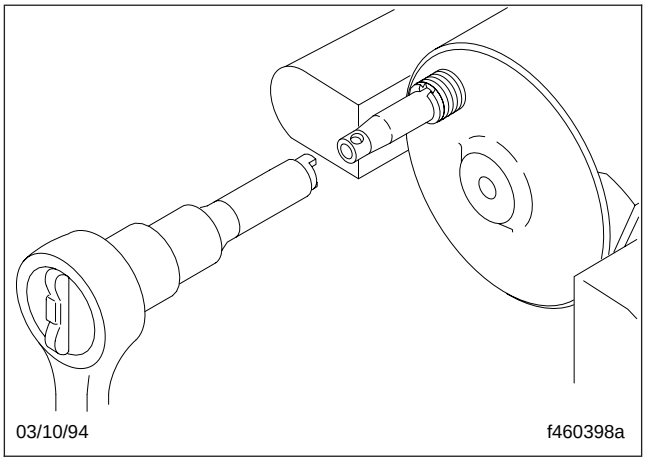


Fig. 77, Install a Poppet Adjuster Seat and Sleeve Assembly

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

⚠ WARNING

Wear eye protection while assembling the poppets. The poppets are spring-loaded, and could be ejected, which could result in serious eye injury.

30. In the other end of the hole, install the poppet assembly parts in the following order. See **Fig. 78**: one poppet, the poppet spring, the nylon spacer rod, the push tube, the other poppet, and the other poppet adjuster seat and sleeve assembly.

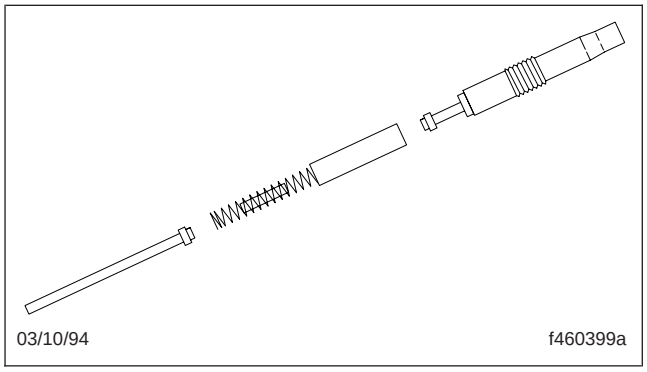


Fig. 78, Install the Poppet Assembly Parts

31. Using special tool J36452 or J38713, tighten both poppet adjuster seat and sleeve assemblies 10 lbf·ft (14 N·m). See **Fig. 79**.

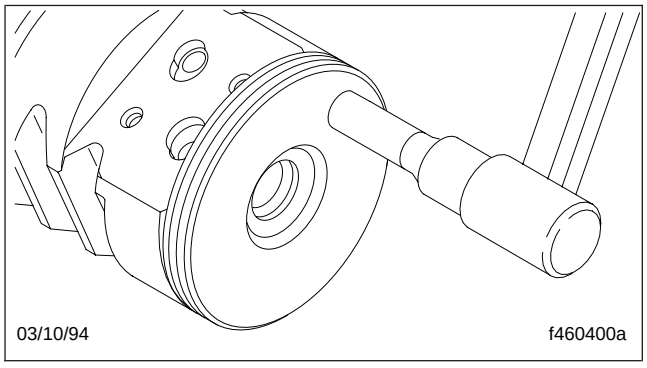


Fig. 79, Tighten both Poppet Adjuster Seat and Sleeve Assemblies

32. Put the rack piston on a clean, cloth-covered bench, with the worm end of the piston near the edge of the bench, and the ball guide holes facing up.

NOTE: When made to the correct dimensions to raise and support the piston, a wooden V-block will make the following steps easier.

33. Insert the worm shaft and input shaft assembly into the worm end of the rack piston, close to the maximum depth, without the valve housing contacting the upper poppet. See **Fig. 80**.

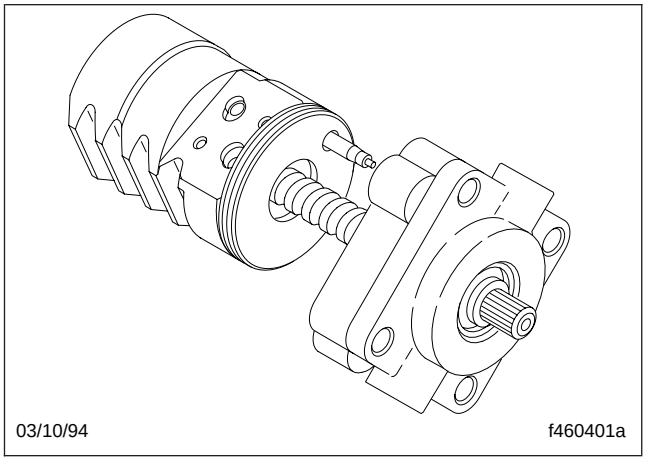


Fig. 80, Insert the Worm Shaft and Input Shaft Assembly

34. Line up the grooves in the worm shaft with the ball guide holes in the rack piston.

    Make sure the valve housing extends over the edge of the bench, or the rack piston is put on a V-block, so that the valve housing and worm shaft can turn freely. See **Fig. 80**.

⚠ WARNING

In the next step, do not seat the ball return guides with a hammer. This could damage them and cause steering gear lockup or loss of steering, resulting in an accident causing personal injury or property damage.

35. Install *new* ball return guide halves in the rack piston. See **Fig. 81**. Make sure they are correctly seated.

NOTE: Left-side ball return guide halves are copper-plated, and right-side ones are not. Make sure the correct new ball return guide halves are installed, by comparing them with the old ones; then discard the old ones.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

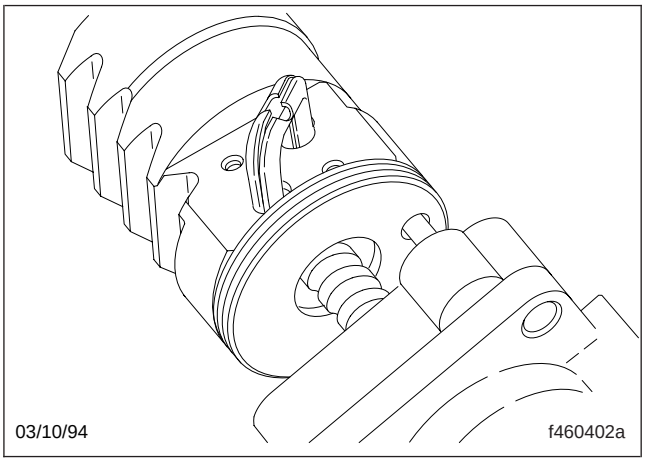


Fig. 81, Install new Ball Return Guide Halves

CAUTION

If you are installing a new rack piston, or a new input-shaft/valve/worm assembly, don't install the existing steel balls. Use a new set of steel balls, or damage to the steering gear may result.

36. Insert the steel balls in the ball return guide hole, as shown in **Fig. 82**. As the balls are dropped into the guide, turn the worm shaft so that the balls are pulled down into its grooves.

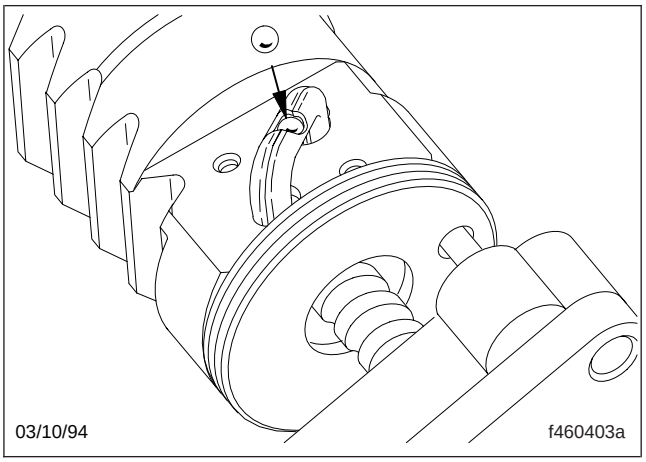


Fig. 82, Insert the Steel Balls

WARNING

Make sure the ball return guide halves stay down and in place while you are inserting the steel balls or turning the input shaft. Failure to hold the ball guide halves down may result in a ball being trapped outside the closed ball-track loop. A trapped ball could cause a steering lockup, which could result in an accident and personal injury or property damage.

37. If the ball guide halves raise up at any time during or after the installation of the steel balls, remove all of the balls, and the input-shaft/valve/worm assembly from the rack piston. Repeat the previous steps as needed.

IMPORTANT: Don't let the valve housing pilot face touch the poppet adjuster, or move more than 2.7 inches (69 mm) from the upper end of the rack piston. See **Fig. 83**, Ref. A. If this happens, the poppet adjuster could be incorrectly preset or the worm could be backed out beyond the closed ball loop.

38. Lubricate the new seal for the ball return guide cap, and install it in the groove in the cap. See **Fig. 84**.

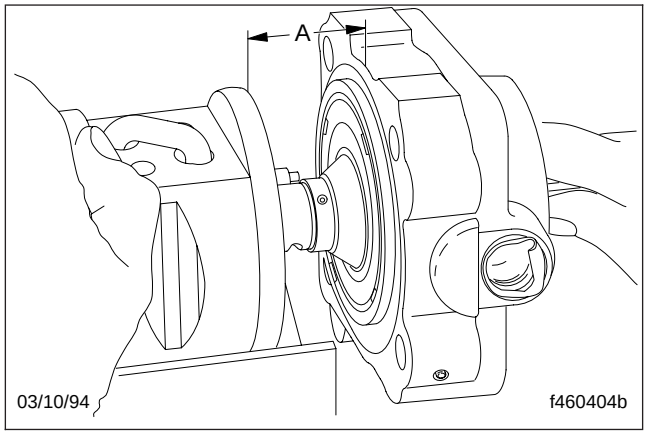


Fig. 83, Check the Valve Housing Pilot Face

39. Using a 5/32-inch allen socket and two new 5/32-inch allen screws (or a T–30 Torx wrench and two new Torx head screws), install the ball return guide cap on the rack piston. Make sure the seal makes full contact with the rack piston surface. Tighten the fasteners alternately once or twice, to a final torque of 14 to 22 lbf·ft (19 to 30 N·m).

40. To ensure that the steel balls have been correctly installed, turn the worm shaft from one end of travel to the other, without allowing the valve housing to contact the poppet adjuster, and with-

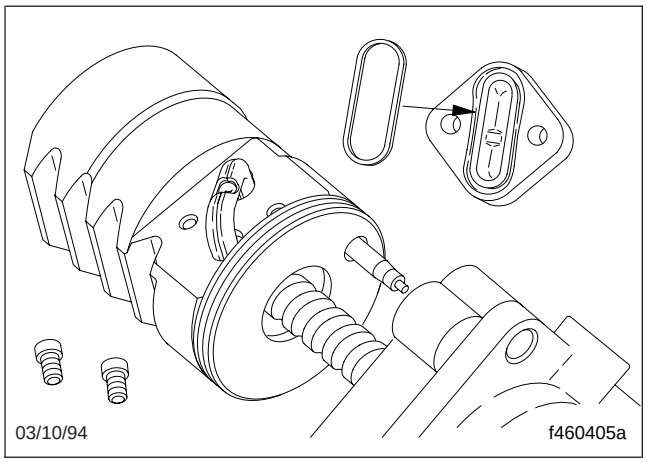


Fig. 84, Install the Seal

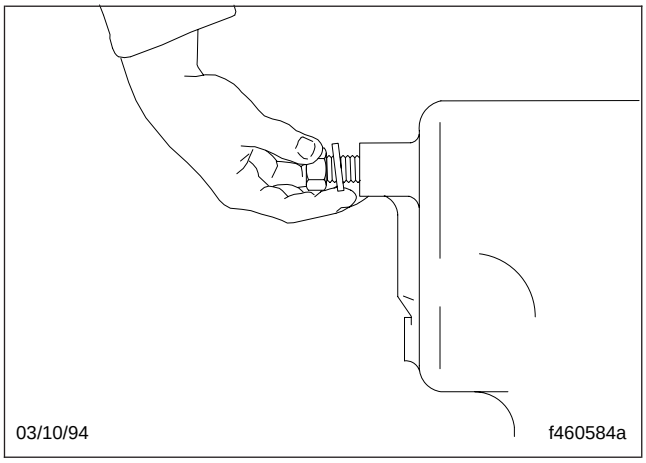


Fig. 85, Install a new Poppet Stopscrew

out moving the valve housing pilot face more than 2.7 inches (69 mm) from the input end (upper end) of the rack piston. See **Fig. 83**, Ref. A.

If the worm shaft doesn't turn, remove of the steel balls, and install them again, following the instructions in the previous steps.

41. If the poppet stopscrew is being replaced, install the new one and its washer in the gear housing. See **Fig. 85**. Tighten it 38 to 42 lbf·ft (52 to 57 N·m).

    If the service poppet adjusting screw and the service sealing jam nut are being used for automatic poppet adjustment, turn the adjusting screw into the jam nut until 1.03 to 1.09 inches (26 to 28 mm) protrudes from the bottom of the jam nut. See **Fig. 1** and **Fig. 86**. Install the assembly into the gear housing. Tighten the jam nut 33 to 37 lbf·ft (45 to 50 N·m).

42. Put clean oil on the rack piston Teflon seal ring and into the bore of the gear housing. Position the rack piston on the worm gear with a gap of 3/8 to 1/2 inch (10 to 13 mm) between the valve housing and the upper poppet adjuster seat and sleeve assembly.

IMPORTANT: This gap is to ensure that the poppets don't make contact with anything while the steering gear is being assembled.

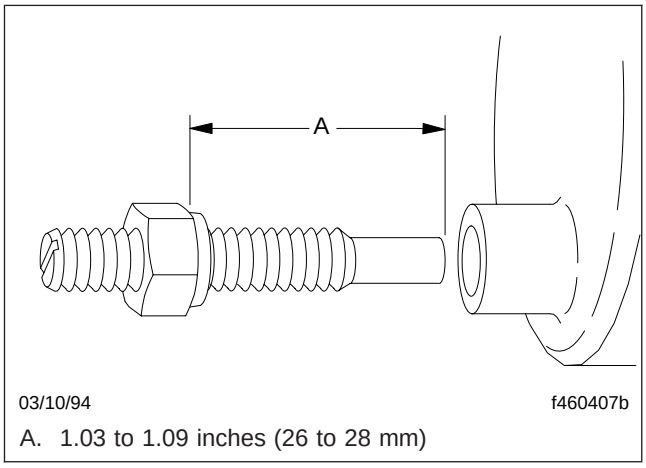


Fig. 86, Check the Distance from the Bottom of the Jam Nut

CAUTION

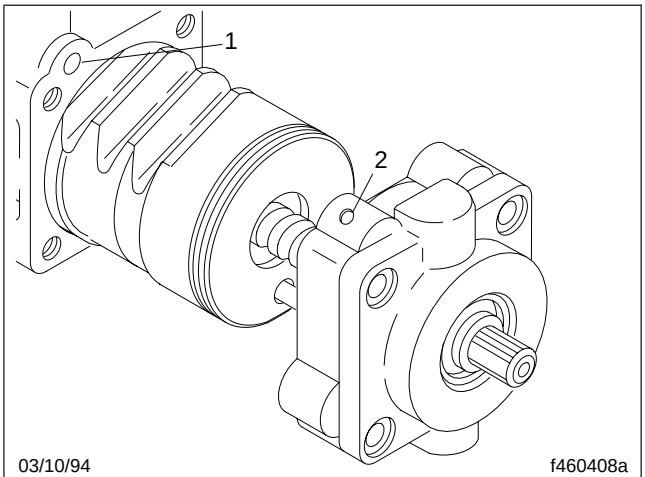
When installing the rack piston in the steering gear housing, be careful not to damage the seal ring on the rack piston, as this could seriously affect the operation of the steering gear.

Do not let the poppet adjuster seat and sleeve assemblies on the rack piston bottom out when installing the rack piston in the gear housing.

43. Install the rack piston and worm shaft assembly in the gear housing, being careful not to damage the seal ring on the rack piston. Don't let the poppet adjuster sleeve assemblies bottom out inside the gear housing. Install the piston with

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

the rack teeth toward the sector shaft hole in the housing. See **Fig. 87**. Be sure the valve housing cylinder feed hole lines up with the gear housing feed hole.



1. Gear Housing Feed Hole
2. Valve Housing Cylinder Feed-Hole Boss

Fig. 87, Install the Piston with the Rack Teeth toward the Sector Shaft Hole

44. Using an E–16 Torx socket wrench, install and tighten the four valve housing bolts 75 to 85 lbf·ft (102 to 115 N·m). See **Fig. 88**.

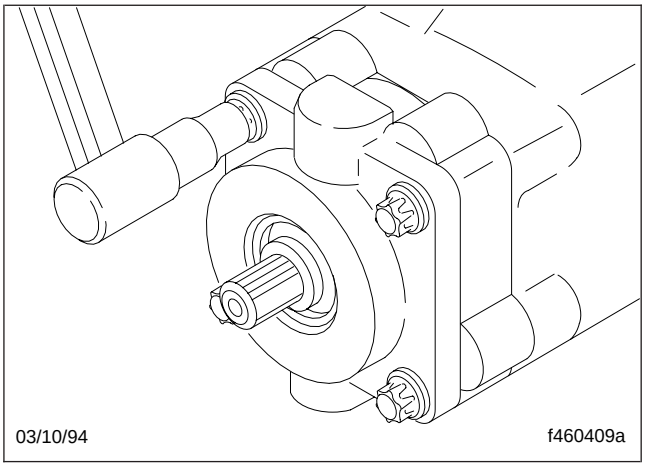


Fig. 88, Install the Valve Housing Bolts

45. If the sector shaft adjusting screw is being replaced, do the following:

    45.1 Coat the end of the new adjusting screw with wheel bearing grease, and with the sector shaft in a padded vise, insert the new adjusting screw into the recess in the sector shaft end.

    45.2 Install a new sector-shaft screw retainer in the sector shaft. Adjust the retainer so that the sector shaft adjusting screw can be turned freely by hand. It should have a maximum end play of 0.002 inch (0.05 mm).

⚠ WARNING

Be careful when staking the sector-shaft screw retainer. If the retainer is broken or cracked, the sector shaft could come loose, resulting in loss of manual and power steering control. This could cause an accident resulting in personal injury or property damage. Replace a broken or cracked sector-shaft screw retainer.

    45.3 Stake the sector-shaft screw retainer to the slots in the sector shaft. See **Fig. 89**. Check the adjusting screw again for free movement and end play.

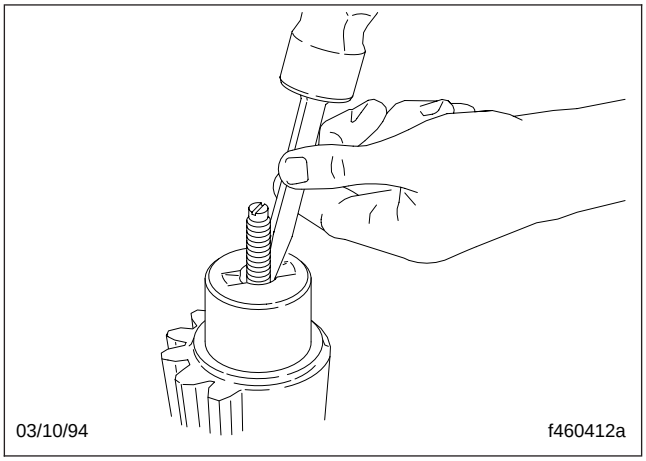


Fig. 89, Stake the Sector-Shaft Screw Retainer

46. Lightly oil the side-cover "DU" bushing. Do not grease it. See **Fig. 90**.

47. Put a new seal on special tool J37705 (TAS40), or J37071 (TAS/5565) so that the garter spring is against the shoulder of the tool. See **Fig. 91**. Press the new seal into the side cover with a force of 100 to 800 lb (45 to 363 kg). Make sure the seal is seated against the bottom of the counterbore.

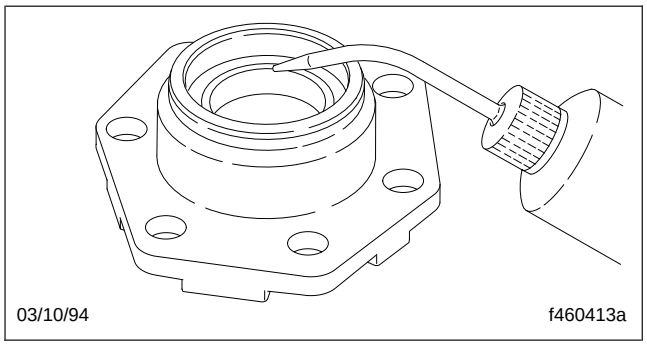


Fig. 90, Applying Oil to the DU Bushing

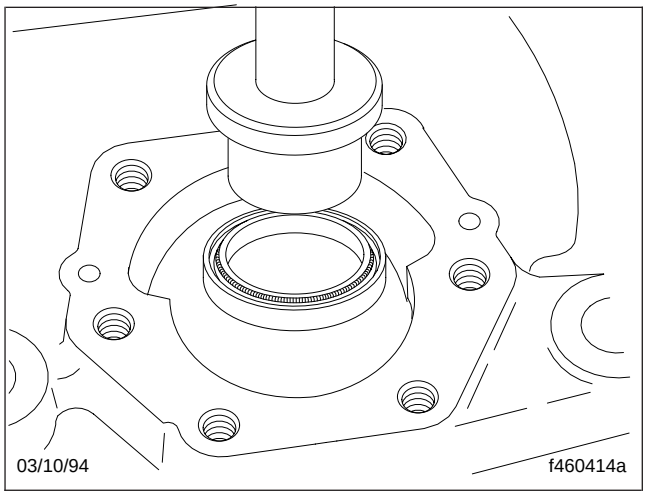


Fig. 91, Press in the new Seal

48. Lightly oil the short bearing end of the sector shaft. Screw the sector shaft adjusting screw counterclockwise into the side cover, until the screw seats. See **Fig. 92**. Then rotate the adjusting screw clockwise one turn, so that the side cover rotates freely on the sector shaft.

49. Loosely install the sector-shaft adjusting screw jam nut onto the sector-shaft adjusting screw a few threads. See **Fig. 93**. Final adjustment will be made later.

50. Press a new rubber plug into the hole provided in the side cover, until the plug is flush. See **Fig. 94**.

⚠ WARNING

Do not weld or plug this hole permanently. This is a safety vent which functions only if the side cover output shaft seal doesn't work. If the seal doesn't work and the plug cannot vent, the steering gear can lock up or otherwise malfunction. This could result in a loss of steering control, which could cause personal injury or property damage.

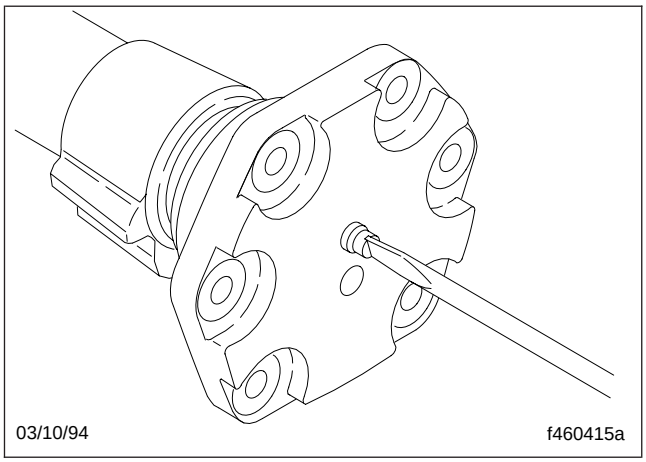


Fig. 92, Install the Sector Shaft Adjusting Screw

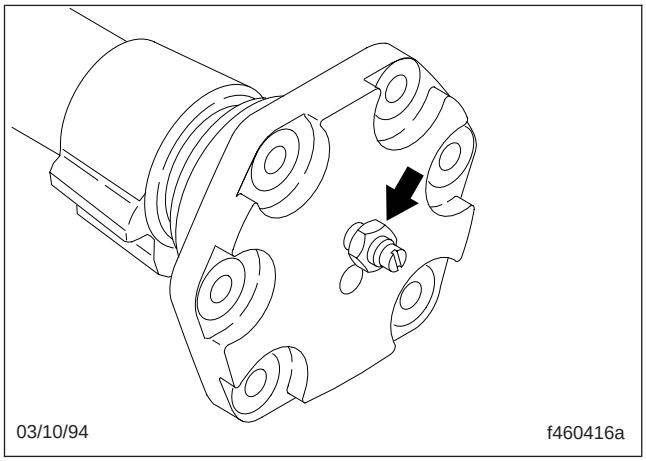


Fig. 93, Loosely Install the Sector-Shaft Adjusting Screw Jam Nut

51. Apply clean grease to a new side cover gasket, and install it on the side cover. See **Fig. 95**. Apply enough grease to hold the gasket in place.

52. There are four teeth on the rack piston. Turn the input shaft as needed to position the rack piston so that the tooth space identified by the pencil in **Fig. 96** (it is the space between the second and the third tooth), is in the center of the sector shaft opening. See **Fig. 97**. This will center the rack piston in the opening.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

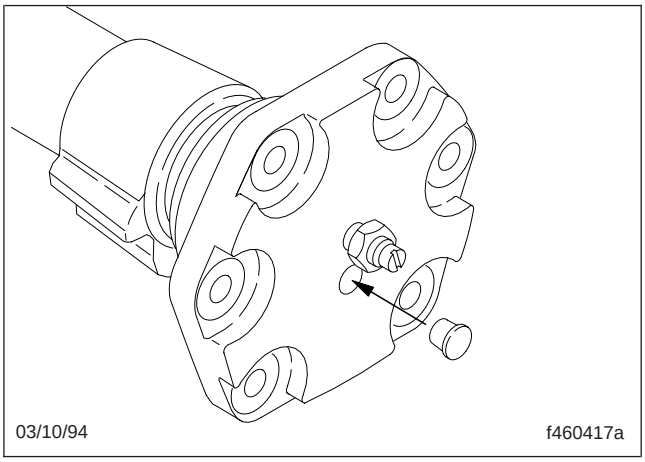


Fig. 94, Press in a new Rubber Plug

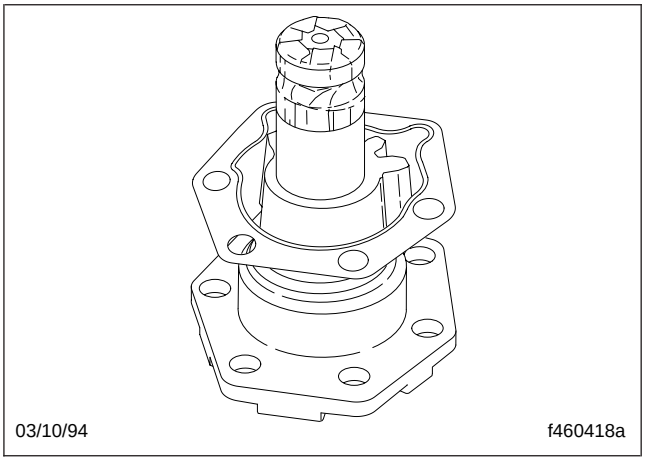


Fig. 95, Install the Side Cover Gasket

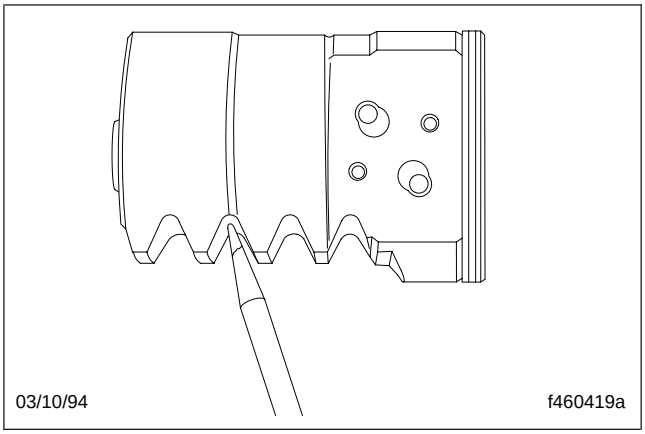


Fig. 96, Check the Tooth Space

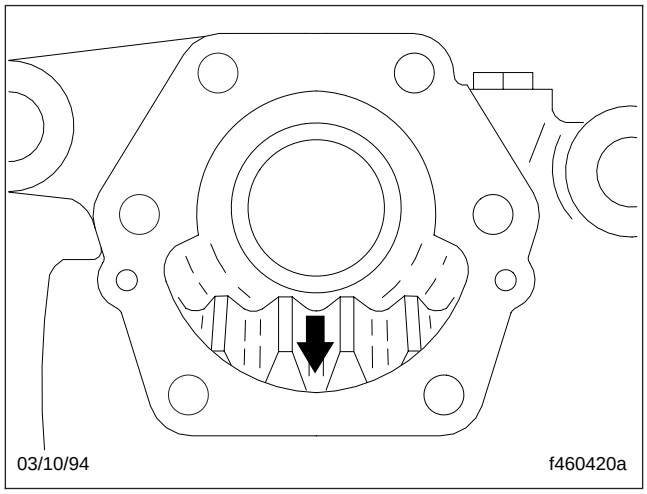


Fig. 97, Check the Tooth Position

⚠ WARNING

If the rack piston is not centered, steering gear travel will be severely limited in one direction. This could cause an accident, resulting in personal injury or property damage.

53. Remove all tape from the sector shaft splines. Retape the splines and the bolt groove with *one layer* of masking tape.

⚠ CAUTION

If the splines on the sector shaft are not taped correctly, the splines will damage the housing seal during assembly, causing the seal to leak.

54. Install the sector shaft and side cover, as an assembly, in the gear housing. See **Fig. 98**. Make sure the center tooth of the sector shaft engages the center space (between the second and third teeth) of the rack piston.

55. Install the special side cover bolts in the side cover. Using the torque pattern shown in **Fig. 99** or **Fig. 100**, tighten as follows: TAS40 dry bolts 160 lbf·ft (217 N·m); or lubricated bolts 118 lbf·ft (160 N·m); TAS55/65 dry bolts 230 lbf·ft (312 N·m); or lubricated bolts 170 lbf·ft (230 N·m). See **Fig. 101**.

56. Remove the tape from the sector shaft, and pack the end of the housing trunnion area at the sector shaft with Mobil Temp 1 or 2 grease, or

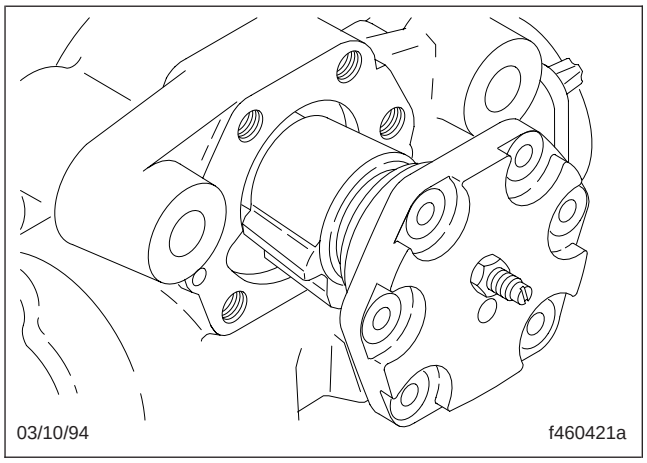


Fig. 98, Install the Sector Shaft and Side Cover

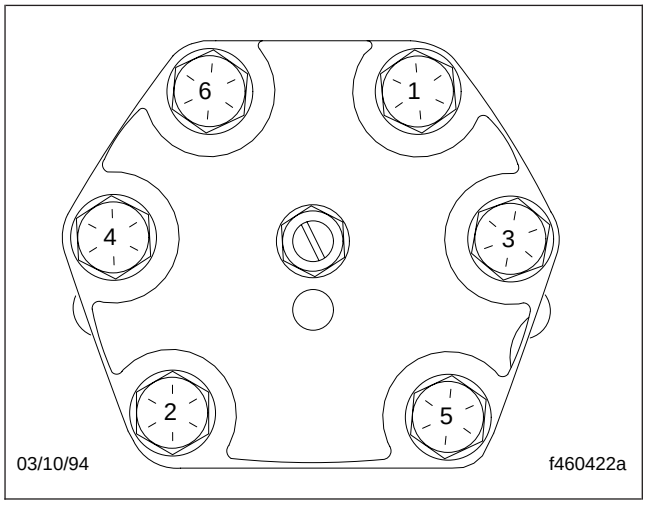


Fig. 99, Six-Bolt Tightening Sequence

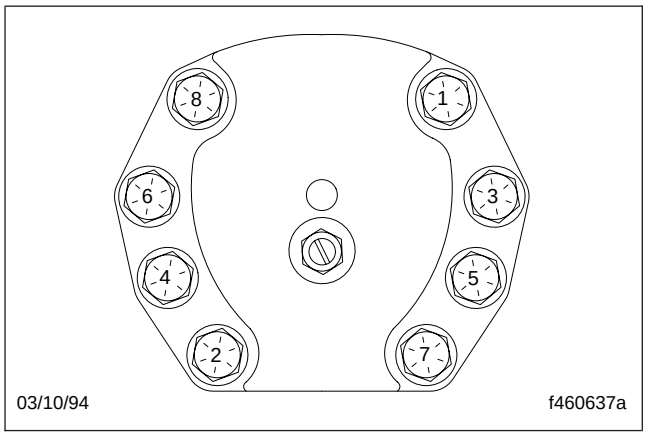


Fig. 100, Eight-Bolt Tightening Sequence

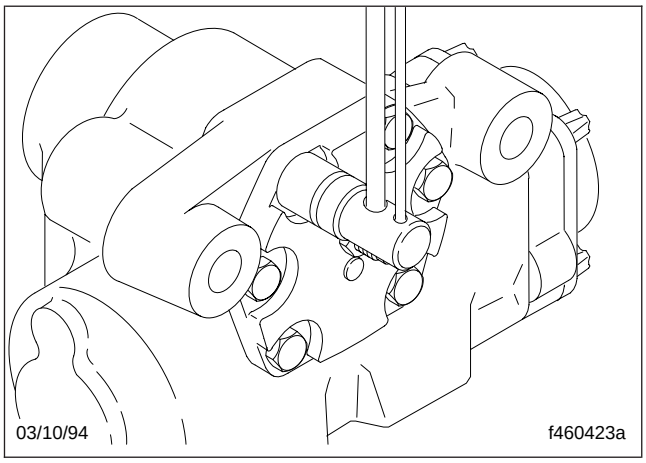


Fig. 101, Install the Special Side Cover Bolts

equivalent. Put grease on the new trunnion dirt seal, and install it over the sector shaft and into the trunnion bore. See **Fig. 102**.

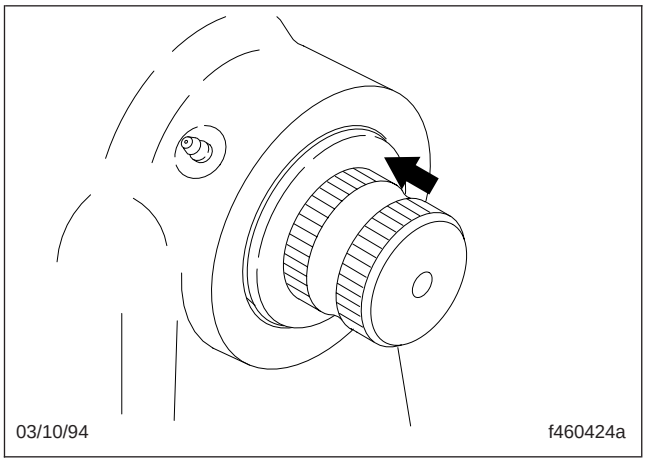
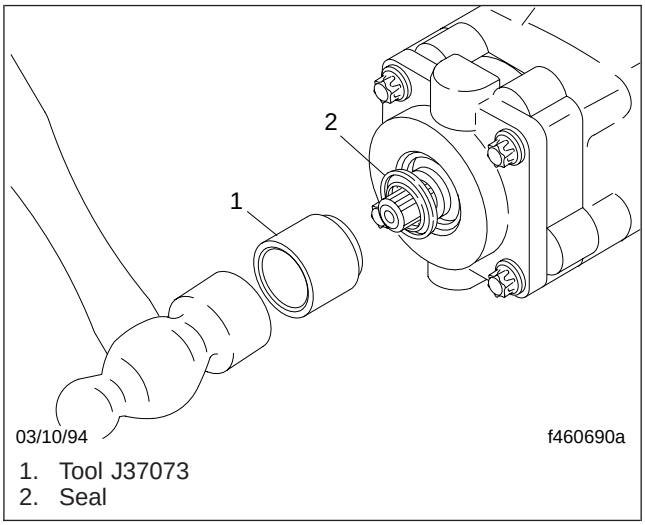


Fig. 102, Install a new Trunnion Dirt Seal

IMPORTANT: Make sure the input shaft seal is installed squarely in the seal bore.

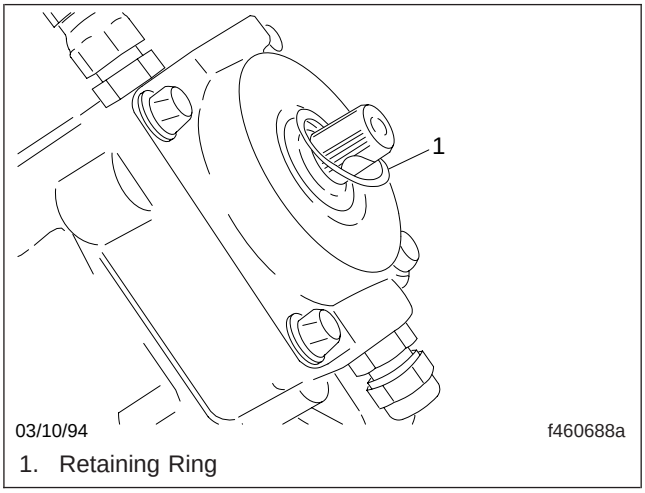
57. Apply clean grease to the new input shaft seal; then place it, garter spring side first, over the input shaft. Using special tool J37073 and a mallet, tap the seal into the valve housing seal bore until it clears the retaining ring groove. See **Fig. 103**. Remove any seal material that may have sheared off in the retaining ring groove.
58. Install a new retaining ring into its groove in the valve housing. See **Fig. 104**.

Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments



1. Tool J37073
2. Seal

Fig. 103, Tap the Seal into the Valve Housing Bore



1. Retaining Ring

Fig. 104, Install a new Retaining Ring

59. Pack the end of the valve housing bore (around the input shaft) with Mobil Temp 1 or 2 grease, or equivalent. Apply grease to the new dirt-and-water seal, and install it over the input shaft. Seat the dirt-and-water seal in the groove behind the serrations of the input shaft, and against the valve housing. See **Fig. 105**.
60. If the grease fitting is being replaced, install a new one in the gear housing, using a piece of metal tubing over the head of the new fitting, as shown in **Fig. 106**. Tap the new grease fitting in place.

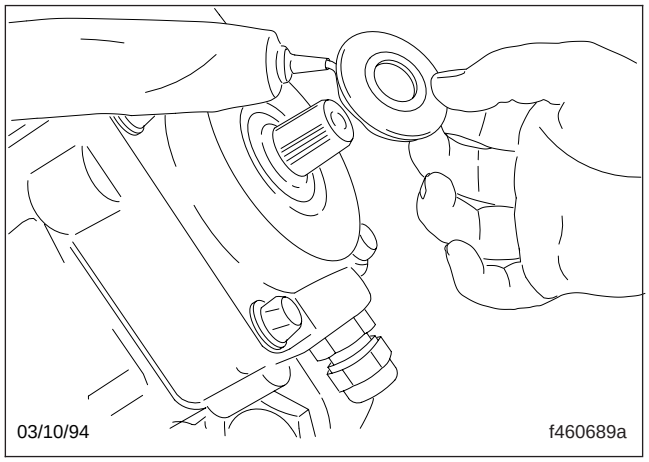


Fig. 105, Install the Dirt-and-Water Seal

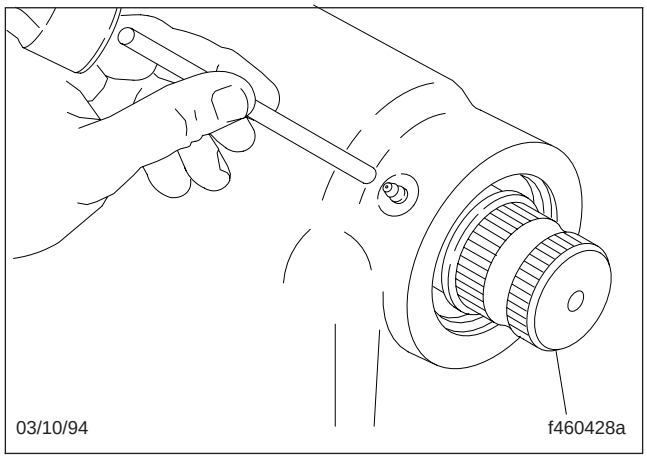


Fig. 106, Install a new Grease Fitting

61. If the auxiliary port plugs were removed, install new O-rings on them, and install the plugs in the gear housing. Tighten them 25 to 35 lbf·ft (34 to 47 N·m).

Final Adjustments

Before installing the steering gear on the vehicle, make these adjustments:

NOTE: Worm shaft preload adjustment was done when the input shaft was installed in the valve housing during the assembly procedure.

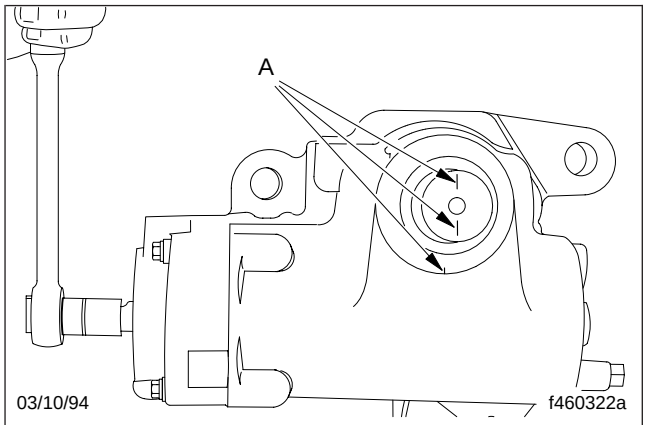
Steering Gear Disassembly, Inspection, Assembly, and Final Adjustments

⚠ CAUTION

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 either disassembling the gear to position the poppet seat and sleeve assemblies for automatic adjustment, or using the special poppet adjusting screw kit 021407–X1 for manual poppet adjustment.

1. Center the steering gear by turning 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. See **Fig. 107**. Use a 12-point, 11/16-or 3/4-inch socket wrench to turn the input shaft.

   If the input shaft is turned more than 1-1/2 turns from the center position, you will have to either disassemble the gear to adjust the poppets again, or install the special poppet adjusting screw kit 021407–X1.



A. Timing Marks

Fig. 107, Check the Timing Marks

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. Adjust the sector shaft adjusting screw while turning the input shaft 180 degrees each side of center, until the input shaft reaches a torque of 30 to 35 lbf·in (340 to 400 N·cm). See **Fig. 108**. Use a 12-point socket and an inch-pound torque wrench to turn the input shaft.

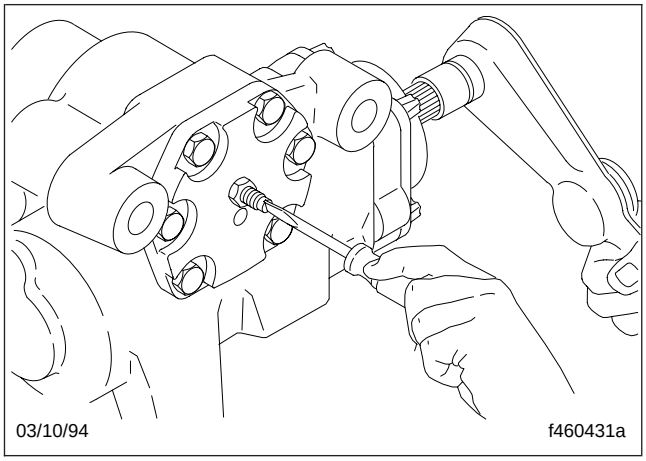


Fig. 108, Adjust the Sector Shaft Adjusting Screw

3. Back out the sector shaft adjusting screw one turn. Note the torque needed to turn the input shaft through 180 degrees each side of center.
4. Tighten the sector shaft adjusting screw so that the torque noted in the previous step is increased by 2 to 4 lbf·in (20 to 40 N·cm). Then, while holding the adjusting screw in place, tighten the sector shaft adjusting screw jam nut 40 to 45 lbf·ft (54 to 61 N·m).
5. Check the torque needed to turn the input shaft. If it is more than 35 lbf·in (400 N·cm), repeat the two previous steps to adjust the input shaft again.

Removal

1. Disconnect the return line from the steering gear and plug the line. See **Fig. 1**. Also cap the return port of the gear with a high pressure fitting.

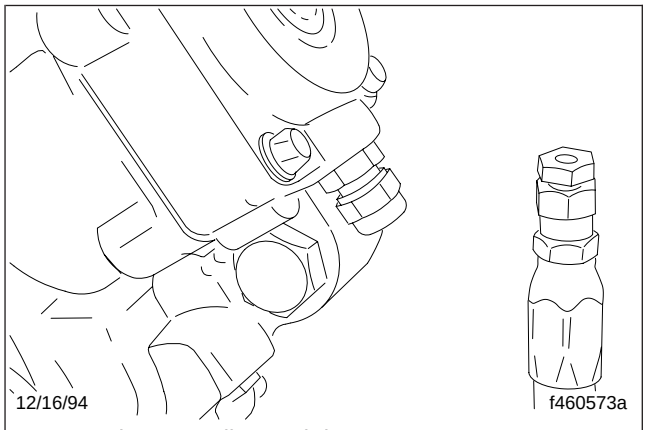


Fig. 1, Disconnect the Return Line

2. Disconnect the steering driveline from the steering gear input shaft as follows:

   2.1 Remove the pinch-bolt nut and pinch bolt from the steering driveline lower end yoke. Discard the nut.

CAUTION

Do not pound the U-joint or lower end yoke on or off the input shaft. Internal damage to the steering gear can result.

   2.2 Remove the lower end yoke from the input shaft. Don't turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft into the driveline tube, as you remove the lower end yoke.

3. Remove the dirt-and-water seal from the steering gear. See **Fig. 2**.

4. Wipe out the grease and then remove the spiral retaining ring. See **Fig. 3**. Use a screwdriver inserted into the notch formed in the end of the ring.

5. Slip the input yoke back onto the input shaft with the pinch bolt installed, but not tightened. See **Fig. 4**.

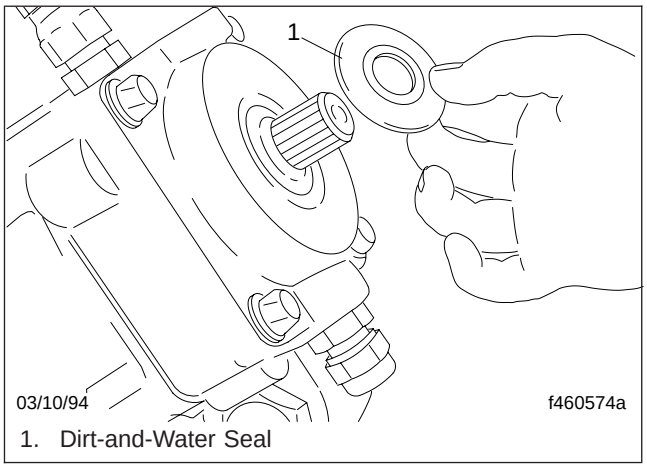


Fig. 2, Remove the Dirt-and-Water Seal

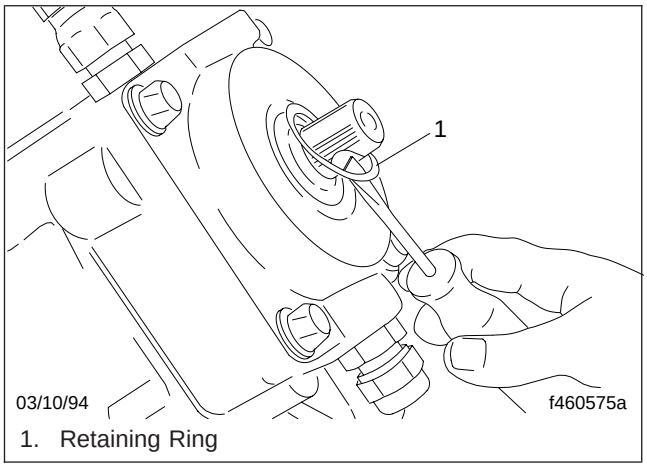


Fig. 3, Remove the Retaining Ring

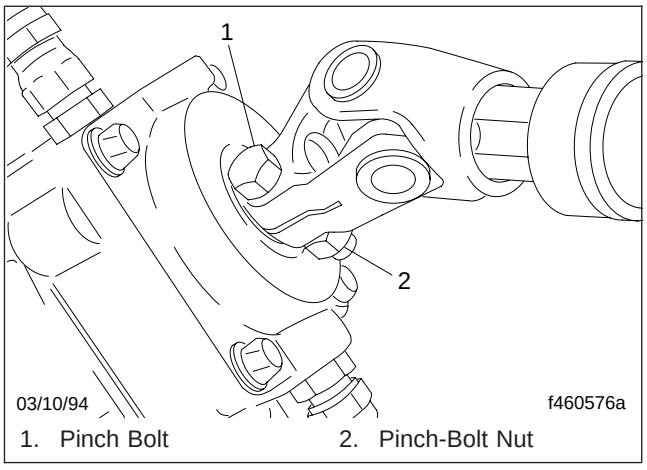
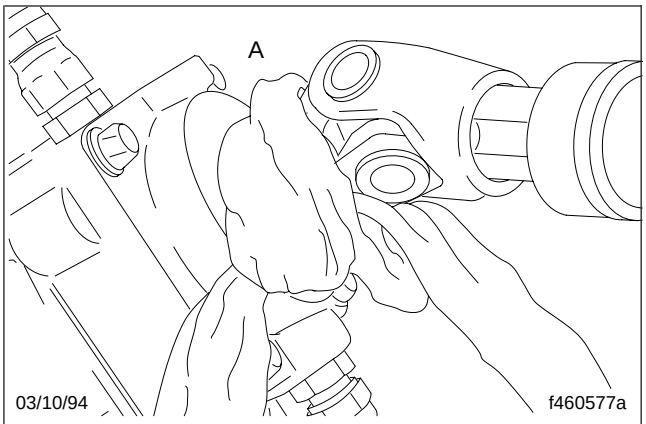


Fig. 4, Install the Pinch Bolt

Input Shaft Seal Removal and Installation

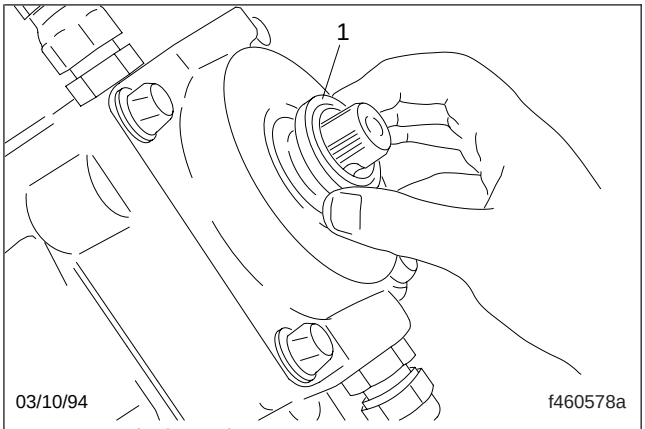
6. Tie or wrap a shop towel around the input shaft area, and place a drip pan under the vehicle to catch the oil. See **Fig. 5**.



A. Cover the input shaft area.

Fig. 5, Shop Towel Covering the Input Shaft

7. Add Dexron II type ATF as necessary to the fill line on the dipstick.
8. With the vehicle in neutral, momentarily turn the starter (quickly turn off the engine if it starts).
9. Remove the shop towel, pinch bolt, and input yoke.
10. Remove the seal. See **Fig. 6**.



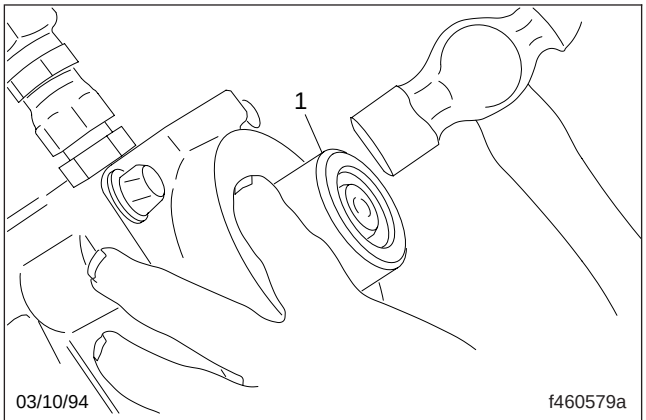
1. Input Shaft Seal

Fig. 6, Remove the Input Shaft Seal

11. Check the seal area of the valve housing for any seal fragments. Remove any that are found.
12. Check the seal for heat damage. If the seal is stiff and brittle, and not pliable like the new seal, it is probably heat damaged. You need to determine and fix the cause of excessive heat in the vehicle. For Instructions, refer to **Troubleshooting 300**.

Installation

1. Put clean grease on the new input shaft seal, and place it over the input shaft, garter spring side first. See **Fig. 6**. Place seal installer tool J37073 over the input shaft and against the seal, small diameter end first. See **Fig. 7**. Tap the seal installer tool until the tool shoulder is square against the valve housing. Remove any seal material that may have sheared off in the seal bore or retaining ring groove.

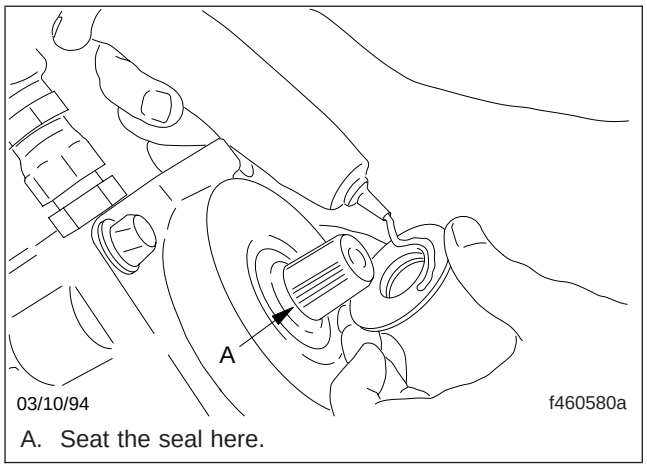


1. Seal Installer Tool

Fig. 7, Position the Seal Installer Tool

2. Insert the new retaining ring into the groove.
3. Pack the end of the valve housing bore around the input shaft with clean high temperature industrial grease (Mobil Temp 1 or 2 or equivalent). Apply more of the grease to a new dirt-and-water seal and install it over the input shaft. See **Fig. 8**. Seat it in the groove behind the serrations and against the valve housing.
4. Connect the steering driveline to the steering gear input shaft.

   4.1 Clean the input shaft and the inside of the driveline yoke.



A. Seat the seal here.

Fig. 8, Install the Dirt-and-Water Seal

4.2 Apply a thin film of grease to the yoke splines. Use lithium-based grease, NLGI grade 2.

4.3 Slide the yoke onto the input shaft, and install the new yoke pinch bolt. Before installing the pinch-bolt nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a *new* pinch-bolt nut, and tighten it 55 to 65 lbf·ft (75 to 88 N·m).

4.4 Apply white Torque Seal F–900 to the exposed pinch-bolt threads and the locknut.

5. Connect the return line to the steering gear return port.

6. Fill and bleed the steering system.

IMPORTANT: Do not turn the steering wheel in the following steps until instructed. Doing so can cause air to enter the system, which can make it more difficult and time-consuming to bleed air from the system.

6.1 Fill the power steering reservoir with Dexron II type ATF until nearly full.

Crank the engine for 10 seconds without allowing it to start; if the engine does start, shut it down immediately. Check and fill the reservoir as needed.

Repeat this procedure three times, each time checking and filling the reservoir.

6.2 Start the engine and let it idle for two minutes. Shut down the engine, and check the fluid level in the reservoir.

6.3 Start the engine again. Steer the vehicle from full-left to full-right, several times. As needed, add fluid to the full line on the reservoir dipstick.

Checks

After power steering components have been worked on, and before the vehicle is placed into service, make the following checks.

⚠ WARNING

Failure to make the following checks 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. With the engine turned off and warm, check the power steering reservoir fluid level.
2. Check for air in the system.
   - 2.1 Place a thermometer in the power steering reservoir, then warm the hydraulic system to normal operating temperature of 125° to 135°F (51° to 57°C), by operating the engine at low idle, while turning the steering wheel through several full left and right turns.
   - 2.2 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 needed. Bleed the air from the system.
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 this, reset the axle stops.
4. Check that the automatic poppets or the manual poppet adjusting screw (if equipped) are set correctly. If needed, adjust them. For instructions refer to **Subject 100**.
5. If there are still problems with the power steering system, go to **Section 46.07, Subject 300** and do the steering system 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. With the front tires pointing straight ahead, check the position of the steering wheel spokes.They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 1**. If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.

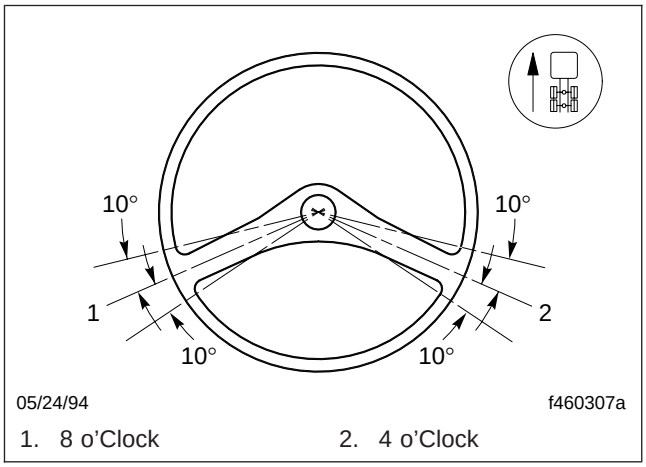


Fig. 1, Steering Wheel Centered

See **Fig. 1** for a plumbing diagram of the steering system.

Kent-Moore Part Number		Tool
TAS40	**TAS55/65**	
J37070	J37070	Adjuster Tool
J37464	J37464	Adjuster Locknut Tool
J37705	J37071	Bearing and Seal Tool
J37073	J37073	Input Seal Installer
J38713	J38713	Poppet Adjuster Seat Tool, Heavy-Duty (preferred)
J36452	J36452	Poppet Adjuster Seat Tool
J37130	J37130	Relief Valve Plug
J8092	J8092	Tool Handle

Table 1, Kent-Moore Tools, Kent-Moore Tool Division, 29784 Little Mack, Roseville, MI 48066

Description	Bolt or Nut Size	Grade	Torque lbf·ft (N·m)
Valve Housing Bolt	1/2–13	—	75–85 (102–115)
Auxiliary Port Plug	—	—	25–35 (34–47)
Poppet Adjuster Sleeve and Seat Assembly	—	—	10 (14)
Ball Return Guide Bolt	—	—	114–22 (9–30)
Sector Shaft Adjusting Screw Jam Nut	—	—	40–45 (54–61)
Side Cover Bolt	9/16–18	—	118 (160)
	5/8–18	—	170 (230)
Relief Valve Cap	—	—	25–35 (34–47)
Drag Link Castle Nut	5/8–18	C	60–115 (81–156)
	3/4–16	C	90–170 (122–230)
	7/8–14	C	160–300 (217–407)
Steering Driveline Lower End Yoke Pinch-Bolt Nut	7/16–20	C	55–65 (75–88)
Pitman Arm Pinch-Bolt Nut	5/8–18	C	120–140 (163–190)
	3/4–16		215–245 (292–332)
Steering Gear Mounting Hexbolt Nut*	7/8–14	C	377–477 (511–647)

* Torque values are for a plain capscrew with a phosphate and oil coated locknut with a hardened washer.

Table 2, Steering Gear Torque Values

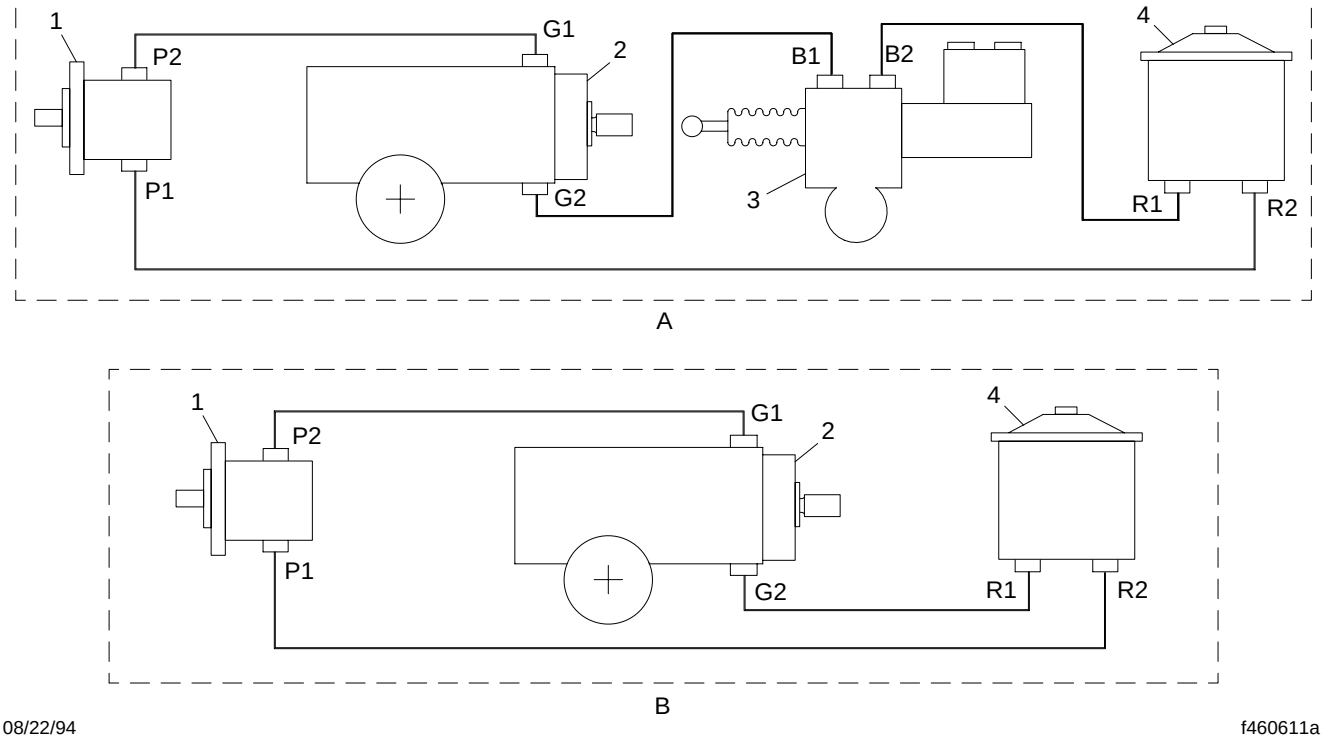
Specifications

WARNING

Fill only with approved clean automatic transmission fluid. Any mixture or any unapproved fluid could lead to seal deterioration and leaks. Any fluid leak could eventually cause loss of power steering assist.

Fluid Type	Recommended Fluid
Automatic Transmission Fluid	Dexron II

Table 3, Power Steering Fluid



A. Vehicles with Hydraulic Brakes
B. Vehicles with Air Brakes

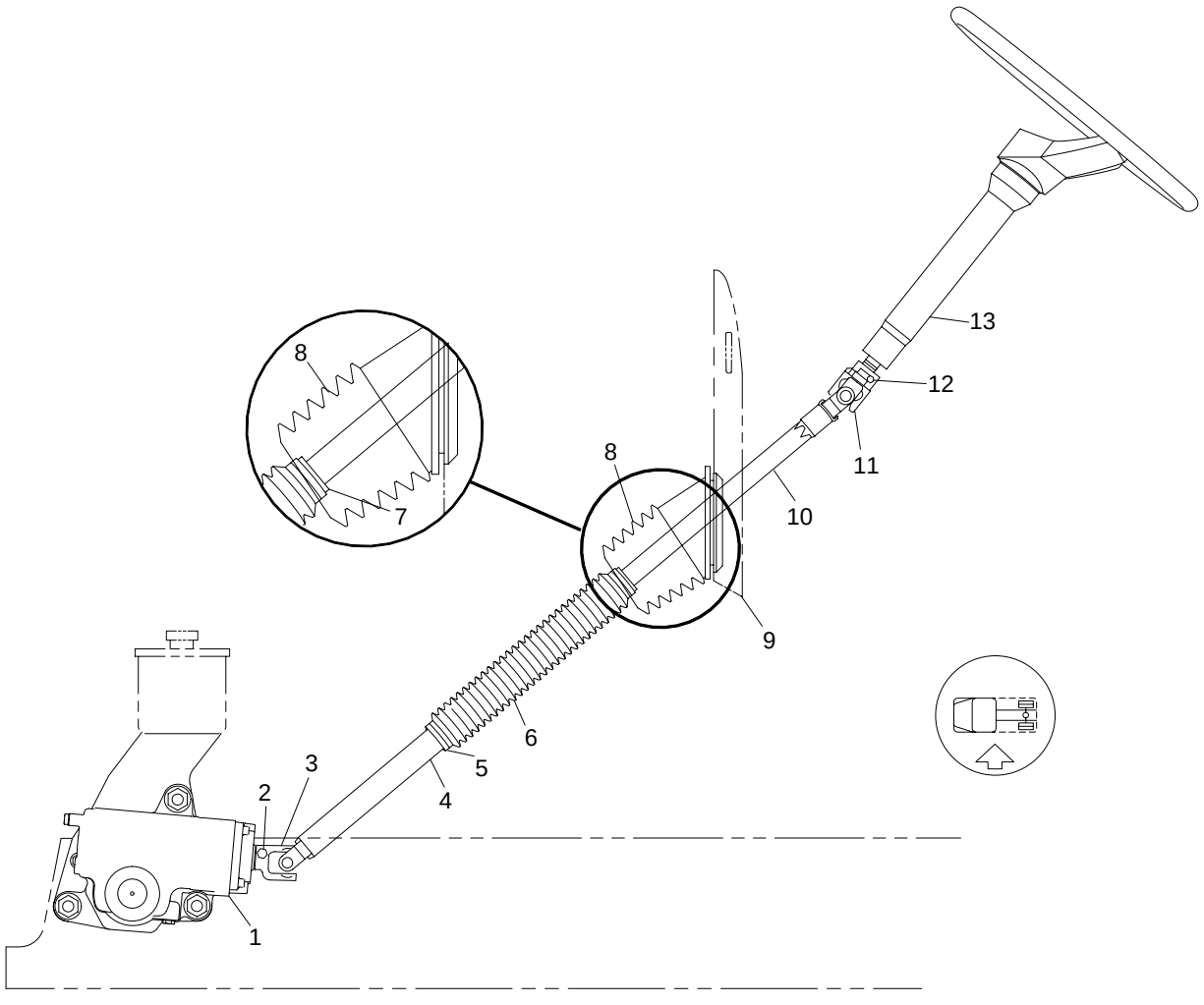
1. Steering Pump
2. Steering Gear
3. Brake Booster
4. Reservoir

Fig. 1, Plumbing Diagram

General Description

The steering driveline connects the steering column and jacket assembly to the steering gear by means of a telescoping shaft with an upper and a lower end yoke, and a pair of universal joints. See **Fig. 1**.

The driveline shaft consists of a tubular upper section, splined on the outside, which mates with an internally splined lower section. The telescoping shaft eases installation and removal of the steering column, steering driveline, and steering gear. It also compensates for changes in distance between the



09/19/96 f461083

1. Power Steering Gear
2. Lower End Yoke Pinch Bolt and Nut
3. Lower End Yoke Assembly
4. Outer Tube
5. Boot Clamp
6. Steering Driveline Boot
7. Bushing
8. Upper Steering Driveline Boot
9. Cowl
10. Inner Tube
11. Upper End Yoke Assembly
12. Upper End Yoke Pinch Bolt and Nut
13. Fixed Steering Column Assembly

Fig. 1, Steering Driveline Installation

steering column and steering gear, which occur when

General Description

the relative positions of the frame rails and body change during vehicle operation.

The upper end yoke is internally serrated to match the external serrations at the end of the steering column shaft; the lower end yoke is internally serrated to match the external serrations on the steering gear input shaft. Each end yoke is secured to its respective shaft by a pinch bolt that engages a notch in the shaft.

The universal joint at each end of the steering driveline allows the transfer of steering motion from the steering column shaft, to the steering driveline, and to the steering gear input shaft, even though the driveline is at an angle to both of the other shafts. Each universal joint cross rides in four needle bearing cups, two carried in the end yoke, and two carried in the steering driveline's integral yoke. The needle bearing cups are held in place in each yoke by snap rings.

Steering Driveline Removal and Installation

Removal

NOTE: It is not necessary to loosen the steering wheel and column assembly to do this procedure.

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. Apply the parking brakes, and chock the tires. Tilt the hood.
3. Disconnect the lower end yoke. See **Fig. 1**.
   - 3.1 Remove the pinch-bolt nut and pinch bolt from the lower end yoke. Discard the nut.
   - 3.2 Remove the yoke from the steering gear input shaft. Don't turn the steering gear input shaft when removing the lower end yoke. Push the driveline shaft onto the driveline tube, as you remove the lower end yoke.
4. Disconnect the upper end yoke.
   - 4.1 Remove the pinch-bolt nut and pinch bolt from the upper end yoke. Discard the nut.
   - 4.2 Remove the upper end yoke from the steering column shaft.
5. Remove the driveline from the engine compartment.

Installation

1. Clean the steering gear input shaft, steering driveline, and end yokes. Do not separate the steering driveline.
   - 1.1 Thoroughly clean the end yokes, the steering driveline, and the steering gear input shaft with a clean, dry cloth.
   - 1.2 Apply a thin film of grease to the yoke splines. Use lithium-based grease, NLGI grade 2.
2. Slide the driveline's upper end yoke onto the steering column shaft, then install the end yoke pinch bolt. See **Fig. 1**. Before installing the pinch-bolt nut, make sure the pinch bolt is centered in the steering column shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a *new* pinch-bolt nut, and tighten it 45 to 55 lbf·ft (61 to 75 N·m).
3. Apply white Torque Seal F-900 to the exposed pinch-bolt thread and to the locknut.
4. Before attaching the lower end yoke to the steering gear input shaft, be sure the front tires are straight ahead, the steering gear is centered, the arrows on the driveline inner tube and the outer tube are aligned, and the driveline slides freely.

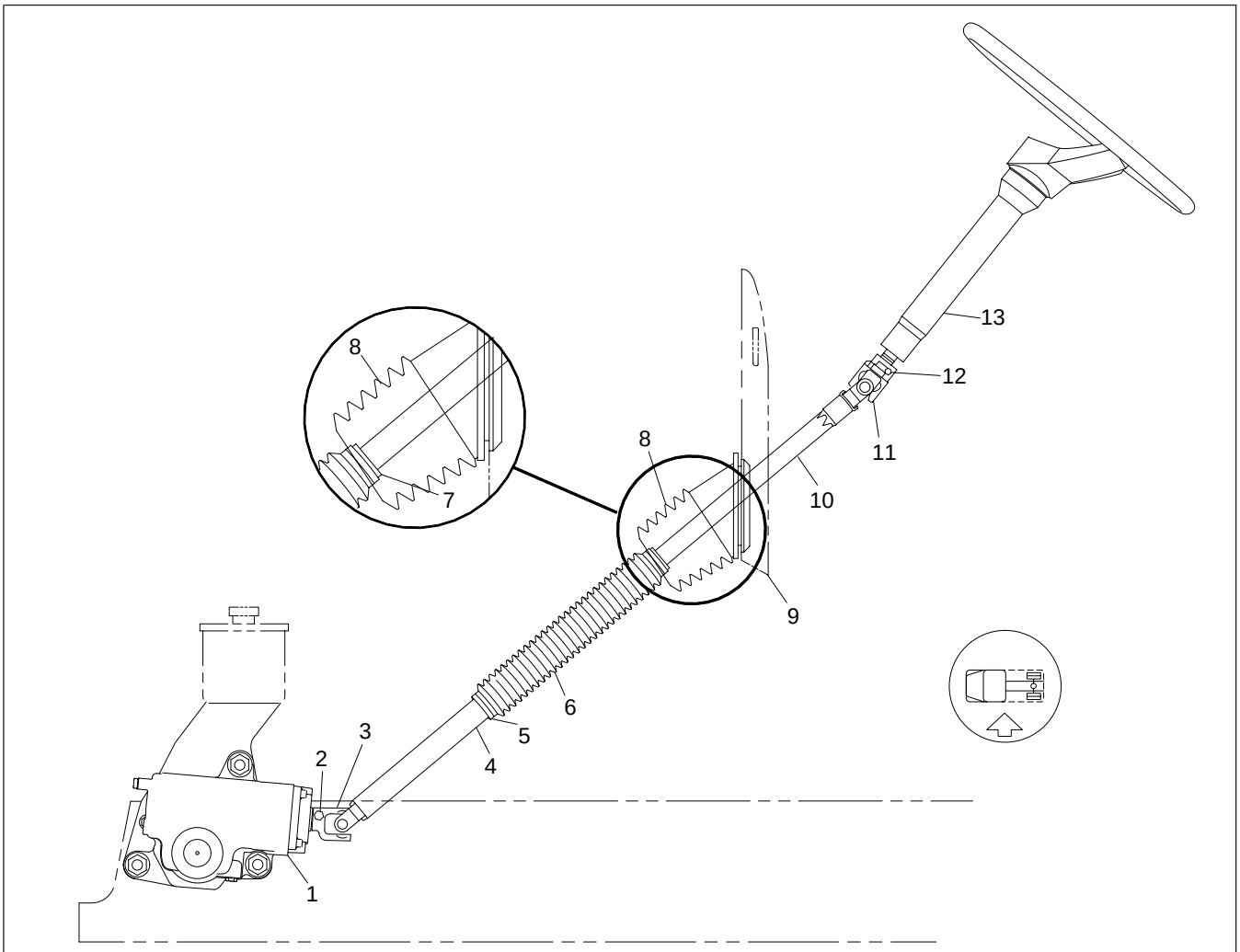
⚠ CAUTION

CAUTION: If the arrow on the driveline inner tube is not aligned with the arrow on the outer tube, the U-joints will not be correctly oriented. Assembling the driveline with the U-joints incorrectly oriented could cause binding at the U-joints.

5. Install the lower end yoke on the steering gear input shaft. Before installing the pinch-bolt nut, make sure the pinch bolt is centered in the steering gear input shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a *new* pinch-bolt nut, and tighten it 45 to 55 lbf·ft (61 to 75 N·m).
6. Apply white Torque Seal F–900 to the exposed pinch bolt thread and to the locknut. See **Fig.2**.
7. Using a hand-type grease gun, lubricate the driveline tube at the lower end yoke assembly with lithium-based grease, NLGI grade 2. Apply until grease appears at all four U-joint cross seals.
8. With the front tires pointing straight ahead, check the position of the steering wheel spokes. They must be pointing within ±10 degrees of the 4 o'clock and 8 o'clock positions. See **Fig. 3**.

   If not, remove the steering wheel and install it in the correct position. For instructions, refer to the applicable section in this group.
9. Lower the hood, and secure the hood latches. Leave the parking brakes applied and the chocks at the rear tires.
10. Raise the front of the vehicle so that the front tires are off the ground, then place safety stands under the frame.
11. Turn the steering wheel through full travel, checking for hard steering or binding. If there is difficulty, check the assembly and installation of

Steering Driveline Removal and Installation



09/19/96 f461083

1. Power Steering Gear
2. Lower End Yoke Pinch Bolt and Nut
3. Lower End Yoke Assembly
4. Outer Tube
5. Boot Clamp
6. Steering Driveline Boot
7. Bushing
8. Upper Steering Driveline Boot
9. Cowl
10. Inner Tube
11. Upper End Yoke Assembly
12. Upper End Yoke Pinch Bolt and Nut
13. Fixed Steering Column Assembly

Fig. 1, Steering Driveline Installation

the driveline parts. If the cause is not the driveline, refer to the applicable steering gear section in this group.

WARNING

WARNING: Do not drive a vehicle with hard steering or binding in the steering system. This could result in partial or complete loss of steering control during vehicle operation, possibly causing personal injury and property damage.

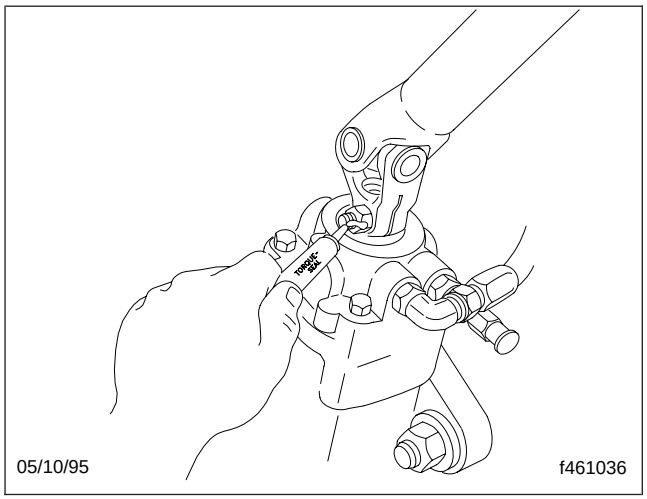


Fig. 2, Apply White Torque Seal F-900

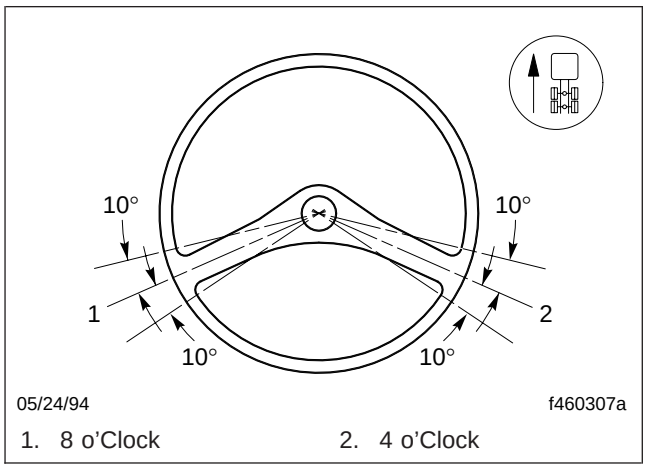


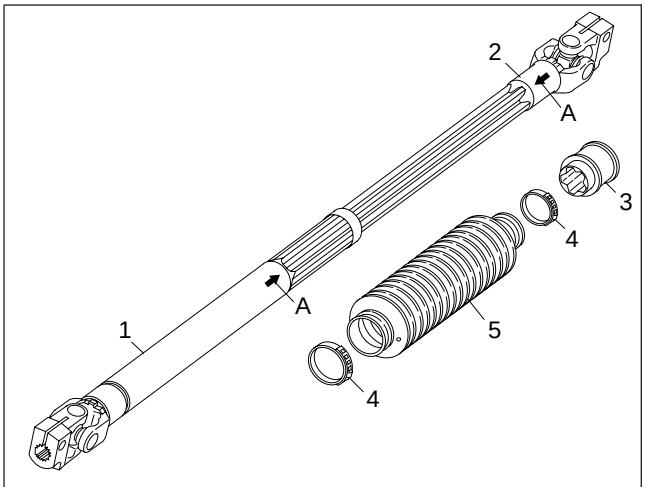
Fig. 3, Steering Wheel Centered

12. Remove the chocks from the tires, and secure the hood.

Steering Driveline Boot and Adaptor Replacement

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. Apply the parking brakes, and chock the tires. Tilt the hood.
3. Disconnect the lower end yoke.
   - 3.1 Remove the pinch-bolt nut and pinch bolt from the lower end yoke. Discard the nut.
   - 3.2 Remove the yoke from the steering gear input shaft. Don't turn the steering gear input shaft when removing the lower end yoke. Push the driveline outer tube onto the inner tube as you remove the lower end yoke.
4. Slide the inner tube out of the outer tube. Leave the adaptor in place. See **Fig. 1**.



A. Alignment Arrows
1. Outer Tube (to the steering gear)
2. Inner Tube (to the steering column)
3. Adaptor
4. Clamp
5. Boot

Fig. 1, Steering Driveline

5. Using pliers, remove the clamps that secure the boot on the outer tube and inner tube.
6. Discard the boot, clamps, and the adaptor.
7. Using a clean, dry cloth, clean the splined section of the inner tube.
8. Place the adaptor over the inner tube. Align the arrows on the adaptor and the inner tube.
9. Clamp the small end of the new boot on the adaptor.
10. Apply a thin film of grease to the splined portion of the inner tube. Use lithium-based grease, NLGI grade 2.

⚠ CAUTION

CAUTION: If the arrow on the driveline inner tube is not aligned with the arrow on the outer tube, the U-joints will not be correctly oriented. Assembling the driveline with the U-joints incorrectly oriented could cause binding at the U-joints.

11. Align the arrows on the driveline inner tube and the outer tube.
12. Slide the inner tube into the outer tube.
13. Clamp the boot on the outer tube (just above the formed section).
14. Stroke the driveline several times to ensure that the boot and adaptor are firmly in place, and that the driveline slides freely.
15. Before attaching the lower end yoke to the steering gear input shaft, be sure the front tires are straight ahead, the steering gear is centered, the arrows on the driveline inner tube and the outer tube are aligned, and the driveline slides freely.
16. Install the lower end yoke on the steering gear input shaft. Before installing the pinch-bolt nut, make sure the pinch bolt is centered in the steering gear input shaft notch. The pinch bolt is centered if it can slip in and out of the end yoke with ease. Install a *new* pinch-bolt nut, and tighten it 45 to 55 lbf·ft (61 to 75 N·m).
17. Apply white Torque Seal F–900 to the exposed pinch bolt thread and to the locknut. **See Fig.2.**
18. Remove the chocks from the tires, and secure the hood.

Steering Driveline Boot and Adaptor Replacement

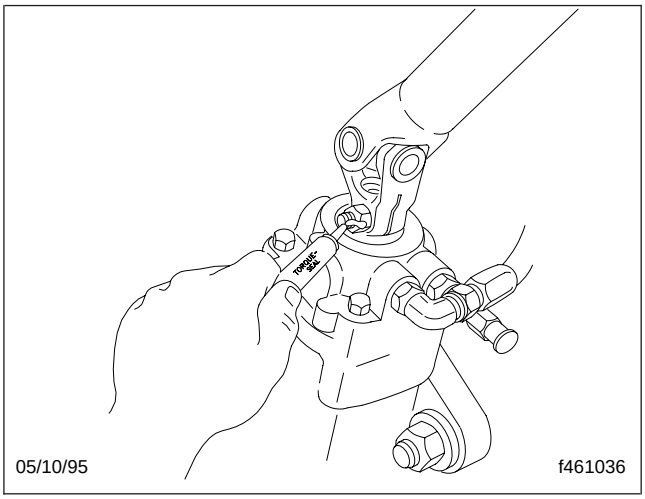


Fig. 2, Apply White Torque Seal F-900

Specifications

Description	Grade	Size	Torque lbf·ft (N·m)
End Yoke Pinch-Bolt Nut	8 or 8.2	7/16–20 UNF	45 to 55 (61 to 75)

Table 1, Torque Values

Power Steering Pump Removal and Installation

Removal

1. Apply the parking brake, chock the tires, disconnect the batteries, and tilt 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**.

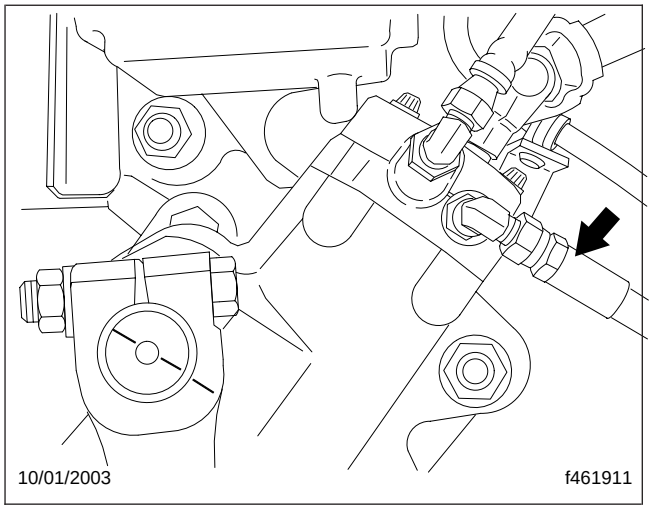


Fig. 1, Pressure Line on the Power Steering Gear

3. Drain the fluid from the power steering system. Disconnect the hydraulic lines 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.

   If the power steering pump is mounted on the air compressor, remove the mounting capscrews. If the power steering pump is mounted on the engine, remove the mounting bolts, nuts, and washers.
6. If the power steering pump is being replaced, remove the fittings and lines from the old pump, and install them on the new pump.

Installation

1. Install the power steering pump.

   1.1 Install a new gasket or O-ring on the power steering pump.

   1.2 If the power steering pump mounts on the air compressor, use capscrews to attach the steering pump to the air compressor and tighten the capscrews 27 to 32 lbf·ft (37 to 43 N·m).

   If the power steering pump mounts on the engine, use the bolts, nuts, and washers to attach the steering pump to the engine. Tighten the nuts 27 to 32 lbf·ft (37 to 43 N·m).
2. Unplug the pressure line and attach it to the steering gear.
3. Unplug the remaining hydraulic lines and fittings and connect the lines.
4. Connect the batteries.
5. Fill the power steering reservoir to between the MAX HOT and MIN COLD lines. For approved lubricants, see **Specifications 400**.
6. Start the engine and turn the steering wheel from full right to full left two or three times to remove air from the lines.
7. Check the power steering reservoir and add fluid if needed.
8. Check the hydraulic lines for leaks.
9. Close the hood and remove the chocks from the tires.

Troubleshooting Tables

Problem—The Power Steering Pump Is Making Noise

Possible Cause	Remedy
The oil level is too low.	Repair the leaks and add oil.
The pump sucks in air.	Repair the leaks, add oil, and vent the steering system.

Problem—No Pressure

Possible Cause	Remedy
The valve spool is jammed.	Replace the power steering pump.
The sealing parts are not working.	Replace the power steering pump.
There is foreign material between the pressure plate and rotor set.	Replace the power steering pump.

Problem—The Power Steering Pump Doesn't Deliver Fluid

Possible Cause	Remedy
The valve spool is dirty or not working.	Replace the power steering pump.
The throttle insert is dirty or not working.	Replace the power steering pump.
The vanes in the rotor set are worn.	Replace the power steering pump.

Problem—Delivery Too High

Possible Cause	Remedy
The valve spool is jammed.	Replace the power steering pump.

Problem—Maximum Pressure Too High

Possible Cause	Remedy
The valve spool is not working.	Replace the power steering pump.

Specifications

Approved power steering fluids are:

- Automatic Transmission Fluid (ATF), Dexron® II
- Automatic Transmission Fluid (ATF), Dexron® III

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.

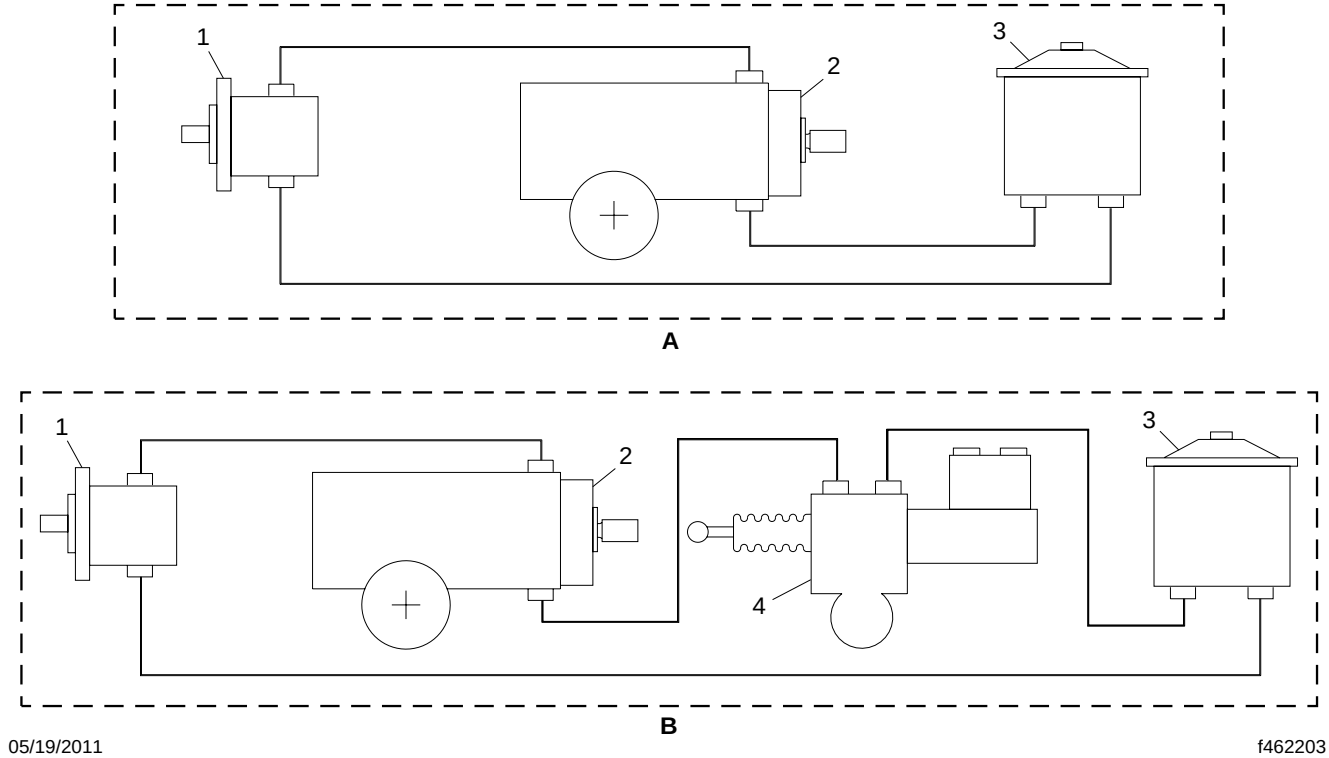
  If the total system back pressure is less than 100 psi (689 kPa), or 140 psi (965 kPa) for a vehicle with hydraulic brakes, restriction is not a problem—go to step 6.

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.

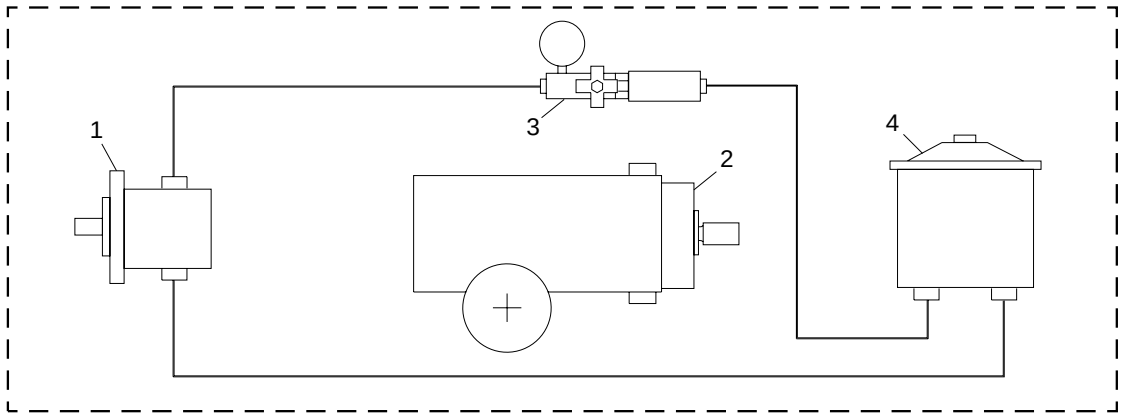
  If the drop in system pressure from the value found in substep 5.3 is greater than 40 psi (276 kPa), the brake booster has excessive restriction. If the drop in pressure is less than 40 psi (276 kPa), reconnect the booster input and output lines and continue with this substep.

- 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.

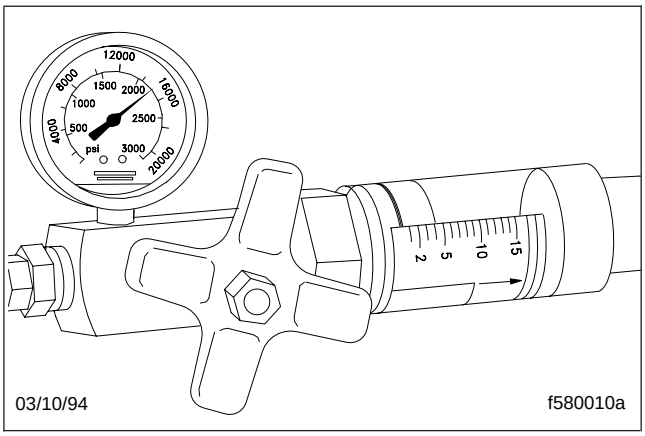


Fig. 3, Power Steering System Analyzer

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.

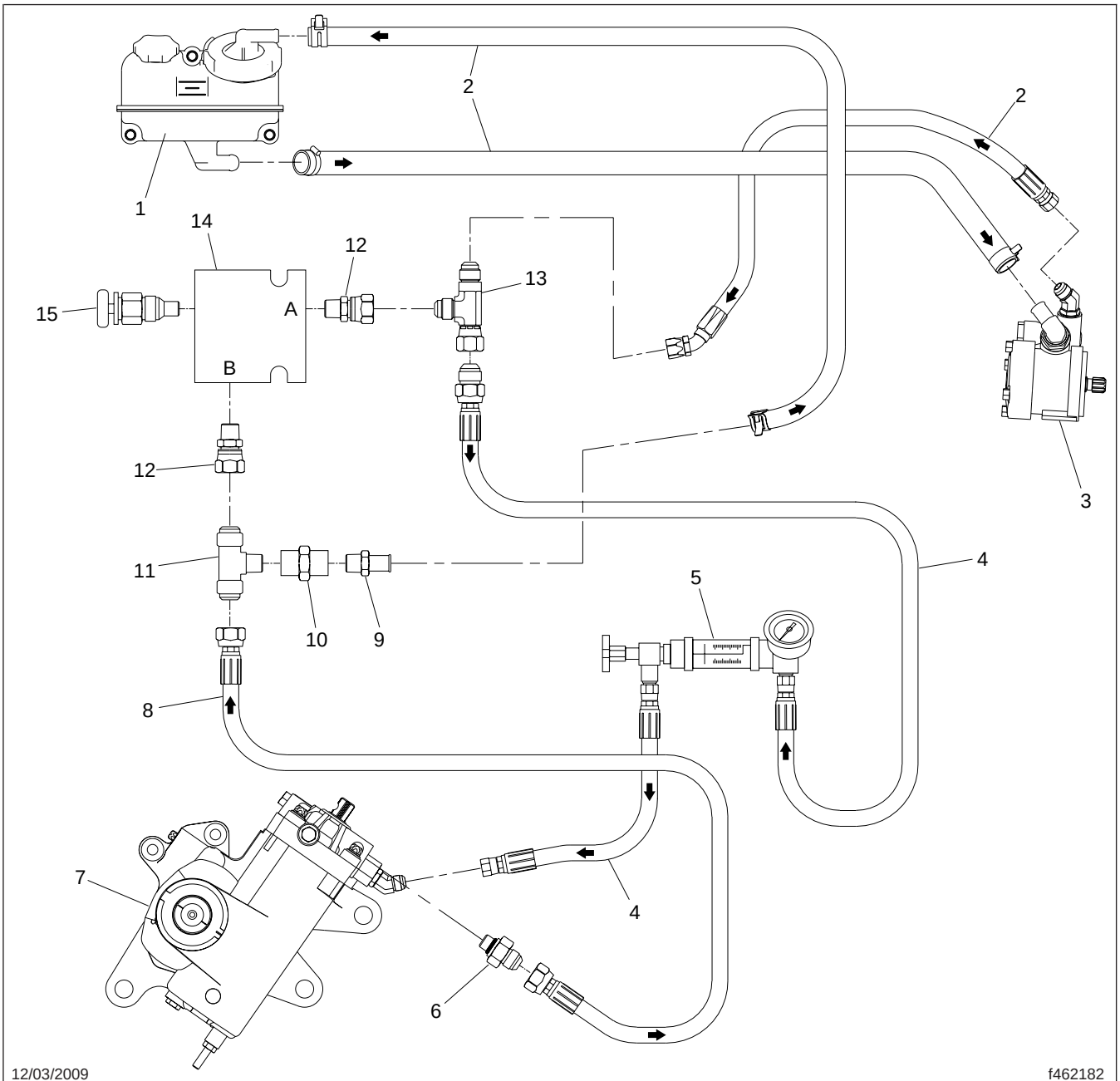
8. With the engine on, close the shutoff valve on the PSSA.
9. Set the system relief pressure by closing the external relief valve (**Fig. 4**, Item 15) until the gauge on the PSSA reaches 2,000 psi (13 790 kPa), then fully open the shutoff valve on the PSSA.
10. Continue with the steering gear internal 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 tanks 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 provide a clean storage area for fuel, is held in place by metal straps that transfer the weight load to the vehicle frame. 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 primary tank, with an electric fuel level gauge mounted in the cab 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. Disconnect the wires from the fuel level gauge sender.

5. Remove the fuel tank and the fuel tank cage or guard assembly.

   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 capscrews 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 capscrews attaching 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.

   6.1 Remove the nuts and washers from the tank strap T-bolts.

   6.2 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.

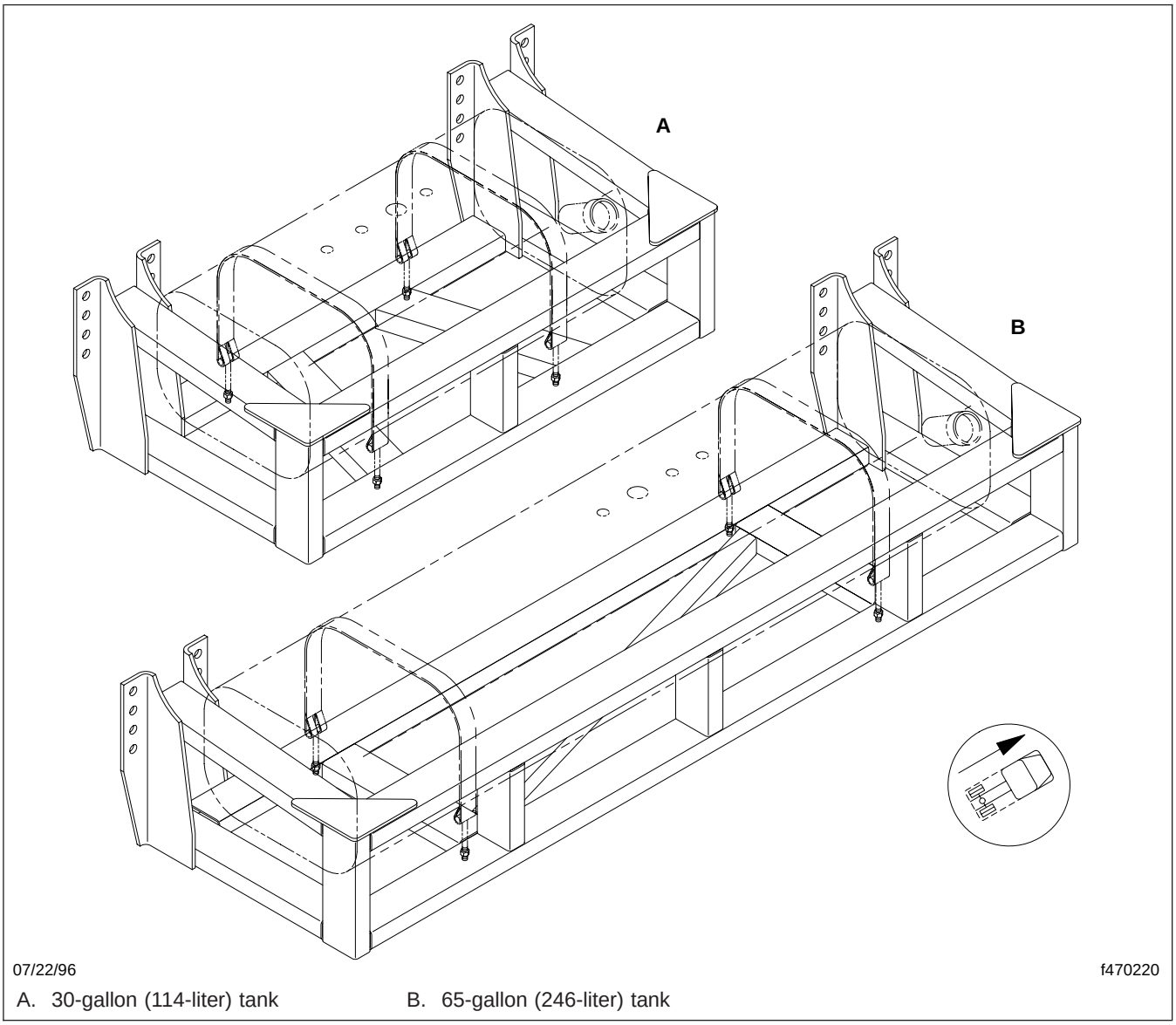
⚠ WARNING

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.

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation



A. 30-gallon (114-liter) tank B. 65-gallon (246-liter) tank

Fig. 1, Side-Mounted Fuel Tanks and Fuel Tank Cages

9.2 Inspect the vent line for wear or damage. Replace the vent line if it is worn or damaged. Clean a plugged vent line by directing shop air through the vent line. An undamaged vent line may be transferred from the old tank to the new tank.

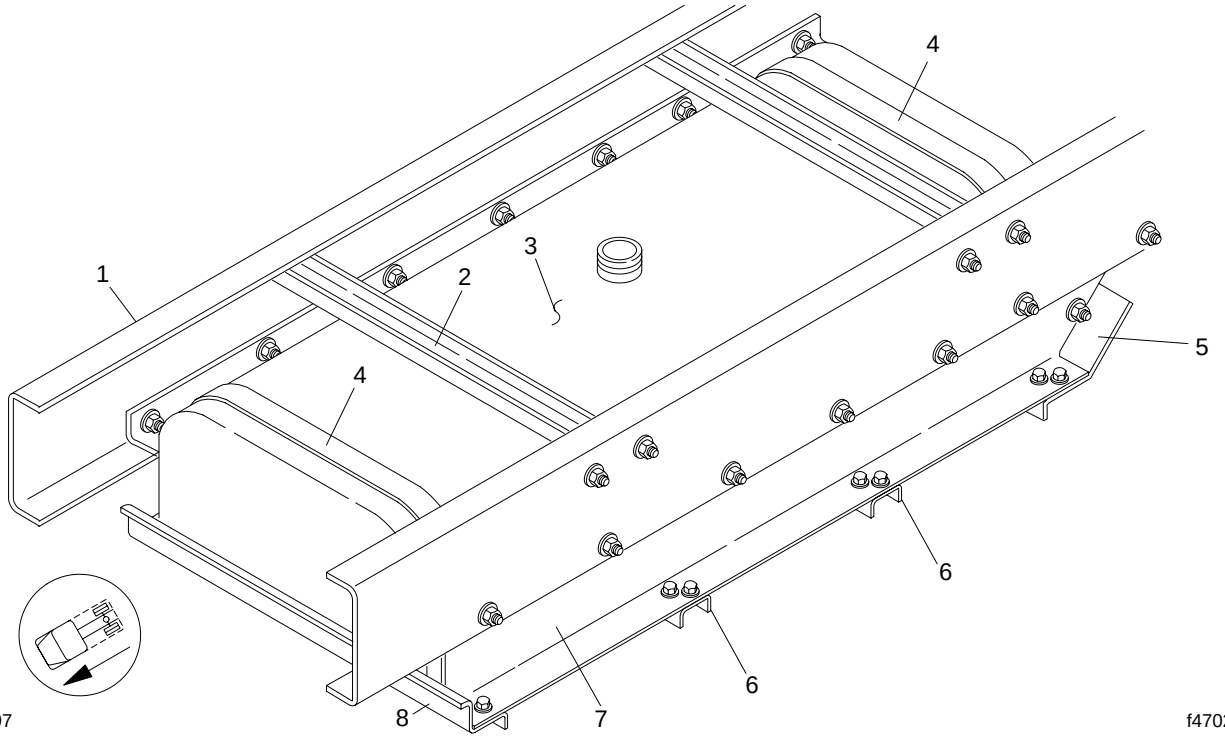
9.3 Transfer the fuel level gauge sender and gasket to the new tank. See **Fig. 3**. Securely and evenly tighten the machine screws.

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.

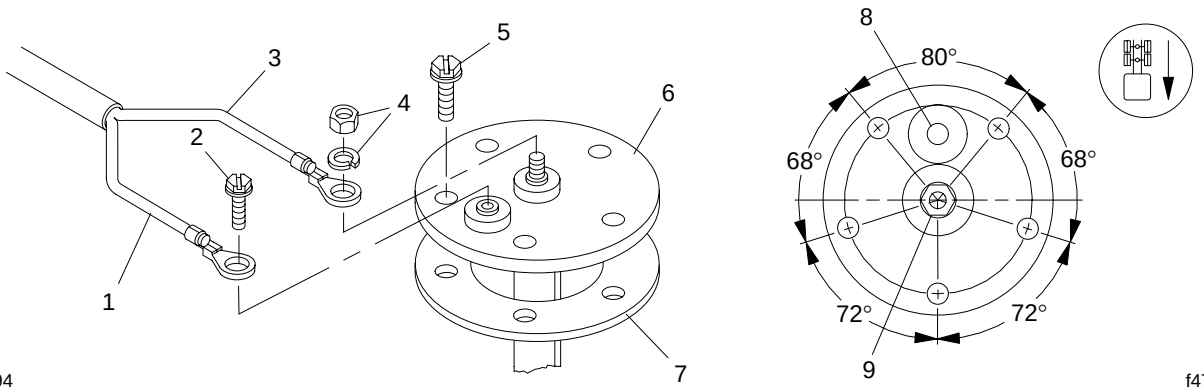
   Make sure the fuel filler neck is properly positioned.

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



1. Ground Wire
2. 10–24 Machine Screw
3. Circuit 47 Wire
4. 10–32 Hexnut and Split Lockwasher
5. 10–32 Machine Screw
6. Electric Fuel Level Gauge Sender
7. Fuel tank Gasket
8. 10–24 UNC–2B Threaded Hole (GND)
9. 10–32 UNF–2A Stud (sender)

Fig. 3, Fuel Level Gauge Sender Installation

Fuel Tank and Fuel Tank Cage or Guard Removal and Installation

For side-mounted tanks, move the tank fore or aft until the distance from the centerline of the filler cap to the fuel tank cage is 10-13/16 ± 3/16 inches (275 ± 5 mm).

For frame rail-mounted tanks, move the tank fore or aft until the distance from the centerline of the filler cap to the fuel tank cage is 57-1/2 inches (1461 mm).

2. Install the isolators and the tank straps.

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.

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 capscrews and hardened washers. Position the new tank bracket on the capscrews, 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 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, and then install the center lower crossmembers. Install the forward and aft lower crossmembers to 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.

Fuel Tank Strap Replacement

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.

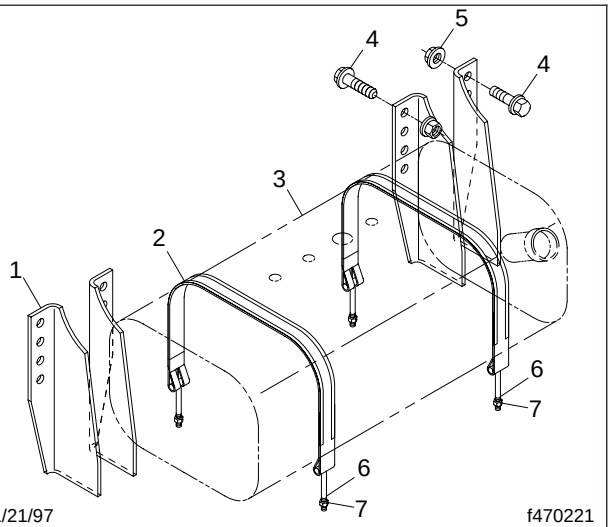
6. Install the rubber isolators and the new tank straps onto the fuel tank. Install each strap end evenly so that the amount of each bolt length is approximately the same.

   IMPORTANT: Fuel tanks can be damaged by overtightening the fuel tank straps.

   6.1 Install a bearing washer and two nuts on the tank strap T-bolt. Tighten the first nut 15 lbf·ft (20 N·m).

   6.2 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 (30-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.

Fuel lines must be free of droops, sharp bends, and kinks in the lines.

Fuel lines must not extend more than 5 cm (2 inches) 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 lines must be made of reinforced flexible hose assemblies that meet or exceed SAE specification J1402.

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.

Replacement

NOTE: Vehicles equipped with a Cummins ISB02 or MBE900 engine have an inline fuel strainer. The inline fuel strainer is located on the left-hand frame rail under the cowl area.

1. Remove the tie bands that secure the fuel strainer.

IMPORTANT: The fuel flow arrow on the fuel strainer must be pointed toward the front of the vehicle.

2. Remove the strainer, and replace it with a new strainer.
3. Secure the fuel strainer with tie bands.

Specifications

This subject contains the following table: • Fastener Torques

Description	Size	Grade	Torque lbf·ft (N·m)
Fuel Tank Strap T-Bolt:			
Hexnut	1/2–13	B	15 (20)
Jam Nut	1/2–13	B	30 (41)
Fuel Tank Bracket Mounting Locknut	1/2–13	C	68 (92)
Compression Brace Mounting Locknut	1/2–13	C	68 (92)

Table 1, Fastener Torques

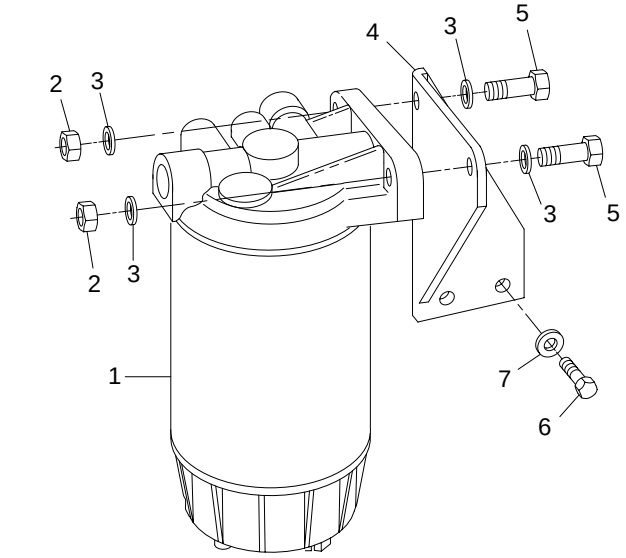
General Information

The fuel/water separator removes water and solid contaminants from diesel fuel. See **Fig.1**. Installed between the fuel tank and the fuel transfer pump, the separator has an optional ignition-controlled fuel heater to prevent ice and wax in the diesel fuel from clogging fuel filters.

Principles of Operation

Diesel fuel enters at the top of the separator, flowing down past the heater element (if so equipped), and on to the top of the filter element. As the fuel flows down the sides of the element, the heavier contaminants and some water fall directly to the collection bowl below the element. The filter element itself contains a resin which repels water, forcing any remaining water to bead against or within the element and fall to the collection bowl. As the fuel passes from the outside to the inside of the filter element, the last traces of water collect on the inner surface of the element and fall to the collection bowl.

The filtered fuel is drawn out through the top of the separator, and the water and solid contaminants remain in the collection bowl. As the water collects, it completes the circuit between the two prongs of the water sensor probe. A warning light in the cab alerts the operator to drain the bowl.



01/09/97 f470258

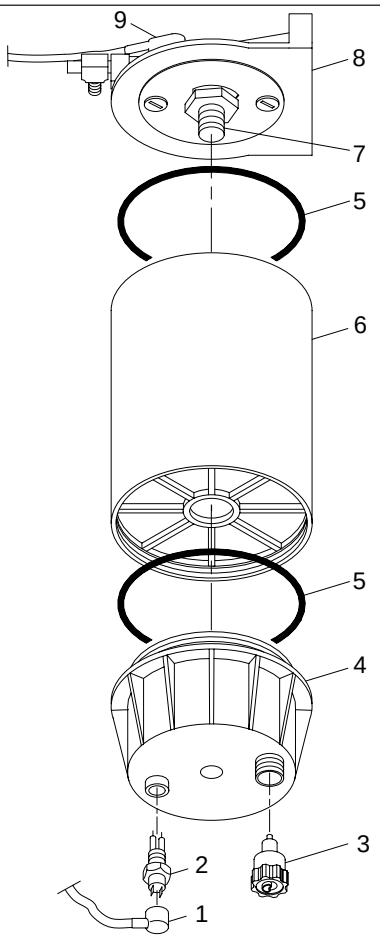
1. Filter Element
2. Hexnut, 3/8–16
3. Hardened Washer
4. Mounting Bracket
5. Hexhead Capscrew, 3/8–16
6. Hexhead Capscrew, 5/16–18
7. Plated Steel Washer

Fig. 1, Fuel/Water Separator and Mounting Bracket

Filter Element Replacement

Replacement

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Drain the fuel/water separator. See **Fig. 1**.
   - 2.1 Place a suitable container under the separator.
   - 2.2 Turn the drain counterclockwise to remove it.
3. Disconnect the wiring connector from the water sensor probe.
4. Remove the bowl from the element.
5. Remove the element from the adapter fitting and the mounting head.
6. Install the bowl on the bottom of the new filter element.
7. Install the drain by turning it clockwise into the bottom of the bowl.
8. Lubricate the O-ring in the top of the filter element with clean motor oil or diesel fuel.
9. Fill the element and bowl assembly with clean fuel.
10. Install the new filter element on the mounting head. Tighten the element 72 lbf·in (820 N·cm).
11. Connect the wiring connector to the water sensor probe.
12. Start the engine and check for leaks. Repair any leaks.
13. Lower the hood, and remove the chocks from the tires.

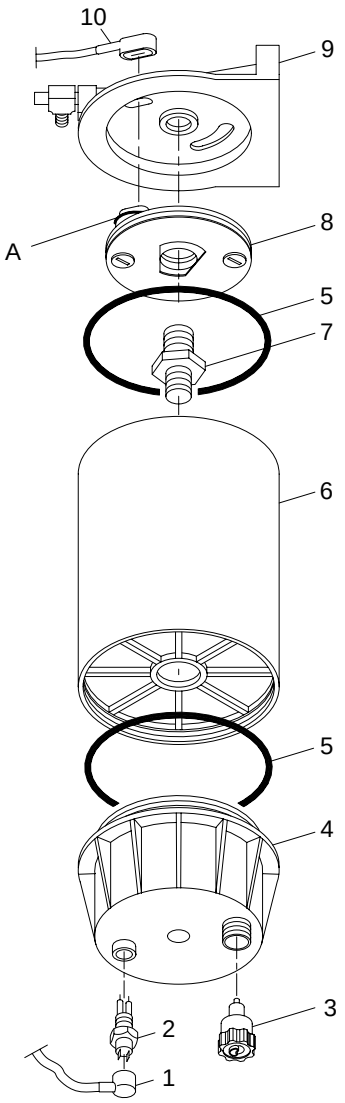


1. Wiring Connector
2. Water Sensor Probe
3. Self-Venting Drain
4. Bowl
5. Filter Element O-Ring
6. Filter Element
7. Adapter Fitting
8. Mounting Head
9. Wiring Connector

Fig. 1, Fuel/Water Separator (exploded view)

Replacement

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Drain the fuel/water separator. See **Fig. 1**.
   - 2.1 Place a suitable container under the separator.
   - 2.2 Turn the drain counterclockwise to remove it.
3. Disconnect the wiring connector from the water sensor probe.
4. Remove the bowl from the element.
5. Remove the element from the adapter fitting and the mounting head.
6. Remove the brass adapter fitting from the mounting head.
7. Disconnect the wiring connector from the heater element.
8. Remove the heater element from the mounting head.
9. Clean the inside surface of the mounting head, and install the new heater element with a new, lubricated element O-ring.
10. Apply Loctite 271 (or equivalent) to the adapter fitting threads, and install the adapter on the mounting head. Tighten the adapter 30 lbf·ft (40 N·m).
11. Connect the wiring connector to the element.
12. Install the bowl on the bottom of the replacement filter element.
13. Screw the drain into the bottom of the bowl.
14. Lubricate the O-ring in the top of the filter element with clean motor oil or diesel fuel.
15. Fill the element and bowl assembly with clean fuel.
16. Install the replacement filter element on the adaptor fitting. Tighten the element 72 lbf·in (820 N·cm).
17. Connect the wiring connector to the water sensor probe.



A. Install the heater element O-ring here.

1. Wiring Connector
2. Water Sensor Probe
3. Self-Venting Drain
4. Bowl
5. Filter Element O-Ring
6. Filter Element
7. Adapter Fitting
8. Heater Element
9. Mounting Head
10. Wiring Connector

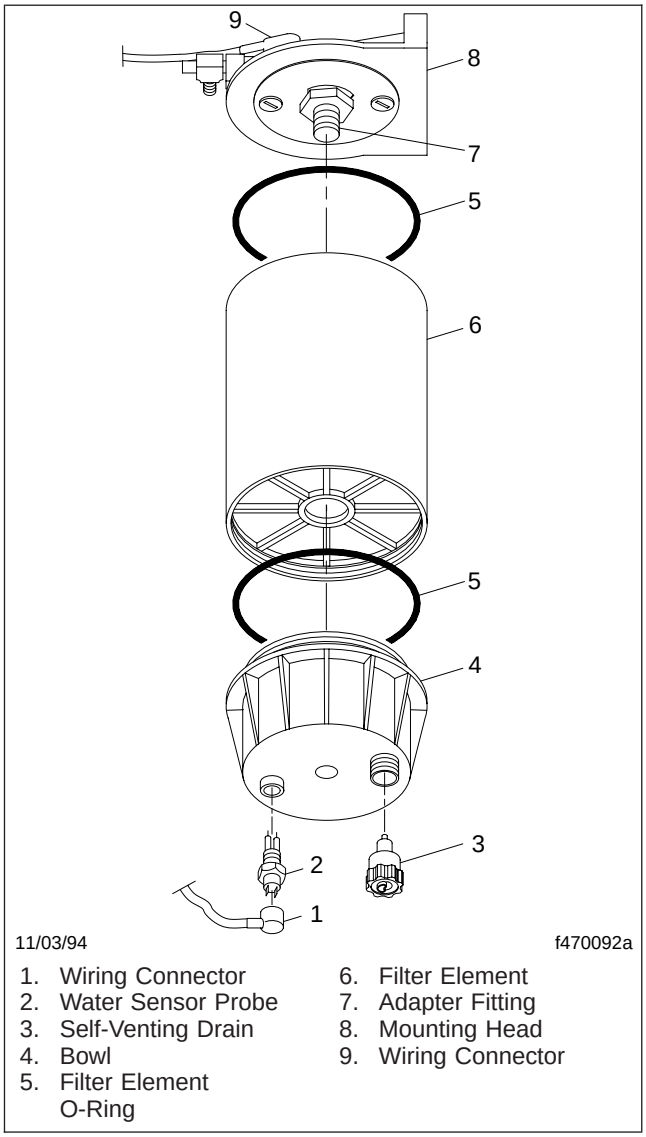
Fig. 1, Fuel/Water Separator (with heater element)

18. Start the engine and check for leaks. Repair any leaks.
19. Lower the hood, and remove the chocks from the tires.

Fuel/Water Separator Replacement

Replacement

1. Apply the parking brakes, chock the tires, and tilt the hood.
2. Drain the fuel/water separator. See **Fig. 1**.
   - 2.1 Disconnect the fuel lines from the separator, and mark the lines for reassembly.
   - 2.2 Place a suitable container under the separator.
   - 2.3 Turn the drain counterclockwise to remove it.
3. Remove the wiring connectors from the water sensor probe and the heater element.
4. Remove the fuel/water separator mounting bolts, and remove the separator from its mounting bracket.
5. Place the new separator against the mounting bracket, and secure it with the mounting bolts. Tighten the bolts 40 lbf·ft (55 N·m).
6. Remove the bowl and the filter element, as a unit, from the new separator.
7. Using clean motor oil or diesel fuel, lubricate the O-ring in the top of the filter element.
8. Make sure the drain in the bowl is closed, then fill the filter element and bowl assembly with clean fuel.
9. Install the element on the mounting head, and tighten the element 72 lbf·in (820 N·cm).
10. Connect the fuel lines to the separator.
11. Connect the wiring connectors to the water sensor probe and the heater element.
12. Prime the fuel system. For instructions, refer to the fuel system priming section in this group.
13. Start the engine and check for leaks. Repair any leaks.
14. Lower the hood, and remove the chocks from the tires.



1. Wiring Connector
2. Water Sensor Probe
3. Self-Venting Drain
4. Bowl
5. Filter Element O-Ring
6. Filter Element
7. Adapter Fitting
8. Mounting Head
9. Wiring Connector

Fig. 1, Fuel/Water Separator

Troubleshooting

1. Turn the ignition to "Accessory." The high water light should go on for 2 to 5 seconds, then go off.
2. With the ignition still on, disconnect the wiring connector from the water sensor probe, and run a jumper wire from one connector terminal to the other. The high water light should go on. If it doesn't, check all wiring connections. Check that power is on, and that the separator is grounded. Check for damaged wiring in the sensor probe circuit. For a diagram of the sensor circuit, see **Specifications, 400**. If the circuit is intact and undamaged, replace the sensor probe.
3. Repeat the steps to test the new sensor probe.
4. Connect the wiring connector to the sensor probe.

Specifications

This subject contains the following table:

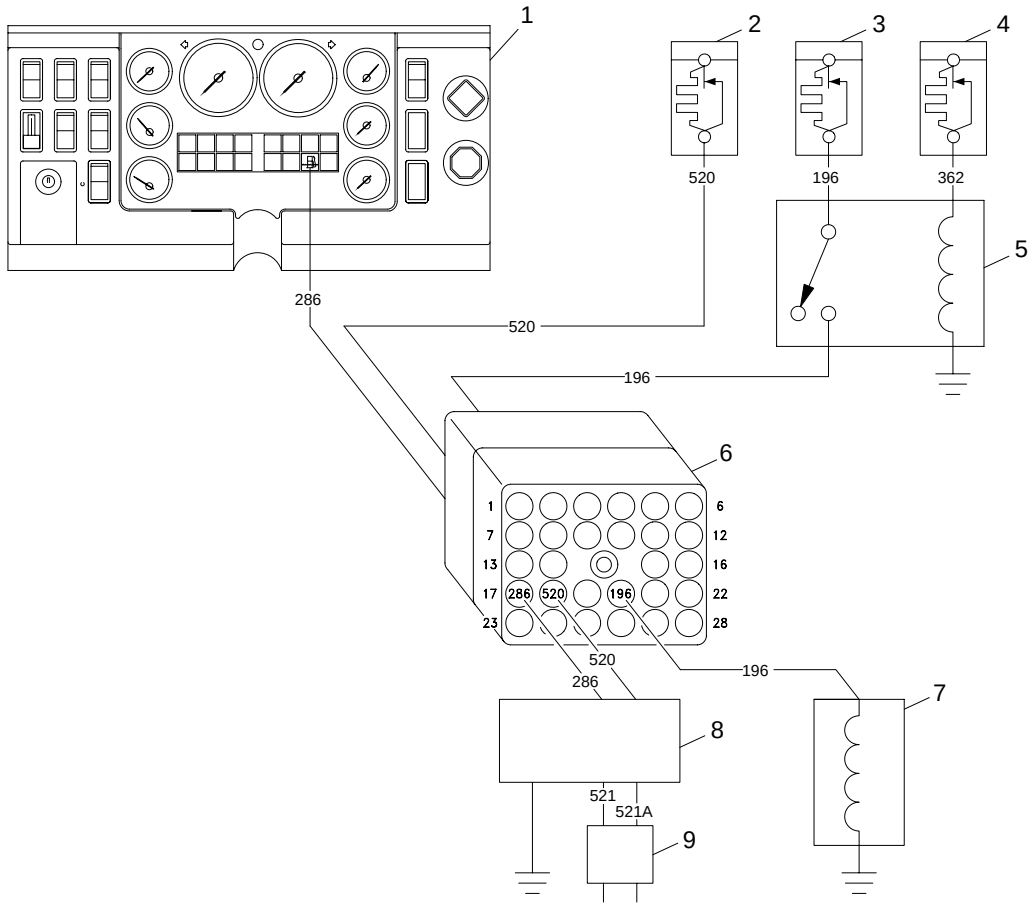
- Fastener Torques

See **Fig. 1** for a fuel/water separator wiring diagram.

Description	Grade	Size	Torque	
			lbf·ft (N·m)	lbf·in (N·cm)
Adapter Fitting	—	—	30 (40)	—
Filter Element	—	—	—	72 (820)
Separator Mounting Bolts	8	3/8-16	40 (55)	—

Table 1, Fastener Torques

Specifications



1. Instrument Panel
2. 3-Amp Circuit Breaker (in the electrical center)
3. 20-Amp Circuit Breaker (in the electrical center)
4. 5-Amp Circuit Breaker (in the electrical center)
5. Heater Relay (in the electrical center)
6. Bulkhead Connector
7. Heater Element
8. Fuel/Water Separator Module (on the engine-side of the bulkhead, below the bulkhead wiring connector)
9. Water Sensor

Fig. 1, Fuel/Water Separator Wiring Diagram

General Information

Your vehicle is equipped with either a muffler or a catalytic converter muffler. Vehicles equipped with a Caterpillar CFE engine use a muffler. Vehicles with a Cummins B or C Series engine or a Caterpillar 3126 EPA '02 engine use a catalytic converter muffler. Refer to the following information applicable to your vehicle. For exhaust pipe routing, see **Fig. 1** and **Fig. 2**.

stalled to vent the exhaust out the right or left side of the vehicle. See **Fig. 3**.

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

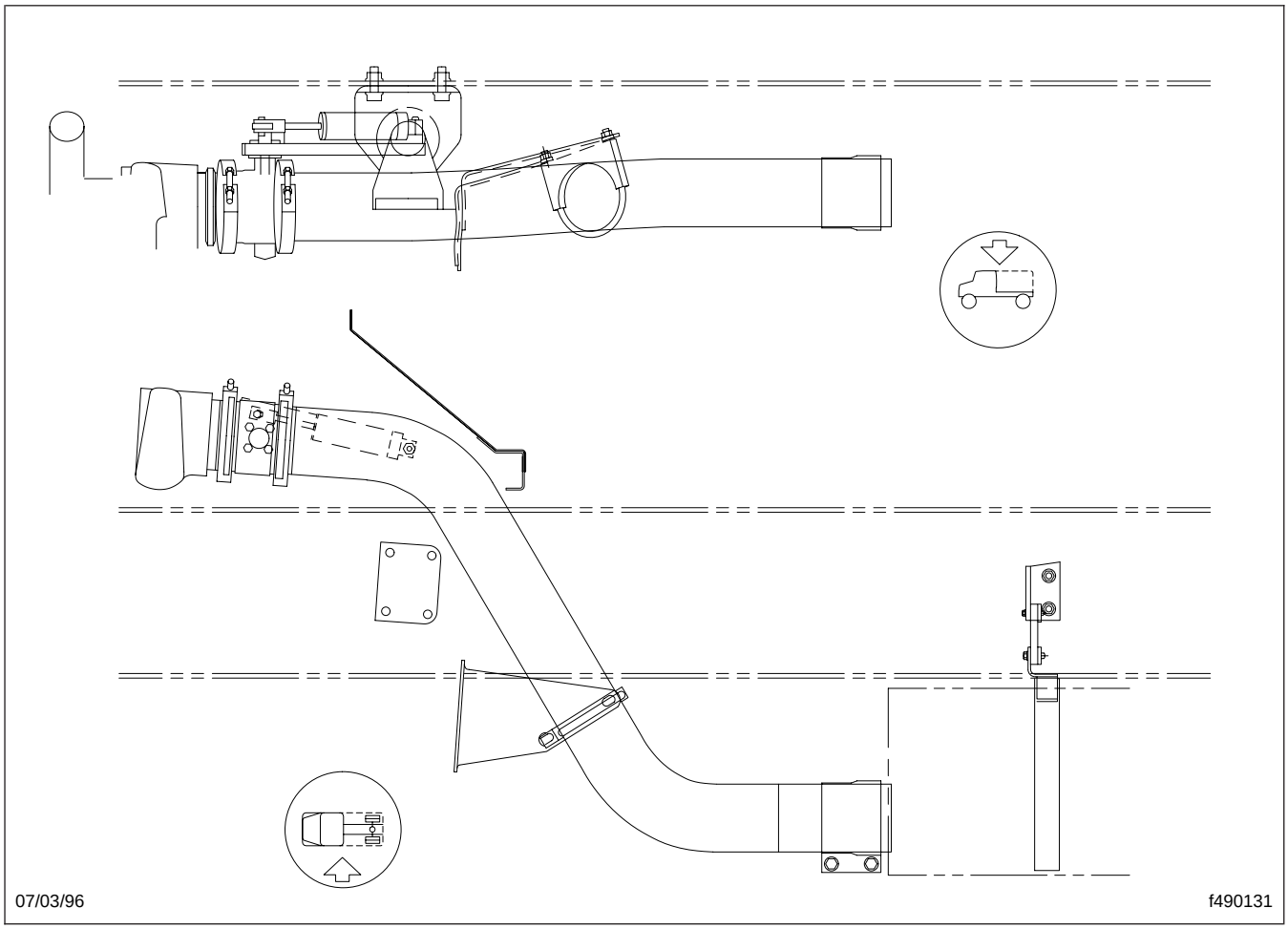


Fig. 1, Exhaust Pipe Routing, Engine to Muffler

Muffler

The exhaust system routes hot exhaust gas away from the cab, and reduces engine exhaust noise. The muffler is horizontally mounted and can be in-

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.

General Information

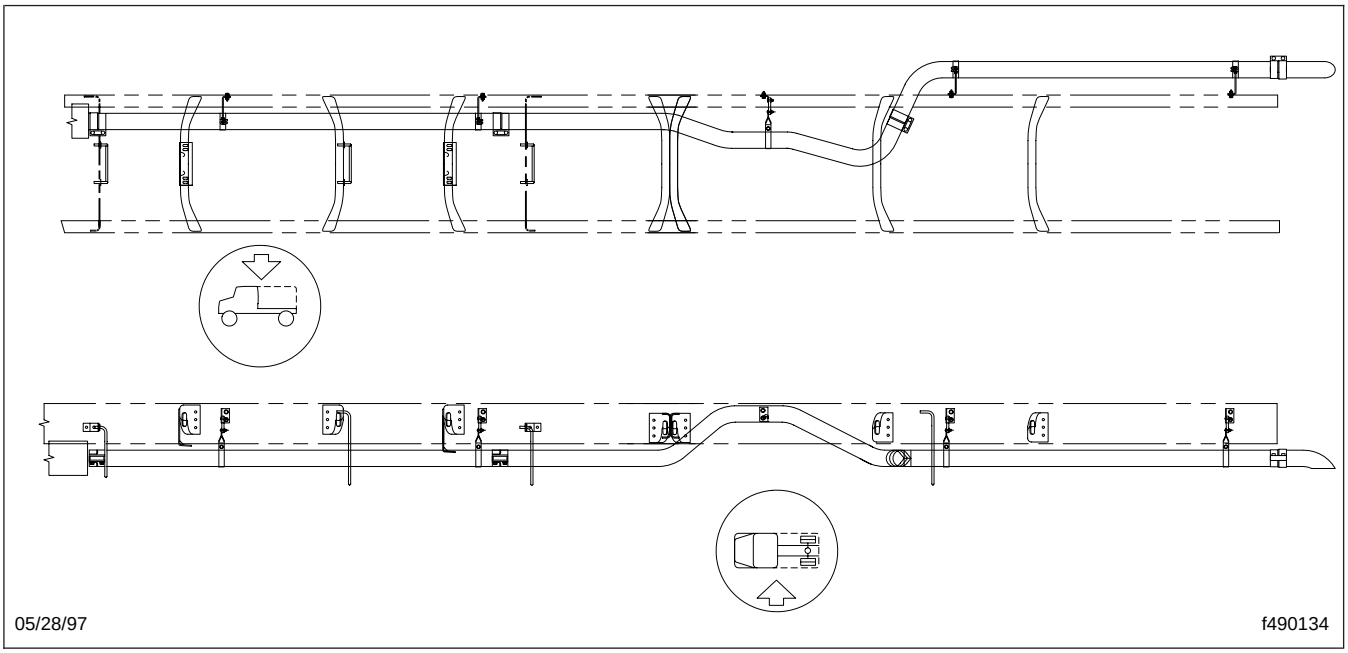


Fig. 2, Exhaust Pipe Routing, Muffler to Tail Pipe

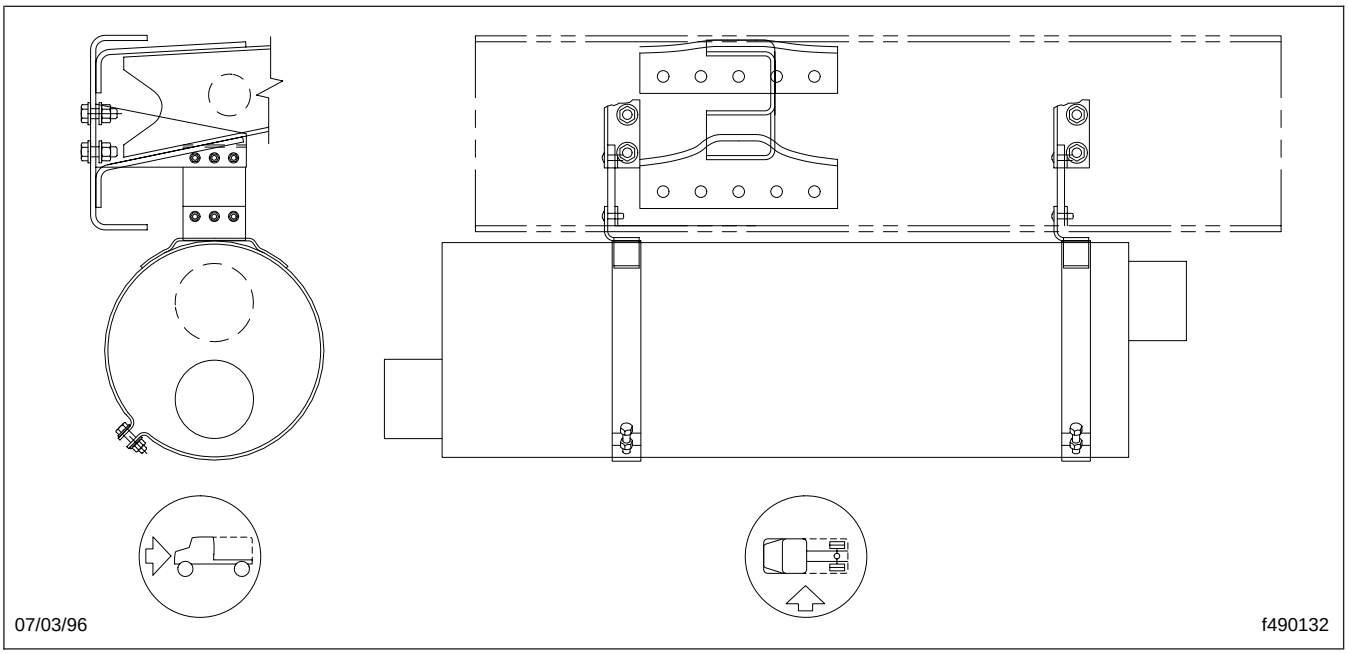


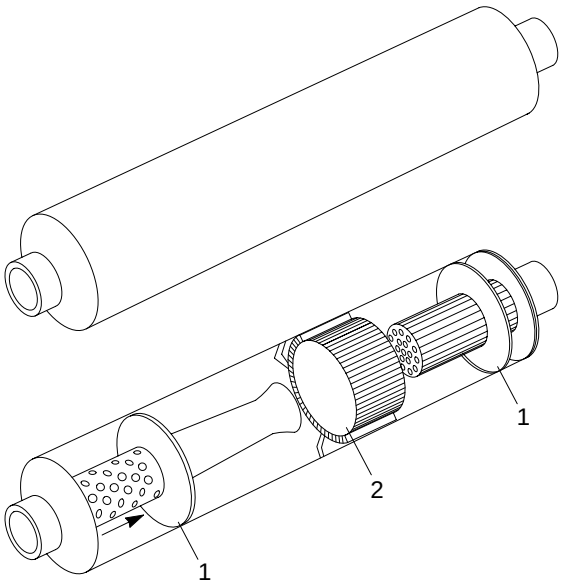
Fig. 3, Catalytic Converter Muffler Mounting

Catalytic Converter Muffler

To clean vehicle exhaust and reduce exhaust noise, the Cummins B and C Series engines and the Caterpillar 3126 EPA '02 engine use mufflers and catalytic converters combined in the same housing.

Exhaust pipes route the exhaust from the engine to the catalytic converter.

The converter muffler consists of three sections: a muffler section, the catalytic converter, and another muffler section. See **Fig. 4**.



1. Baffle
2. Substrate

Fig. 4, Typical Catalytic Converter Muffler

Inside the converter muffler, a series of baffles dampens the noise of the exhaust by breaking the sound waves into shorter lengths. Then the exhaust is channeled through the catalytic converter, a section of fine ceramic honeycomb called the substrate. The substrate is coated with gold, and the heat of the exhaust heats the gold plate. Once the catalytic converter is warmed to operating temperature, the hot gold plate ignites any unburned fuel and oil in the exhaust. The remaining fuel and oil burn, and the cleaned exhaust, passes through another section of baffles that further muffle any noise. After the second muffler section, the exhaust vents to the atmosphere.

Although the catalytic converter muffler is the same size as a standard muffler assembly, the converter muffler weighs about 50 percent more. A standard muffler may weigh about 20 lbs (9 kg), while a converter muffler the same size will weigh 33 lbs (15 kg). To be fully effective, the gold plate on the ceramic honeycomb of the substrate must stay clean so that it can contact and burn any fuel and oil in the exhaust. A layer of pollutants on the gold plate will insulate it and allow unburned fuel and oil to pass through the catalytic converter muffler. To prevent pollution build-up on the gold plate, the muffler is built with aluminized stainless steel, which is thicker and heavier than the aluminized steel used in standard mufflers.

Use parts specified by PartsPro® when replacing any of the exhaust system components.

Replacement

1. Remove and discard the wide-band exhaust clamp from the muffler inlet connection. See **Fig. 1** and **Fig. 2**.

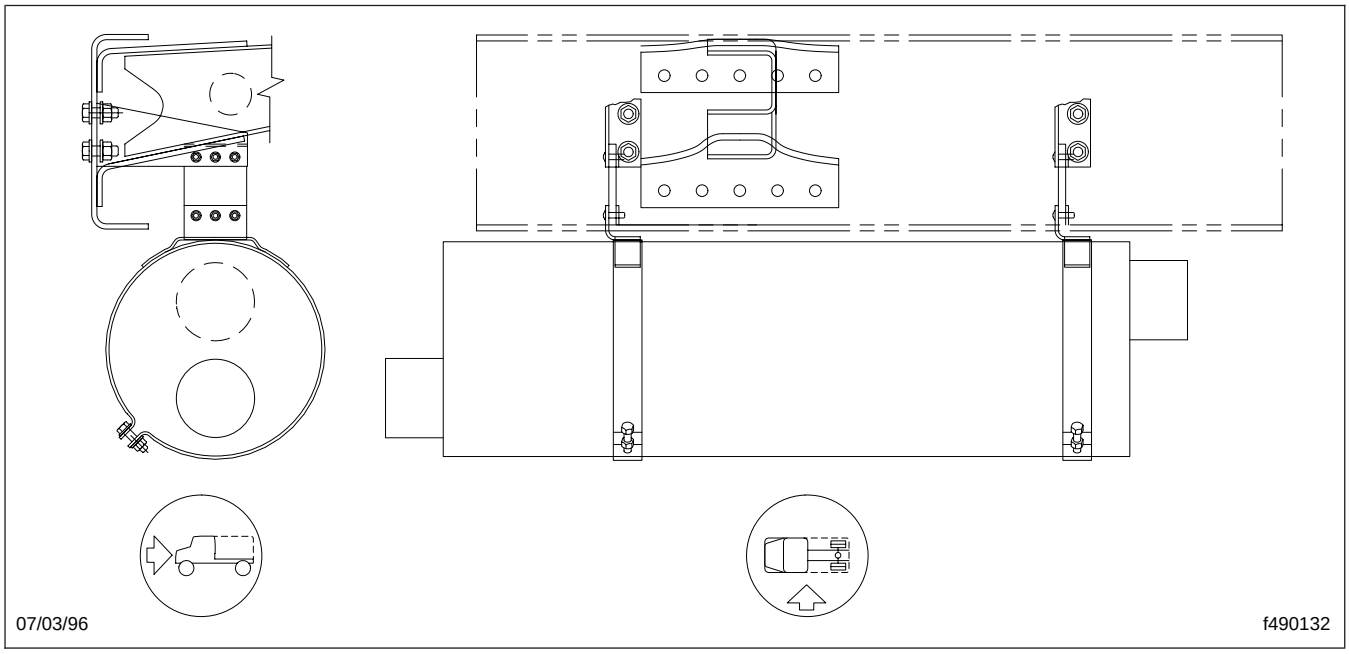


Fig. 1, Catalytic Converter Muffler Mounting

2. Pull the muffler outlet exhaust pipe out of the muffler outlet tube.

⚠ WARNING

A catalytic converter muffler is heavier than a standard muffler. To avoid personal injury, use care when lifting or lowering a catalytic converter muffler.

⚠ CAUTION

A catalytic converter muffler contains a fragile ceramic core. To prevent damage to the muffler, do not drop or strike any part of the muffler assembly.

3. Remove the bolts and locknuts on the front and rear muffler mounting bands. Open the mounting bands, and remove the muffler.
4. Connect the new muffler's inlet tube to the muffler inlet exhaust pipe.

NOTE: When installing the mounting bands, make sure the bands do not cover the drain holes in the underside of the muffler.

5. Install the front and rear muffler mounting bands. Install the bolts and locknuts on the mounting bands, but do not tighten them at this time.
6. Install a new wide-band exhaust clamp at the muffler inlet tube as follows:
   - 6.1 Coat the lap joint area with chassis grease, so the clamp will slide freely without scratching the surface of the pipe.
   - 6.2 Wrap a new wide-band exhaust clamp by hand around the lap joint.
   - 6.3 Install the fasteners in the clamp. Starting from the larger end of the clamp, alternately tighten the fastener in three increments to a final torque of 50 to 60 lbf·ft (68 to 81 N·m).
7. Install the saddle clamp U-bolt on the muffler outlet tube (where applicable). Tighten the saddle

Muffler Replacement

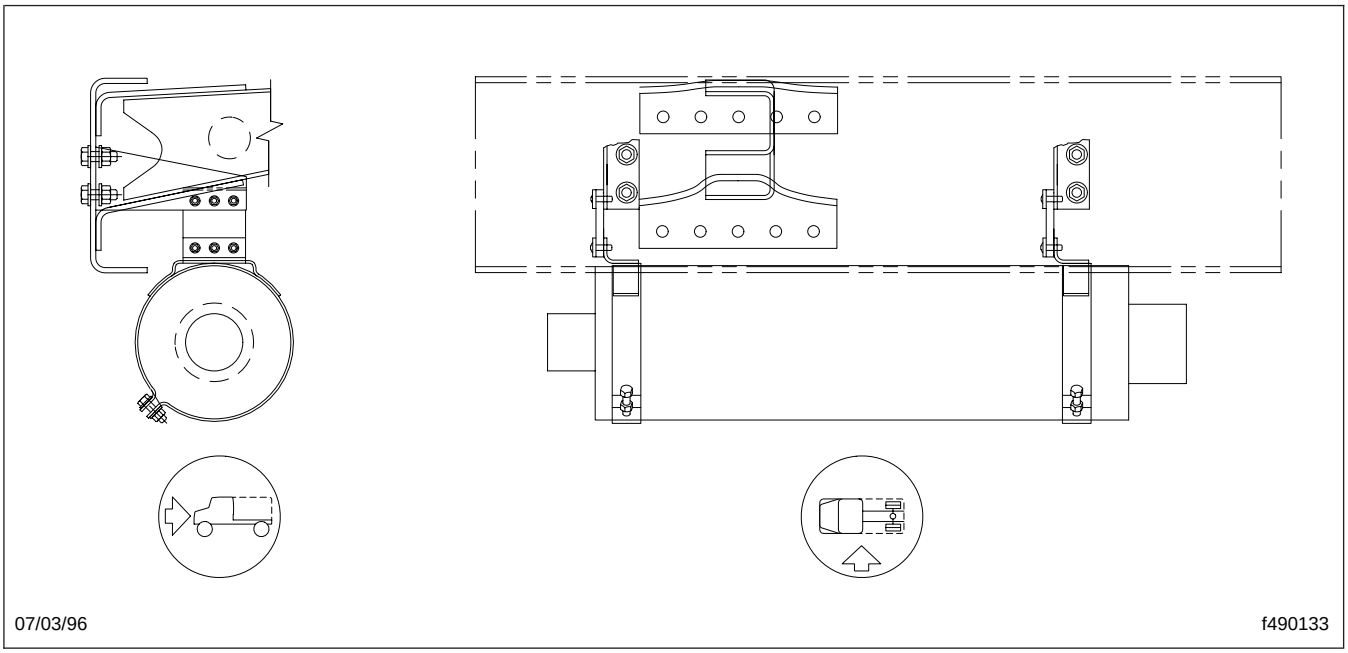


Fig. 2, Muffler Mounting

clamp flanged nuts alternately in three increments to a final torque of 24 lbf·ft (33 N·m).

8. Tighten the muffler mounting band fasteners 10 lbf·ft (14 N·m).
9. Run the engine, and check for exhaust leakage at the exhaust clamp joints. Replace the wide-band exhaust clamps if they leak.

Wide-Band Exhaust Clamp Replacement

Replacement

1. Remove and discard the leaking or damaged wide-band exhaust clamp.
2. Grease the lap joint area.
3. Hand-form a new wide-band exhaust clamp around the lap joint, with the larger end of the clamp around the larger diameter tubing, and the smaller end of the clamp around the smaller diameter tubing. Position one third to one half of the exhaust clamp width onto the larger diameter tubing, or completely cover the slots in the larger tubing.
4. Install the fasteners in the clamp. Starting from the larger end of the clamp, alternately tighten the fasteners in three increments to a final torque of 50 to 60 lbf·ft (68 to 81 N·m).
5. Run the engine, and check for exhaust leakage at the exhaust clamp joint. Replace the wide-band exhaust clamp if it leaks.

Specifications

Description	Size	Torque: lbf·ft (N·m)
Wide-Band Exhaust Clamp	—	50–60 (68–81)
Saddle Clamp U-Bolt	3/8–16	24 (33)
Mounting Band Fasteners	—	10 (14)

Table 1, Fastener Torques

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 Connectors

Parts and Tools

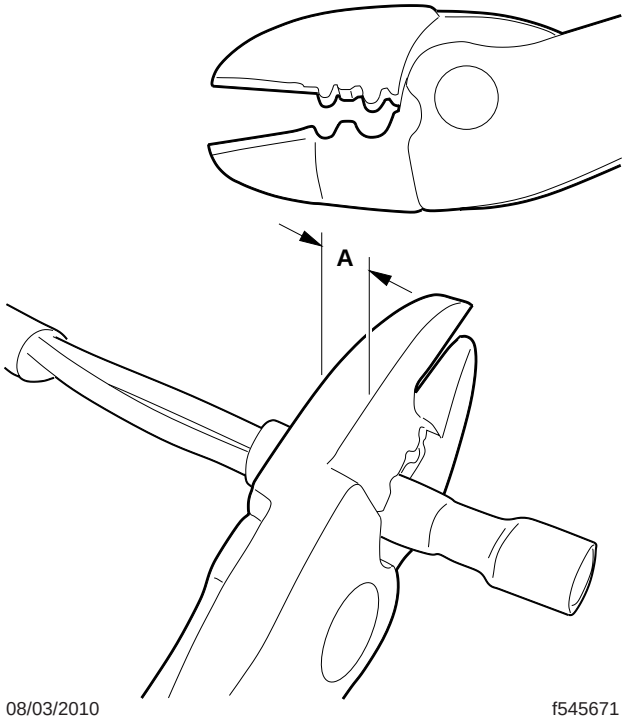
Parts are available through the Parts Distribution Centers (PDCs) in packages of 25 connectors. Use the connectors and adhesive lined shrinkable tubing shown in **Table 1** when making a wiring splice.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 1000°F (538°C).

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**.
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.



A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

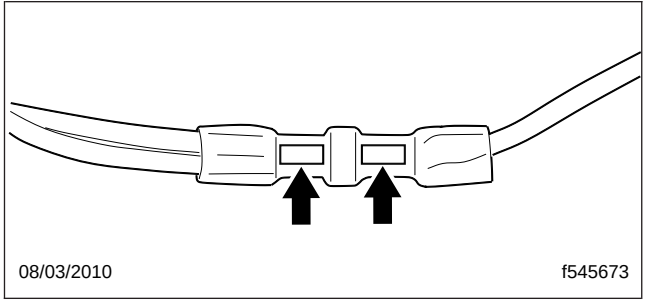


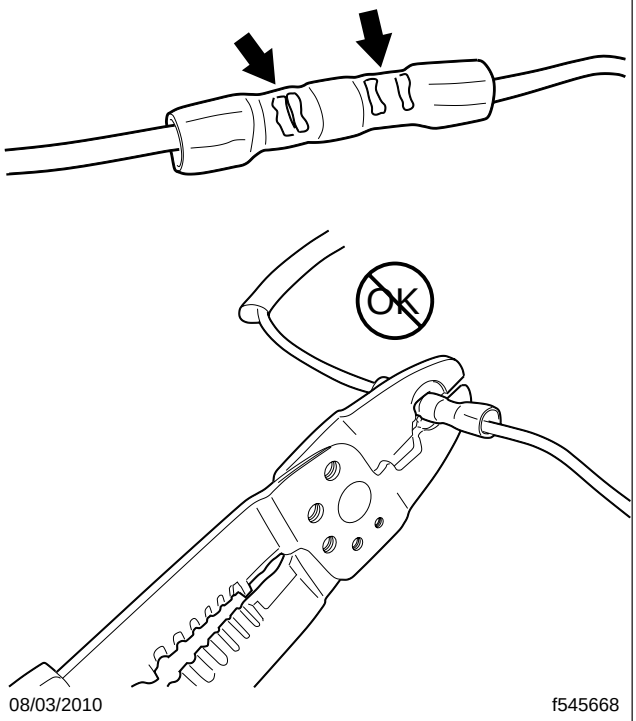
Fig. 2, Properly Crimped Splice

Wiring Repair Using Phillips STA-DRY® Solderless Connectors

Solderless Connector Parts		
Wire Size: gauge (mm)	**Connector Part Number***	**Shrinkable Tubing (Daimler Part Number)**
20 to 18 (0.5 to 0.8)	PHM 1 1863	1/4 inch with internal adhesive coating (48-02461-025)
16 10 14 (1 to 2)	PHM 1 1862	1/4 inch with internal adhesive coating (48-02461-025)
12 to 10 (3 to 5)	PHM 1 1861	3/8 inch with internal adhesive coating–4 foot length (48-02461-038)
8 or larger (5 or larger)	Replace the terminal or the entire cable	Use adhesive lined red for positive cables and black for negative cables.

* Twenty-five connectors per pack.

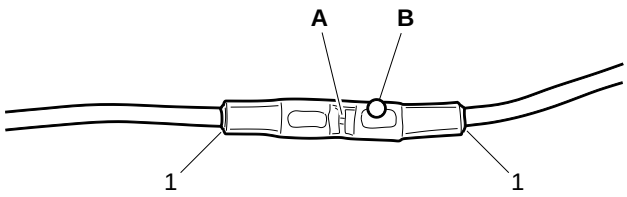
Table 1, Solderless Connector Parts



08/03/2010 f545668

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

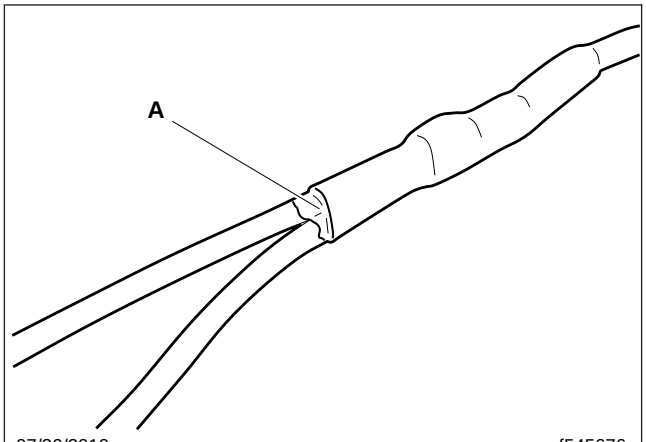


08/03/2010 f545674

A. The solder band is completely melted.
B. Insulation rupture; gently shake off the solder bead.

1. Adhesive Fillet

Fig. 4, Solder Bead Rupture



07/30/2010 f545676

A. The fillet of adhesive at the ends of the shrink tube indicate a complete seal.

Fig. 5, Completed Three-Wire Tap Splice

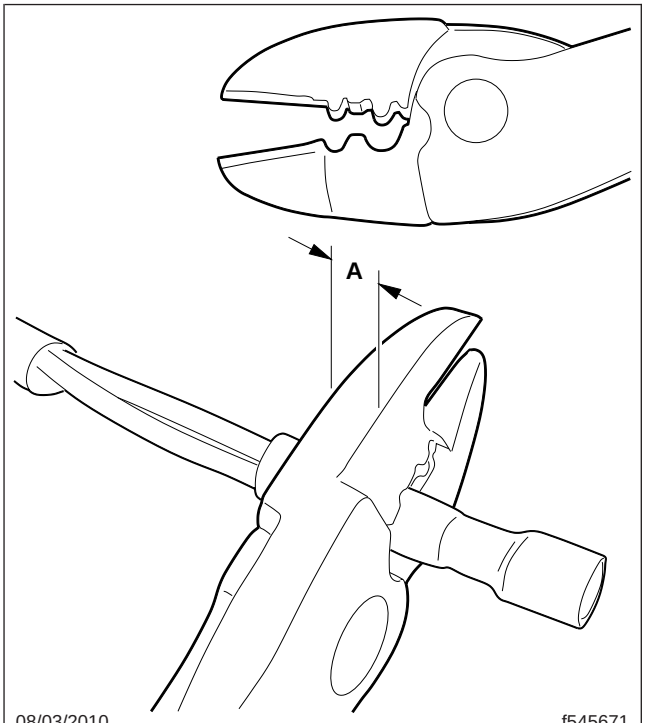
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404

Parts and Tools

Parts are available through the Parts Distribution Centers (PDCs) in kits with material for 50 splices. This kit may be used on 16 to 14 gauge (1 to 2 mm) wire.

Tools needed for wiring repair using solderless connectors include the following.

- A dimple-type crimp tool with a minimum 3/16 inch width. See **Fig. 1** for an example of a proper crimp tool. A typical manufacturer for this tool is Thomas & Betts.
- A heat gun rated at 250°F (121°C).



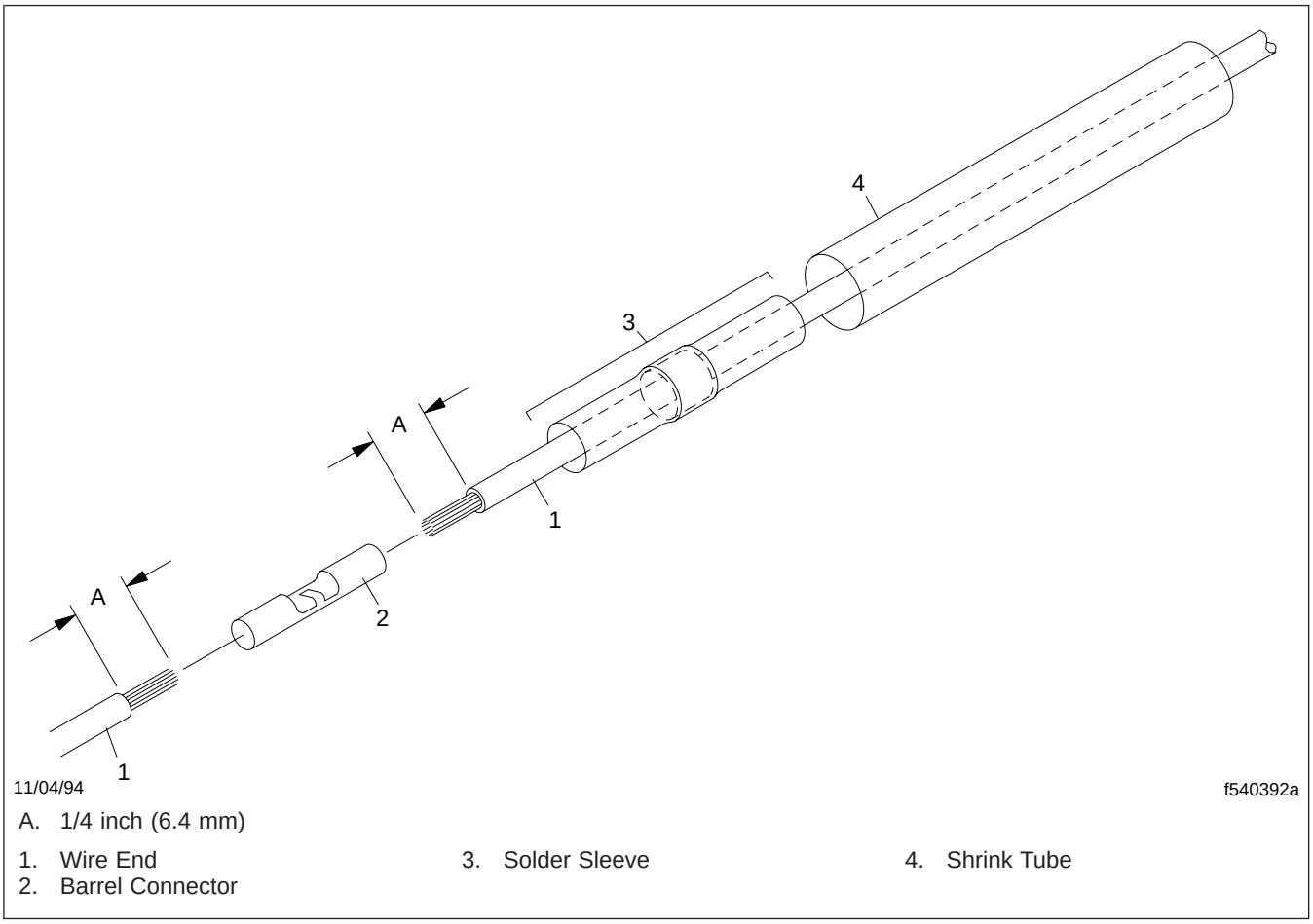
A. Minimum 3/16 inch width.

Fig. 1, Dimple-Type Crimp Tool

Procedure

1. Dress the wires to be spliced by stripping the insulation to expose 1/4 inch of copper. Slide a piece of the shrink tubing from the kit onto one of the wires.
2. Slide a shrinkable solder sleeve from the kit onto one of the wires.
3. Place the wires that will be spliced into each end of the barrel connector. See **Fig. 2** for an example of the splice.
4. Crimp each end of the barrel using a dimple-type crimp tool to secure the wires. See **Fig. 1** for an example of a proper crimp tool.
5. Pull test the wires by hand to ensure the crimp is mechanically solid.
6. Slide the shrinkable solder sleeve onto the barrel connector so the solder band is at the center of the barrel connector.
7. Heat the splice using a heat gun rated at 250°F (121°C) until the sleeve has completely shrunk against the wire and the solder flows into the barrel connector. A small fillet of adhesive may be visible at the ends of the connector. See **Fig. 3**.
8. Slide the shrinkable tubing over the splice and apply heat with a heat gun rated at 250°F (121°C) until it has completely shrunk against the wire insulation. A small fillet of adhesive should be visible at the ends of the shrinkable tubing.

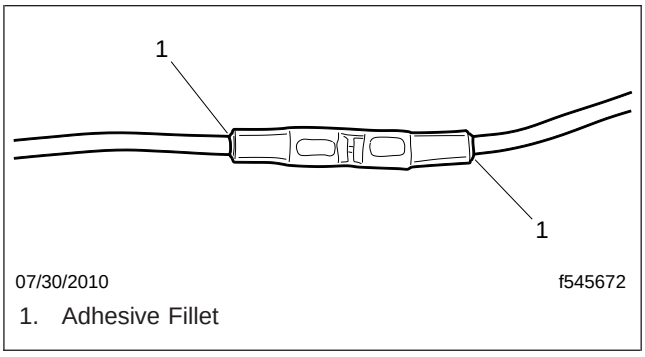
Wiring Repair Using Daimler Trucks North America (DTNA) Kit ESY ES66 404



A. 1/4 inch (6.4 mm)

1. Wire End
2. Barrel Connector
3. Solder Sleeve
4. Shrink Tube

Fig. 2, Splice Prepared with Parts in Kit ESY ES66 404



1. Adhesive Fillet

Fig. 3, Heated Solder Sleeve with Solder Band Melted into the Splice

Parts

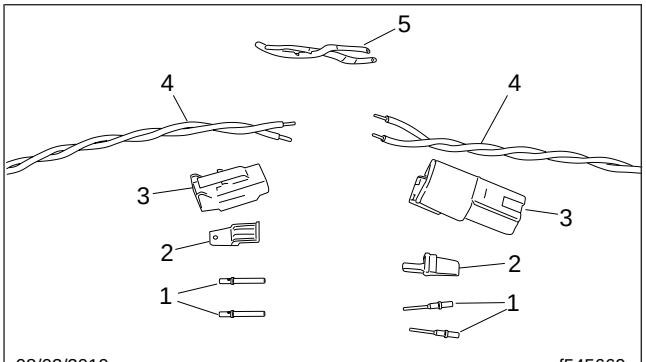
Twisted-pair datalink wires may be spliced using a mating connector set. See **Table 1** for a typical set of datalink connector parts.

Datalink Connector Parts		
Description	**Part Number**	**Quantity**
Connector Body Plug	23-13148-204	1
Terminal Lock	23-13303-015	1
Terminals	23-13210-020	2
Connector Body Receptacle	23-13148-206	1
Terminal Lock	23-13303-013	1
Terminals	23-13210-030	2

Table 1, Datalink Connector Parts

Procedure

1. Cut out any damaged section of datalink wire, keeping the lengths of the two wires equal. See **Fig. 1** for an example of a damaged section of datalink wire that has been removed and the datalink prepared for repair.



1. Terminals
2. Terminal Lock
3. Connector
4. Twisted-Pair Datalink Wires
5. Damaged Section of Datalink Wires

Fig. 1, Datalink Splice Parts

2. Crimp the terminals onto the wires using the proper crimp tool.
3. Pull test the terminals by hand to ensure the crimp is mechanically solid.
4. Insert the terminated wires into the connector body and install the terminal lock. The protocol for J1939 is for the yellow wire to be in cavity 1 and the green wire to be in cavity 2. Note that the lock is installed while holding the wires in position. Test the installation. If the wires slipped back during the lock installation, they will pull out of the connector.
5. Make certain the wires are twisted as close to the entry point of the connector as possible. Plug the two connector halves together. See **Fig. 2**.

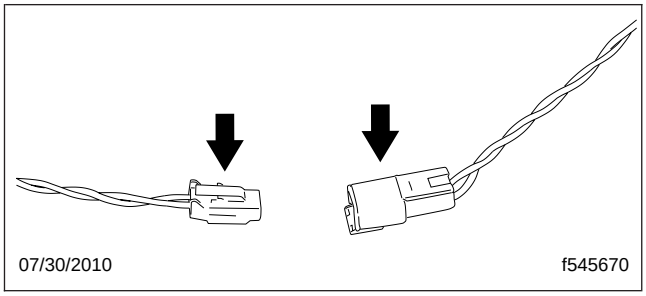


Fig. 2, Datalink Connectors

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

Electrical Harness Connectors

Most of the vehicle wiring is included in just three major wiring harnesses: the engine harness (varies by engine), the chassis harness, and the main cab harness. A fourth major wiring harness is used with vehicles having an electronic engine, like the Caterpillar CFE. The main cab harness is joined to the engine harness(es) and the chassis harness at two (or, three for electronic engines) 28-pin bulkhead connectors attached to a junction plate on the right-hand side of the firewall. See **Fig. 1** for the Caterpillar CFE engine. See **Fig. 2** for the Cummins "B" engine. The anti-lock brake system (ABS) has a separate wiring harness and connector. Additional harnesses are used for variable and optional components.

Circuit Protection

Plug-in blade-type fuses are standard for circuit protection; automatic-reset circuit breakers are optional except as noted.

For fuse/circuit breaker and relay locations on the main power distribution module (PDM), see **Fig. 3**. The PDM is divided into three blocks, labeled A, B, and C.

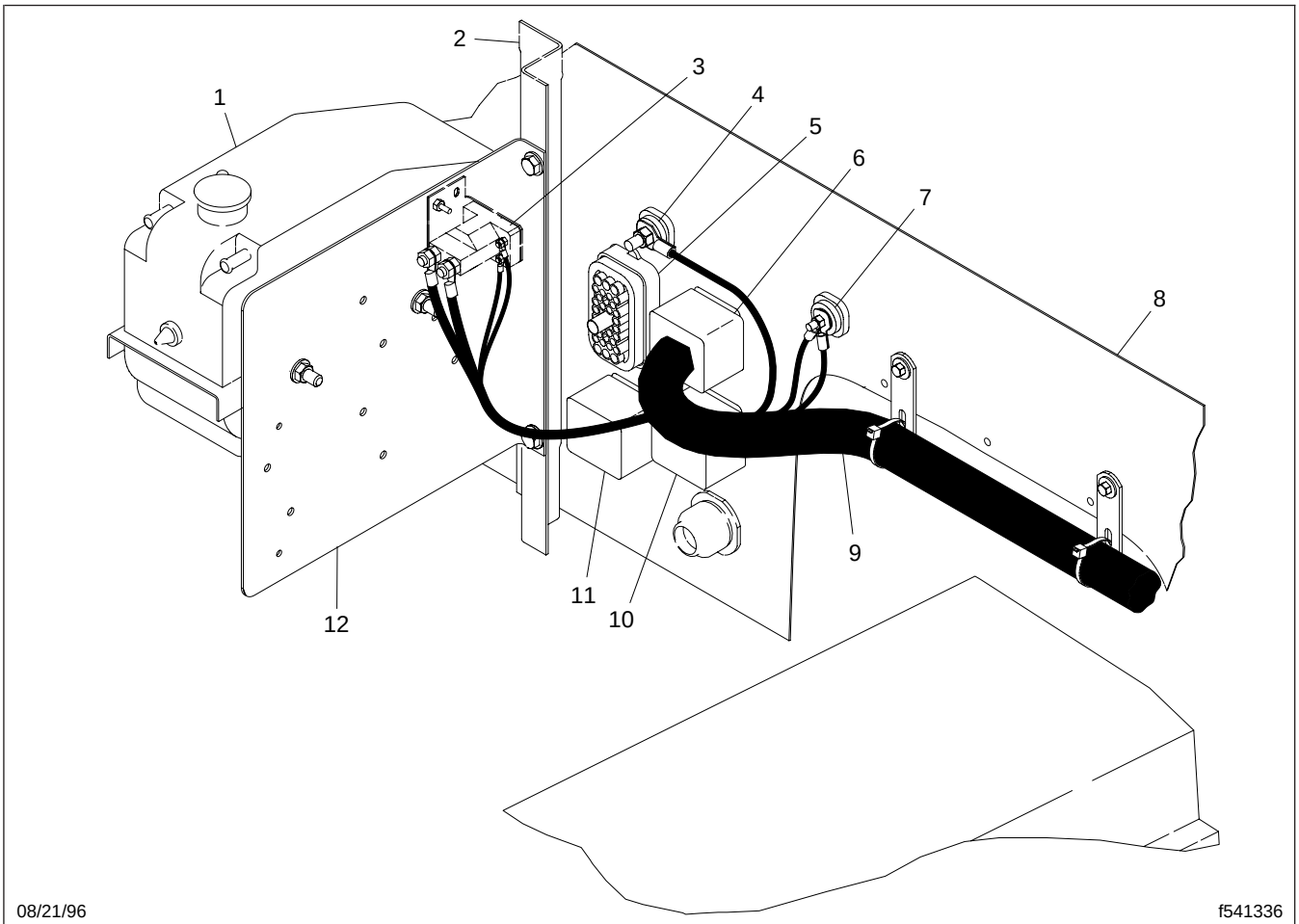
For a list of fuses/circuit breakers and relays installed in Block A, see **Table 1**. For a list of fuses/circuit breakers and relays installed in Block B, see **Table 2**. For a list of fuses/circuit breakers and relays installed in Block B, see **Table 3**.

Block A Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
AA	—	Micro Relay	IGN Bus Standard Circuits
AB	—	Micro Relay	Parking Brake/DRL
AC	—	Micro Relay	IGN Bus Optional Circuits
AD	—	Mini Relay	Stoplights
AE	—	Mini Relay	Open
A1	5-Amp	Fuse	Fuel/Water Separator
	10-Amp	C/B	
A2	10-Amp	Fuse (C/B)	Fuel Solenoid
A3	5-Amp	Fuse	ABS
	10-Amp	C/B	
A4	10-Amp	Fuse (C/B)	Fan Clutch
A5	10-Amp	Fuse (C/B)	Transmission Shift
	15-Amp	Fuse (C/B)	MD Transmission
A6	10-Amp	Fuse (C/B)	Instruments
A7	5-Amp	Fuse	Exhaust Brake
	10-Amp	C/B	
A8	5-Amp	Fuse only	Hydraulic Brakes
A9	10-Amp	Fuse (C/B)	Air Dryer
A10	10-Amp	Fuse (C/B)	Relay Coil Feed
A11	15-Amp	C/B	ABS Air
	25-Amp	C/B	ABS Hydraulic
A12	—	Fuse (C/B)	Open*
A13	—	Fuse (C/B)	Open*
A14	—	Fuse (C/B)	Open*
A15	20-Amp	Fuse (C/B)	IGN Bus Options

* An overlay harness plugs into this position

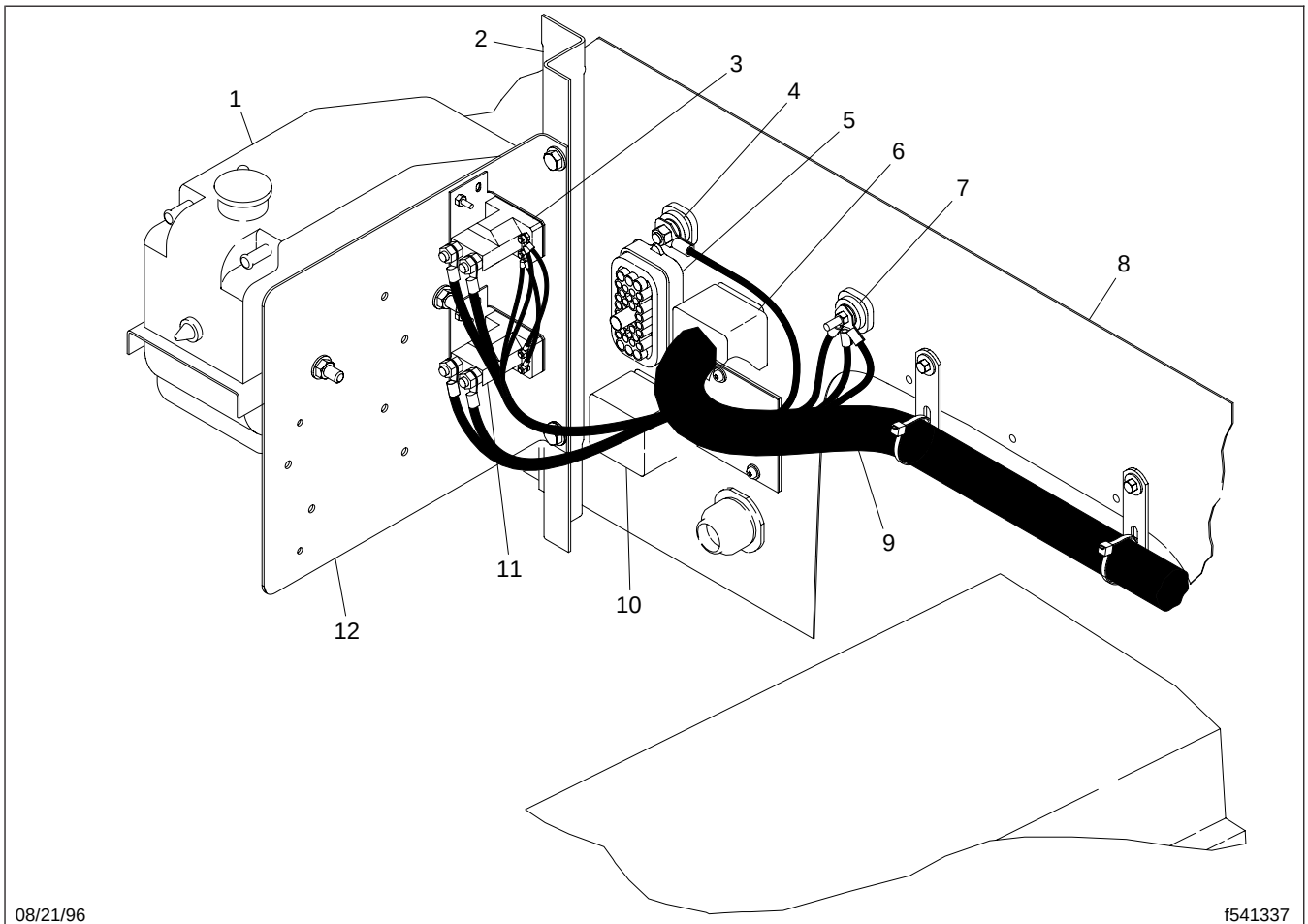
Table 1, Block A Fuse/Circuit Breaker/Relay ID

Specifications



1. Surge Tank
2. Cab Mount Support
3. Magnetic Switch
4. Power (positive) Stud
5. ABS Connector
6. Engine Connector
7. Ground Stud
8. Bulkhead
9. Engine Harness
10. Electronic Engine Connector
11. Chassis Connector
12. Mounting Plate

Fig. 1, Electrical Harness Connectors, Caterpillar CFE Engine



1. Surge Tank
2. Cab Mount Support
3. Magnetic Switch
4. Power (positive) Stud
5. ABS Connector
6. Engine Connector
7. Ground Stud
8. Bulkhead
9. Engine Harness
10. Chassis Connector
11. Fuel Solenoid
12. Mounting Plate

Fig. 2, Electrical Harness Connectors, Cummins B Engine

Block B Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
BA	—	Mini Relay	Fog Lights
BB	—	Mini Relay	Tail/Marker Lights
BC	—	Micro Relay	Panel Lights
BD	—	Micro Relay	RH Headlights
BE	—	Micro Relay	LH Headlights
B1	15-Amp	Fuse (C/B)	Taillights
B2	15-Amp	Fuse (C/B)	Instrument Lights/Parking Brake

Block B Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
B3	25-Amp	Fuse (C/B)	Fog Lights
B4	15-Amp	Fuse (C/B)*	Stoplights
B5	20-Amp	Fuse (C/B)*	Daytime Running Lights
B6	15-Amp	Fuse (C/B)	Horn
B7	20-Amp	Fuse (C/B)	Turn Signal Flasher
B8	15-Amp	Fuse (C/B)	Ignition Switch
B9	15-Amp	Fuse (C/B)*	RH Headlights

Specifications

Block B Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
B10	15-Amp	Fuse (C/B)*	LH Headlights
B11	—	Fuse (C/B)	Open†
B12	—	Fuse (C/B)	Open†
B13	—	Fuse (C/B)	Open†
B14	20-Amp	Fuse (C/B)	IGN-Controlled Relay Power
B15	15-Amp	C/B	ABS Air
	50-Amp	C/B	ABS Hydraulic

* Type 1 circuit breaker only

† An overlay harness plugs into this position

Table 2, Block B Fuse/Circuit Breaker/Relay ID

Block C Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
C1	—	Flasher	Turn Signals
C2	10-Amp	Fuse (C/B)	Body Builder's Accessory Feed
C3	10-Amp	Fuse (C/B)	Ether Start Solenoid
C4	20-Amp	Fuse (C/B)	Fuel/Water Separator
C5	5-Amp	Fuse	Diagnostic Connector
	10-Amp	C/B	
C6	5-Amp	Fuse	Hydraulic ABS
	10-Amp	C/B	
C10	—	Mini Relay	Fuel/Water Separator
C15	—	Mini Relay	AT/MT Transmission Modulator
C16	—	Mini Relay	Corsair Fan (optional)
C17	—	Mini Relay	Open–Reserved for ABS
C18	—	Mini Relay	Hydraulic ABS Valve
C19	—	Mini Relay	Hydraulic ABS Warning Lights
C20	—	Mini Relay	Open–Reserved for ABS
C21	—	Mini Relay	Engine Shutdown (optional)
C22	—	Mini Relay	Engine Shutdown Lights (optional)
C23	—	Mini Relay	Exhaust Brake (with electronic engine)
C24	—	Mini Relay	MD Transmission

Block C Fuse/Circuit Breaker/Relay ID			
Pos.	**Rating**	**Component**	**Description**
C25	—	Mini Relay	MD Transmission
C26	—	Mini Relay	MD Transmission

Table 3, Block C Fuse/Circuit Breaker/Relay ID

Basic Wiring Diagrams

See **Fig. 4** for a standard vehicle wiring diagram. For detailed (partial) views of the standard vehicle wiring diagram, see **Fig. 5**, **Fig. 6**, **Fig. 7**, or **Fig. 8**.

See **Fig. 9** for the main cab harness diagram. For detailed (partial) views of the main cab harness diagram, see **Fig. 10**, **Fig. 11**, or **Fig. 12**.

See **Fig. 13** for the chassis harness diagram.

See **Fig. 14** for the air intake pre-heat wiring on the Caterpillar CFE engine. See **Fig. 15** for the air intake pre-heat harness on the Cummins "B" engine.

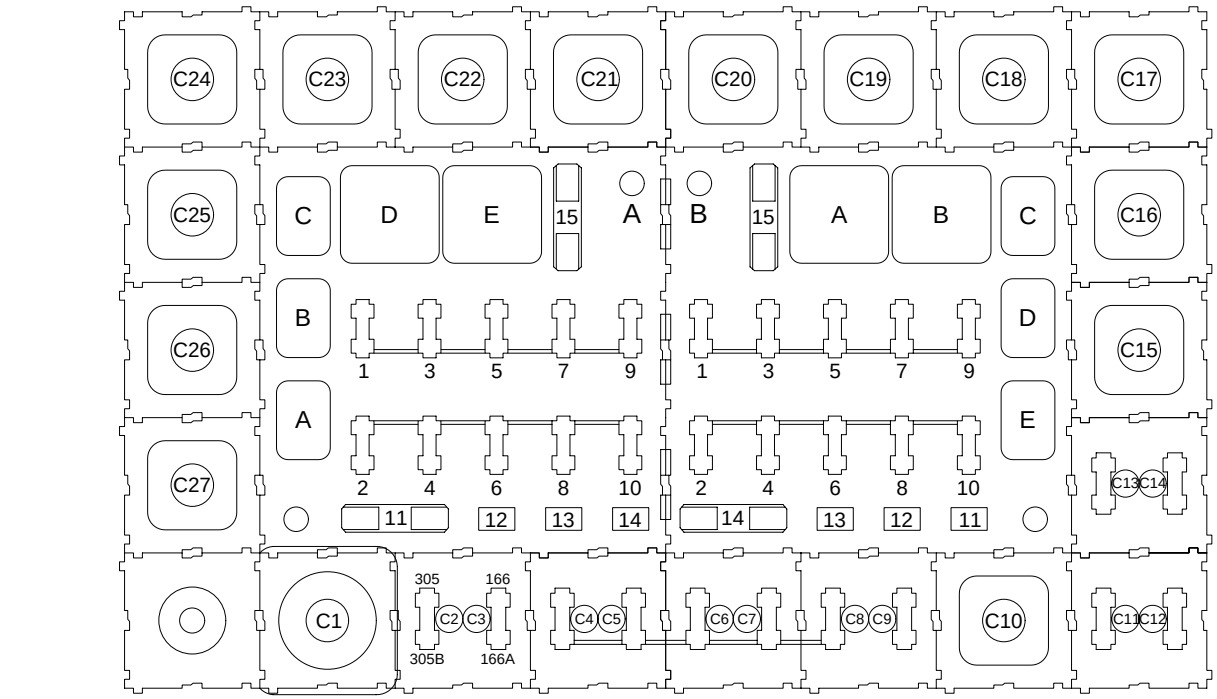


Fig. 3, Fuse/Circuit Breaker/Relay Locations

Wiring List

Circuits 14 Through 29F	
Circuit	**Description**
14	Main Power Feed
14A	IGN Bus Relay #1 Feed
14B	IGN Bus Relay #2 Feed
15	Starter Magnetic Switch Coil Feed
16	Alternator Output
18B	Low Air Pressure Indicator Feed
18C	High Coolant Temperature Indicator Feed
20	Left Headlight Switch Supply
20A	Right Headlight Switch Supply
20L	Left Headlight Relay Feed
20R	Right Headlight Relay Feed
21	Left Headlight High Beam

Circuits 14 Through 29F	
Circuit	**Description**
21B	High Beam Indicator Feed
21D	Right Headlight High Beam
22	Left Headlight Low Beam
22D	Right Headlight Low Beam
23A	Vehicle Tail Light Feed
23D	Marker Light Control
23F	Marker Light Relay (NC)
25	Horn Button Feed
26	Horn Feed
27	Road Light Feed
28	Road Light Relay Feed
29	Panel Light Switch Feed
29A	Panel Light Feed
29D	Panel Light Control

Specifications

Circuits 14 Through 29F	
Circuit	**Description**
29F	Panel Light Relay (NC)

Table 4, Circuits 14 Through 29F

Circuits 30 Through 380	
Circuit	**Description**
30	Transmission Fluid Temperature Gauge Feed
34	Low Oil Pressure Indicator Feed
36	Brake Light Switch Feed
36E	Body Builder's Brake Light Feed
36F	Pressure Differential Switch
36G	Brake Light Relay Coil
38	Body Builder's Left Turn Signal Light Feed
39	Body Builder's Right Turn Signal Light Feed
46	Front Marker Light Feed
46E	Left Side Marker Light Feed
46F	Right Side Marker Light Feed
47	Fuel Level Gauge Feed
52	Ignition Switch Feed (Battery)
60	Left Front Turn Signal Feed
60A	Left Turn Signal Indicator Feed
61	Right Front Turn Signal Feed
61A	Right Turn Signal Indicator Feed
71	Ignition-Controlled Relays and Alternator Excitation
74	Starter Solenoid Feed
74A	Fuel Solenoid Relay
75	Automatic Transmission Neutral Start Feed
81C	Instrument Feed
82	Starter Control Solenoid Feed
87	Axle Lock Indicator Feed
99	Fuel Pump Solenoid Feed
117	Speedometer Sensor (+ Signal)
118	Speedometer Sensor (– Signal)
119	Coolant Temperature Gauge Feed
119B	Ground, Coolant Temperature Sending Unit
120	Back-Up Light Switch Feed

Circuits 30 Through 380	
Circuit	**Description**
150D	Shutdown Indicator Light
150G	Shutdown Module Feed
150R	Shutdown Module Start Indicator
162	Tachometer Sensor (+ Signal)
163	Tachometer Sensor (– Signal)
166	Ether Injector Push Button Feed
166A	Ether Injector Solenoid Feed
166B	Ether Injector Thermostat Feed
183A	Air Restriction Indicator
191B	Air Intake Pre-Heat Indicator Light
196	Fuel/Water Separator Relay and Heater Element Feed
222	Headlight Dimmer Switch Feed
223	Do-Not-Shift Warning Light
234	Fan Clutch Thermostat Control Feed
286	Water in Fuel
303	Low Air Switch Jumper
304	Body Builder's Back-Up Light Feed
305	Accessory—Breaker Feed
305B	Body Builder's Accessory Power Feed
306	Ignition—Breaker Feed
304	Body Builder's Ignition Power Feed
309	Parking Brake Switch Feed
313	Turn Signal Flasher Feed
314	Turn Signal Switch Feed
324	High Coolant Temperature Shutdown
325	Low Oil Pressure Shutdown
333	Air Dryer Feed
334	Dome Light Feed
337	Road Light Switch Feed
339	Light Bar Feed—Battery
342	Ammeter Feed
362	Fuel/Water Separator Relay Coil Power
373	Fuel Solenoid Relay
379B	Park Brake Input—DRL Ground

Circuits 30 Through 380	
Circuit	**Description**
380	DRL Ignition Power

Table 5, Circuits 30 Through 380

Circuits 381 Through 500	
Circuit	**Description**
381	DRL Module—Battery (+)
382	Left Headlight Relay—Common, DRL
383	Right Headlight—DRL
386	DRL—Left
387	DRL—Right
388	Ignition On
389	Relay Coil Feed
390	Brake Pressure Warning Light
391	Hydraulic Brake Relay Feed
392	Hydraulic Motor Power
393	Flow Switch and Relay Coil Ground
394	Parking Brake Indicator Light
395	Low Fluid Indicator
396	Audible Alarm
396A	Audible Alarm (Horn Splice)
397	Door Open Switch
398	Motor Pump Coil Sensing Signal
500	Hydraulic Brake Switch Sensing Signal

Table 6, Circuits 381 Through 500

Specifications

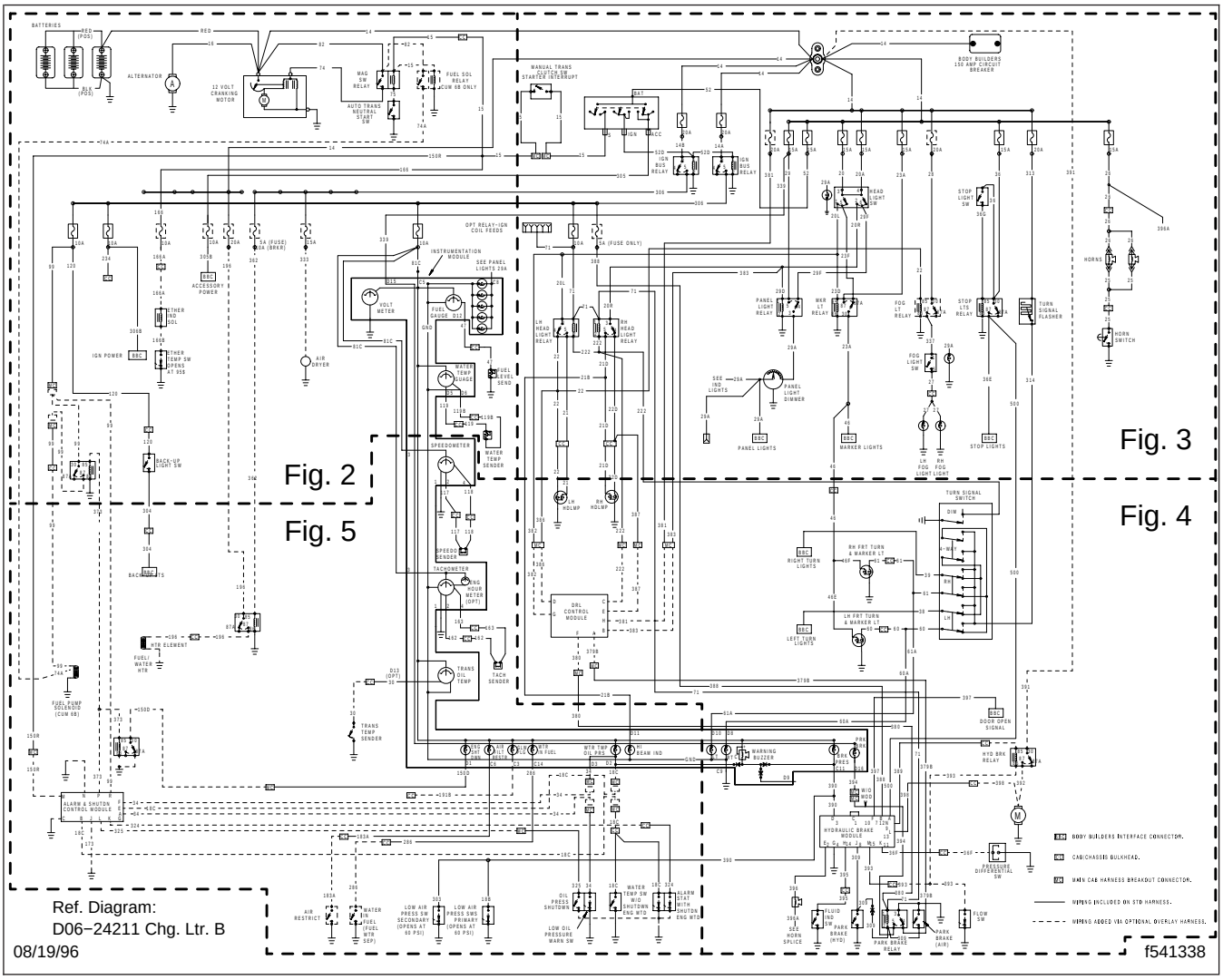
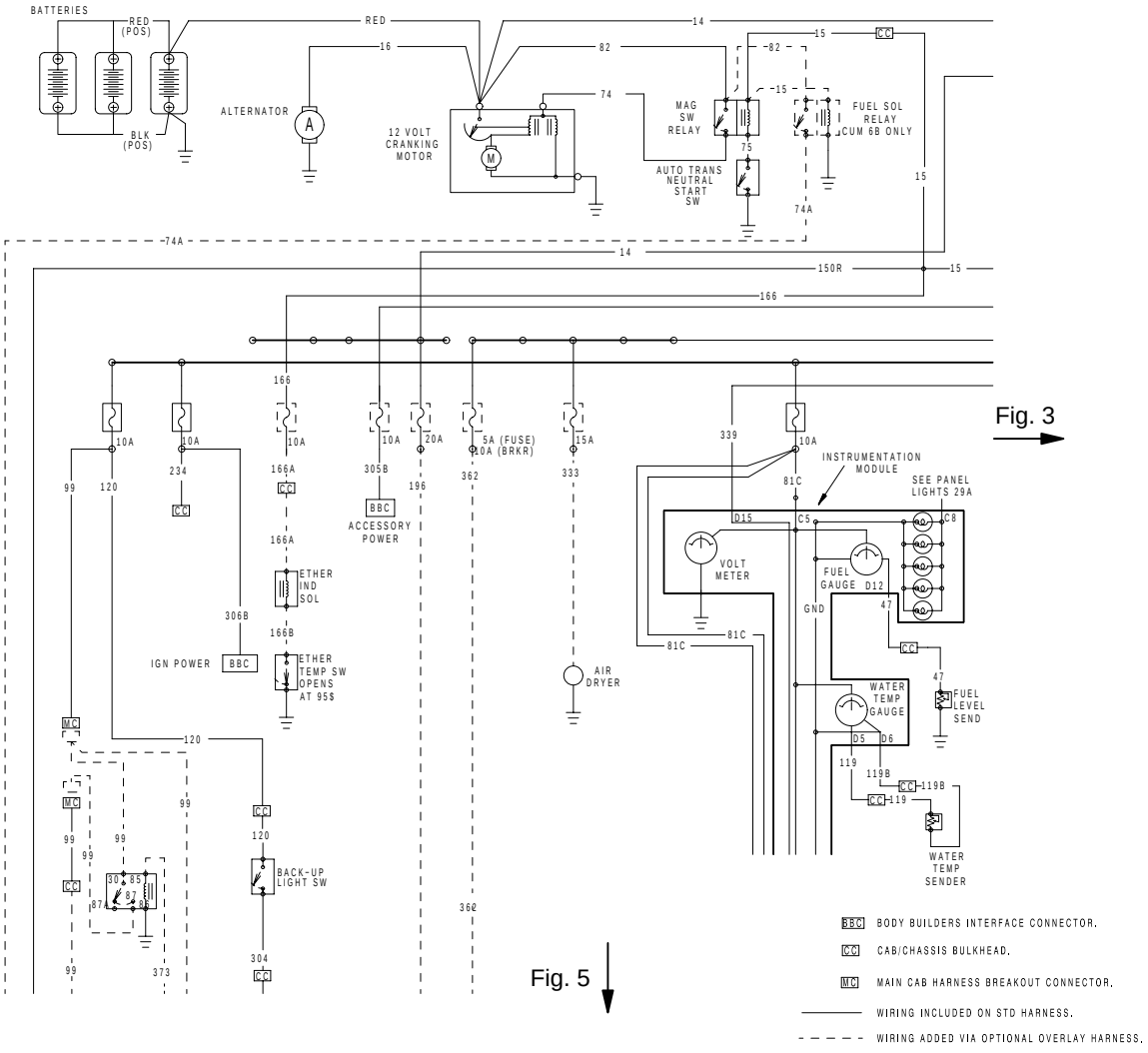


Fig. 4, Standard Vehicle Wiring Diagram



08/21/96 Ref. Diagram: D06−24211 Chg. Ltr. B f541339

Fig. 5, Standard Vehicle Wiring Diagram (partial view)

Specifications

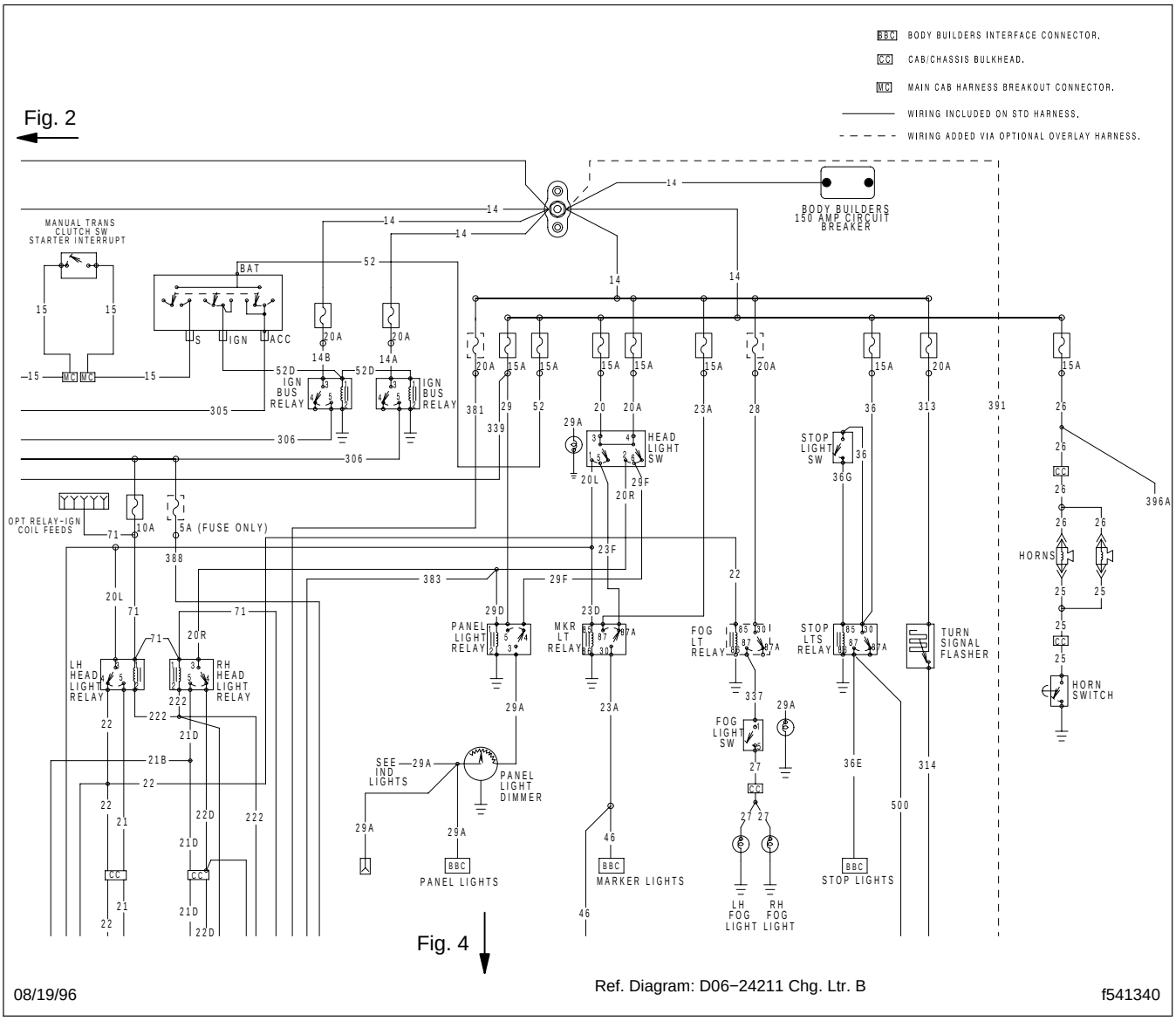


Fig. 6, Standard Vehicle Wiring Diagram (partial view)

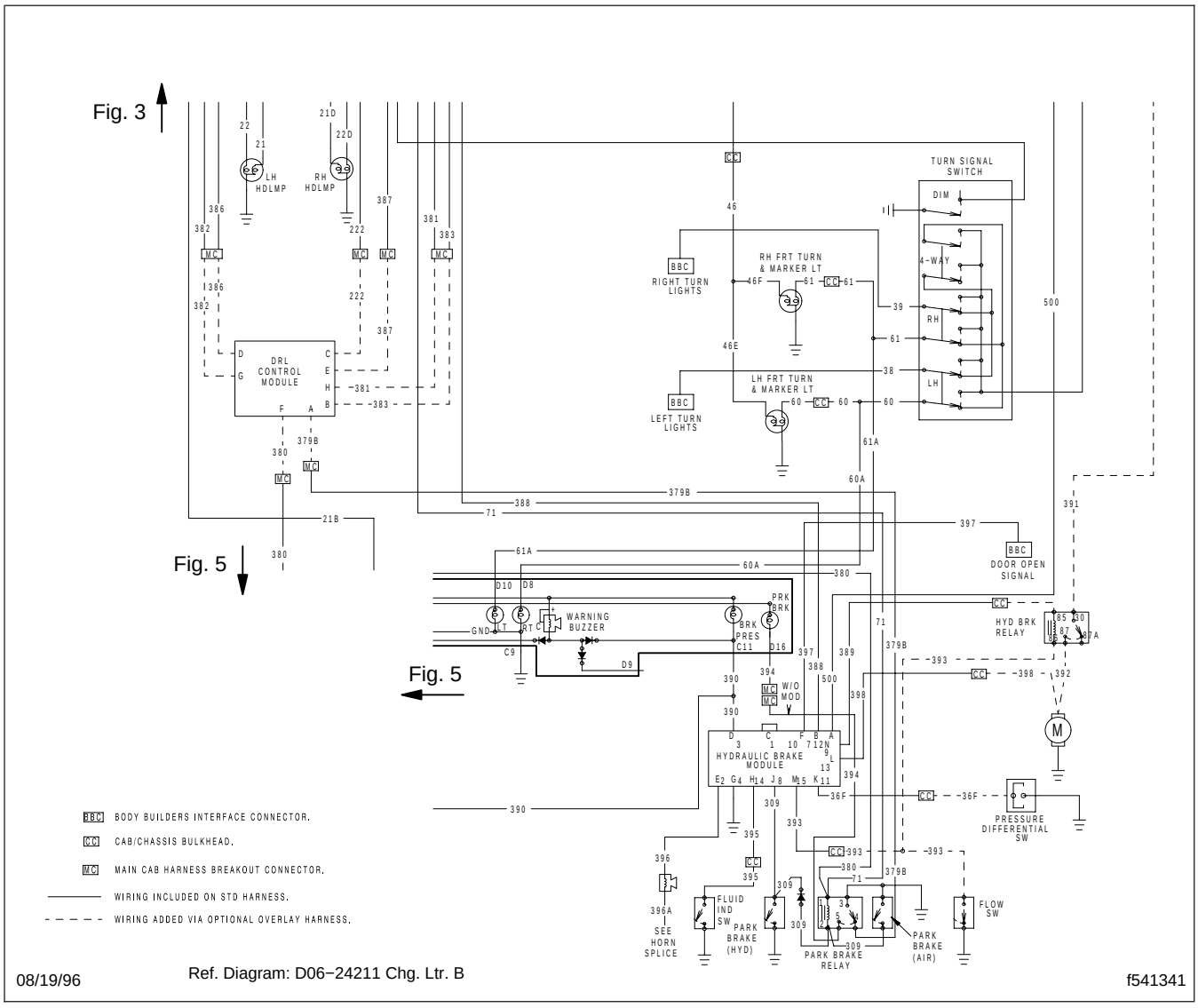


Fig. 7, Standard Vehicle Wiring Diagram (partial view)

Specifications

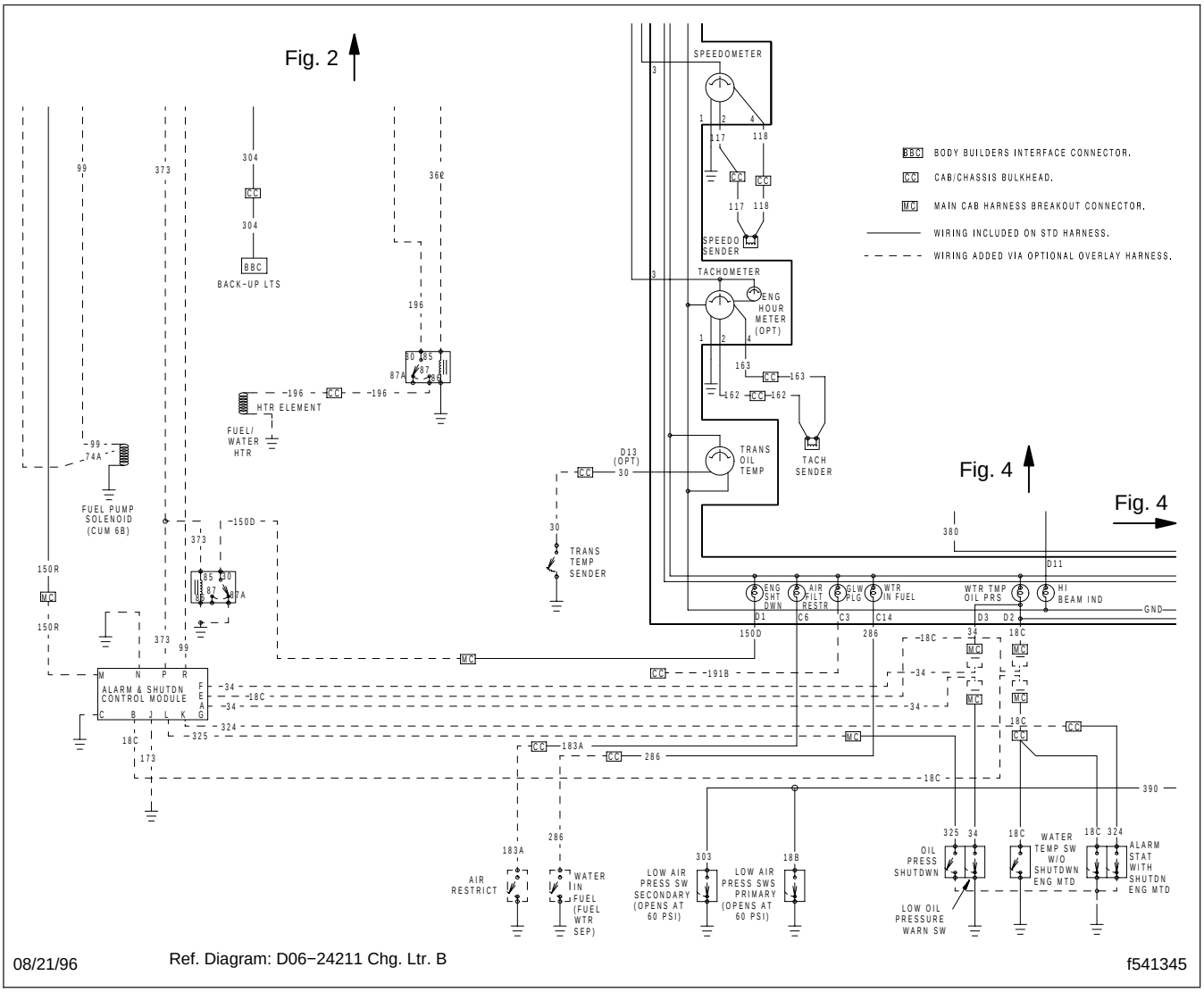


Fig. 8, Standard Vehicle Wiring Diagram (partial view)

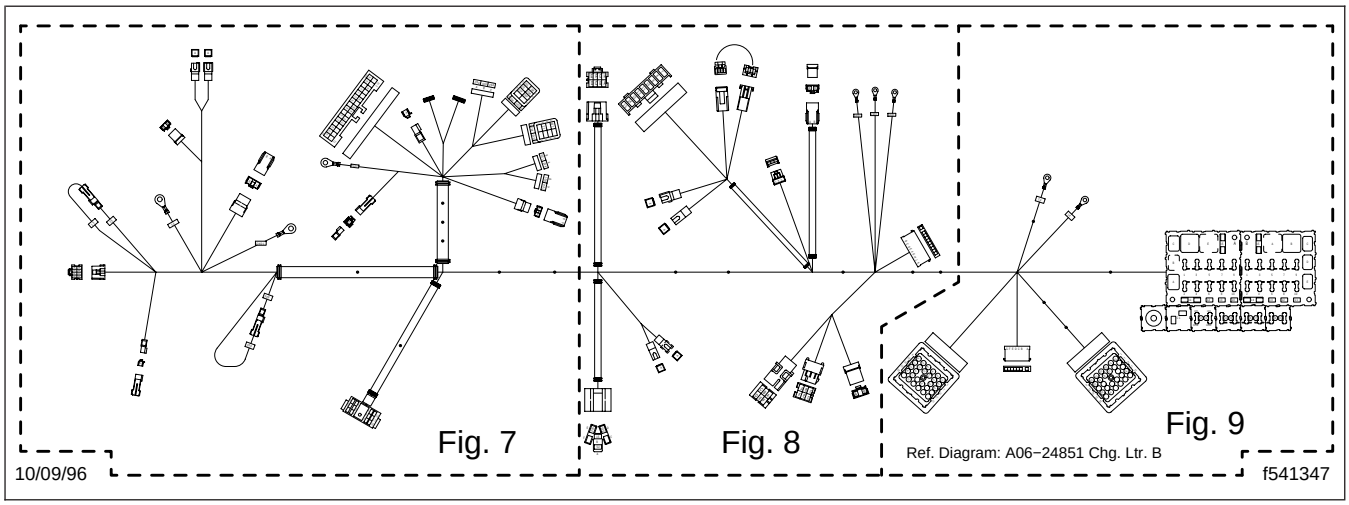
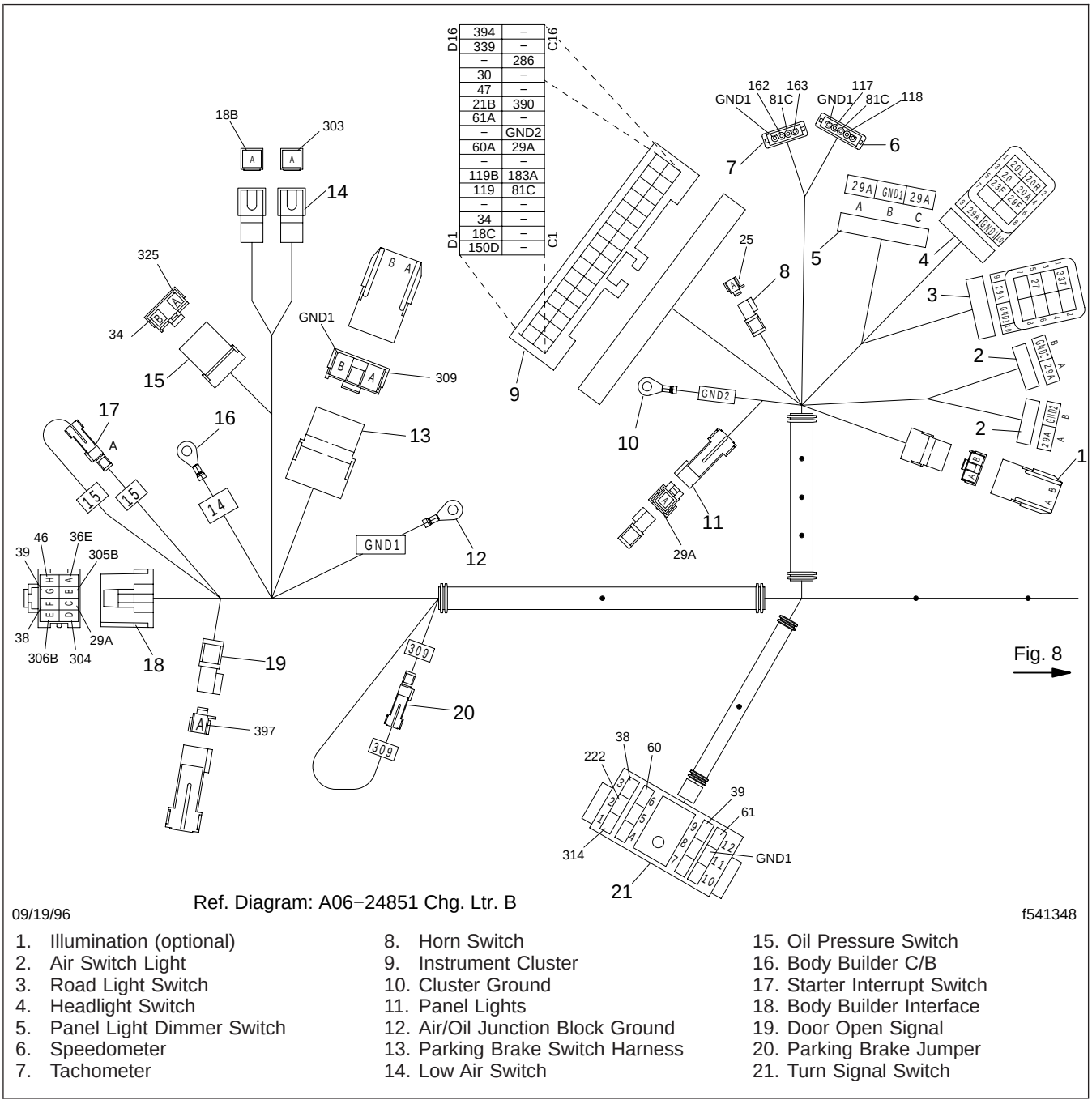


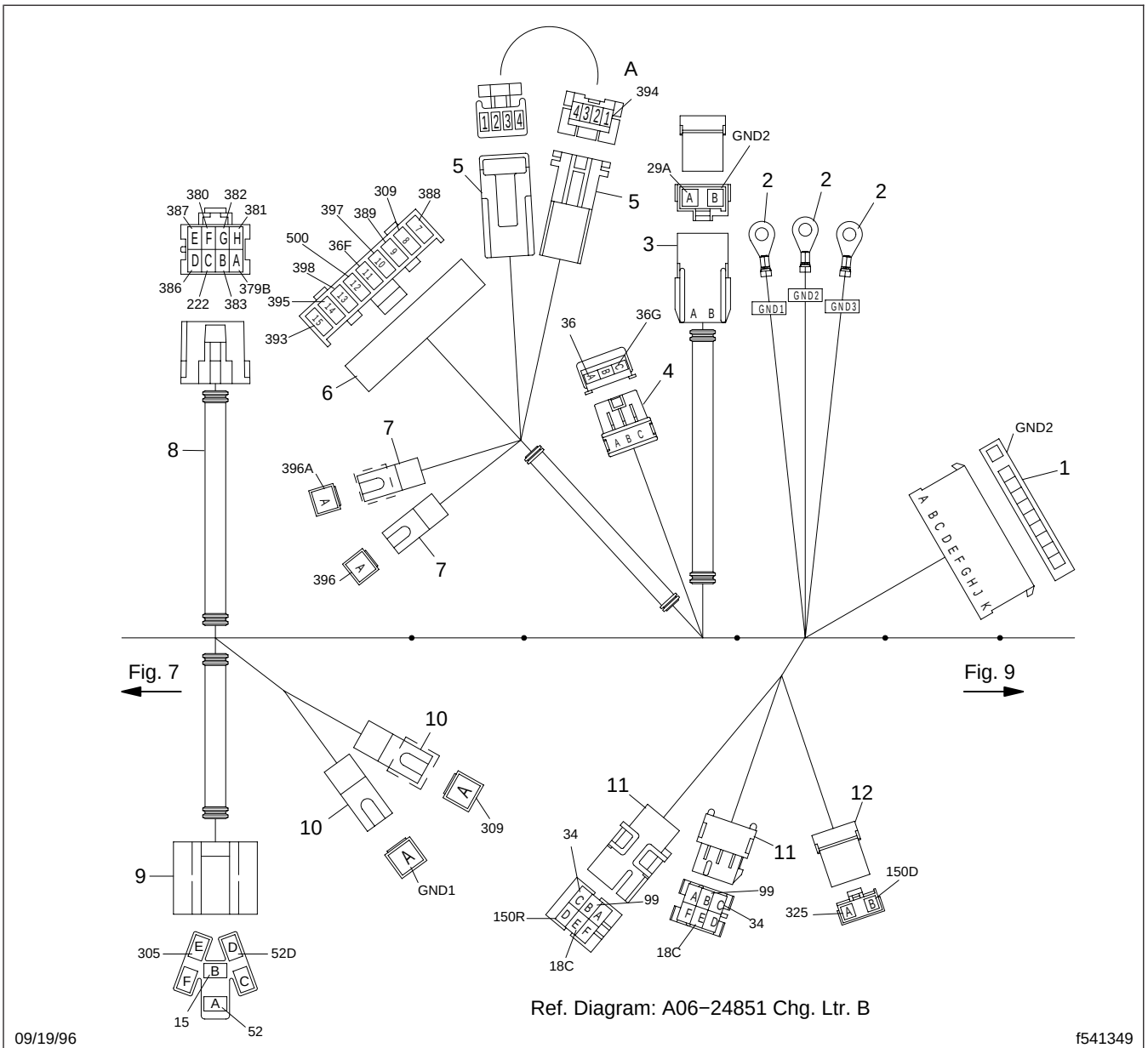
Fig. 9, Main Cab Harness Diagram

Specifications



1. Illumination (optional)
2. Air Switch Light
3. Road Light Switch
4. Headlight Switch
5. Panel Light Dimmer Switch
6. Speedometer
7. Tachometer
8. Horn Switch
9. Instrument Cluster
10. Cluster Ground
11. Panel Lights
12. Air/Oil Junction Block Ground
13. Parking Brake Switch Harness
14. Low Air Switch
15. Oil Pressure Switch
16. Body Builder C/B
17. Starter Interrupt Switch
18. Body Builder Interface
19. Door Open Signal
20. Parking Brake Jumper
21. Turn Signal Switch

Fig. 10, Main Cab Harness Diagram (partial view)



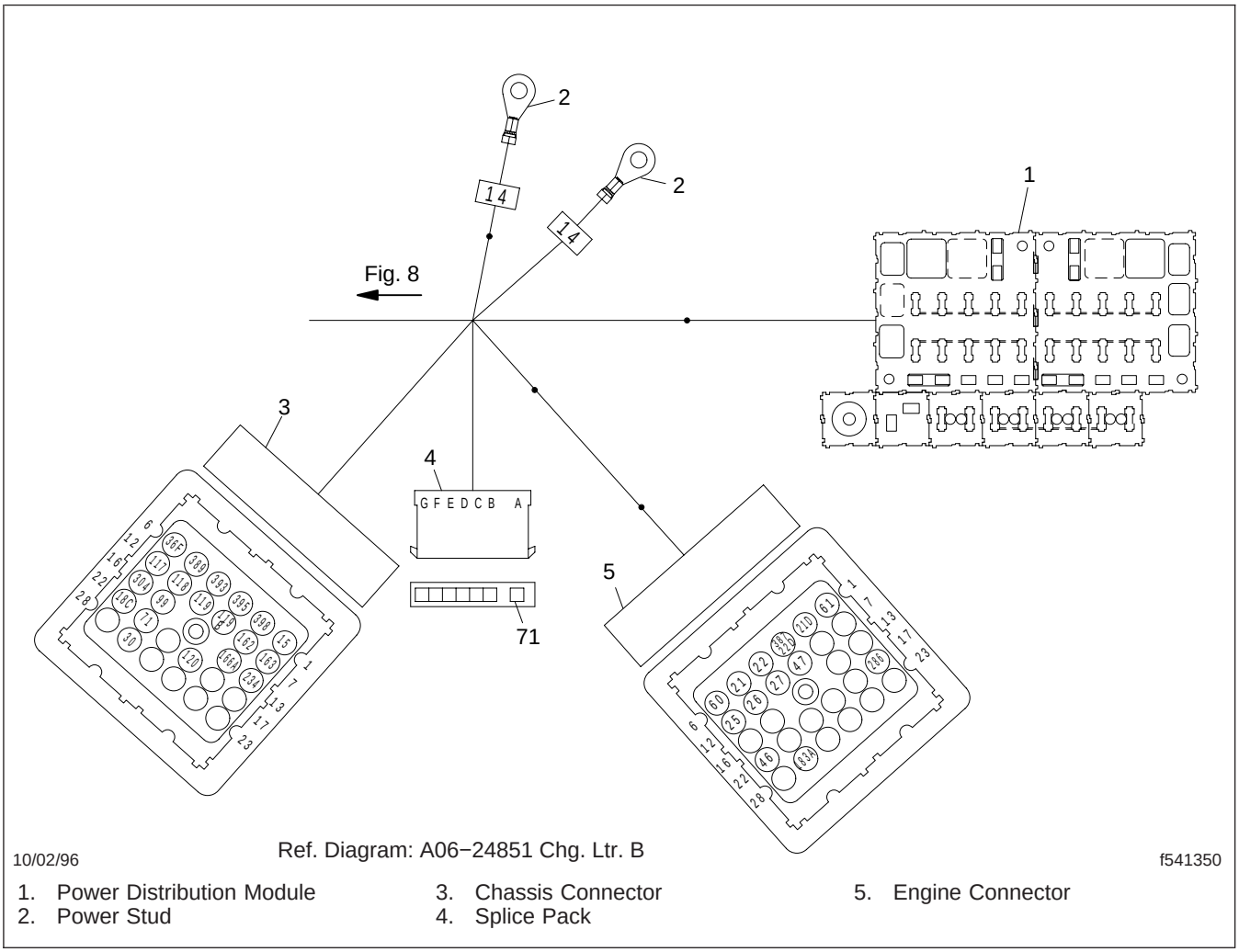
Ref. Diagram: A06−24851 Chg. Ltr. B

A. Vendor to supply connected together.

1. Splice Pack
2. Ground Terminal
3. Shift Tower (automatic trans. only)
4. Brake Light Switch
5. Air Brakes (optional)
6. Hydraulic Brakes
7. Audible Alarm
8. Daytime Running Light Module
9. Ignition Keyswitch
10. Park Brake Air Pressure Switch
11. Kysor Shutdown Module (opt.)
12. Oil Pressure Shutdown

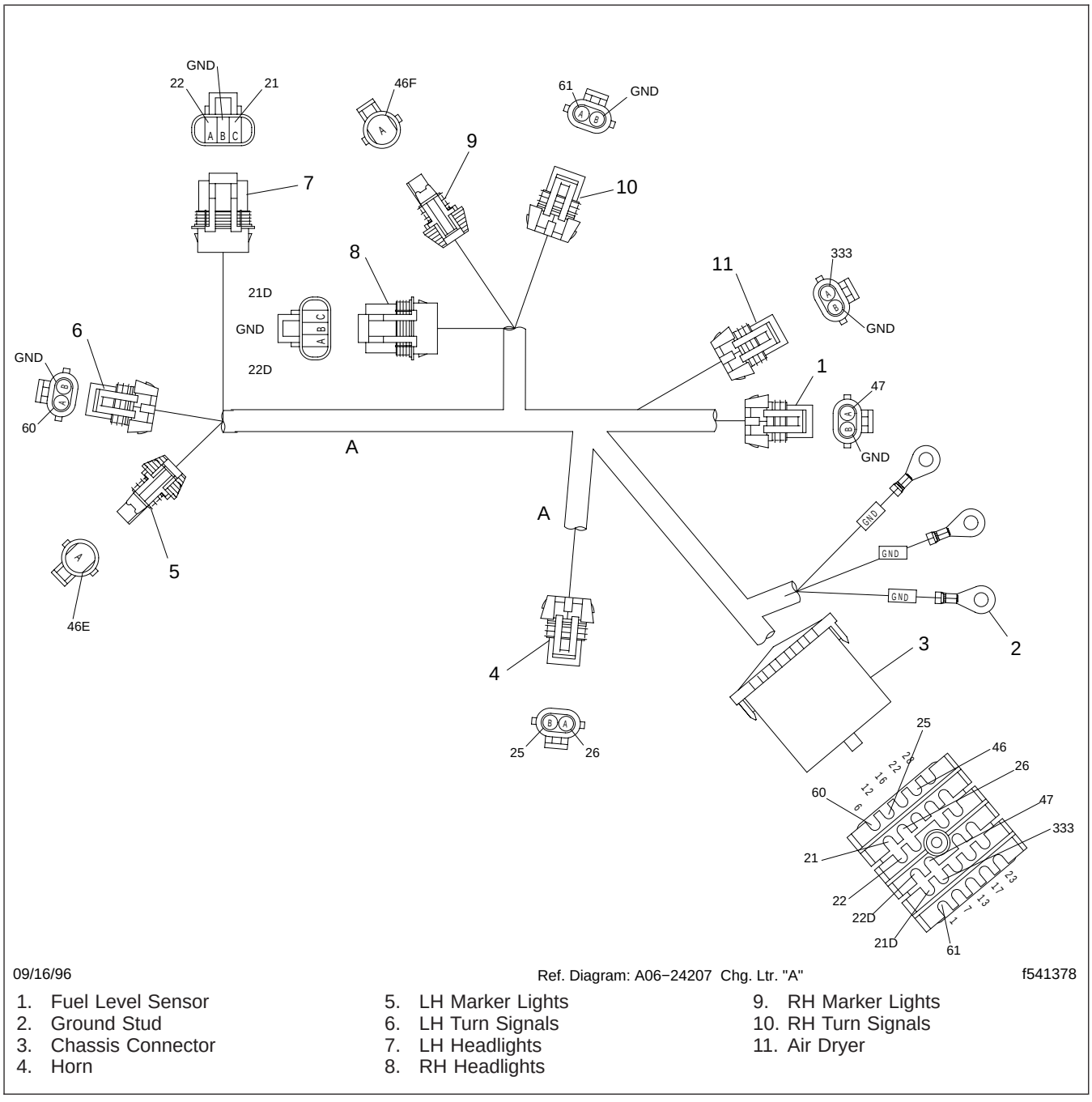
Fig. 11, Main Cab Harness Diagram (partial view)

Specifications



1. Power Distribution Module
2. Power Stud
3. Chassis Connector
4. Splice Pack
5. Engine Connector

Fig. 12, Main Cab Harness Diagram (partial view)

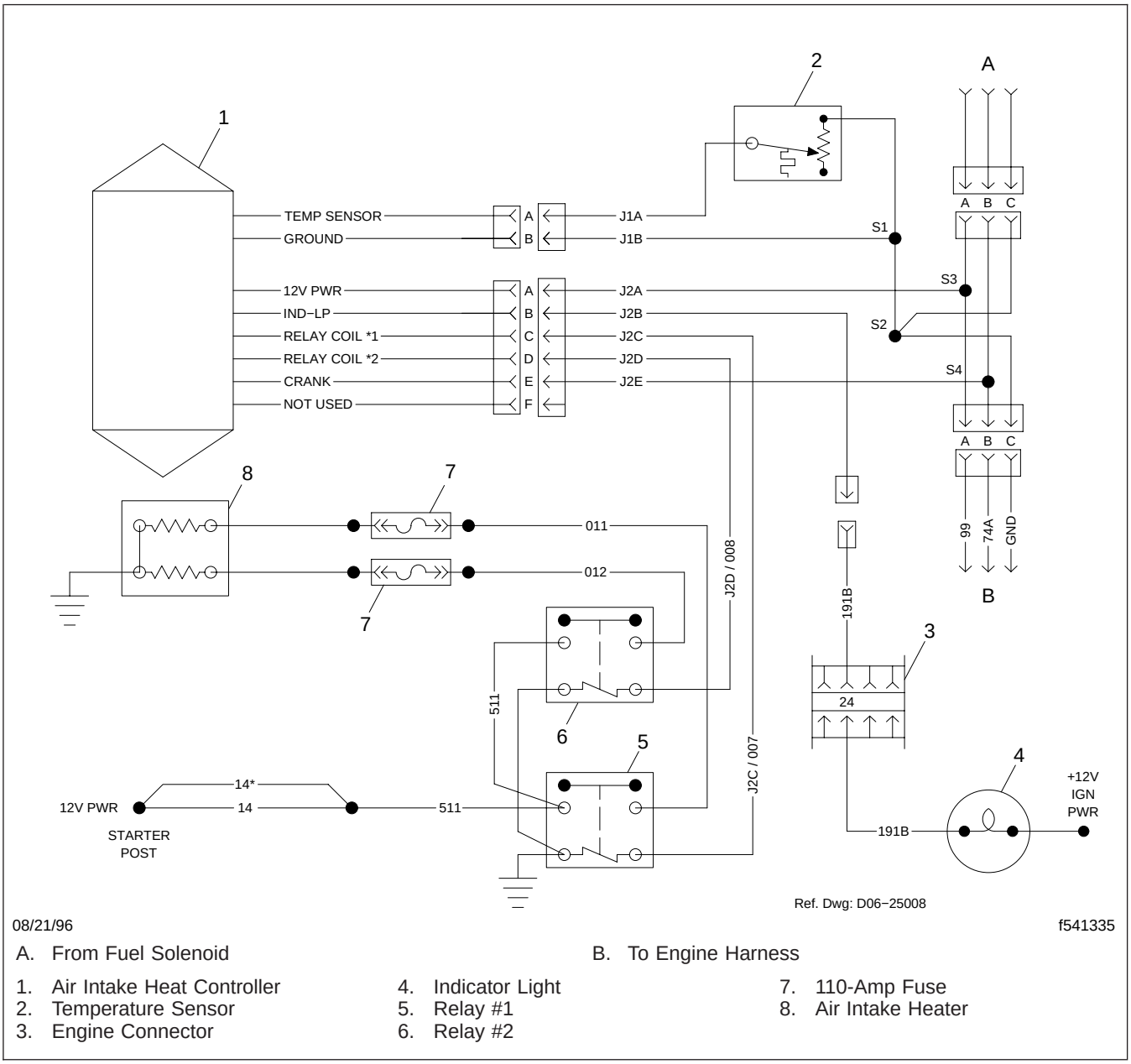


09/16/96 Ref. Diagram: A06−24207 Chg. Ltr. "A" f541378

1. Fuel Level Sensor
2. Ground Stud
3. Chassis Connector
4. Horn
5. LH Marker Lights
6. LH Turn Signals
7. LH Headlights
8. RH Headlights
9. RH Marker Lights
10. RH Turn Signals
11. Air Dryer

Fig. 13, Chassis Harness Diagram

Specifications

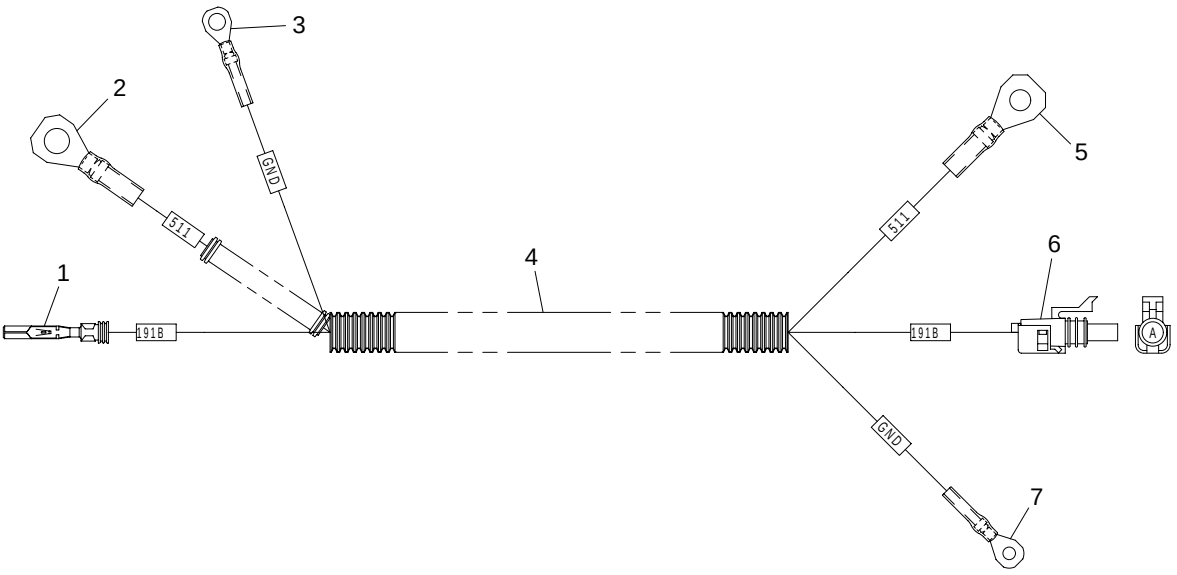


A. From Fuel Solenoid

B. To Engine Harness

1. Air Intake Heat Controller
2. Temperature Sensor
3. Engine Connector
4. Indicator Light
5. Relay #1
6. Relay #2
7. 110-Amp Fuse
8. Air Intake Heater

Fig. 14, Air Intake Pre-Heat Wiring (CAT CFE engine)



1. To Bulkhead Connector
2. Power Stud Connector
3. Ground Stud Connector
4. Flexible Conduit
5. Relay Power Connector
6. Control Module Connector
7. To Relay Ground

Fig. 15, Air Intake Pre-Heat Harness (Cummins B engine)

Headlight Replacement

1. Remove the headlight bezel. See **Fig. 1**.

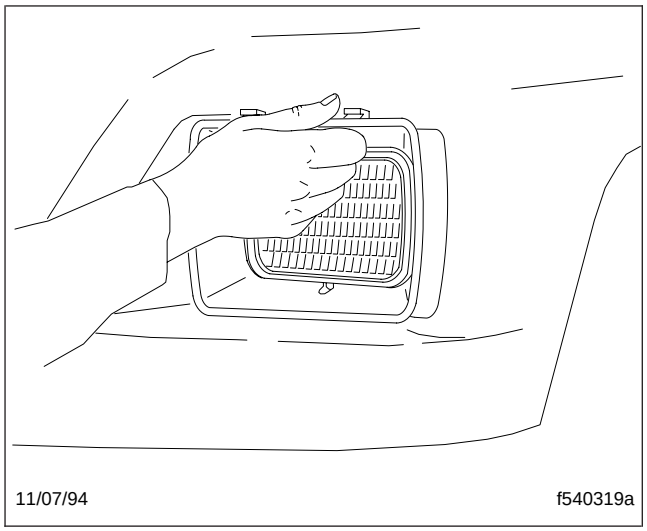


Fig. 1, Headlight Bezel Removal

2. Remove the retaining ring screws.
3. Remove the retaining rings.
4. Remove the lamp from the housing; then disconnect the wiring connector from the back of the lamp.
5. To provide corrosion protection, coat the prongs/base of the new lamp with dielectric grease. For approved electrical lubricants, see the applicable table in **Specifications, 400**.
6. Push the wiring connector onto the prongs at the rear of the new lamp.
7. Place the new lamp in the headlight housing.
8. Place the retaining ring over the lamp and install the retaining ring screws; then tighten the screws securely.
9. Check and, if necessary, adjust the headlight aim as described in the electrical group of the vehicle maintenance manual.
10. Install the headlight bezel.

Front Turn Signal/Side Marker Bulb Replacement

1. Remove the lens-to-housing attaching screws. See **Fig. 2** and **Fig. 3**.

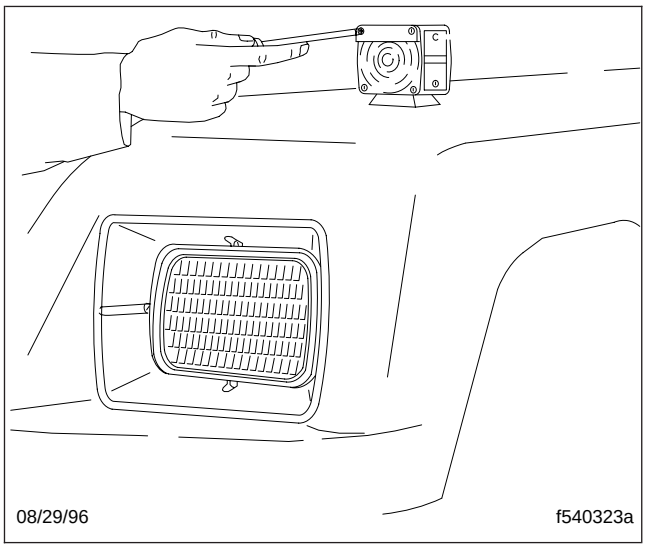


Fig. 2, Front Attaching Screws, Turn Signal

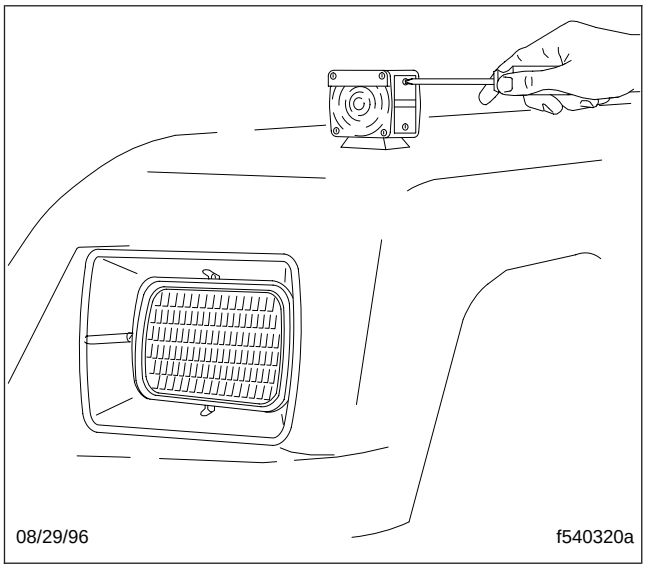


Fig. 3, Side Attaching Screws, Turn Signal

2. Remove the bulb from the socket.
3. To provide corrosion protection, coat the base of the new bulb with dielectric grease. For approved

Exterior Light Replacement

lubricants, see the applicable table in **Specifications, 400**. Install the new bulb.

4. Check for proper operation.
5. Install the lens and attaching screws.

Fog Light Replacement, Per-Lux

1. Gain access to the front of the light assembly by removing the mounting bracket locknut. Remove the light assembly from the mounting bracket. See **Fig. 4**.

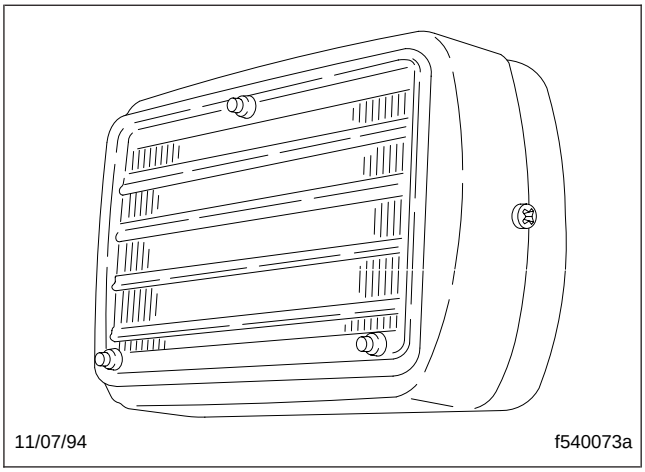


Fig. 4, Per-Lux Fog Light

2. Remove the crosshead screws from both sides of the lens retainer.
3. Separate the lens retainer and louver from the main housing. Pull the lamp from the housing, and disconnect the blade connectors from the blade terminals on the bulb. See **Fig. 5**.
4. To provide corrosion protection, coat the blade terminals on the new bulb with dielectric grease. For approved electrical lubricants, see the applicable table in **Specifications, 400**.
5. Install the blade connectors on the terminals of the new lamp. Place the unit in the housing and test it for proper operation.
6. Place the lens and louver over the lamp. Make sure the word "TOP" appears on the top of the lamp. See **Fig. 6**. If not properly installed, the

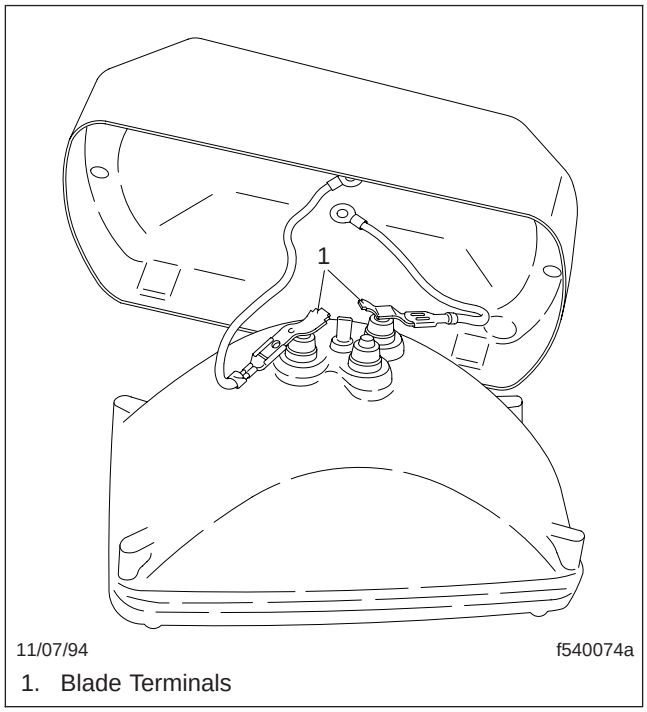


Fig. 5, Blade Terminal Removal, Per-Lux Fog Light

beam from the light will be directed upward instead of down.

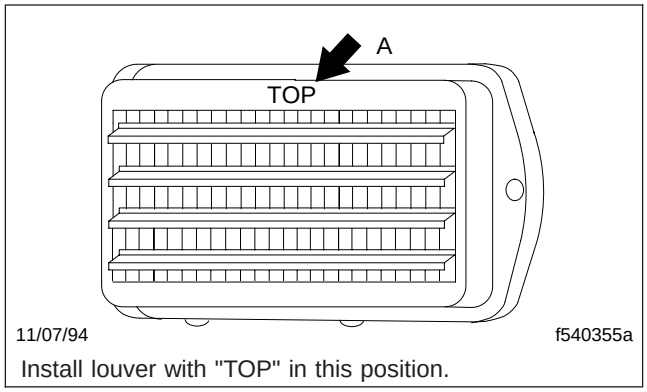


Fig. 6, Louver Positioning, Per-Lux Fog Light

7. Place the lens retainer over the louver. Install the crosshead screws.
8. Place the fog light assembly in the mounting bracket. Install the locknut. Make sure the lamp is aimed directly ahead. Then, tighten the locknut 75 lbf·ft (102 N·m).

Instrument Panel Bulb Replacement

1. Loosen the Torx®-head screws located in the access holes in the instrument panel cover. See **Fig. 1**.

Fig. 1, Removing the Instrument Panel

2. Pull the panel out of the dash to provide access to the back of the panel, as shown in **Fig. 2**.
3. Remove the bulb holder by twisting it 1/8 turn counterclockwise and pulling it away from the panel. Remove the bulb by pulling it straight out.
4. Install the new bulb and replace the bulb holder. Test the bulb for proper operation.
5. Place the instrument panel back in the dash, making sure that none of the wires are pinched, kinked, or otherwise incorrectly positioned. Install the screws.

Rocker Switch Bulb Replacement

1. Remove the vinyl extrusion trim from the groove above the switch panel.

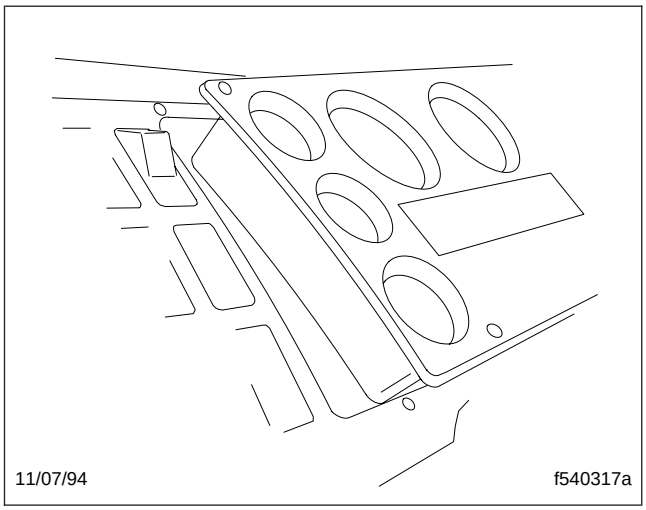
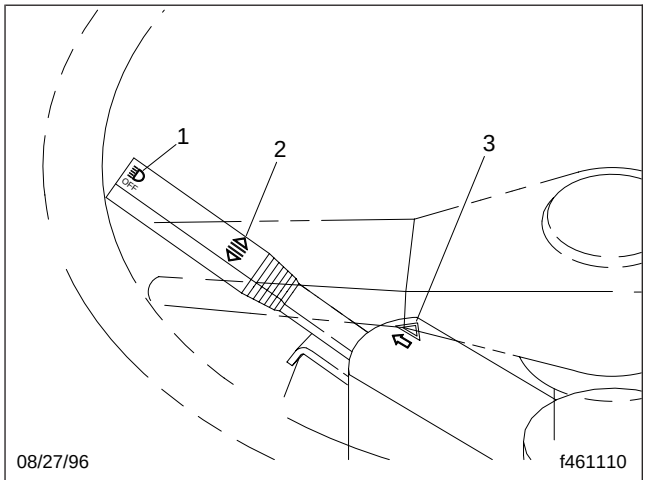


Fig. 2, Pulling the Instrument Panel Away From the Dash

2. Remove the screws from the top of the panel. Swing the panel out and lift it from the slots.
3. Unplug the wiring connector from the back of the switch. Pull the bulb holder from the switch and replace the bulb; then install the bulb holder in the switch. Reconnect the wiring harness to the switch.
4. Check the bulb for proper operation. Install the panel and the vinyl extrusion trim.

Replacement

1. By hand, remove the turn signal switch cover. See **Fig. 1**.



1. Headlight Dimmer
2. Turn Signals
3. Hazard Warning Symbol

Fig. 1, Turn Signal Switch

2. Remove the two allen-head screws that fasten the switch to the steering column.
3. Disconnect the wiring harness connector from the switch.
4. Reverse the procedure to install the new switch.

Headlight Aim Checking and Adjusting

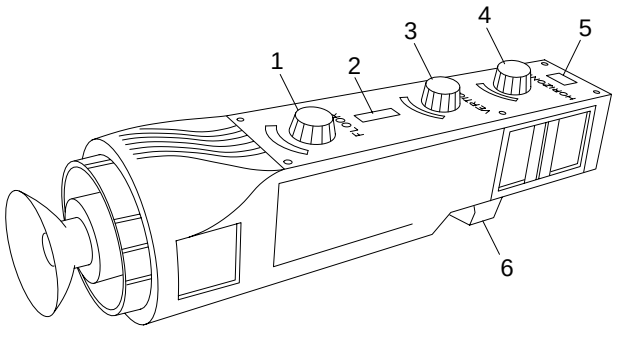
Before checking or adjusting the headlight aim, do the following:

- Remove large amounts of mud or ice from the undersides of the fenders.
- Check the springs for sagging or broken leaves. Check the suspension for proper functioning of the leveling mechanism.
- Clean the headlight lenses and aiming pads.
- Check the bulbs for burnout and broken aiming pads. Switch the beams from low to high to make sure they switch properly.
- With the vehicle unloaded, check that the tires are inflated to the recommended air pressure. Clean the headlight lenses.

Checking

For a quick check to see if the headlights need aiming, do the following procedure.

1. Move the vehicle onto a flat surface that has been calibrated for slope. Shut down the engine, set the parking brake, and chock the tires.
2. Attach a headlight aimer to each headlight. See **Fig. 1**.

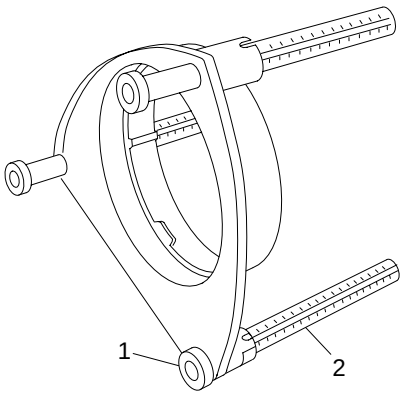


04/11/97 f580162

1. Floor Slope Dial
2. Level Vial
3. Vertical Dial
4. Horizontal Dial
5. Split Image View Port
6. Piston Handle

Fig. 1, Headlight Aimer

2.1 Attach the black universal adaptor to the aimer. Set the adjustment rods to "0" (zero). See **Fig. 2**.



04/14/97 f580165

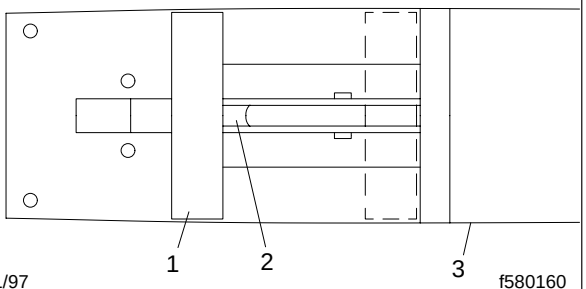
Set the adjustment rods to "0" (zero).

1. Adaptor Foot
2. Adjustment Rod

Fig. 2, Universal Adaptor

2.2 Align the adaptor with the aiming pads on the headlight lens.

2.3 Push the piston handle on the base of the aimer forward to engage the vacuum cup. Immediately pull the handle backward until it locks. See **Fig. 3**.



04/11/97 f580160

To attach, push the piston handle forward to engage the vacuum cup. Immediately pull the handle backward until it locks.
To remove, press the vacuum release button.

1. Piston Handle
2. Vacuum Release Button
3. Base of Aimer

Fig. 3, Aimer Attachment and Removal

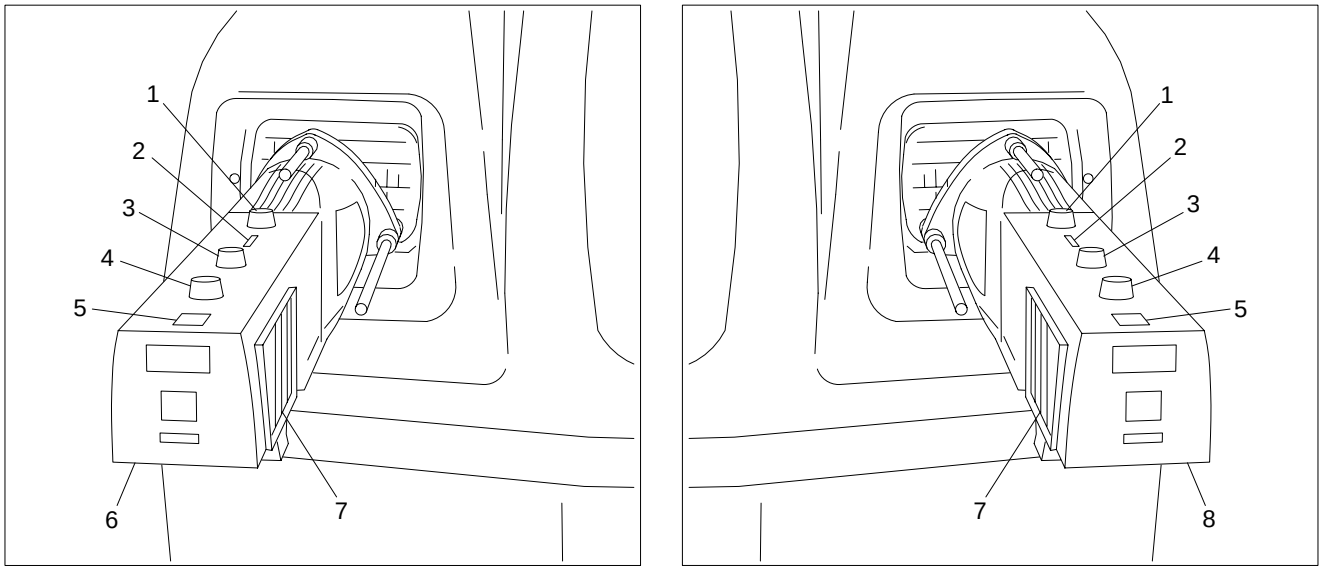
Headlight Aim Checking and Adjusting

2.4 Do the same procedure with the other aimer.

3. Check the floor slope dial for the correct setting. See **Fig. 4**.

4.2 If the horizontal dial scale on either aimer reads more than "4," re-aim the headlight.

NOTE: If adjustment is required, see the procedures under "Adjusting" below.



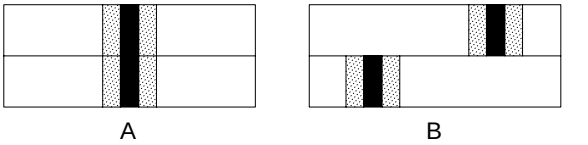
05/27/97 f580168

The sight openings must face each other.

1. Floor Slope Dial
2. Vertical Aim Level Vial
3. Vertical Dial
4. Horizontal Dial
5. Split Image View Port
6. Aimer (RH side)
7. Sight Opening
8. Aimer (LH side)

Fig. 4, Set-Up for Aiming

4. Check the horizontal aim. See **Fig. 5**.



04/11/97 f580161

View through the split image view port.

A. Split Image Aligned
B. Split Image Not Aligned

Fig. 5, Horizontal Aim Split Image

4.1 Turn the horizontal dial until the split image is in alignment.

5. Check the vertical aim. See **Fig. 6**.

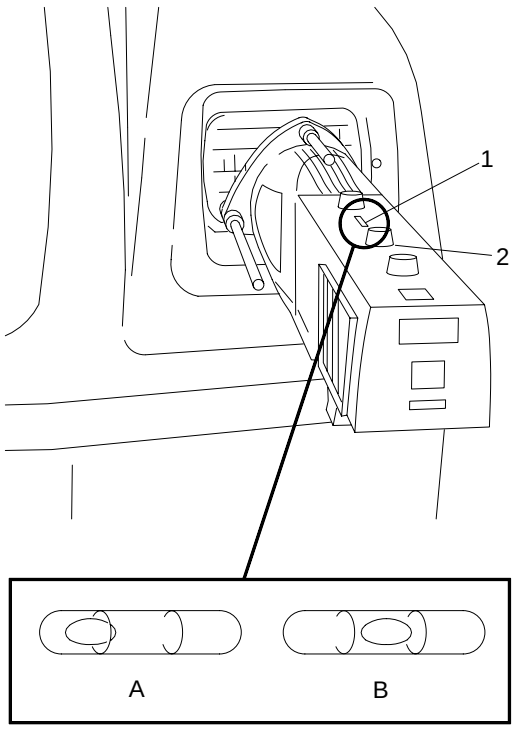
5.1 Turn the vertical dial until the level vial is centered.

5.2 If the vertical dial scale on either aimer reads more than "4," re-aim the headlight.

NOTE: If adjustment is required, see the procedures under "Adjusting" below.

6. Remove the two headlight aimers. Hold each aimer securely, and then press the vacuum release button.

7. Remove the chocks from the tires.



07/28/97 f580177

Set the vertical dial to "0" (zero).

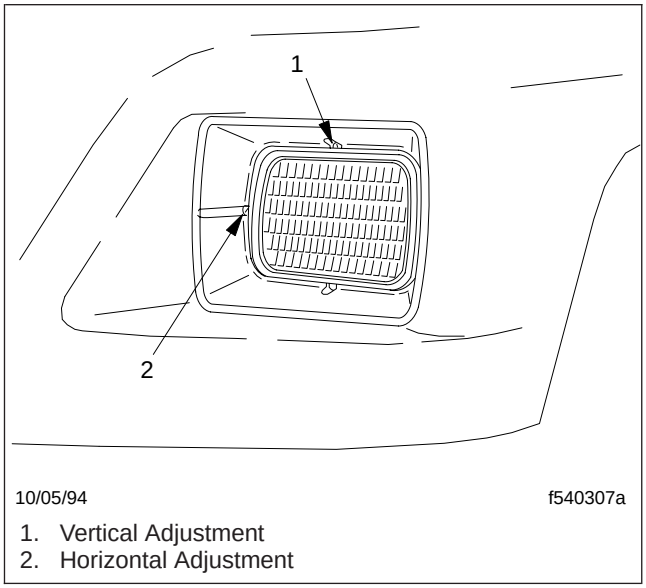
A. Bubble Not Centered
B. Bubble Centered
1. Level Vial
2. Vertical Dial

Fig. 6, Vertical Aim Level Vial

Adjusting

If the headlights need adjusting, do this procedure.

1. If not already there, move the vehicle onto a flat surface that has been calibrated for slope. Shut down the engine, set the parking brake, and chock the tires.
2. Attach a headlight aimer to each headlight. See the procedures above under "Checking" for detailed instructions.
3. Check the floor slope dial for the correct setting. See **Fig. 4**.
4. Adjust the horizontal aim. See **Fig. 5**.
   - 4.1 Set the horizontal dial to "0" (zero).
   - 4.2 Look in the viewing port for the split image target lines. If necessary, rotate either or both aimers until the lines are visible.
   - 4.3 Turn the horizontal adjusting screw as needed to make the split image appear as one solid line. See **Fig. 7**.



10/05/94 f540307a

1. Vertical Adjustment
2. Horizontal Adjustment

Fig. 7, Headlight Adjustment Screws

IMPORTANT: To avoid backlash, make the final adjustment by turning the screw clockwise.

   - 4.4 Do the same procedure for the other headlight.

5. Adjust the vertical aim. See **Fig. 6**.
   - 5.1 Set the vertical dial to "0" (zero).
   - 5.2 Turn the vertical adjusting screw as needed to center the bubble in the level vial between the lines. See **Fig. 7**.

IMPORTANT: To avoid backlash, make the final adjustment by turning the screw clockwise.

   - 5.3 Do the same procedure for the other headlight.

6. Recheck the horizontal alignment on both aimers. Readjust if necessary.

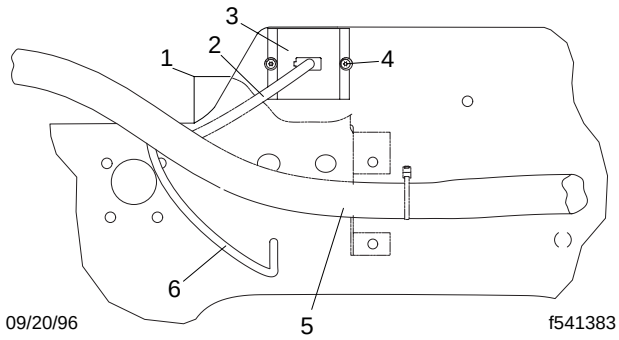
Headlight Aim Checking and Adjusting

7. Remove both headlight aimers. While holding the aimer securely, press the vacuum release button. See **Fig. 3**.
8. Remove the chocks from the tires.

Daytime Running Light Module Replacement

Replacement

1. Disconnect the batteries.
2. Remove the wiring connector from the front of the daytime running light (DRL) module. The DRL module is located on the cab side of the bulkhead just to the right of the dash support bracket.
3. Remove the two 10–24 machine screws attaching the DRL module to the bulkhead. See **Fig. 1**.



1. Dash Support Bracket
2. DRL Wiring
3. DRL Module
4. 10–24 Machine Screw
5. Main Cab Harness
6. To Ignition Keyswitch

Fig. 1, DRL Module Installation

4. Position the new DRL module on the bulkhead and install the two 10–24 machine screws.
5. Connect the DRL wiring to the connector on the front of the DRL module.
6. Connect the batteries and test the daytime running lights for proper operation using the test in **Troubleshooting, 300**.

Troubleshooting

Daytime Running Light Test

Before troubleshooting the daytime running lights (DRLs), do the following test of DRL operation.

1. Be sure the ignition keyswitch, headlights and turn signals are off. Chock the wheels, set the parking brake, and be sure that the DRLs are off.
2. Turn on the ignition keyswitch. Make sure that the DRLs stay off.
3. With the ignition still on, turn the headlight switch on. Make sure that the headlights come on at normal brightness.
4. With the wheels chocked, release the parking brake. Make sure that both DRLs turn on.

NOTE: The DRL module activates the low beam circuit at approximately 86 percent of the nominal voltage, ranging between 10.5 volts with the engine shut down and 12.5 volts with the engine running.

5. Switch between the high and low beams using the dimmer switch. Make sure that the low beams do not turn totally off when the high beams are on (this is a DRL mode).

When the DRLs are operating, they will deactivate under the following conditions:

- The ignition keyswitch is turned off.
- The headlight switch is turned on (with the ignition on or off).
- The parking brake is set.

Daytime Running Light Troubleshooting

If the DRLs are not operating properly, do the following steps.

1. Check the bulbs in the DRLs. Replace any bulb that is burned out.
2. Disconnect the electrical connector to the DRL module and check the pins for proper contact with the plug. Reconnect the DRL module and test again.
3. If the DRLs are still not operating, disconnect the electrical connector again and use a volt/ohmmeter (VOM) to do a voltage test on each pin (use the harness side). For the correct voltages, see **Table 1**.

DRL Module Pin Voltages

No.	Name	Instructions	Voltage
A	Ground	None	0
B	Right Headlight Switch Signal	Headlights Off	0
		Headlights On	12
C	High Beam Sensing	Ignition Off	0
		Ignition On, Dimmer Switch Low	12
		Ignition On, Dimmer Switch High	0
D	Left Headlight Low Beams	Headlights Off	0
		Headlights On	12
E	Right Headlight Low Beams	Headlights Off	0
		Headlights On	12
F	Ignition	Ignition Off	0
		Ignition On, Parking Brake Set	0
		Ignition On, Parking Brake Off	12
G	Left Headlight Switch Signal	Headlights Off	0
		Headlights On	12
H	Battery	None	12

Table 1, Daytime Running Light Module Pin Voltages

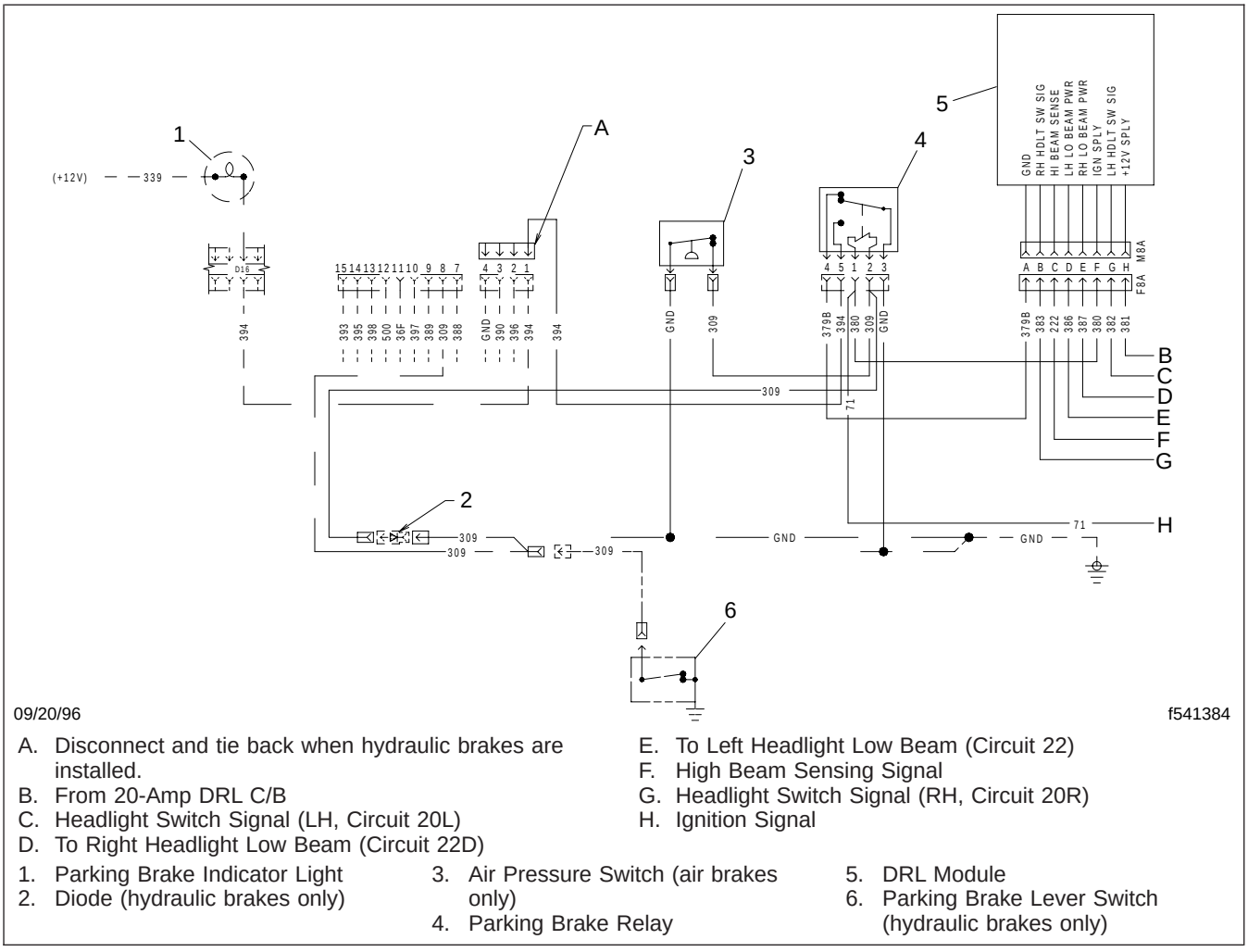
4. If any voltage tested does not match the value given in **Table 1**, correct the fault and do the test again.
5. If one or both of the DRLs still do not function at this point, check the wiring to the DRLs for open circuits or circuits shorted to ground. When only one DRL is not working, the typical cause is a failure in one of these wires.
6. If the DRLs are still not working, replace the DRL module.

Specifications

Manufacturer	Lubricant or Part Number
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 1, Approved Electrical Lubricants

For a wiring diagram of the daytime running light (DRL) circuits, see **Fig. 1**.



A. Disconnect and tie back when hydraulic brakes are installed.
B. From 20-Amp DRL C/B
C. Headlight Switch Signal (LH, Circuit 20L)
D. To Right Headlight Low Beam (Circuit 22D)
E. To Left Headlight Low Beam (Circuit 22)
F. High Beam Sensing Signal
G. Headlight Switch Signal (RH, Circuit 20R)
H. Ignition Signal

1. Parking Brake Indicator Light
2. Diode (hydraulic brakes only)
3. Air Pressure Switch (air brakes only)
4. Parking Brake Relay
5. DRL Module
6. Parking Brake Lever Switch (hydraulic brakes only)

Fig. 1, Daytime Running Lights (DRL) Wiring

General Information

Maintenance-free lead-acid batteries are electrochemical devices which 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 modern automotive battery has three functions:

- To supply power to the starter and ignition system so the engine can be cranked and started.
- To supply extra power when the vehicle's electrical load requirements go beyond what the charging system can supply.
- To stabilize the voltage in the electrical system by reducing temporary high voltages in the electrical system. These high transient voltages could damage other electrical components if they were not protected by the battery.

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. See **Fig. 1**.

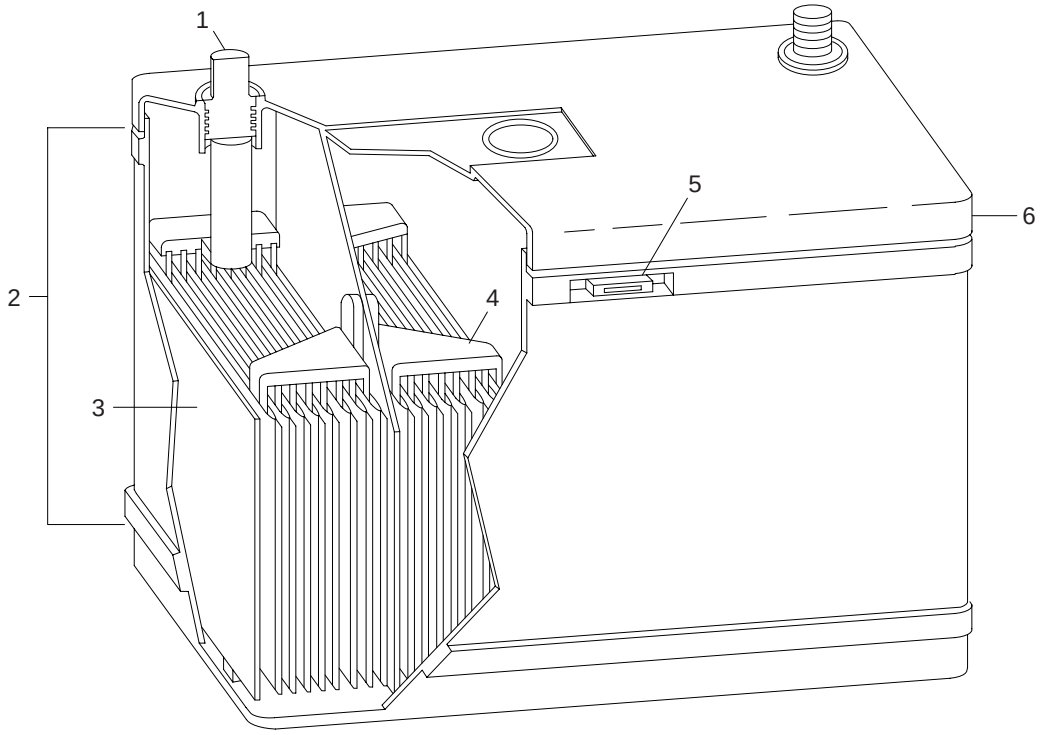
In conventional liquid-electrolyte batteries (wet cells), each group of plates is immersed in a separate cell in a solution of electrolyte (dilute sulfuric acid).

Electrical energy is produced in each cell by chemical changes in the plates (and in the electrolyte whenever a battery is discharged). See **Fig. 2**. A battery produces maximum electrical energy only when the cells are fully-charged. As the cells discharge, chemical changes in the plates gradually reduce the potential electrical energy available. Recharging the battery with an opposite flow of direct current reverses the chemical changes within the cells and restores them to their active state. See **Fig. 3**.

Only good care can ensure long battery life. Proper testing will indicate the battery condition. For more information, see **Subject 130**.

Maintenance-free batteries do not need additional water during normal service life.

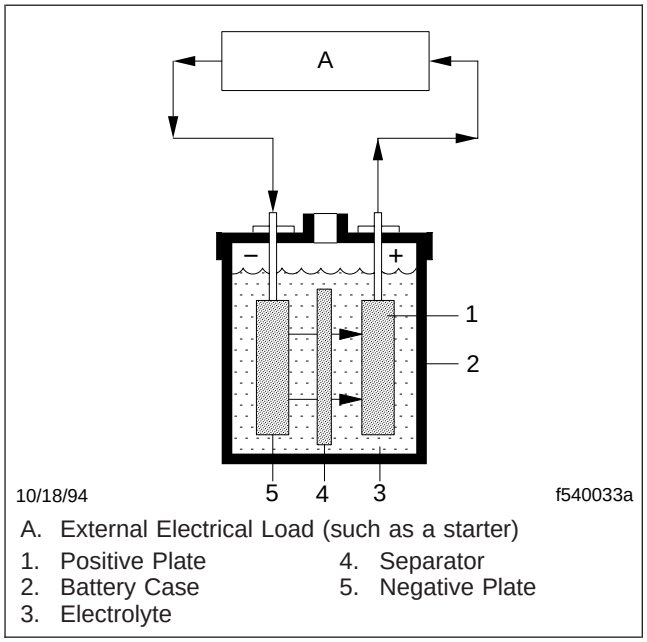
General Information



07/20/95 f540025a

1. Terminal
2. Electrolyte Reservoir
3. Positive Plate Envelope
4. Intercell Connection
5. Vent Hole
6. Plastic Cover

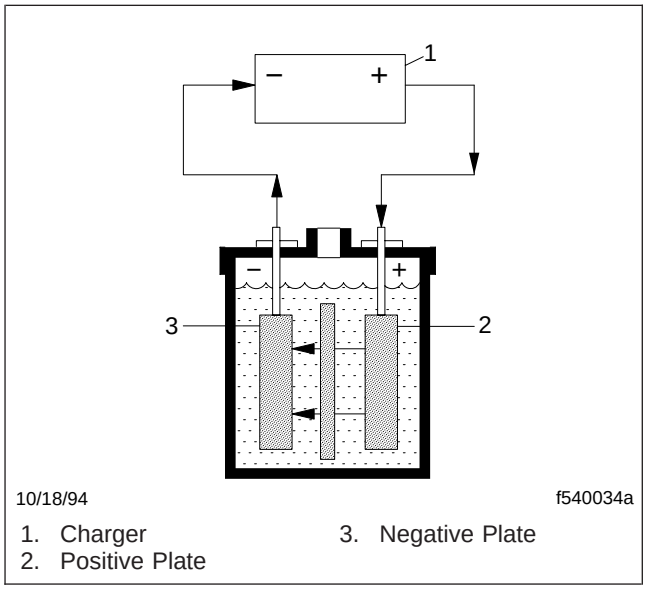
Fig. 1, Typical Maintenance-Free 12-Volt Battery



A. External Electrical Load (such as a starter)

1. Positive Plate
2. Battery Case
3. Electrolyte
4. Separator
5. Negative Plate

Fig. 2, Discharging the Battery



1. Charger
2. Positive Plate
3. Negative Plate

Fig. 3, Charging the Battery

General Safety Precautions

WARNING

WARNING: Never charge a battery while it is connected to the vehicle. If sensitive vehicle components are exposed to excessive charging current, it can cause fires, leading to personal injury and possible loss of life.

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:

WARNING

WARNING: Keep sparks, flames, burning cigarettes, etc. away from batteries. Batteries generate explosive gases, which could cause a battery to explode, causing serious personal injury, including blindness.

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

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 on 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

CAUTION: If a metal object connects an ungrounded battery terminal to a nearby metal part of the vehicle which is grounded, it could short out the batteries, causing sparks and possible property damage.

Battery Electrolyte Safety Precautions

WARNING

WARNING: Protect skin and eyes from battery electrolyte (acid). Electrolyte is corrosive and could result in serious personal injury if splashed on your skin or in your eyes.

If electrolyte is splashed on your skin or in your eye, force the eye open, rinse it with cool, clean water for about 15 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.

Battery Safety Precautions

To prevent possible skin burns, do not wear watches, rings, or other jewelry while performing maintenance work on the batteries.

⚠ WARNING

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 (Jump) Starting

WARNING

WARNING: Before jump starting a vehicle, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Handle both the charged and the discharged batteries carefully when using jumper cables. Follow the procedure below, being careful not to cause sparks.

CAUTION

CAUTION: Make sure the starting systems on both vehicles have the same voltage outputs, and make connections as described below. Otherwise, the starter or the charging system could be damaged.

IMPORTANT: At no time during this operation should the vehicles touch each other, as this could establish a ground connection and offset the benefits of this procedure.

WARNING

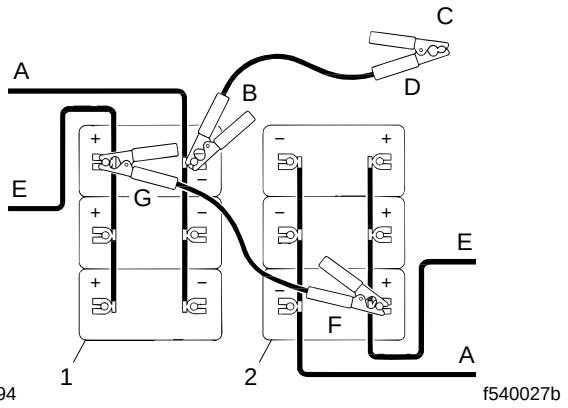
WARNING: Use the following procedure when jump starting. Incorrect battery handling procedures could result in battery explosion and severe personal injury, including blindness.

1. Apply the parking brakes. Turn off the lights, heater, and all other electrical loads.

IMPORTANT: If the vehicles are exposed to traffic, activate the warning flashers on the booster vehicle.

2. For your first connection, attach one end of the jumper cable to the positive terminal of the booster battery. For your second connection, attach the opposite end of the same cable to the positive terminal of the discharged battery. See **Fig. 1**.

3. For your third connection, attach one end of the other jumper cable to the negative terminal of the booster battery. For the fourth connection, attach the opposite end of that cable to a ground at least 12 inches (300 mm) from the battery of the vehicle being started. See **Fig. 1**. The vehicle frame is usually a good ground.



NOTE: This procedure is for negative-ground vehicles only.

A. To Ground
B. Third Connection
C. To Frame
D. Fourth Connection
E. To Starter
F. Second Connection
G. First Connection
1. Booster Battery
2. Discharged Battery

Fig. 1, Jumper Connections, 12-Volt Starting System

IMPORTANT: The final ground connection must provide good electrical conductivity and current-carrying capacity. To prevent sparks and explosions of hydrogen gas, don't connect directly to the negative post of the discharged battery.

4. Make sure that the clamps from one cable do not touch the clamps on the other cable. Don't lean over the batteries when making connections.

5. Make sure that everyone is standing away from the vehicles. Start the engine of the vehicle with the booster batteries. Wait a few minutes, then attempt to start the engine of the vehicle with the discharged batteries.

   Don't operate the starter longer than 30 seconds. Wait at least two minutes between starting attempts to allow the starter to cool. If the engine doesn't start after several attempts, check for the cause.

6. After starting, allow the engine to idle. Disconnect the ground connection from the vehicle with the discharged battery. Then disconnect the opposite end of the cable.

Emergency (Jump) Starting a Battery

7. Disconnect the other cable from the discharged battery first, then disconnect the opposite end.

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.

Conventional Battery Charging

To ensure the optimum condition of the starting and charging system, the starting battery(s) should be kept at a high state of charge. In particular, if operating a vehicle with undercharged battery(s), the alternator can be overworked, which can result in its premature failure.

To charge a conventional liquid-electrolyte battery (wet cell), apply a charge rate in amperes for a period of hours. For example, a 10-ampere charge rate for five hours would produce a 50 ampere-hour charge to the battery.

General Guidelines for Charging Batteries

When charging multiple batteries on one charger, group batteries that have similar voltages and are of similar age. If not, the group will only charge as fast as the battery with the lowest state of charge. Batteries below 5 volts should be charged individually.

IMPORTANT: Do not overcharge maintenance-free batteries. Overcharging causes excessive loss of water from the electrolyte and eventual battery damage.

Use the following tables as a guide for determining how long to charge the battery(s).

Recharge Time (hours) Using a Shop Charger for a Single Battery					
Open Circuit Voltage (OCV)	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6 volts	100%	Ready to Use			
12.4 volts	75%	0.6 hours	0.9 hours	1.3 hours	2.5 hours
12.2 volts	50%	1.2 hours	1.9 hours	2.7 hours	5.1 hours
12.0 volts	25%	1.8 hours	2.9 hours	4.3 hours	7.8 hours
11.8 volts	0%	2.5 hours	4.0 hours	5.7 hours	10.7 hours

Table 1, Using a Shop Charger for a Single Battery

Recharge Time (hours) Using a Shop Charger for a Two Battery System					
Open Circuit Voltage (OCV)	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6 volts	100%	Ready to Use			
12.4 volts	75%	1.2 hours	1.8 hours	2.6 hours	5.0 hours
12.2 volts	50%	2.4 hours	3.8 hours	5.4 hours	10.2 hours
12.0 volts	25%	3.6 hours	5.8 hours	8.6 hours	15.4 hours
11.8 volts	0%	5.0 hours	8.0 hours	11.4 hours	21.4 hours

Table 2, Using a Shop Charger for a Two Battery System

Battery Charging

Recharge Time (hours) Using a Shop Charger for a Three Battery System					
Open Circuit Voltage (OCV)	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6 volts	100%	Ready to Use			
12.4 volts	75%	1.8 hours	2.7 hours	3.9 hours	7.5 hours
12.2 volts	50%	3.6 hours	5.7 hours	8.1 hours	15.3 hours
12.0 volts	25%	5.4 hours	8.7 hours	12.9 hours	23.1 hours
11.8 volts	0%	7.5 hours	12.0 hours	17.1 hours	32.1 hours

Table 3, Using a Shop Charger for a Three Battery System

Recharge Time (hours) Using a Shop Charger for a Four Battery System					
Open Circuit Voltage (OCV)	State of Charge	Charger Maximum Rate			
		50 Amps	30 Amps	20 Amps	10 Amps
12.6 volts	100%	Ready to Use			
12.4 volts	75%	2.4 hours	3.6 hours	5.2 hours	10.0 hours
12.2 volts	50%	4.8 hours	7.6 hours	10.8 hours	20.4 hours
12.0 volts	25%	7.2 hours	11.6 hours	17.2 hours	31.2 hours
11.8 volts	0%	10.0 hours	16.0 hours	22.8 hours	42.8 hours

Table 4, Using a Shop Charger for a Four Battery System

Batteries below 11.8 volts should be charged at no more than 10 amps for a minimum of 24 hours per battery. Check after the first hour and ensure that the battery is not getting hot.

If after using the above charging method you receive a "Charge and Retest" result from a Midtronics battery tester and the voltage is above 11.8 volts, continue to charge normally. If the battery voltage is below 11.8 volts, replace the battery.

On optional batteries with a built-in hydrometer (charge indicator), 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.

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 not be charged if the indicator color is clear or light yellow; this indicates low electrolyte level. Replace these batteries.

To charge a wet cell battery, 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 until the recommended ampere value is reached. Charge rates between 3 and 50 amperes are generally satisfactory for maintenance-free batteries.

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 from the battery. 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 130**.

   If the battery does not pass the test, replace it.

   If the battery passes the test, check the fuel, ignition, cranking, and charging systems to find and correct the problem.

Gel Cell Charging

⚠ CAUTION

To avoid shortening the life of a gel cell, carefully regulate the charging voltage between 13.8 and 14.1 volts.

It is hard to determine how long to charge a gel cell. Recharging time depends on the following factors:

- Depth of discharge
- Temperature
- Size and efficiency of the charger
- Age and condition of the battery

Because the chemical charging reaction slows down as it nears completion, about 60% of the total charging time will be spent bringing the battery from 10.5 volts under load (11.8 volts with no load) to 90% of full charge (12.92 volts, including surface charge). The other 40% of the time is required to charge the remaining 10% (full charge equals 13.0 volts, including surface charge).

For example, if it takes 3-1/2 hours to charge a battery to 90%, it will take another 2-1/2 hours to bring it to full (100%) charge.

See **Table 5** for a list of estimated charging times to 90% of full charge. See **Table 6** for a list of estimated charging times to 100% of full charge. All charging times are based on the initial charge current accepted by the battery, using an automatic, temperature-sensing voltage-regulating charger set at 13.8 (2.30 to 2.35 volts per cell) on a totally discharged battery (at 11.80 to 12.00 volts, with no load).

Charging Time to 90% of Full Charge			
Battery	**Initial Amps Needed To Recharge Battery in a Specific Number of Hours**		
	13 Hours	**6 Hours**	**3-1/2 Hours**
Group 27	8 Amps	21 Amps	41 Amps
Group 31	9 Amps	24 Amps	45 Amps

Table 5, Gel Cell Charging Guide (90% Charge)

Charging Time to 100% of Full Charge			
Battery	**Initial Amps Needed To Recharge Battery in a Specific Number of Hours**		
	22 Hours	**10 Hours**	**6 Hours**
Group 27	8 Amps	21 Amps	41 Amps
Group 31	9 Amps	24 Amps	45 Amps

Table 6, Gel Cell Charging Guide (100% Charge)

How To Use These Charts

Read amps about one minute after the charger is first turned on. Use this initial reading to estimate the approximate charging time.

For example, if a Group 31 (G31) battery reads about 24 amps when first turned on, the battery will be at 90% charge in about six hours, and will be fully charged (100%) in about ten hours.

To charge a gel cell battery, do the following steps:

1. Remove the gel cell from the vehicle.
2. Clean the battery terminals.

Battery Charging

NOTE: If the gel cell is cold, let it warm up to 68°F (20°C). This will allow a normal charging rate.

3. Make sure that the charger is turned off.

CAUTION

Use a reliable, automatic, temperature-sensing, voltage-regulated charger to charge the cells. Any other type of charger will damage the gel cell.

4. Connect the charger leads directly to the battery, following the charger manufacturer's instructions. Rock the charger lead clamps to make sure there is a good connection.
5. Turn on the charger and set the charging rate between 13.8 and 14.1 volts (2.30 to 2.35 volts per cell).
6. After about one minute, check the initial charge current. To charge to 90% of full charge, see **Table 5** to determine the approximate time of completion. To charge to 100% of full charge, see **Table 6** to determine the approximate time of completion.
7. Turn the charger off when finished.

WARNING

Always turn the charger off before disconnecting it from the battery. Touching a charger lead when the circuit is live could create a spark and cause an explosion, resulting in personal injury.

8. Disconnect the charger cables from the battery.

General Information

WARNING

Before testing a battery, read the instructions in Subject 100. Failure to follow the safety precautions could result in personal injury.

Test any maintenance-free battery that does not hold a charge to see if it needs to be replaced, or if the problem lies elsewhere in the electrical system. Accuracy of the test depends on variables such as temperature and age of the battery. Follow the recommended testing instructions listed below.

IMPORTANT: Two types of battery tests are discussed in this subject. The first, Midtronics PowerSensor Micro740 Test, uses the Midtronics Micro740 battery tester and must be used by all U.S. and Canadian dealers for battery warranty claims. The second test is a load test using a carbon pile type tester and should **not** be used by U.S. or Canadian dealers for battery warranty claims.

Visual Inspection

Check for obvious damage such as a cracked or broken case that could permit loss of electrolyte. If there is physical damage replace the battery. Find the cause of the damage and correct it as needed.

On maintenance-free batteries without a built-in hydrometer, perform the Midtronics PowerSensor Micro740 test or the load test.

On maintenance-free batteries with a built-in hydrometer, check the sight glass. If a green dot shows in the sight glass test the battery. If the sight glass is dark recharge the battery, then test it. See **Subject 120**. If the sight glass is clear replace the battery. See **Fig. 1**.

Prior to Testing

1. Clean the battery terminals with a soft wire brush before testing.
2. At the start of the test, make sure all vehicle accessory loads are off and the ignition is in the off position.

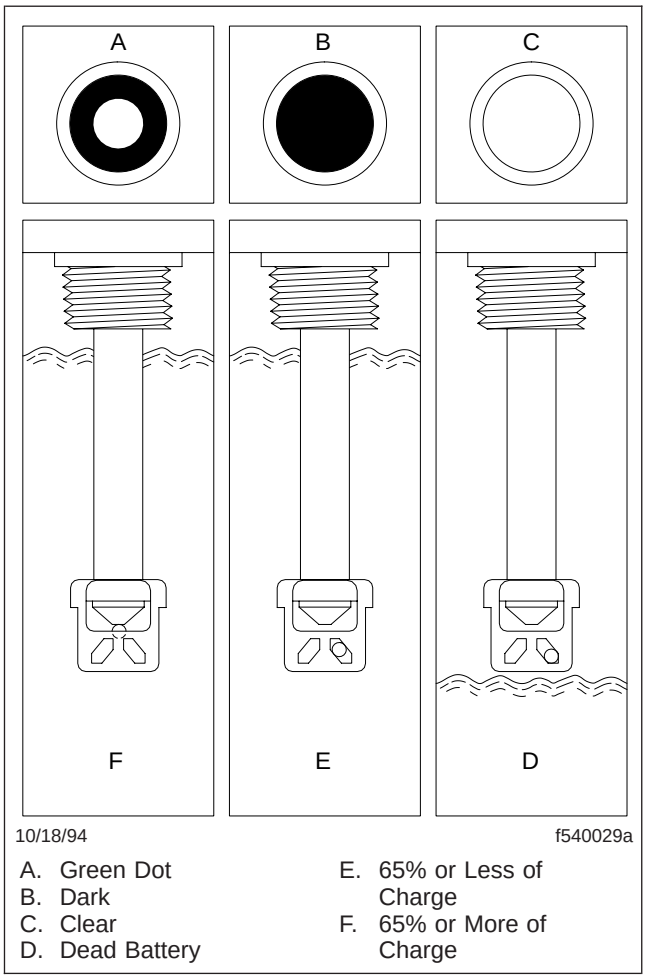


Fig. 1, Built-In Hydrometer or Charge Indicator (on optional batteries only)

Midtronics PowerSensor Micro740 Test

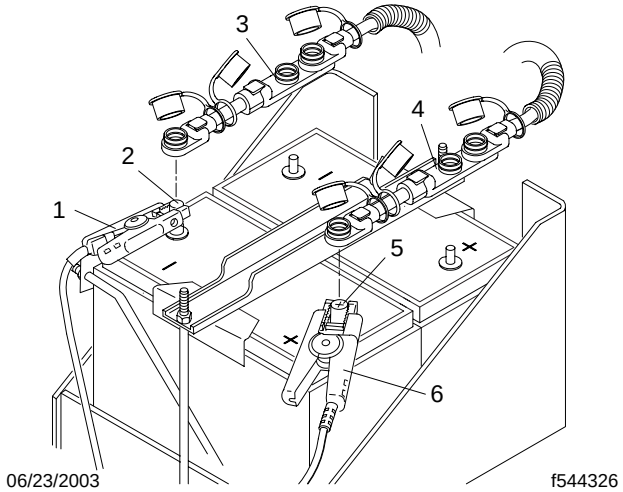
NOTE: This test must be used by all U.S and Canadian dealers for battery warranty claims.

Every battery in a pack of two or more must be disconnected before testing. If more than one battery is selected to be tested, the analyzer will test the first battery, then prompt you to connect to the next battery after the test has been completed. If the analyzer detects that the batteries are connected it will remind you to disconnect the pack before starting the test.

Battery Testing

Connecting the Midtronics Tester

1. Screw an adapter onto the negative-terminal stud and one onto the positive-terminal stud. See **Fig. 2**.



1. Negative-Terminal Clamp
2. Negative-Terminal Adaptor
3. Negative-Terminal Battery Jumper
4. Positive-Terminal Jumper
5. Positive-Terminal Adaptor
6. Positive-Terminal Clamp

Fig. 2, Battery Connection

IMPORTANT: For accurate test results, connect the clamps to the lead adaptors or to the lead bases of threaded studs. Lead stud adaptors are included with the Micro740. Do not connect the clamps directly onto the threaded studs or an inaccurate test result may occur.

2. Connect the red clamp to the positive-terminal stud adaptor.
3. Connect the black clamp to the negative-terminal stud adaptor.
4. Rock the clamps back and forth to ensure a secure connection. Both sides of the clamp must be firmly connected to the adaptors before testing. If the test message CHECK CONNECTION appears, clean the terminals and/or reconnect the clamps.

Battery Test

NOTE: If the analyzer displays a test message after you start the test see *Test Messages* to determine the cause and remedy.

1. Use the arrow buttons at the top of the keypad to scroll to menu choices. Select BATTERY TEST. Press ENTER to select.
2. Enter the number of batteries being tested (1 to 6) and press ENTER to select.
3. Select the rating system; CCA, SAE, EN, IEC, DIN, or JIS then press ENTER.
4. Select the appropriate rating value then press ENTER. See **Table 1**.
5. If the analyzer detects that the temperature of the battery may make a difference in the results it will ask you to select whether the battery temperature is above or below 32°F (0°C). It will resume the test after you make the selection and press ENTER.
6. At the end of the test, the Micro740 will display one of the following results from **Table 2** and the measured voltage and CCA, if applicable.

   If the result is REPLACE BATTERY or BAD CELL—REPLACE, the analyzer will prompt you to press ENTER to generate a battery code.

   When the prompt BAT.SERIAL # appears enter the battery serial number. Use the ARROW buttons to scroll to the correct digit, then press ENTER to select it and move to the next digit. Pressing the BACK button will move the cursor back one space. When finished, press ENTER.
7. Turn on the printer and align the analyzer transmitter with the printer receiver. Press and hold the MENU button. Select PRINT RESULTS from the option menu by using the arrow buttons and pressing ENTER. It will take about 30 seconds to print all test results, which are displayed simultaneously on the screen.

Battery Rating Systems		
Rating System	**Description**	**Value Range**
CCA	Cold Cranking Amps, as specified by SAE. The most common rating for cranking batteries at 0 F (-18 C)	100 to 1700 A
SAE	European labeling of CCA	100 to 1700 A
EN	Europa-Norm	100 to 1700 A
IEC	International Electrotechnical Commission	100 to 1000 A
DIN	Deutsche Industrie-Norm	100 to 1000 A
JIS	Japanese Industrial Standard: (shown on a battery as a combination of numbers and letters, for example: 80D26)	43 values from 26A17 to 245H52

Table 1, Battery Rating Systems

Battery Test Results	
Result	**Recommendation**
Good Battery	Return to service.
Good – Recharge	The battery is good, but has an insufficient state of charge. Fully charge the battery and return to service. See **Subject 120**.
Charge and Retest	The battery has a very low state of charge. Fully charge the battery and retest. Failure to fully charge the battery before retesting may cause false readings. See **Subject 120**.
Replace Battery	Replace the battery and generate a test code.
Bad Cell – Replace	Replace the battery and generate a test code.

Table 2, Battery Test Results

Test Messages

Test Message—SYSTEM NOISE

Test Message—SYSTEM NOISE	
Possible Cause	**Remedy**
The analyzer has detected computer or ignition noise and will attempt to retest.	Make sure all vehicle loads are off and the ignition is in the off position. The analyzer will automatically retest when it no longer detects system noise
You may be testing too close to a noise source.	Move away from any high-current device and retest.
Battery charge is too low to test properly.	Recharge the battery and retest. If the message reappears, replace the battery. See **Subject 120**.
Poor connection at battery terminal.	Connect the battery cables and retest.

Test Message—NON 12-VOLT BATTERY DETECTED

Test Message—NON 12-VOLT BATTERY DETECTED	
Possible Cause	**Remedy**
You are attempting to test both batteries in a 24-volt system at the same time.	Disconnect the batteries and test each one individually.

Battery Testing

Test Message—INTERNAL ERROR, SERVICE REQUIRED

Test Message—INTERNAL ERROR, SERVICE REQUIRED	
Possible Cause	**Remedy**
The analyzer has detected a hardware or software problem.	See the Midtronics Micro740 *Instruction Manual*.

Test Message—REVERSE CONNECTION

Test Message—REVERSE CONNECTION	
Possible Cause	**Remedy**
The clamps are connected in reverse polarity. IE: Red to negative(-), and black to positive (+).	Disconnect the clamps and reclamp to proper polarity.

Test Message—UNSTABLE BATTERY

Test Message—UNSTABLE BATTERY	
Possible Cause	**Remedy**
Batteries that are very weak or that have just been charged may have sufficient electrical activity to alter test results. The analyzer will automatically retest when the battery has stabilized. Fully charged batteries should stabilize quickly.	Charge weak batteries and then retest. See **Subject 120**.

Test Message—CHECK CONNECTION

Test Message—CHECK CONNECTION	
Possible Cause	**Remedy**
Poor connection. Both sides of the clamps must be firmly connected before testing.	Clean the battery terminals using a wire brush and a mixture of baking soda and water. Inspect and clean the clamps. Liberally apply baking soda and water with a clean cloth and thoroughly rub the jaw and spring. Use a soft wire brush to remove corrosion buildup. Rinse with water and let dry.

Load Test

NOTE: This test must **not** be used by U.S and Canadian dealers for battery warranty claims.

1. Before beginning the load test, make sure the battery to be tested is fully charged. See **Subject 120** for conventional battery and gel cell charging instructions.

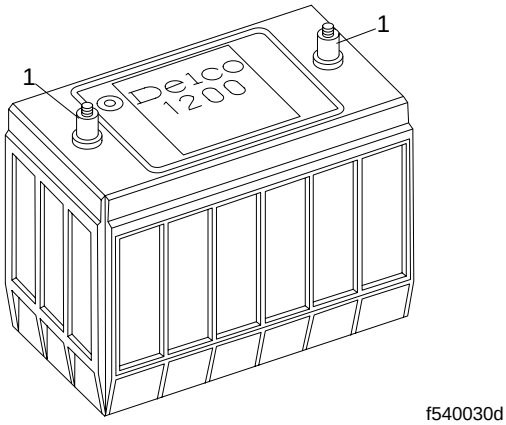
⚠ WARNING

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.

2. Test each battery separately, either installed or removed. Disconnect the battery ground cable first.

3. Connect the tester leads to the battery terminals following the tester manufacturer's instructions. Batteries with sealed terminals require adaptors to provide a place for attaching the tester's leads. See **Fig. 3**.



1. Terminal Adaptor

Fig. 3, Sealed Battery

4. Check the rated CCA of the battery. Apply a load equal to one-half the rated CCA across the terminals for 15 seconds to remove the surface charge from the battery. Remove the load and wait 15 seconds for the battery to recover.

   Example: For a battery rated at 620 CCA, apply a load of 310 amperes across the terminals.

5. Estimate the battery temperature by touch and by the ambient temperature the battery was exposed to before this test, then find the voltage in Table 1, **Specifications 400** that must be maintained while the battery supplies a specified electrical load.

   Example: At 70°F, (21°C) the battery must supply 9.6V minimum.

6. Apply the specified test load to the battery for 15 seconds. The test load (amperes) is equal to one-half of the cold-cranking amperes of the 0°F (–18°C) rating of the battery.

7. Read the terminal voltage at the end of 15 seconds with the load still connected. Do not keep the load attached for a longer period of time before reading the voltage, as this would alter the test results.

8. Remove the load after 15 seconds and note the tester reading.

   If the voltage drops below the minimum listed in the table replace the battery.

   If the voltage is the same or greater than the minimum listed in the table the battery is capable of further service.

WARNING

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.

Cleaning and Inspection

1. Inspect the battery cables for wear, and replace them if necessary. Clean the cable connector terminals with a wire brush and tighten all battery interconnecting cables.
2. Clean and tighten the battery ground cable, terminals, and clamps.
3. Inspect the retainer assembly (or battery hold-downs) 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.

Storage

Always store batteries in an upright position. Don't store batteries on their sides, as electrolyte may escape through the vent holes.

Maintain inventory levels in balance with demand and always rotate battery stock on a strict first-in, first-out basis. To protect against self-discharge, check the date codes stamped on the battery cartons and on the batteries themselves.

IMPORTANT: One of the major causes of problems with replacement batteries is failure to follow the first-in, first-out stock procedure.

Roller racks provide the best way to store batteries. If loaded properly from the back, they insure that the oldest battery of a particular type will always appear in the front.

Mark the racks clearly, both front and back, to ensure that the same battery type will go in the same rack every time.

If roller racks are not available, use wooden shelving reachable from both the front and the back. Otherwise, old batteries must be removed, to put new batteries in the back.

Never stack batteries on top of one another. If nothing else is available, simple battery storage racks can be made from loose, flat boards.

Maintenance-free batteries can have a shelf life of up to twelve months or more, depending upon storage temperatures, before charging is needed.

NOTE: Batteries in vehicles that are not in service are considered to be in storage. When a vehicle is to be out of service for 30 days or more, disconnect the negative ground terminal of each battery to prevent self-discharge caused by various components.

To minimize self-discharge, store batteries in as cool a place as possible, away from heat ducts in winter, and shielded from direct sunlight in summer.

The best storage conditions are in clean, dry areas where ambient temperatures are stable between 32° and 80°F (0° and 27°C). Storage in temperatures above 80°F (27°C) is not recommended, as this increases the rate of self-discharge. Avoid temperatures below 32°F (0°C) to prevent freezing if a battery becomes discharged.

Selection

Long and trouble-free service is assured when the reserve capacity of the battery is equal to or exceeds 160 minutes and the cold cranking amp (CCA) rating of each replacement battery is at least 625 amperes. The CCA rating of the battery is a measure of its ability to supply high cranking power to the cranking motor at 0°F (–18°C).

The use of an undersized battery may cause poor performance and early failure. It may also cause damage to or reduced life of the starter. With falling temperatures, battery power decreases while the need for engine cranking power increases. Subzero temperatures reduce the capacity of a fully charged battery to 45 percent of the normal power, and at the same time, increase cranking load to 3-1/2 times the normal warm-weather load.

Batteries of a greater capacity should be considered if the electrical load has been increased through the addition of accessories, or if driving conditions are such that the charging system cannot keep the batteries charged.

IMPORTANT: Don’t replace a battery with one designed for automobiles and light trucks. The cold cranking amp (CCA) rating may be the same or higher, but the plates are lighter, and the battery won’t provide the reserve life that is needed. Also, these batteries don’t have the extra vibration protection or temperature resistance required on a heavy-duty vehicle.

Troubleshooting

If the battery tests good, but fails to perform satisfactorily in service, check for the following causes:

1. Accessories were left on overnight.
2. A slipping alternator belt, high resistance in the wiring, or an inoperative voltage regulator is causing the batteries to discharge.
3. The electrical load is 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 battery is 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 six to eight weeks. A battery left in a discharged condition for a prolonged period of time is subject to freezing and may become difficult to charge.

Problem—The Batteries Seem Undercharged

Problem—The Batteries Seem Undercharged	
Possible Cause	**Remedy**
The drive belt is loose.	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 amperage output. See the troubleshooting subject in the appropriate 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 amperage output. See the troubleshooting subject in the appropriate alternator section **in Group 15** for instructions.
The battery is undercharged.	Do a load test on the battery. See **Subject 130** for instructions. Charge or replace the battery as needed. If the batteries were discharged, start the engine and check the alternator voltage and amperage output. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.
The cranking circuit is broken.	If the batteries were fully charged and passed the load test, check the cranking circuit. Go to "Cranking Circuit Test" in **Section 15.00** for instructions. Make repairs as needed. Start the engine to verify the repair.
The control circuit is broken.	Check the starter wiring. Go to "Starter Wiring Test" in **Section 15.00** for instructions. Make repairs as needed. Start the engine to verify the repair.
The starter is cold.	Go to "Cold Weather Starting Test" in **Section 15.00** for instructions.
The battery cables do not deliver sufficient voltage to the starter.	Check the available cranking voltage. Go to "Available Cranking Voltage Test" in **Section 15.00** for instructions.
The starter ring gear or pinion gear is damaged.	Visually check the ring and pinion gears. Go to "Ring and Pinion Gear Test" in **Section 15.00** for instructions.
The starter is damaged.	Replace the starter.
The alternator is malfunctioning.	See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions.

Troubleshooting

Problem—The Starting Batteries Seem Overcharged

Problem—The Starting Batteries Seem Overcharged	
Possible Cause	**Remedy**
The voltage regulator is damaged.	Run engine at approximately 2000 RPM. Using a digital voltmeter, check the voltage at the alternator. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If the voltmeter reads 15.0V or above (15.5V or above on Leece-Neville alternators), replace the alternator.
The dash voltmeter is broken.	Run engine at approximately 2000 RPM. Using a digital voltmeter, check the voltage at the alternator. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If the voltmeter reads below 15.0V (15.5V on Leece-Neville alternators), check voltage at the gauge terminals and, if necessary, replace the dash voltmeter.
The batteries are overheated.	Check battery temperatures. If 120°F (49°C) or above, connect cool, fully charged batteries and recheck the voltage at the alternator. See the troubleshooting subject in the appropriate alternator section in **Group 15** for instructions. If 119°F (48°C) or below, load test the batteries. See **Subject 130** for instructions.
The batteries need replacing.	Check battery temperatures. If 119°F (48°C) or below, load test the batteries. See **Subject 130** for instructions.

Specifications

Minimum Permissible Voltages	
Ambient Temperature °F (°C)	**Minimum Voltage (after 15 seconds at 300 amps)**
70 (21) and Above	9.6
60 (16)	9.5
50 (10)	9.4
40 (4)	9.3
30 (–1)	9.1
20 (–7)	8.9
10 (–12)	8.7
0 (–18)	8.5

Table 1, Minimum Permissible Voltage at Various Ambient Temperatures

Charging Rates for Starting Batteries				
Rated Battery Capacity (Reserve Minutes)	**Slow Charge ***	**Fast Charge †**		
	Hours @	**Amperes**	**Hours @**	**Amperes**
180	30	5	7-1/2	20
	15	10	5	30
	—	—	2-1/2	45

* Slow charging is recommended for completely charging the batteries.
† An emergency boost charge, which consists of a high charging rate, can be obtained by reducing the fast-charge time to half, while maintaining the same recommended ampere charge may be used to crank an engine.

Table 2, Charging Rates

Manufacturer	Lubricant or Part Number
Shell Oil Co.	No. 71032; No. 71306
Texaco, Inc.	No. 955
Quaker State	No. NYK-77

Table 3, Approved Electrical Lubricants

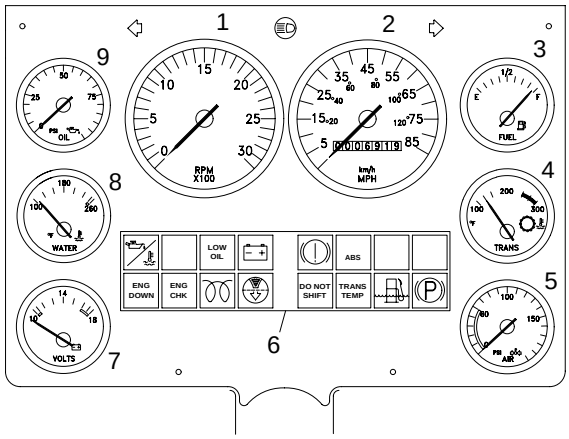
Reserve Capacity	Cold Cranking Amps (CCA)
180 minutes	650

Table 4, Standard Battery Specifications

General Information

DASH FUNCTIONS

The school bus instrument cluster contains all the gauges and indicators required for safe operation of the vehicle. See **Fig. 1** for a typical installation. An auxiliary gauge panel sits to the left of the instrument cluster. See **Fig. 2** for a typical installation.



10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

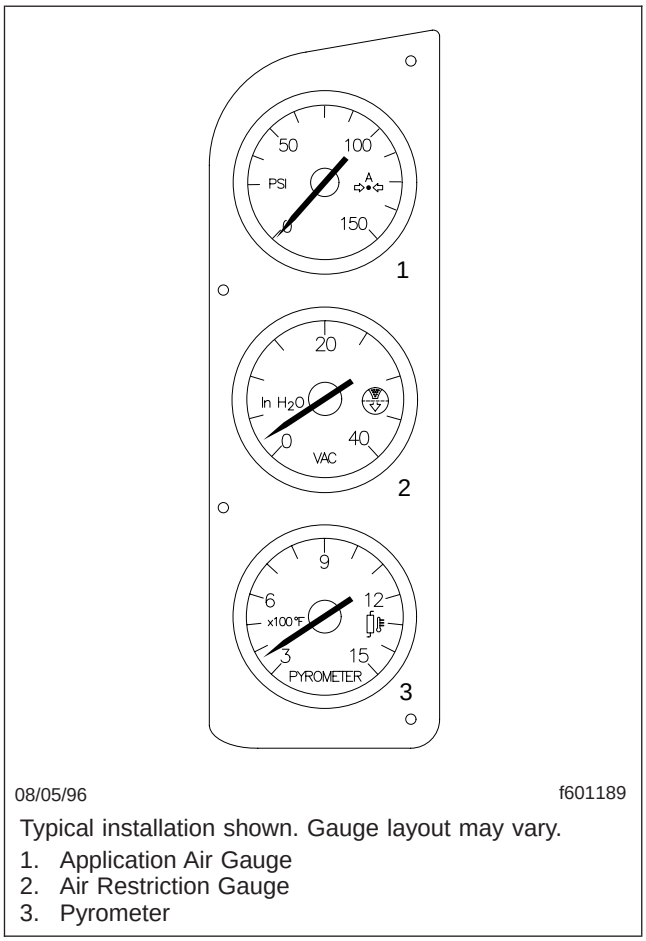
1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster

When a gauge position is not used, the hole in the panel is blocked off with a gauge blank. For gauge installation, see **Subject 100**.

A switch panel sits to the right of the instrument cluster. See **Fig. 3** for a typical installation.

The instrument cluster contains a double row of warning and indicator lights. See **Fig. 4**. A blank bezel indicates that a particular light is not implemented. In a typical installation, these lights include warnings about low engine oil level, brake system



08/05/96 f601189

Typical installation shown. Gauge layout may vary.

1. Application Air Gauge
2. Air Restriction Gauge
3. Pyrometer

Fig. 2, Auxiliary Gauge Panel

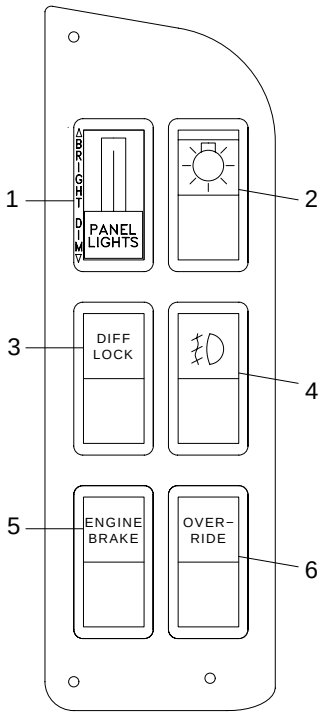
failure, high transmission fluid temperature, and water in fuel. If a problem occurs, a dashboard light illuminates.

The Freightliner® engine warning system alerts the driver to any problem associated with low engine oil pressure, and/or high coolant temperature. If a problem occurs in one of these systems, a dashboard warning light illuminates and a buzzer sounds.

The light and buzzer are activated by switches. The engine oil pressure switch is located on the bulkhead, near the engine electrical connectors. The coolant temperature switch is located on the engine block. For switch replacement, see **Subject 110**.

NOTE: The low oil pressure switch and the high coolant temperature switch activate the same warning light (LOW OIL PRESSURE/HIGH

General Information



08/05/96 f601191

Typical installation shown. Switch layout may vary.

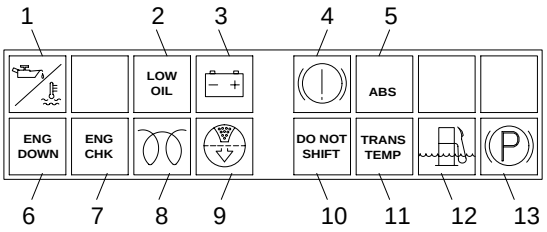
1. Panel Light Dimmer
2. Headlights
3. Differential Lock
4. Fog Lights
5. Engine Brake
6. ATC Override

Fig. 3, Switch Panel

COOLANT TEMPERATURE). See **Fig. 4**. The warning light comes on and the buzzer sounds whenever one of the following conditions occurs:

- The engine oil pressure drops below 10 psi (70 kPa); or
- The coolant temperature rises above 210°F (99°C).

Because power is supplied to these circuits through the ignition switch, turning the ignition switch off also shuts off the warning system.



09/16/96 f601192

Typical installation shown; all lights may not be implemented.

1. Low Oil Pressure/High Coolant Temp. Warning
2. Low Oil Warning
3. Charging Indicator
4. Brake System Failure Warning
5. Anti-Lock Brake System Indicator
6. Engine Shutdown Warning (optional)
7. Check Engine Indicator (optional)
8. Engine Pre-Heat Indicator (glow plug)
9. Air Restriction Indicator
10. Do Not Shift Warning
11. Transmission Fluid Temp. Warning
12. Water in Fuel Warning
13. Parking Brake Indicator

Fig. 4, Warning and Indicator Lights

ENGINE FUNCTIONS

The low oil pressure switch controls a ground-activated circuit with a switch that is normally closed (NC). During vehicle operation, the switch is held open by engine oil pressure. If the oil pressure drops below 10 psi (70 kPa), the switch returns to its normally closed position and connects wire 34 to ground. This completes the circuit, activating the warning light and buzzer.

The coolant temperature switch also controls a ground-activated circuit, but the switch is normally open (NO). If the coolant temperature rises above 210°F (99°C), the switch closes and connects wire 18C to ground. This completes the circuit, activating the warning light and buzzer.

Removal

1. Shut down the engine, apply the parking brake, and chock the tires.
2. Disconnect the batteries.
3. Remove the instrument cluster bezel. See **Fig. 1**.

NOTE: On some vehicles, the bezel is also secured to the instrument panel with four Torx®-head screws. See **Fig. 1**.

3.1 If present, remove the four Torx-head screws from the bezel.

3.2 Insert a stubby, flat-tipped screwdriver into the opening above the upper left-hand corner of the instrument cluster bezel and release the bezel locking tab by gently pivoting the screwdriver handle toward the vehicle windshield. See **Fig. 1** and **Fig. 2**.

While keeping pressure on the screwdriver, use your other hand to pull the corner of the bezel away from the instrument panel about 1/2 inch (13 mm).

3.3 Repeat the previous substep for the upper right-hand corner of the bezel.

3.4 With both corners released, tilt the entire top edge of the bezel away from the instrument panel about 1 inch (25 mm) and try to work the bottom edge of the bezel loose.

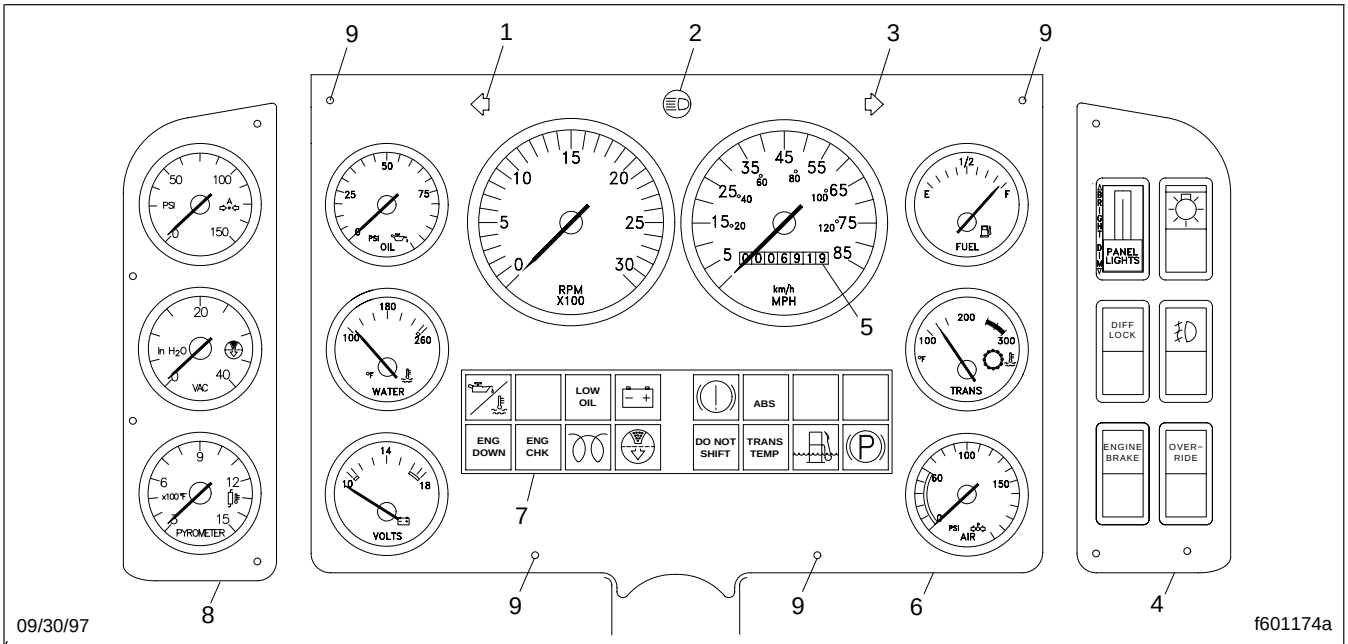
If the bottom of the bezel won't come loose, use the screwdriver to release the locking tabs at the bottom edge of the bezel. See **Fig. 3**.

Set the bezel aside.

4. Remove the gauge from the dash.

4.1 Using finger pressure, release the locking clip from the side of the gauge.

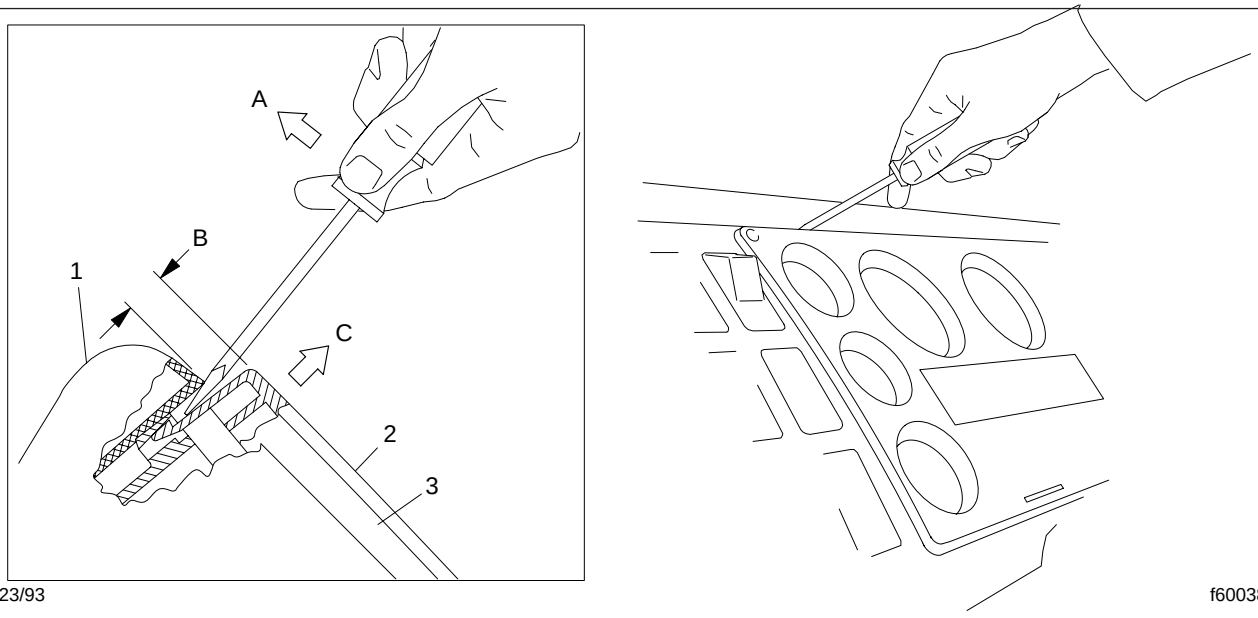
4.2 Grasp the gauge firmly and pull it straight out of the mounting panel.



1. Left Turn Signal
2. High Beam Indicator
3. Right Turn Signal
4. Switch Panel
5. Odometer
6. Instrument Cluster Bezel
7. Warning and Indicator Lights
8. Auxiliary Gauge Panel
9. Location of Torx-Head Mounting Screw

Fig. 1, Instrument Cluster

Gauge Removal and Installation



A. Pivot screwdriver toward windshield.
B. 1/2 inch (13 mm)
C. While holding screwdriver forward, pull bezel away from instrument cluster about 1/2 inch (13 mm).
1. Instrument Panel Upper Cover 2. Instrument Cluster Bezel 3. Foam Gasket

Fig. 2, Releasing the Bezel Upper Edge

4.3 The gauge illumination bulb remains in the gauge mounting panel. Remove and replace the bulb if necessary.

5. On mechanical gauges like the engine oil pressure gauge, remove the pressure line from the back of the gauge. Remove the gauge mounting panel if necessary to disconnect the fitting.

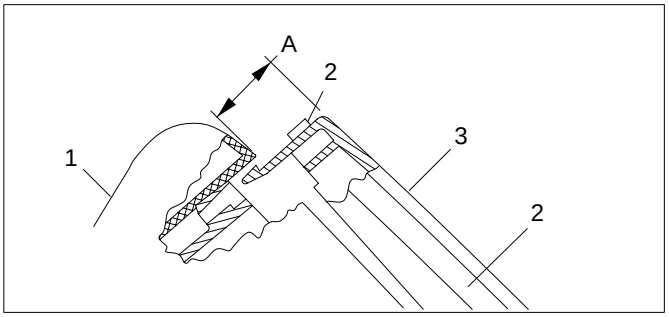
NOTE: Air pressure gauges use "push-to-connect" fittings, oil pressure gauges use compression fittings.

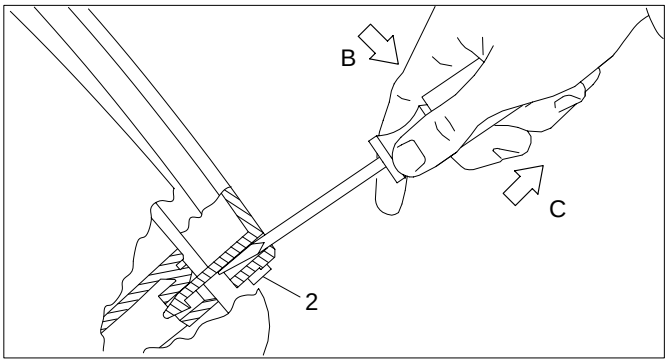
Installation

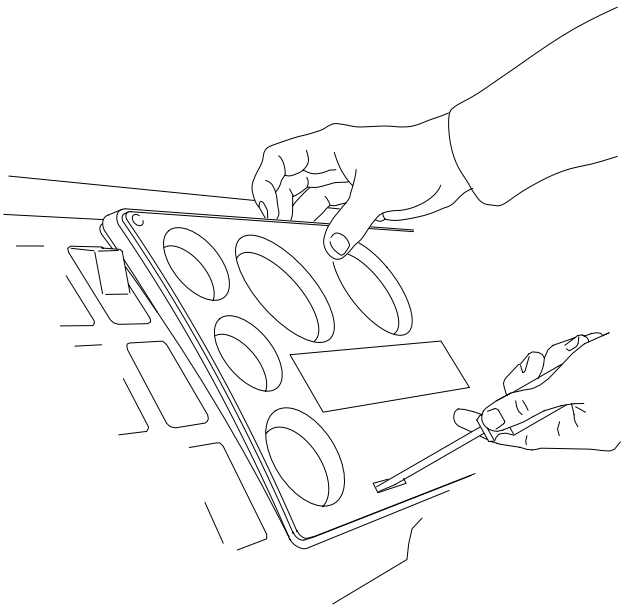
1. On mechanical gauges like the engine oil pressure gauge, install the pressure line in the back of the gauge.
2. Position the gauge over the gauge mounting panel, making sure that the panel terminals line up with the gauge sockets.
3. Install the gauge in the gauge mounting panel.
   3.1 Grasp the gauge firmly and insert it in the mounting panel.
   3.2 Make sure that the gauge is firmly seated and that the locking clip is holding it in place.
4. Position the instrument cluster bezel against the instrument panel. Starting with the lower corners, alternately push against the bottom and top corners of the bezel, until all four locking tabs are locked and the face of the bezel is flush with the surfaces of the instrument panel. Don't push against the gauge lenses or gauge blanks (block-off plugs).

NOTE: On some vehicles, the bezel is secured to the instrument panel with four Torx®-head screws. See **Fig. 1**.

5. If removed, install the screws in the instrument cluster bezel.
6. Connect the batteries.
7. Start the engine and verify that the gauge is operating properly.
8. Remove the chocks from the tires.







11/28/95 f600385a

A. 1 inch (25 mm)
B. Pivot screwdriver toward floor.
C. While holding screwdriver downward, pull bezel away from instrument cluster.

1. Instrument Panel Upper Cover
2. Foam Gasket
3. Instrument Cluster Bezel

Fig. 3, Releasing the Bezel Lower Edge

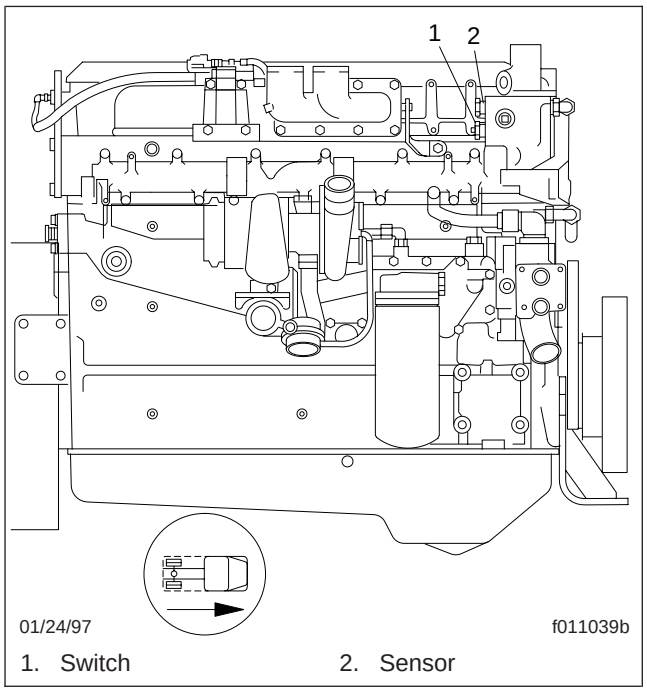
Replacement

HIGH COOLANT TEMPERATURE SWITCH

⚠ CAUTION

Remove the switch only when the coolant and engine are cool. Removing it when these are hot could cause hot coolant to spray out of the engine, causing personal injury.

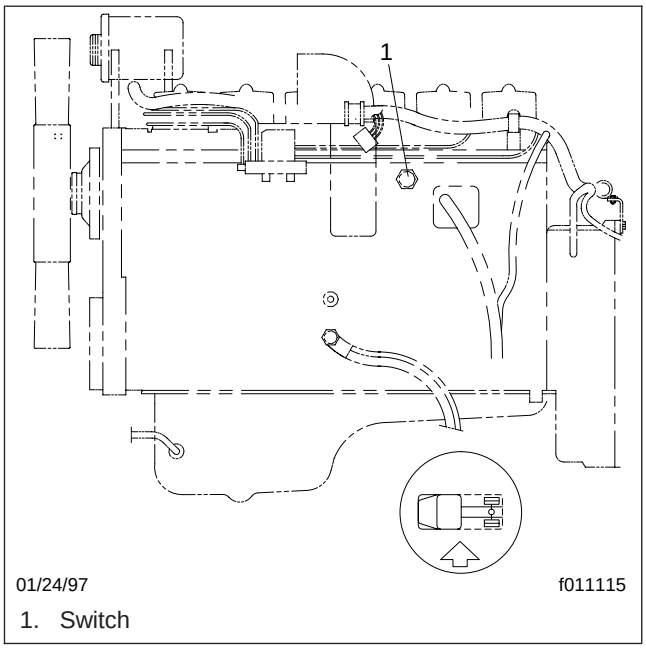
1. If necessary, allow the engine to cool before attempting to remove the high coolant temperature switch.
2. Remove the connector (with wire 18C) holding the high coolant temperature switch. See **Fig. 1** and **Fig. 2** for the Caterpillar CFE engine and for the Cummins B Series engine. Remove the switch from the connector.



1. Switch
2. Sensor

Fig. 1, Coolant Temperature Switch Location, Caterpillar CFE Engine

3. Install the new switch and attach the connector to the engine port.



1. Switch

Fig. 2, Coolant Temperature Switch Location, Cummins B Series Engine

LOW ENGINE OIL PRESSURE SWITCH

1. Turn off the ignition keyswitch.
2. Disconnect the pin on wire 34 from the connector mounted on the switch. See **Fig. 3**.
3. Remove the switch from the tee.
4. Install the new switch. Tighten securely, but do not overtighten. Connect wire 34 to the switch.
5. Start the engine and check that the warning light and buzzer shut off when the oil pressure reaches approximately 9 psi (65 kPa). Check the system to be sure there is no oil leakage, taking special care to note leakage around the switch installation.

Switch Replacement

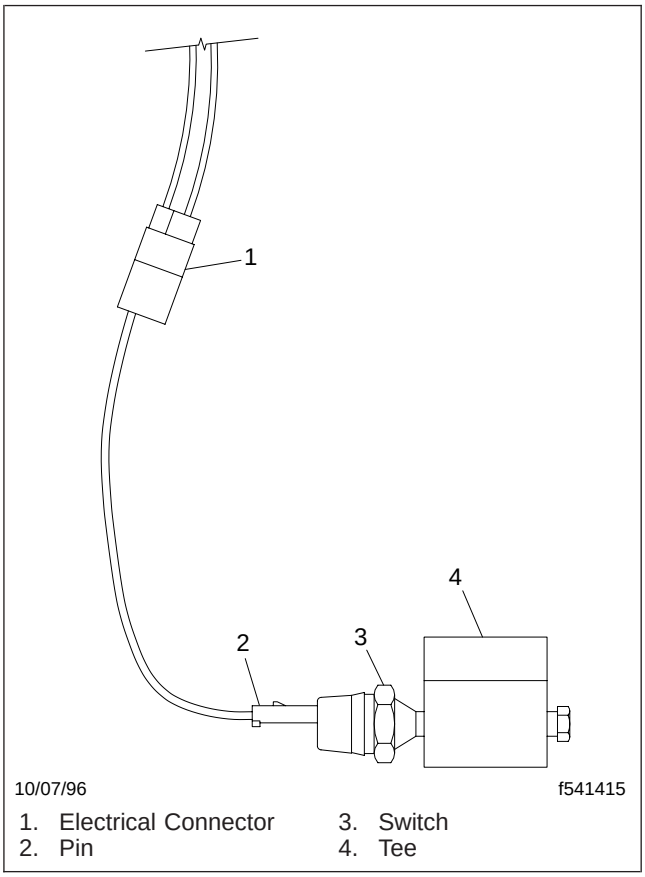


Fig. 3, Engine Oil Pressure Switch Wiring

Replacement

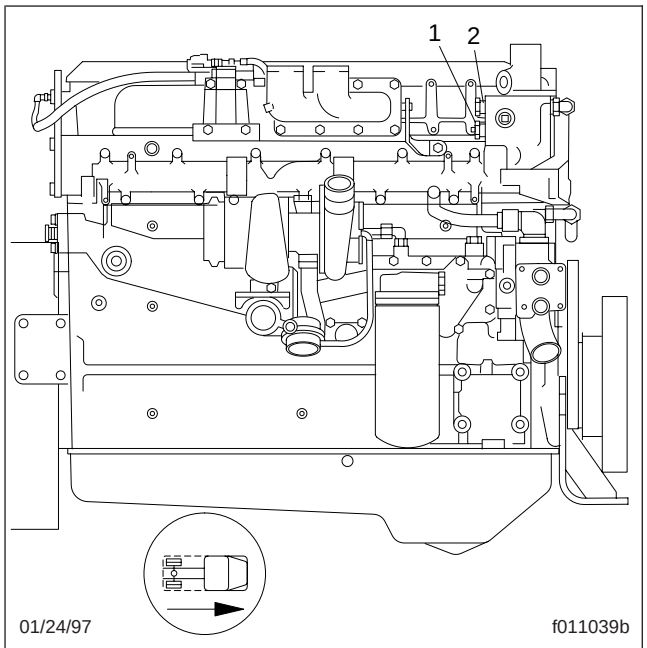
HIGH COOLANT TEMPERATURE SENSOR

1. Turn off the ignition switch and let the engine cool. Remove the surge tank cap to release system pressure.

⚠ WARNING

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

2. Drain the coolant from the engine.
3. Disconnect wires 119 and 119B from the coolant temperature sensor. See **Fig. 1** for the Caterpillar CFE engine and **Fig. 2** for the Cummins B Series engine. Remove the sensor.



1. Switch 2. Sensor

Fig. 1, Coolant Temperature Sensor Location, Caterpillar CFE Engine

4. Install the new sensor. Tighten securely, but do not overtighten. Connect wire 119 and 119B to the switch.

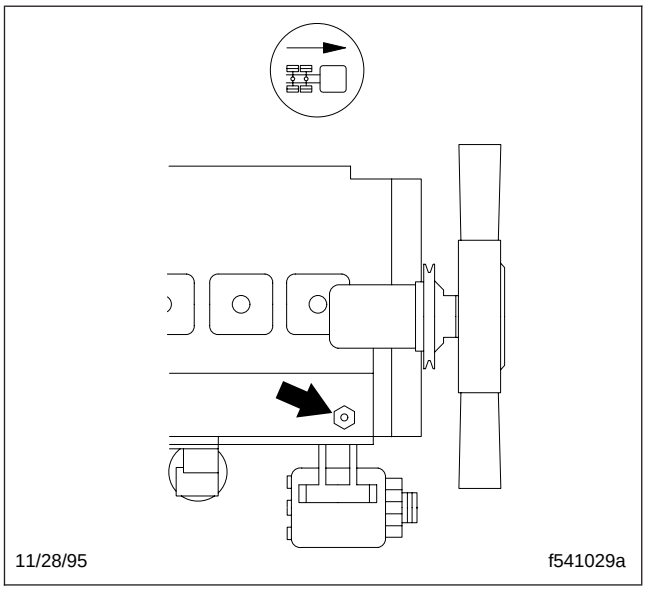


Fig. 2, Coolant Temperature Sensor Location, Cummins B Series Engine

5. Add coolant to the system as needed; then install the cap. Start the engine and check that the high coolant temperature light and buzzer do not stay activated. Check the system to be sure there are no coolant leaks, taking special care to note leakage around the sensor installation.

Troubleshooting Tables

Problem—Warning Light Comes On But the Buzzer Does Not Sound

Possible Cause	Remedy
The buzzer assembly is damaged.	Replace the buzzer assembly.
There is a break in the wiring between the fuse and the buzzer assembly, or between the buzzer assembly and the switch.	Repair or replace the wiring as needed.

Problem—Buzzer Sounds But the Warning Light Does Not Come On

Possible Cause	Remedy
One or more of the warning lights is loose or damaged.	Check each bulb and replace as needed.
There is a break in the wiring between the fuse and the warning lights, or between the warning lights and the switch.	Repair or replace the wiring as needed.

Problem—Buzzer Does Not Sound and Light Does Not Come On When the Systems Are Known to Be Operating Incorrectly

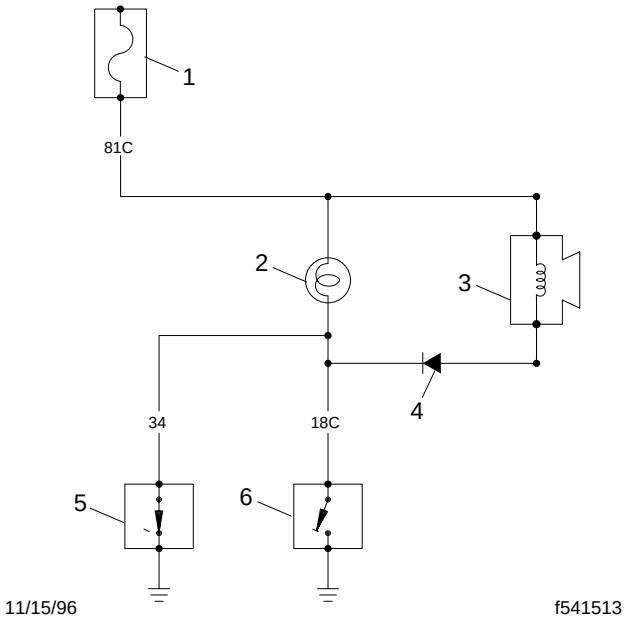
Possible Cause	Remedy
The fuse is damaged.	Replace the fuse.
A switch is damaged.	Replace the damaged switch, as needed.
There is a short or break in the wiring from the fuse to both the buzzer assembly and the warning light.	Repair or replace the wiring as needed.

Problem—Warning Light or Buzzer or Both Stay On When the Systems Are Known to Be Operating Correctly

Possible Cause	Remedy
A switch is damaged.	Replace the damaged switch, as needed.
The circuits are closing to ground due to a short in the wiring from the warning lights or the buzzer assembly to the switches.	Repair or replace the wiring as needed.

Specifications

For a schematic of the Freightliner warning system, see **Fig. 1**.

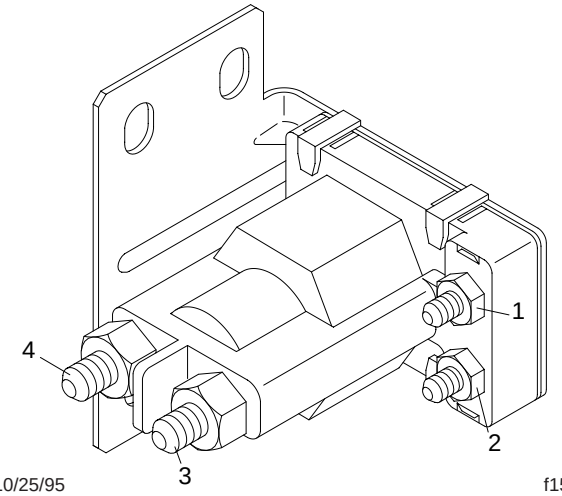


1. 10-Amp Circuit Breaker (ignition-controlled)
2. Oil Pressure/Coolant Temperature Light
3. Warning Buzzer
4. Diode
5. Low Oil Pressure Switch
6. High Coolant Temperature Switch

Fig. 1, Freightliner Warning System Schematic

General Information

All 12-volt starting systems are equipped with a heavy duty starter relay, referred to as a magnetic switch. See **Fig. 1**. The magnetic switch is attached to the lower left-hand firewall. When the ignition switch is held in the extreme clockwise (start) position, the magnetic switch closes, connecting electrical current to the starter solenoid, which engages the starter motor pinion with the engine flywheel ring gear, and then energizes the starter motor.



1. Coil Terminal (to ground)
2. Coil Terminal (to ignition switch)
3. Switch Terminal (to solenoid)
4. Switch Terminal (to starter BAT terminal)

Fig. 1, Magnetic Switch

The magnetic switch consists of a winding, mounted around a hollow cylinder containing a movable core or plunger, with a contact disk that is assembled onto the plunger.

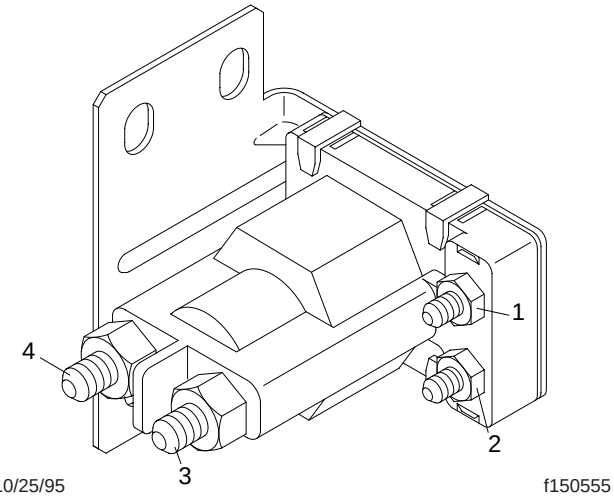
When the winding is energized, plunger movement causes the contact disk to be held tightly against the two main switch terminals; this closes the circuit between these terminals, and activates the starter solenoid. When the winding is de-energized, a return spring causes the plunger to return to its original position, opening the circuit to the starter solenoid.

Before replacing the magnetic switch, or repairing or replacing any of the starting circuits, do the preliminary checks and the magnetic switch circuit test in **Troubleshooting, 300**.

Replacement

The magnetic switch cannot be disassembled. If the switch does not work, replace it.

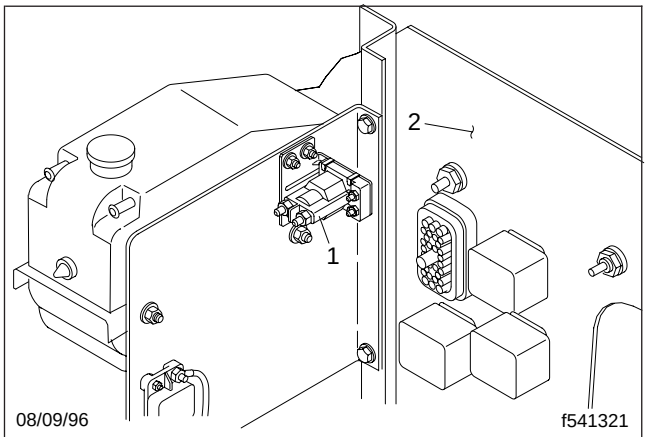
1. Apply the parking brakes, and chock the tires.
2. Disconnect the batteries and tilt the hood.
3. Mark the wires for later reference, then disconnect the wires that are attached to the magnetic switch. See **Fig. 1**.



1. Coil Terminal (to ground)
2. Coil Terminal (to ignition switch)
3. Switch Terminal (to solenoid)
4. Switch Terminal (to starter BAT terminal)

Fig. 1, Magnetic Switch Terminals

4. Remove the magnetic switch from the vehicle. See **Fig. 2**.
   - 4.1 Remove the two mounting screws that hold the magnetic switch to the mounting plate bolted to the bulkhead.
   - 4.2 Remove the two large terminal nuts.
   - 4.3 Remove the magnetic switch.
5. Install the new magnetic switch on the vehicle.



1. Magnetic Switch 2. Bulkhead

Fig. 2, Magnetic Switch

   - 5.1 Position the magnetic switch on the mounting plate and install the mounting screws.
   - 5.2 Tighten the mounting screws 84 lbf·in (940 N·cm).
   - 5.3 Connect the wires to the magnetic switch, using the marks made on removal. Tighten the terminal nuts securely.
6. Spray any exposed terminal connectors with dielectric red enamel. See **Table 1**.

Protectant Material	Approved Brands
Spray-On Application	MMM 1602 IVI–Spray Sealer, Red Electric Grade; order from the PDC
Brush-On Application	Glyptal 1201EW– Low VOC, Red; order at www.glyptal.com or 1-800-GLP-1201

Table 1, Approved Dielectric Red Enamel

7. Connect the batteries and lower the hood.
8. Remove the chocks from the tires.

Preliminary Checks

Before replacing the magnetic switch, or repairing or replacing any of the starting circuits, do these preliminary checks and the "Magnetic Switch Circuit Test."

1. Apply the parking brakes, and chock the tires.
2. Check the condition of the batteries. Follow the battery testing procedure in **Section 54.02**. Be sure the batteries are fully charged.

NOTE: The wiring, switches, and starter motor cannot be checked if the batteries are damaged or discharged.

3. Check the starting motor, ignition switch, and solenoid for damage or wear. Repair or replace the component(s), as needed.

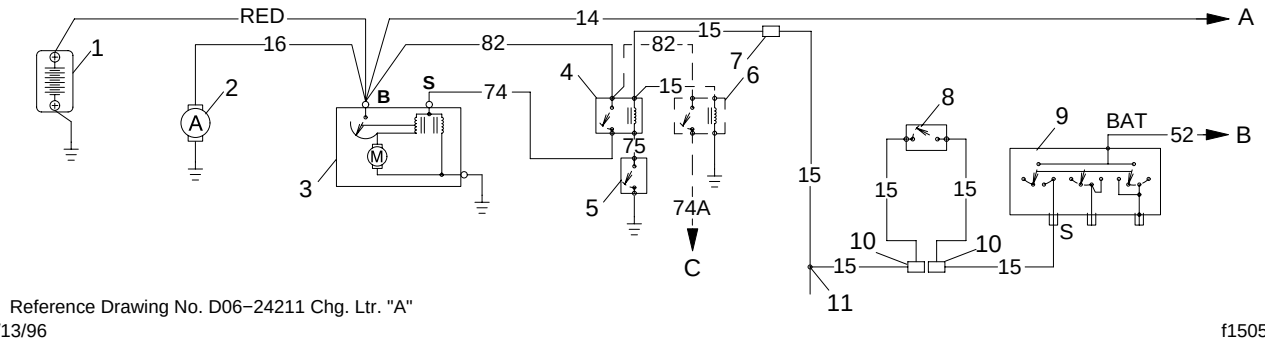
Magnetic Switch Circuit Test

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

1. Apply the parking brakes, and chock the tires. Do the "Preliminary Checks" listed above.
2. Check the wiring and the magnetic switch for wear or damage. See **Fig. 1**.
3. Check the circuit between the magnetic switch and the starter "B" terminal (circuit 82) for correct voltage.
   - 3.1 Disconnect the circuit running from the starter "S" terminal to the magnetic switch (circuit 74).
   - 3.2 Connect a voltmeter to the magnetic switch terminal where the circuit from the starter "B" terminal is connected (circuit 82).
   - 3.3 If the voltmeter reading is 0 volts, 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.
   - 4.1 Connect an ohmmeter between the magnetic switch ground terminal and a known good ground.



Reference Drawing No. D06−24211 Chg. Ltr. "A"
08/13/96

f150589

A. To Power Stud
B. To 15-Amp Circuit Breaker
C. To Fuel Pump Solenoid

1. Battery
2. Alternator
3. Starter
4. Magnetic Switch
5. Neutral Start Switch (automatic transmission only)
6. Fuel Solenoid Relay (Cummins "B" engine only)
7. Bulkhead Connector
8. Starter Interrupt Switch
9. Ignition Keyswitch
10. Main Cab Harness Connector
11. Wire 15 Splice

Fig. 1, Charging Circuit Switch Wiring

Troubleshooting

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.

   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 15) and a known good ground.

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

   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 74) for correct voltage.

   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 74) 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 eleven volts or more, disconnect the voltmeter, and remove the chocks from the tires. If the reading is still less than eleven volts, replace the magnetic switch. For instructions, see **Subject 100**.

Magnetic Switch Contactor Test

The cranking circuit includes the battery, starter solenoid, cranking motor, magnetic switch, and ignition keyswitch.

If there is excessive voltage loss in the cranking circuit, the starter may not engage the flywheel at all, or it may drop out too soon when battery voltage goes down. In this case, check the cranking circuit and starter solenoid for voltage loss. For instructions, see **Section 15.00**.

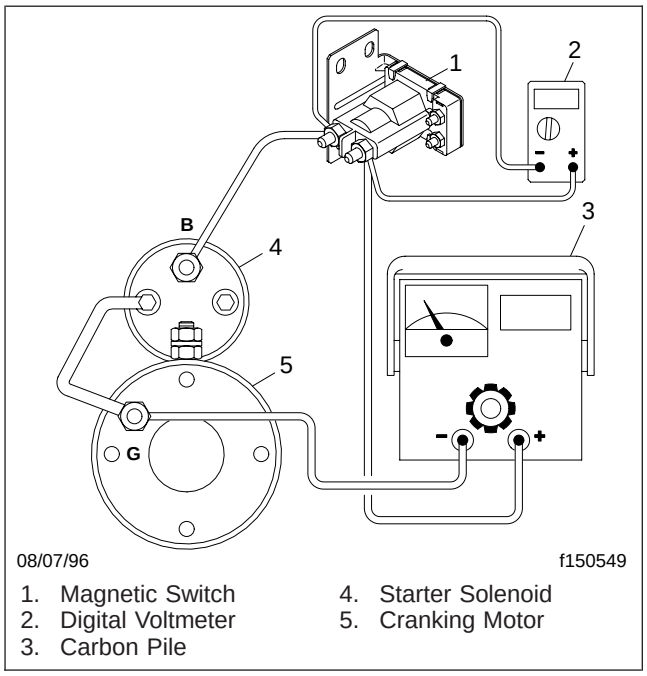
If the magnetic switch closes during the cranking circuit test and the starter wiring test, also check the magnetic switch contactors for voltage loss.

1. Disconnect the lead from the magnetic switch to the "S" (solenoid) terminal on the starter (leave as in "Starter Wiring Test"). See **Section 15.00, Troubleshooting, 300**.
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 Wiring Test"). See **Section 15.00, Troubleshooting, 300**.
3. Connect a digital voltmeter set on the low scale across the two small coil terminals on the magnetic switch. Connect the negative lead to the other large terminal on the magnetic switch. See **Fig. 2**.
4. Start the engine and read the voltage on the voltmeter. It should read 0 volts.
5. Turn on the carbon pile and adjust it to the rated amperage output of the alternator.

   5.1 Now read and record the voltage on the voltmeter. Turn off the carbon pile.

   5.2 If the voltage reads 0.2 volts or less, the magnetic switch contactors are OK.

   If the voltage reads more than 0.2 volts, replace the magnetic switch.



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

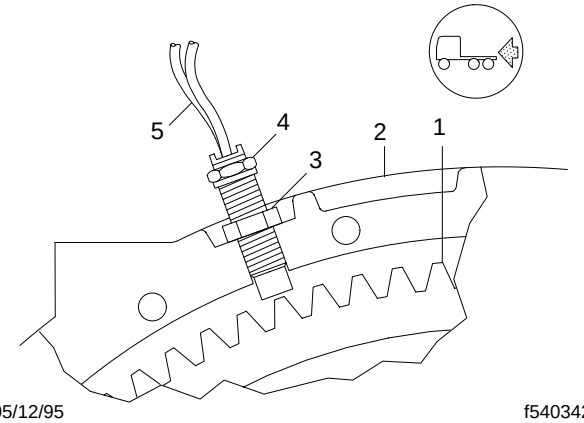
Fig. 2, Magnetic Switch Contactor Test

General Information

The Ametek electronic tachometer consists of a dash-mounted gauge (tachometer head), the necessary electrical wires, and, on non-electronic engines like the Cummins "B," a magnetic sensor mounted on the flywheel housing. On electronic engines like the Caterpillar CFE, the engine speed signal comes directly from the engine ECU.

The tachometer head registers engine speed in revolutions per minute (rpm). As an option, the tachometer can be equipped with a 7-wheel hourmeter that records total hours of engine operation.

The magnetic sensor is mounted with its magnetic end extending through a threaded bore in the flywheel housing. When installed and adjusted correctly, it stops about 0.04 inch (a little over one millimeter) from the teeth of the flywheel ring gear. See **Fig. 1**.



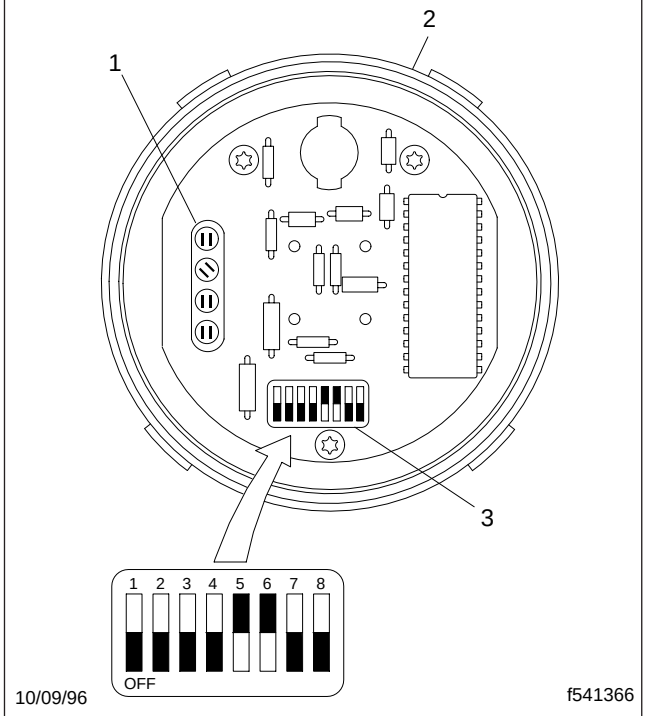
1. Flywheel Ring Gear
2. Flywheel Housing
3. Jam Nut
4. Magnetic Sensor
5. Sensor Wiring

Fig. 1, Tachometer Magnetic Sensor (cutaway view)

When the engine is running, the teeth of the turning flywheel interrupt the sensor's magnetic field, causing the sensor to generate a pulsed signal.

At the back of the tachometer are 8 rocker-type dual in-line pin (DIP) switches. See **Fig. 2**. The tachometer is calibrated by positioning the rocker switches ON or OFF to correspond to the calibration settings determined for the particular type of engine.

Always calibrate a new tachometer head before installing it. For detailed procedures, see **Subject 110**.



When the lower half of the switch is depressed, the switch is OFF. When the upper half of the switch is depressed, the switch is ON.

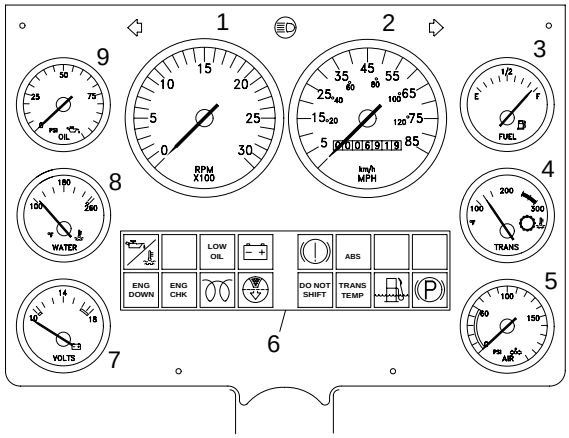
1. Connector
2. Tachometer Head
3. DIP Switch Panel

Fig. 2, Tachometer Head (rear view)

Tachometer Head Removal and Installation

Removal

1. Apply the parking brake, shut down the engine, and chock the tires.
2. Remove the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.



10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster

IMPORTANT: Don't touch the tachometer face or pointer.

3. Remove the tachometer head from the dashboard.
   - 3.1 Remove the tachometer head from the gauge mounting panel by grasping the gauge firmly and pulling it straight out of the mounting panel.
   - 3.2 Remove the pigtail electrical connector from the rear of the tachometer.

Installation

NOTE: Before installing the tachometer head, be sure it is calibrated; see **Subject 110**.

IMPORTANT: Don't touch the tachometer face or pointer.

1. Install the tachometer head.
   - 1.1 Connect the pigtail electrical connector to the tachometer head.
   - 1.2 Grasp the gauge firmly and insert it in the mounting panel.
2. Install the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.
3. Remove the chocks from the tires.

Calibration

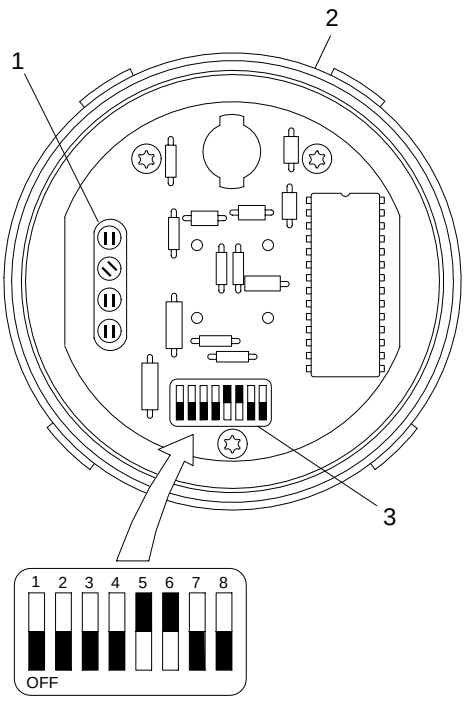
Always calibrate a new tachometer head before installing it.

1. To determine the tachometer calibration setting, see **Table 1**.

Tachometer Calibration Settings										
Engine	Flywheel Teeth	Pulses/ Rev	S1	S2	S3	S4	S5	S6	S7	S8
Caterpillar CFE	—	12	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
Cummins B	103	—	OFF	ON	ON	OFF	OFF	ON	ON	ON

Table 1, Tachometer Calibration Settings

2. Remove the tachometer head from the dash. For detailed instructions, see **Subject 100**.
3. Set each of the eight DIP switches to the correct calibration settings. See **Fig. 1**.



When the lower half of the switch is depressed, the switch is OFF. When the upper half of the switch is depressed, the switch is ON.

1. Connector
2. Tachometer Head
3. DIP Switch Panel

Fig. 1, Tachometer Head Calibration

3.1 Note down the correct setting for each switch, either ON or OFF.

3.2 Using a tool that will not break off, depress the upper part of the rocker to set it to ON; depress the lower part to set it to OFF.

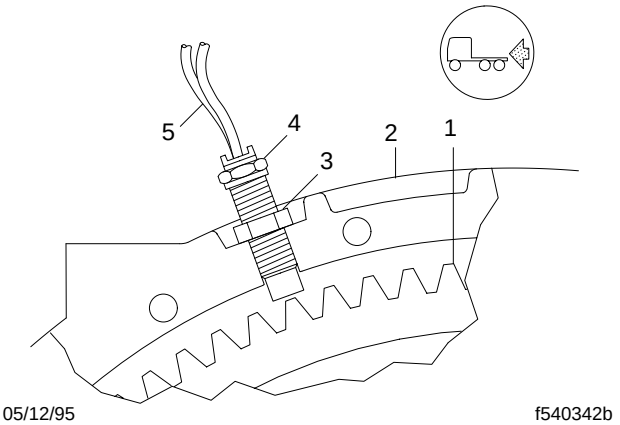
Example: On Caterpillar CFE engines, the number 1 switch rocker is OFF (the lower part is depressed), the number 2 switch is OFF, number 3 is OFF, 4 is OFF, 5 is ON (the upper part is depressed), 6 is ON, 7 is OFF, and 8 is OFF, as shown in **Fig. 1**.

4. Install the tachometer head. For detailed instructions, see **Subject 100**.

NOTE: For other engines with a flywheel-mounted tachometer sensor, find the number of teeth on the flywheel and look up the correct calibration settings in the tables in **Specifications, 400**.

Replacement and Adjustment

1. Park the vehicle on a level surface. Apply the parking brakes, shut down the engine, and chock the tires.
2. Remove the magnetic sensor. See **Fig. 1**.



1. Flywheel Ring Gear
2. Flywheel Housing
3. Jam Nut
4. Magnetic Sensor
5. Sensor Wiring

Fig. 1, Tachometer Magnetic Sensor (cutaway view)

   2.1 Disconnect the electrical connector.

   2.2 Loosen the magnetic sensor jam nut. Turn the magnetic sensor until it comes out of the flywheel housing.

3. If installing a new sensor, leave the plastic shim on the end of the sensor. This shim serves as a gap gauge.
4. Insert the sensor into the flywheel and make sure it is properly adjusted.

   4.1 Back off the jam nut to the outboard end of the sensor.

   4.2 Turn the sensor by hand into the flywheel housing until it bottoms out against the flywheel teeth.

   4.3 If no plastic shim is installed on the sensor, back the sensor out one-half turn.

   NOTE: If the plastic shim is installed, do not back out the sensor. The gap has already been set by the plastic shim.

IMPORTANT: Maintain the correct sensor adjustment. Otherwise, the tachometer will not read correctly.

5. With the gap correctly adjusted, tighten the sensor jam nut and attach the electrical connector.

   5.1 Hold the sensor in place to keep it from turning. Tighten the jam nut 18 lbf·ft (25 N·m).

   5.2 Attach the electrical connector and make sure it is securely locked into place.

6. Start the engine and check the tachometer for correct operation. With the engine at idle, check that the tachometer shows a reading. Increase engine speed and check that the tachometer reading increases accordingly. If necessary, readjust the sensor. If there is no tachometer reading, see **Troubleshooting, 300**.
7. Remove the chocks from the tires.

Troubleshooting Procedures

Tachometer malfunctions are usually one of two types: either the tachometer does not operate at all, or the tachometer readings are incorrect.

TACHOMETER IS INACCURATE

If the tachometer is inaccurate, recalibrate the tachometer head using the procedure in **Subject 110**.

On vehicles with a magnetic sensor, check its adjustment. Make sure the gap between the magnetic sensor and tone wheel is set correctly, using the procedure in **Subject 120**.

NOTE: On electronic engines without an engine speed sensor installed on the flywheel, check the programming of the engine ECU. See the engine manufacturer's service literature for detailed instructions.

TACHOMETER DOES NOT OPERATE

There are three malfunctions that would cause a totally inoperative tachometer:

- A faulty magnetic sensor (if installed),
- Open or shorted circuits in the wiring,
- A faulty tachometer head.

To isolate the problem, follow the troubleshooting procedures in the order given.

1. Check the output voltage of the magnetic sensor, if installed. Measure the resistance of the sensor. If no magnetic sensor is installed, skip both this step and the next step.

   1.1 Disconnect the electrical connector on the magnetic sensor. Make sure that both halves of the connection are free of corrosion and moisture. Clean and repair as needed.

   1.2 Using a digital voltmeter set on the AC scale, connect the leads of the voltmeter to the pins on the sensor side of the connector.

   1.3 Run the engine at idle. Check the voltage output from the sensor, and then shut down the engine.

   1.4 If the voltage is less than one volt, check sensor adjustment and adjust or replace it as necessary.

   If the voltage is at least one volt, go to the next step.

2. Check for an open or shorted magnetic sensor. Measure the resistance of the sensor.

   2.1 Connect the leads of an ohmmeter to the pins on the magnetic sensor side of the connector.

   2.2 If the resistance is below 360 ohms or above 440, replace the sensor; see **Subject 120**.

   If the resistance is from 360 to 440 ohms, go to the next step.

3. Check that the magnetic sensor is not shorted to ground. Measure the sensor's resistance to ground.

   3.1 Connect the red ohmmeter lead to a pin on the magnetic sensor. Touch the black ohmmeter lead to a good ground source.

   3.2 If the resistance reads less than infinite ohms, the magnetic sensor is grounded and must be replaced; see **Subject 120**.

   If the resistance reads infinite ohms, reconnect the magnetic sensor connector and go to the next step.

4. Check the wiring between the magnetic sensor and the tachometer head for an open circuit.

   4.1 Remove the tachometer head from the dash and disconnect the wiring harness from the tachometer head, leaving the sensor connected. For detailed removal instructions, see **Subject 100**.

   4.2 Connect the ohmmeter leads to the tachometer connector, at terminals 2 (circuit 162) and 4 (circuit 163). See **Fig. 1**.

   4.3 If the resistance is significantly above 440 ohms, there are probably bad connections in the wiring between the tachometer head and the magnetic sensor. Check all connections and make any necessary repairs.

   If the resistance is below 360 ohms, there is a short between wires 162 and 163.

Troubleshooting

Repair or replace the damaged wiring. Then, install the tachometer head; see **Subject 100** for detailed instructions.

If the resistance is from 360 to 440 ohms, go to the next step.

5. Check the wiring between the magnetic sensor and the tachometer head for a short circuit to ground.

   5.1 Remove the tachometer head from the dash panel. Disconnect the four–pin connector from the tachometer.

   5.2 Connect the positive lead from an ohmmeter to terminal 2 (circuit 162), and connect the negative lead to a good ground source. See **Fig. 1**. If the ohmmeter reads low ohms, repair the short to ground.

   If the ohmmeter reads infinite ohms, go to the next substep.

   5.3 Connect the positive lead from an ohmmeter to terminal 4 (circuit 163), and connect the negative lead to a good ground source. If the ohmmeter reads low ohms, repair the short short to ground.

   If the ohmmeter reads infinite ohms, go to the next step.

6. Check for open circuits in the ground wiring between the tachometer head and its ground.

   6.1 Connect the red ohmmeter lead to the tachometer harness connector terminal 3. Touch the black ohmmeter lead to a good ground source.

   6.2 If the resistance measured is more than 3 ohms, repair the open circuit in the wire.

   If the resistance reading is 3 ohms or less, go to the next step.

7. Check for a faulty tachometer head. Check the battery voltage at the tachometer head connector.

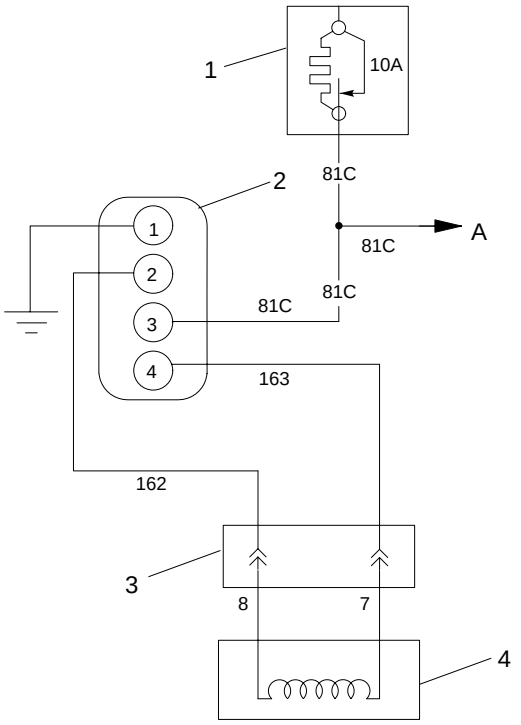
   7.1 Using a digital voltmeter set to the DC scale, connect the positive lead to terminal 3 (circuit 81C). Connect the negative lead to terminal 1 (GND). See **Fig. 1**.

   7.2 Turn the ignition keyswitch on, and check the voltage reading. It should read at least 9 volts.

   7.3 If the voltage reading is not at least 9 volts, check the voltage at the circuit breaker. The voltage there should be at least 9 volts.

   7.4 Check the wiring between the circuit breaker and the tachometer head for damage. Repair any damaged wiring and then install the tachometer head; see **Subject 100**.

   7.5 If the voltage is now at least 9 volts DC, replace the tachometer head.



A. To other gauges
1. Power Distribution Module
2. Tachometer Head
3. Bulkhead Connector
4. Magnetic Sensor (if installed)

Fig. 1, Tachometer Wiring Schematic

Troubleshooting Tables

Problem—Less Than One Volt Reading from Magnetic Sensor

Possible Cause	Remedy
The magnetic sensor gap is incorrectly adjusted.	Adjust the magnetic sensor.
The magnetic sensor is damaged.	Replace the magnetic sensor.

Problem—Tachometer Head Will Not Register

Possible Cause	Remedy
The magnetic sensor gap is incorrectly adjusted.	Adjust the magnetic sensor.
The magnetic sensor is damaged.	Replace the magnetic sensor.
Loose or corroded terminals, broken terminal connections, broken wires, shorting, grounded, or frayed wires are causing an incomplete circuit.	Replace the damaged wiring component(s) as necessary.
The tachometer head is damaged internally.	Replace the tachometer head only after checking all other possible causes.

Problem—Inaccurate or Erratic Tachometer Readings

Possible Cause	Remedy
The magnetic sensor gap is incorrectly adjusted.	Adjust the magnetic sensor.
The tachometer head is incorrectly calibrated.	Calibrate the tachometer head.
Loose electrical connections or intermittent open or short circuits in the tachometer wiring.	Check all the wiring in the tachometer system. Clean all connections.

Ametek Tachometer Calibration Settings, 85 to 116								
Flywheel Teeth	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
85	OFF	ON	OFF	ON	OFF	ON	OFF	ON
86	OFF	ON	OFF	ON	OFF	ON	ON	OFF
87	OFF	ON	OFF	ON	OFF	ON	ON	ON
88	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
89	OFF	ON	OFF	ON	ON	OFF	OFF	ON
90	OFF	ON	OFF	ON	ON	OFF	ON	OFF
91	OFF	ON	OFF	ON	ON	OFF	ON	ON
92	OFF	ON	OFF	ON	ON	ON	OFF	OFF
93	OFF	ON	OFF	ON	ON	ON	OFF	ON
94	OFF	ON	OFF	ON	ON	ON	ON	OFF
95	OFF	ON	OFF	ON	ON	ON	ON	ON
96	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
97	OFF	ON	ON	OFF	OFF	OFF	OFF	ON
98	OFF	ON	ON	OFF	OFF	OFF	ON	OFF
99	OFF	ON	ON	OFF	OFF	OFF	ON	ON
100	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
101	OFF	ON	ON	OFF	OFF	ON	OFF	ON
102	OFF	ON	ON	OFF	OFF	ON	ON	OFF
103	OFF	ON	ON	OFF	OFF	ON	ON	ON
104	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
105	OFF	ON	ON	OFF	ON	OFF	OFF	ON
106	OFF	ON	ON	OFF	ON	OFF	ON	OFF
107	OFF	ON	ON	OFF	ON	OFF	ON	ON
108	OFF	ON	ON	OFF	ON	ON	OFF	OFF
109	OFF	ON	ON	OFF	ON	ON	OFF	ON
110	OFF	ON	ON	OFF	ON	ON	ON	OFF
111	OFF	ON	ON	OFF	ON	ON	ON	ON
112	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
113	OFF	ON	ON	ON	OFF	OFF	OFF	ON
114	OFF	ON	ON	ON	OFF	OFF	ON	OFF
115	OFF	ON	ON	ON	OFF	OFF	ON	ON
116	OFF	ON	ON	ON	OFF	ON	OFF	OFF

Table 1, Ametek Tachometer Calibration Settings, 85 to 116

Specifications

Ametek Tachometer Calibration Settings, 117 to 149								
Flywheel Teeth	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
117	OFF	ON	ON	ON	OFF	ON	OFF	ON
118	OFF	ON	ON	ON	OFF	ON	ON	OFF
119	OFF	ON	ON	ON	OFF	ON	ON	ON
120	OFF	ON	ON	ON	ON	OFF	OFF	OFF
121	OFF	ON	ON	ON	ON	OFF	OFF	ON
122	OFF	ON	ON	ON	ON	OFF	ON	OFF
123	OFF	ON	ON	ON	ON	OFF	ON	ON
124	OFF	ON	ON	ON	ON	ON	OFF	OFF
125	OFF	ON	ON	ON	ON	ON	OFF	ON
126	OFF	ON	ON	ON	ON	ON	ON	OFF
127	OFF	ON	ON	ON	ON	ON	ON	ON
128	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
129	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON
130	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
131	ON	OFF	OFF	OFF	OFF	OFF	ON	ON
132	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF
133	ON	OFF	OFF	OFF	OFF	ON	OFF	ON
134	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
135	ON	OFF	OFF	OFF	OFF	ON	ON	ON
136	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
137	ON	OFF	OFF	OFF	ON	OFF	OFF	ON
138	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
139	ON	OFF	OFF	OFF	ON	OFF	ON	ON
140	ON	OFF	OFF	OFF	ON	ON	OFF	OFF
141	ON	OFF	OFF	OFF	ON	ON	OFF	ON
142	ON	OFF	OFF	OFF	ON	ON	ON	OFF
143	ON	OFF	OFF	OFF	ON	ON	ON	ON
144	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
145	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
146	ON	OFF	OFF	ON	OFF	OFF	ON	OFF
147	ON	OFF	OFF	ON	OFF	OFF	ON	ON
148	ON	OFF	OFF	ON	OFF	ON	OFF	OFF

Ametek Tachometer Calibration Settings, 117 to 149								
Flywheel Teeth	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
149	ON	OFF	OFF	ON	OFF	ON	OFF	ON

Table 2, Ametek Tachometer Calibration Settings, 117 to 149

Ametek Tachometer Calibration Settings, 150 to 170								
Flywheel Teeth	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
150	ON	OFF	OFF	ON	OFF	ON	ON	OFF
151	ON	OFF	OFF	ON	OFF	ON	ON	ON
152	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
153	ON	OFF	OFF	ON	ON	OFF	OFF	ON
154	ON	OFF	OFF	ON	ON	OFF	ON	OFF
155	ON	OFF	OFF	ON	ON	OFF	ON	ON
156	ON	OFF	OFF	ON	ON	ON	OFF	OFF
157	ON	OFF	OFF	ON	ON	ON	OFF	ON
158	ON	OFF	OFF	ON	ON	ON	ON	OFF
159	ON	OFF	OFF	ON	ON	ON	ON	ON
160	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
161	ON	OFF	ON	OFF	OFF	OFF	OFF	ON
162	ON	OFF	ON	OFF	OFF	OFF	ON	OFF
163	ON	OFF	ON	OFF	OFF	OFF	ON	ON
164	ON	OFF	ON	OFF	OFF	ON	OFF	OFF
165	ON	OFF	ON	OFF	OFF	ON	OFF	ON
166	ON	OFF	ON	OFF	OFF	ON	ON	OFF
167	ON	OFF	ON	OFF	OFF	ON	ON	ON
168	ON	OFF	ON	OFF	ON	OFF	OFF	OFF
169	ON	OFF	ON	OFF	ON	OFF	OFF	ON
170	ON	OFF	ON	OFF	ON	OFF	ON	OFF

Table 3, Ametek Tachometer Calibration Settings, 150 to 170

General Information

The Ametek electronic speedometer consists of a dash-mounted gauge (speedometer head), a transmission-mounted magnetic sensor, and the necessary electrical wiring (two sensor wires on mechanical engines, four sensor wires on electronic engines).

A vehicle built for use in the U.S.A. has a speedometer head that registers vehicle speed in miles per hour (mph) on its outer (major) scale and in kilometers per hour (km/h) on its inner (minor) scale, and records total distance traveled in miles on a 7-wheel odometer. A speedometer head for a vehicle built for use in Canada and some other countries registers vehicle speed in km/h on the outer scale (and mph on the inner scale), and has a 7-wheel odometer that records distance in kilometers.

NOTE: Some export vehicles have only a km/h scale and an odometer that reads in km, without the inner mph scale.

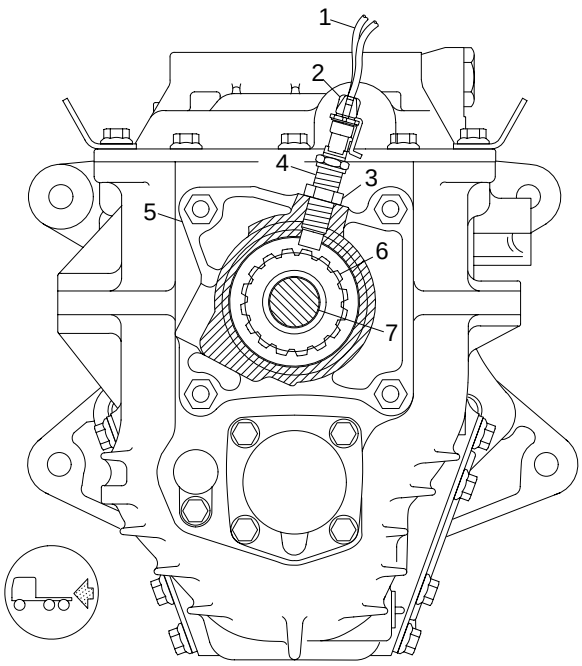
The magnetic sensor is mounted with its magnetic end extending through a threaded bore in the transmission bearing cover. When installed and adjusted correctly, it stops about 0.04 inches (a little over one millimeter) from the teeth of a standard 16-tooth tone wheel located under the cover, on the inboard end of the transmission output shaft. See **Fig. 1**.

When the vehicle is moving, the teeth of the tone wheel, as they turn, interrupt the sensor's magnetic field. When this happens, the sensor generates a pulsed signal.

At the back of the speedometer head are 10 rocker-type DIP switches. See **Fig. 2**. The speedometer is calibrated by positioning the rocker switches ON or OFF to correspond to the calibration settings determined for the specific combination of the number of teeth on the tone wheel, the axle reduction ratio, and the tire size (tire revolutions per mile). For each possible combination, there is a correct setting for each of the ten switches.

Always calibrate a new speedometer head before installing it. On vehicles with mechanical engines, like the Cummins "B," calibrate the speedometer head whenever different tires are installed on the vehicle. For detailed instructions, see **Subject 110**.

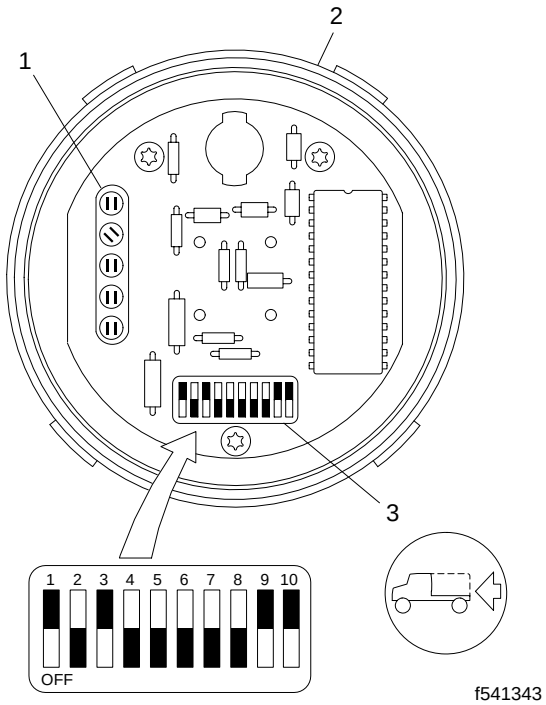
Most vehicles with electronic engines, like the Caterpillar CFE, report the speed data at a steady rate in pulses per mile (pul/mile). On these vehicles, calibrate the engine ECU, not the speedometer, when different tires are installed on the vehicle. See the engine manufacturer's service literature for detailed instructions.



1. Sensor Wiring
2. Electrical Connector
3. Jam Nut
4. Magnetic Sensor
5. Bearing Cover
6. Tone Wheel
7. Output Shaft

Fig. 1, Typical Transmission Magnetic Sensor Installation (cutaway view)

General Information



When the lower half of the switch is depressed, the switch is OFF. When the upper half of the switch is depressed, the switch is ON.

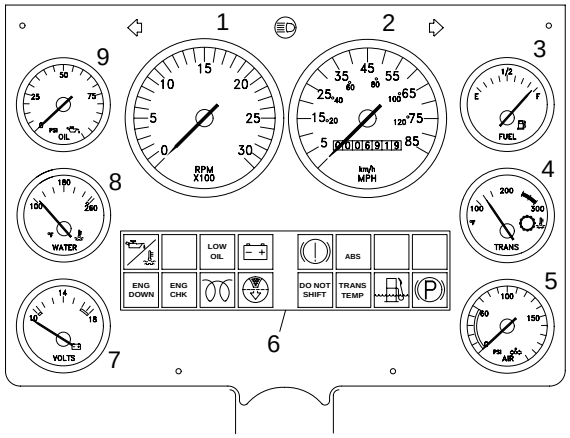
1. Electrical Connector
2. Speedometer Head
3. DIP Switch Panel

Fig. 2, Speedometer Head (rear view)

Speedometer Head Removal and Installation

Removal

1. Apply the parking brake, shut down the engine, and chock the tires.
2. Remove the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.



10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster

3. Remove the speedometer head from the dashboard.
   - 3.1 Remove the speedometer head from the gauge mounting panel by grasping the gauge firmly and pulling it straight out of the mounting panel.
   - 3.2 Remove the pigtail electrical connector from the rear of the speedometer.

Installation

NOTE: Before installing the speedometer head, be sure it is calibrated; see **Subject 110**.

IMPORTANT: Don't touch the speedometer face or pointer.

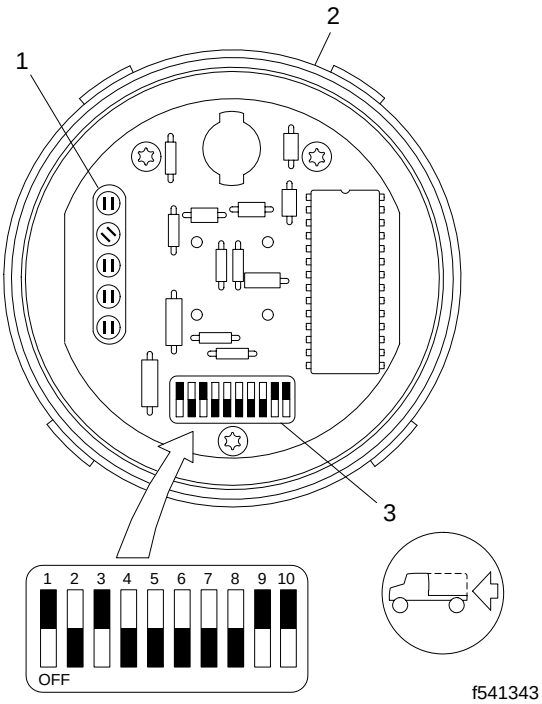
1. Install the speedometer head.
   - 1.1 Connect the pigtail electrical connector to the speedometer head.
   - 1.2 Grasp the gauge firmly and insert it in the mounting panel.
2. Install the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.
3. Remove the chocks from the tires.

Calibration

Always calibrate a new speedometer head before installing it.

IMPORTANT: Use this procedure only for calibrating speedometers on mechanical engines, like the Cummins "B." On electronic engines, like the Caterpillar CFE, the engine ECU sends accurate speed data, provided it has been calibrated according to the engine manufacturer's instructions. The speedometer calibration setting on these engines is always the same: ON, OFF, ON, OFF, OFF, OFF, OFF, OFF, ON, ON. See **Fig. 1**.

1. Determine the pulses per mile (PPM).



When the lower half of the switch is depressed, the switch is OFF. When the upper half of the switch is depressed, the switch is ON.

1. Connector
2. Speedometer Head
3. DIP Switch Panel

Fig. 1, DIP Switch Location

1.1 Look on the sidewall of the vehicle's rear tires to find their size, manufacturer, and tread design. Contact the tire dealer or manufacturer to get the revolutions per mile (rev/mi) for those tires.

1.2 Find the rear axle ratio (RAR) on the vehicle specification decal, or on the identification plate attached to the axle housing.

1.3 Determine the number of teeth (T) on the tone wheel.

NOTE: The number of tone wheel teeth is normally 16.

1.4 Now, calculate the pulses per mile (PPM) using this formula:

PPM = Rev/mi x RAR x T

Explanation of abbreviations:

- Rev/mi = Tire revolutions per mile
- RAR = rear axle ratio
- T = number of tone wheel teeth

2. Determine the calibration settings for the speedometer.

2.1 Divide the PPM by 120 and round it off to the nearest whole number.

2.2 Find this value in the "PPM/120" column of the applicable table in **Specifications, 400**.

2.3 Read across to find the corresponding calibration settings for each of the ten DIP switches.

Example: For a vehicles with a rear axle ratio of 4.11 and tires having 456 revolutions per mile, the calculations would be as follows:

456 x 4.11 x 16 = 29886.56 PPM

32288.16 ÷ 120 = 249.888 (rounded off, this becomes 250)

Look up "250" in the PPM/120 column in **Specifications, 400**. Read off the settings: ON, OFF, ON, OFF, OFF, OFF, OFF, OFF, ON, ON.

3. Remove the speedometer head from the dash. For detailed instructions, see **Subject 100**.

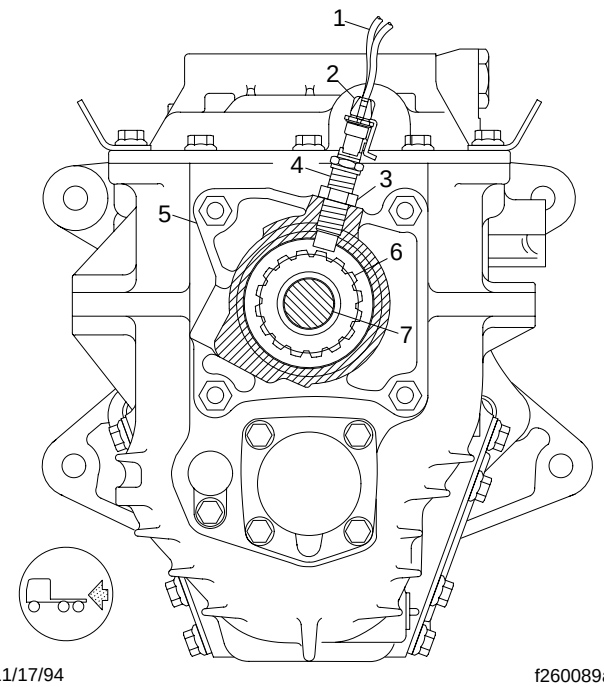
Speedometer Head Calibration

4. Set each of the ten DIP switches to the correct calibration settings. See **Fig. 1**.
   - 4.1 Note the correct setting for each switch, either ON or OFF.
   - 4.2 Using a tool that will not break off, depress the upper part of the rocker to set it to ON; depress the lower part to set it to OFF.
5. Install the speedometer head. For detailed instructions, see **Subject 100**.

Magnetic Sensor Replacement and Adjustment

Replacement and Adjustment

1. Park the vehicle on a level surface. Apply the parking brakes, shut down the engine, and chock the tires.
2. Remove the magnetic sensor. See **Fig. 1**.



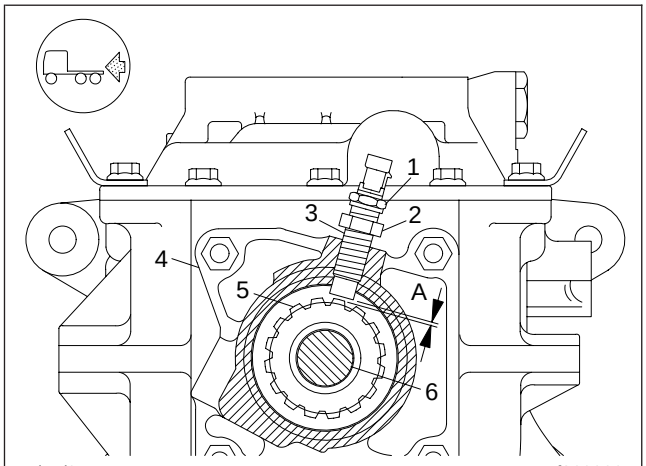
1. Sensor Wiring
2. Electrical Connector
3. Jam Nut
4. Magnetic Sensor
5. Bearing Cover
6. Tone Wheel
7. Output Shaft

Fig. 1, Speedometer Magnetic Sensor

2.1 Disconnect the electrical connector.

2.2 Loosen the magnetic sensor jam nut. Turn the magnetic sensor until it comes out of the transmission bearing cover.

3. If installing a new sensor, leave the plastic shim on the end of the sensor. This shim serves as a gap gauge.
4. Insert the sensor into the transmission and make sure it is properly adjusted. See **Fig. 2**.



To set the gap, back out the sensor one-half turn.

A. Adjust gap to 0.04" (1 mm).

1. Outboard End of Sensor
2. Jam Nut
3. Magnetic Sensor
4. Bearing Cover
5. Tone Wheel
6. Output Shaft

Fig. 2, Adjusting the Gap

4.1 Back off the jam nut to the outboard end of the sensor.

4.2 Turn the sensor by hand into the transmission bearing cover until it bottoms out inside the transmission.

4.3 If no plastic shim is installed on the sensor, back the sensor out one-half turn.

NOTE: If the plastic shim is installed, do not back out the sensor. The gap has already been set by the plastic shim.

IMPORTANT: Maintain the correct sensor adjustment. Otherwise, the speedometer will not read correctly.

5. With the gap correctly adjusted, tighten the sensor jam nut and attach the electrical connector.

5.1 Hold the sensor in place to keep it from turning. Tighten the jam nut 18 lbf·ft (25 N·m).

5.2 Attach the electrical connector and make sure it is securely locked into place.

6. Test drive the vehicle and check that the speedometer is operating. If necessary, readjust the

Magnetic Sensor Replacement and Adjustment

sensor. If there is no speedometer reading, see **Troubleshooting, 300**.

Troubleshooting Procedures

Speedometer malfunctions are usually one of two types: either the speedometer does not operate at all, or the speedometer/odometer readings are incorrect.

SPEEDOMETER IS INACCURATE

If the speedometer is suspected of being inaccurate, test the degree of inaccuracy using a commercial service that specializes in such tests. If a commercial service is not available, drive the vehicle over a measured mile.

1. One cause of inaccuracy is a new speedometer head or new tires. In either case, recalibrate the speedometer head, using the procedure in **Subject 110**.
2. Another cause of inaccuracy is an incorrect magnetic sensor adjustment. Make sure the gap between the magnetic sensor and tone wheel is set correctly, using the procedure in **Subject 120**.

SPEEDOMETER DOES NOT OPERATE

There are three malfunctions that would cause a totally inoperative speedometer:

- A faulty magnetic sensor,
- Open or shorted circuits in the wiring,
- A faulty speedometer head.

To isolate the problem, follow the troubleshooting procedures in the order given.

1. Check for an open or shorted magnetic sensor. Measure the resistance of the sensor.

   1.1 Disconnect the electrical connector on the magnetic sensor. Make sure that both halves of the connection are free of corrosion and moisture. Clean and repair as needed.

   1.2 Connect the leads of an ohmmeter to the pins on the magnetic sensor side of the connector.

   1.3 If the resistance is below 788 ohms or above 964, replace the sensor; see **Subject 120**.

   If the resistance is from 788 to 964 ohms, go to the next step.
2. Check that the magnetic sensor is not shorted to ground. Measure the sensor's resistance to ground.

   2.1 Connect the red ohmmeter lead to a pin on the magnetic sensor. Touch the black ohmmeter lead to a good ground source.

   2.2 If the resistance reads less than infinite ohms, the magnetic sensor is grounded and must be replaced; see **Subject 120**.

   If the resistance reads infinite ohms, reconnect the magnetic sensor connector and go to the next step.
3. Check the wiring between the magnetic sensor and the speedometer head for an open circuit.

   3.1 Remove the speedometer head from the dash and disconnect the wiring harness from the speedometer head; see **Subject 100**.

   3.2 Connect the ohmmeter leads to the speedometer connector, at terminals 2 (circuit 117) and 4 (circuit 118). See **Fig. 1**.

   3.3 If the resistance is above 964 ohms, there is resistance in the wiring between the speedometer head and the magnetic sensor.

   If the resistance is below 788 ohms, there is a short between wires 117 and 118. Repair or replace the damaged wiring. Then, install the speedometer head; see **Subject 100** for detailed instructions.

   If the resistance is from 788 to 964 ohms, go to the next step.
4. Check the wiring between the magnetic sensor and the speedometer head for a short circuit to ground.

   4.1 Remove the speedometer head from the dash panel. Disconnect the five–pin connector from the speedometer.

   4.2 Connect the positive lead from an ohmmeter to terminal 2 (circuit 117), and connect the negative lead to a good ground

Troubleshooting

source. See **Fig. 1**. If the ohmmeter reads low ohms, repair the short to ground.

If the ohmmeter reads infinite ohms, go to the next substep.

4.3 Connect the positive lead from an ohmmeter to terminal 4 (circuit 118), and connect the negative lead to a good ground source. If the ohmmeter reads low ohms, repair the short to ground.

If the ohmmeter reads infinite ohms, go to the next substep.

5. Check for open circuits in the ground wiring between the speedometer head and its ground.

5.1 Connect the red ohmmeter lead to the speedometer harness connector terminal 3. Touch the black ohmmeter lead to a good ground source.

5.2 If the resistance reads more than 3 ohms, repair the open circuit in the wire.

If the resistance reads 3 ohms or less, go to the next step.

6. Check for a faulty speedometer head. Check the battery voltage at the speedometer head connector.

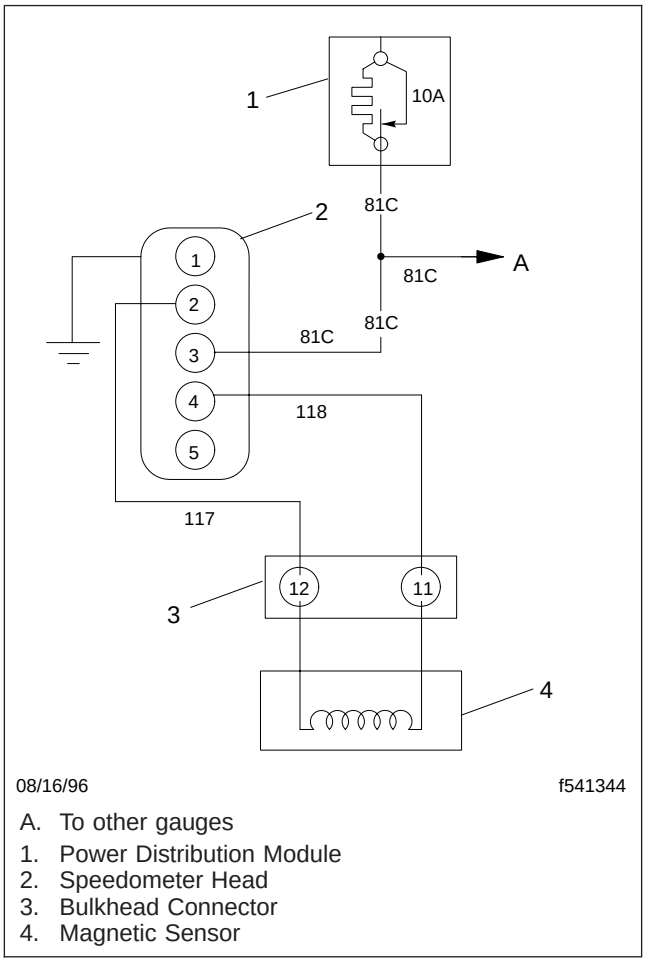
6.1 Using a digital voltmeter set to the DC scale, connect the positive lead to terminal 3 (circuit 81C). Connect the negative lead to terminal 1 (GND). See **Fig. 1**.

6.2 Turn the ignition keyswitch on, and check the voltage reading. It should read between 11 to 13 volts.

6.3 If the voltage reading is not between 11 and 13 volts, check the voltage at the circuit breaker. The voltage there should be 11 to 13 volts ±1 volt.

6.4 Check the wiring between the circuit breaker and the speedometer head for damage. Repair any damaged wiring and then install the speedometer head; see **Subject 100**.

6.5 If the voltage is now between 11 and 13 volts DC, replace the speedometer head.



A. To other gauges
1. Power Distribution Module
2. Speedometer Head
3. Bulkhead Connector
4. Magnetic Sensor

Fig. 1, Speedometer Wiring Schematic

Troubleshooting Tables

Problem—Speedometer Head Will Not Register

Possible Cause	Remedy
The magnetic sensor gap is incorrectly adjusted.	Adjust the magnetic sensor.
The magnetic sensor is damaged.	Replace the magnetic sensor.
Loose or corroded terminals, broken terminal connections, broken wires, shorting, grounded, or frayed wires are causing an incomplete circuit.	Replace the damaged wiring component(s) as necessary.
The speedometer head is damaged internally.	Replace the speedometer head only after checking all other possible causes.

Problem—Inaccurate or Erratic Speedometer Readings

Possible Cause	Remedy
The magnetic sensor gap is incorrectly adjusted.	Adjust the magnetic sensor.
The speedometer head is incorrectly calibrated.	Calibrate the speedometer head.
Loose electrical connections or intermittent open or short circuits in the speedometer wiring.	Check all the wiring in the speedometer system. Tighten all connections.

Specifications

Ametek Speedometer Calibration Settings, 58 to 92										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
58	ON	OFF	ON	OFF	OFF	OFF	ON	ON	ON	ON
59	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	ON	ON
60	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON
61	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON
62	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON
63	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON
64	ON	ON	ON	ON	ON	ON	OFF	ON	ON	ON
65	OFF	ON	ON	ON	ON	ON	OFF	ON	ON	ON
66	ON	OFF	ON	ON	ON	ON	OFF	ON	ON	ON
67	OFF	OFF	ON	ON	ON	ON	OFF	ON	ON	ON
68	ON	ON	OFF	ON	ON	ON	OFF	ON	ON	ON
69	OFF	ON	OFF	ON	ON	ON	OFF	ON	ON	ON
70	ON	OFF	OFF	ON	ON	ON	OFF	ON	ON	ON
71	OFF	OFF	OFF	ON	ON	ON	OFF	ON	ON	ON
72	ON	ON	ON	OFF	ON	ON	OFF	ON	ON	ON
73	OFF	ON	ON	OFF	ON	ON	OFF	ON	ON	ON
74	ON	OFF	ON	OFF	ON	ON	OFF	ON	ON	ON
75	OFF	OFF	ON	OFF	ON	ON	OFF	ON	ON	ON
76	ON	ON	OFF	OFF	ON	ON	OFF	ON	ON	ON
77	OFF	ON	OFF	OFF	ON	ON	OFF	ON	ON	ON
78	ON	OFF	OFF	OFF	ON	ON	OFF	ON	ON	ON
79	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	ON	ON
80	ON	ON	ON	ON	OFF	ON	OFF	ON	ON	ON
81	OFF	ON	ON	ON	OFF	ON	OFF	ON	ON	ON
82	ON	OFF	ON	ON	OFF	ON	OFF	ON	ON	ON
83	OFF	OFF	ON	ON	OFF	ON	OFF	ON	ON	ON
84	ON	ON	OFF	ON	OFF	ON	OFF	ON	ON	ON
85	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	ON	ON
86	ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON	ON
87	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	ON	ON
88	ON	ON	ON	OFF	OFF	ON	OFF	ON	ON	ON
89	OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON	ON
90	ON	OFF	ON	OFF	OFF	ON	OFF	ON	ON	ON
91	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	ON	ON
92	ON	ON	OFF	OFF	OFF	ON	OFF	ON	ON	ON

Table 1, Ametek Speedometer Calibration Settings, 58 to 92

Specifications

Ametek Speedometer Calibration Settings, 93 to 125										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
93	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	ON	ON
94	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	ON
95	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	ON
96	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	ON
97	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON	ON
98	ON	OFF	ON	ON	ON	OFF	OFF	ON	ON	ON
99	OFF	OFF	ON	ON	ON	OFF	OFF	ON	ON	ON
100	ON	ON	OFF	ON	ON	OFF	OFF	ON	ON	ON
101	OFF	ON	OFF	ON	ON	OFF	OFF	ON	ON	ON
102	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	ON
103	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON	ON
104	ON	ON	ON	OFF	ON	OFF	OFF	ON	ON	ON
105	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON	ON
106	ON	OFF	ON	OFF	ON	OFF	OFF	ON	ON	ON
107	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	ON	ON
108	ON	ON	OFF	OFF	ON	OFF	OFF	ON	ON	ON
109	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	ON	ON
110	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	ON
111	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	ON
112	ON	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON
113	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON
114	ON	OFF	ON	ON	OFF	OFF	OFF	ON	ON	ON
115	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	ON	ON
116	ON	ON	OFF	ON	OFF	OFF	OFF	ON	ON	ON
117	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	ON	ON
118	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	ON
119	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	ON
120	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON
121	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON
122	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON
123	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON
124	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON
125	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON

Table 2, Ametek Speedometer Calibration Settings, 93 to 125

Ametek Speedometer Calibration Settings, 126 to 158										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
126	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON
127	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON
128	ON	ON	ON	ON	ON	ON	ON	OFF	ON	ON
129	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	ON
130	ON	OFF	ON	ON	ON	ON	ON	OFF	ON	ON
131	OFF	OFF	ON	ON	ON	ON	ON	OFF	ON	ON
132	ON	ON	OFF	ON	ON	ON	ON	OFF	ON	ON
133	OFF	ON	OFF	ON	ON	ON	ON	OFF	ON	ON
134	ON	OFF	OFF	ON	ON	ON	ON	OFF	ON	ON
135	OFF	OFF	OFF	ON	ON	ON	ON	OFF	ON	ON
136	ON	ON	ON	OFF	ON	ON	ON	OFF	ON	ON
137	OFF	ON	ON	OFF	ON	ON	ON	OFF	ON	ON
138	ON	OFF	ON	OFF	ON	ON	ON	OFF	ON	ON
139	OFF	OFF	ON	OFF	ON	ON	ON	OFF	ON	ON
140	ON	ON	OFF	OFF	ON	ON	ON	OFF	ON	ON
141	OFF	ON	OFF	OFF	ON	ON	ON	OFF	ON	ON
142	ON	OFF	OFF	OFF	ON	ON	ON	OFF	ON	ON
143	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	ON	ON
144	ON	ON	ON	ON	OFF	ON	ON	OFF	ON	ON
145	OFF	ON	ON	ON	OFF	ON	ON	OFF	ON	ON
146	ON	OFF	ON	ON	OFF	ON	ON	OFF	ON	ON
147	OFF	OFF	ON	ON	OFF	ON	ON	OFF	ON	ON
148	ON	ON	OFF	ON	OFF	ON	ON	OFF	ON	ON
149	OFF	ON	OFF	ON	OFF	ON	ON	OFF	ON	ON
150	ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON	ON
151	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	ON	ON
152	ON	ON	ON	OFF	OFF	ON	ON	OFF	ON	ON
153	OFF	ON	ON	OFF	OFF	ON	ON	OFF	ON	ON
154	ON	OFF	ON	OFF	OFF	ON	ON	OFF	ON	ON
155	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	ON	ON
156	ON	ON	OFF	OFF	OFF	ON	ON	OFF	ON	ON
157	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON	ON
158	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	ON

Table 3, Ametek Speedometer Calibration Settings, 126 to 158

Specifications

Ametek Speedometer Calibration Settings, 159 to 191										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
159	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	ON
160	ON	ON	ON	ON	ON	OFF	ON	OFF	ON	ON
161	OFF	ON	ON	ON	ON	OFF	ON	OFF	ON	ON
162	ON	OFF	ON	ON	ON	OFF	ON	OFF	ON	ON
163	OFF	OFF	ON	ON	ON	OFF	ON	OFF	ON	ON
164	ON	ON	OFF	ON	ON	OFF	ON	OFF	ON	ON
165	OFF	ON	OFF	ON	ON	OFF	ON	OFF	ON	ON
166	ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON	ON
167	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	ON	ON
168	ON	ON	ON	OFF	ON	OFF	ON	OFF	ON	ON
169	OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON	ON
170	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON
171	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON
172	ON	ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON
173	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON
174	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	ON
175	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	ON
176	ON	ON	ON	ON	OFF	OFF	ON	OFF	ON	ON
177	OFF	ON	ON	ON	OFF	OFF	ON	OFF	ON	ON
178	ON	OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON
179	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON
180	ON	ON	OFF	ON	OFF	OFF	ON	OFF	ON	ON
181	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	ON	ON
182	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	ON
183	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	ON
184	ON	ON	ON	OFF	OFF	OFF	ON	OFF	ON	ON
185	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	ON	ON
186	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	ON
187	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	ON
188	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	ON
189	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	ON
190	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	ON
191	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	ON

Table 4, Ametek Speedometer Calibration Settings, 159 to 191

Ametek Speedometer Calibration Settings, 192 to 224										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
192	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	ON
193	OFF	ON	ON	ON	ON	ON	OFF	OFF	ON	ON
194	ON	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON
195	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON
196	ON	ON	OFF	ON	ON	ON	OFF	OFF	ON	ON
197	OFF	ON	OFF	ON	ON	ON	OFF	OFF	ON	ON
198	ON	OFF	OFF	ON	ON	ON	OFF	OFF	ON	ON
199	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	ON	ON
200	ON	ON	ON	OFF	ON	ON	OFF	OFF	ON	ON
201	OFF	ON	ON	OFF	ON	ON	OFF	OFF	ON	ON
202	ON	OFF	ON	OFF	ON	ON	OFF	OFF	ON	ON
203	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON	ON
204	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON
205	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON
206	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON
207	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON
208	ON	ON	ON	ON	OFF	ON	OFF	OFF	ON	ON
209	OFF	ON	ON	ON	OFF	ON	OFF	OFF	ON	ON
210	ON	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON
211	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON
212	ON	ON	OFF	ON	OFF	ON	OFF	OFF	ON	ON
213	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	ON	ON
214	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	ON
215	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	ON
216	ON	ON	ON	OFF	OFF	ON	OFF	OFF	ON	ON
217	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	ON	ON
218	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	ON
219	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	ON
220	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
221	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
222	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
223	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	ON
224	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON	ON

Table 5, Ametek Speedometer Calibration Settings, 192 to 224

Specifications

Ametek Speedometer Calibration Settings, 225 to 257										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
225	OFF	ON	ON	ON	ON	OFF	OFF	OFF	ON	ON
226	ON	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON
227	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON
228	ON	ON	OFF	ON	ON	OFF	OFF	OFF	ON	ON
229	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	ON	ON
230	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	ON
231	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	ON
232	ON	ON	ON	OFF	ON	OFF	OFF	OFF	ON	ON
233	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	ON	ON
234	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	ON
235	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	ON
236	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	ON
237	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	ON
238	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	ON
239	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	ON
240	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON
241	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON
242	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON
243	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON
244	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	ON
245	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	ON
246	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	ON
247	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	ON
248	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON
249	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON
250	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	ON
251	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	ON
252	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
253	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
254	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
255	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON
256	ON	ON	ON	ON	ON	ON	ON	ON	OFF	ON
257	OFF	ON	ON	ON	ON	ON	ON	ON	OFF	ON

Table 6, Ametek Speedometer Calibration Settings, 225 to 257

Ametek Speedometer Calibration Settings, 258 to 290										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
258	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	ON
259	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF	ON
260	ON	ON	OFF	ON	ON	ON	ON	ON	OFF	ON
261	OFF	ON	OFF	ON	ON	ON	ON	ON	OFF	ON
262	ON	OFF	OFF	ON	ON	ON	ON	ON	OFF	ON
263	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	ON
264	ON	ON	ON	OFF	ON	ON	ON	ON	OFF	ON
265	OFF	ON	ON	OFF	ON	ON	ON	ON	OFF	ON
266	ON	OFF	ON	OFF	ON	ON	ON	ON	OFF	ON
267	OFF	OFF	ON	OFF	ON	ON	ON	ON	OFF	ON
268	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF	ON
269	OFF	ON	OFF	OFF	ON	ON	ON	ON	OFF	ON
270	ON	OFF	OFF	OFF	ON	ON	ON	ON	OFF	ON
271	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	ON
272	ON	ON	ON	ON	OFF	ON	ON	ON	OFF	ON
273	OFF	ON	ON	ON	OFF	ON	ON	ON	OFF	ON
274	ON	OFF	ON	ON	OFF	ON	ON	ON	OFF	ON
275	OFF	OFF	ON	ON	OFF	ON	ON	ON	OFF	ON
276	ON	ON	OFF	ON	OFF	ON	ON	ON	OFF	ON
277	OFF	ON	OFF	ON	OFF	ON	ON	ON	OFF	ON
278	ON	OFF	OFF	ON	OFF	ON	ON	ON	OFF	ON
279	OFF	OFF	OFF	ON	OFF	ON	ON	ON	OFF	ON
280	ON	ON	ON	OFF	OFF	ON	ON	ON	OFF	ON
281	OFF	ON	ON	OFF	OFF	ON	ON	ON	OFF	ON
282	ON	OFF	ON	OFF	OFF	ON	ON	ON	OFF	ON
283	OFF	OFF	ON	OFF	OFF	ON	ON	ON	OFF	ON
284	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	ON
285	OFF	ON	OFF	OFF	OFF	ON	ON	ON	OFF	ON
286	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	ON
287	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	ON
288	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	ON
289	OFF	ON	ON	ON	ON	OFF	ON	ON	OFF	ON
290	ON	OFF	ON	ON	ON	OFF	ON	ON	OFF	ON

Table 7, Ametek Speedometer Calibration Settings, 258 to 290

Specifications

Ametek Speedometer Calibration Settings, 291 to 323										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
291	OFF	OFF	ON	ON	ON	OFF	ON	ON	OFF	ON
292	ON	ON	OFF	ON	ON	OFF	ON	ON	OFF	ON
293	OFF	ON	OFF	ON	ON	OFF	ON	ON	OFF	ON
294	ON	OFF	OFF	ON	ON	OFF	ON	ON	OFF	ON
295	OFF	OFF	OFF	ON	ON	OFF	ON	ON	OFF	ON
296	ON	ON	ON	OFF	ON	OFF	ON	ON	OFF	ON
297	OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF	ON
298	ON	OFF	ON	OFF	ON	OFF	ON	ON	OFF	ON
299	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF	ON
300	ON	ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON
301	OFF	ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON
302	ON	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	ON
303	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	ON
304	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF	ON
305	OFF	ON	ON	ON	OFF	OFF	ON	ON	OFF	ON
306	ON	OFF	ON	ON	OFF	OFF	ON	ON	OFF	ON
307	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	ON
308	ON	ON	OFF	ON	OFF	OFF	ON	ON	OFF	ON
309	OFF	ON	OFF	ON	OFF	OFF	ON	ON	OFF	ON
310	ON	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	ON
311	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	ON
312	ON	ON	ON	OFF	OFF	OFF	ON	ON	OFF	ON
313	OFF	ON	ON	OFF	OFF	OFF	ON	ON	OFF	ON
314	ON	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON
315	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON
316	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON
317	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON
318	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON
319	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON
320	ON	ON	ON	ON	ON	ON	OFF	ON	OFF	ON
321	OFF	ON	ON	ON	ON	ON	OFF	ON	OFF	ON
322	ON	OFF	ON	ON	ON	ON	OFF	ON	OFF	ON
323	OFF	OFF	ON	ON	ON	ON	OFF	ON	OFF	ON

Table 8, Ametek Speedometer Calibration Settings, 291 to 323

Ametek Speedometer Calibration Settings, 324 to 356										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
324	ON	ON	OFF	ON	ON	ON	OFF	ON	OFF	ON
325	OFF	ON	OFF	ON	ON	ON	OFF	ON	OFF	ON
326	ON	OFF	OFF	ON	ON	ON	OFF	ON	OFF	ON
327	OFF	OFF	OFF	ON	ON	ON	OFF	ON	OFF	ON
328	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	ON
329	OFF	ON	ON	OFF	ON	ON	OFF	ON	OFF	ON
330	ON	OFF	ON	OFF	ON	ON	OFF	ON	OFF	ON
331	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF	ON
332	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON
333	OFF	ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON
334	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	ON
335	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	ON
336	ON	ON	ON	ON	OFF	ON	OFF	ON	OFF	ON
337	OFF	ON	ON	ON	OFF	ON	OFF	ON	OFF	ON
338	ON	OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON
339	OFF	OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON
340	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
341	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON
342	ON	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	ON
343	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	ON
344	ON	ON	ON	OFF	OFF	ON	OFF	ON	OFF	ON
345	OFF	ON	ON	OFF	OFF	ON	OFF	ON	OFF	ON
346	ON	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	ON
347	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	ON
348	ON	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	ON
349	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	ON
350	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	ON
351	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	ON
352	ON	ON	ON	ON	ON	OFF	OFF	ON	OFF	ON
353	OFF	ON	ON	ON	ON	OFF	OFF	ON	OFF	ON
354	ON	OFF	ON	ON	ON	OFF	OFF	ON	OFF	ON
355	OFF	OFF	ON	ON	ON	OFF	OFF	ON	OFF	ON
356	ON	ON	OFF	ON	ON	OFF	OFF	ON	OFF	ON

Table 9, Ametek Speedometer Calibration Settings, 324 to 356

Specifications

Ametek Speedometer Calibration Settings, 357 to 389										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
357	OFF	ON	OFF	ON	ON	OFF	OFF	ON	OFF	ON
358	ON	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	ON
359	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	ON
360	ON	ON	ON	OFF	ON	OFF	OFF	ON	OFF	ON
361	OFF	ON	ON	OFF	ON	OFF	OFF	ON	OFF	ON
362	ON	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	ON
363	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	ON
364	ON	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	ON
365	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	ON
366	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	ON
367	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	ON
368	ON	ON	ON	ON	OFF	OFF	OFF	ON	OFF	ON
369	OFF	ON	ON	ON	OFF	OFF	OFF	ON	OFF	ON
370	ON	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	ON
371	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	ON
372	ON	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	ON
373	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	ON
374	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	ON
375	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	ON
376	ON	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	ON
377	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	ON
378	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON
379	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON
380	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON
381	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON
382	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON
383	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON
384	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	ON
385	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF	ON
386	ON	OFF	ON	ON	ON	ON	ON	OFF	OFF	ON
387	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF	ON
388	ON	ON	OFF	ON	ON	ON	ON	OFF	OFF	ON
389	OFF	ON	OFF	ON	ON	ON	ON	OFF	OFF	ON

Table 10, Ametek Speedometer Calibration Settings, 357 to 389

Ametek Speedometer Calibration Settings, 390 to 422										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
390	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON
391	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON
392	ON	ON	ON	OFF	ON	ON	ON	OFF	OFF	ON
393	OFF	ON	ON	OFF	ON	ON	ON	OFF	OFF	ON
394	ON	OFF	ON	OFF	ON	ON	ON	OFF	OFF	ON
395	OFF	OFF	ON	OFF	ON	ON	ON	OFF	OFF	ON
396	ON	ON	OFF	OFF	ON	ON	ON	OFF	OFF	ON
397	OFF	ON	OFF	OFF	ON	ON	ON	OFF	OFF	ON
398	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	ON
399	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	ON
400	ON	ON	ON	ON	OFF	ON	ON	OFF	OFF	ON
401	OFF	ON	ON	ON	OFF	ON	ON	OFF	OFF	ON
402	ON	OFF	ON	ON	OFF	ON	ON	OFF	OFF	ON
403	OFF	OFF	ON	ON	OFF	ON	ON	OFF	OFF	ON
404	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF	ON
405	OFF	ON	OFF	ON	OFF	ON	ON	OFF	OFF	ON
406	ON	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON
407	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON
408	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON
409	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON
410	ON	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	ON
411	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	ON
412	ON	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	ON
413	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	ON
414	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON
415	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON
416	ON	ON	ON	ON	ON	OFF	ON	OFF	OFF	ON
417	OFF	ON	ON	ON	ON	OFF	ON	OFF	OFF	ON
418	ON	OFF	ON	ON	ON	OFF	ON	OFF	OFF	ON
419	OFF	OFF	ON	ON	ON	OFF	ON	OFF	OFF	ON
420	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	ON
421	OFF	ON	OFF	ON	ON	OFF	ON	OFF	OFF	ON
422	ON	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON

Table 11, Ametek Speedometer Calibration Settings, 390 to 422

Specifications

Ametek Speedometer Calibration Settings, 423 to 455										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
423	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON
424	ON	ON	ON	OFF	ON	OFF	ON	OFF	OFF	ON
425	OFF	ON	ON	OFF	ON	OFF	ON	OFF	OFF	ON
426	ON	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	ON
427	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	ON
428	ON	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	ON
429	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	ON
430	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	ON
431	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	ON
432	ON	ON	ON	ON	OFF	OFF	ON	OFF	OFF	ON
433	OFF	ON	ON	ON	OFF	OFF	ON	OFF	OFF	ON
434	ON	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	ON
435	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	ON
436	ON	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	ON
437	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	ON
438	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	ON
439	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	ON
440	ON	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON
441	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON
442	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	ON
443	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	ON
444	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON
445	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON
446	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON
447	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON
448	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON
449	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON
450	ON	OFF	ON	ON	ON	ON	OFF	OFF	OFF	ON
451	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	ON
452	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF	ON
453	OFF	ON	OFF	ON	ON	ON	OFF	OFF	OFF	ON
454	ON	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON
455	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON

Table 12, Ametek Speedometer Calibration Settings, 423 to 455

Ametek Speedometer Calibration Settings, 456 to 488										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
456	ON	ON	ON	OFF	ON	ON	OFF	OFF	OFF	ON
457	OFF	ON	ON	OFF	ON	ON	OFF	OFF	OFF	ON
458	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	ON
459	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	ON
460	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
461	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
462	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
463	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON
464	ON	ON	ON	ON	OFF	ON	OFF	OFF	OFF	ON
465	OFF	ON	ON	ON	OFF	ON	OFF	OFF	OFF	ON
466	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	ON
467	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	ON
468	ON	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	ON
469	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	ON
470	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	ON
471	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	ON
472	ON	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
473	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
474	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
475	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	ON
476	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON
477	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON
478	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON
479	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON
480	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON
481	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON
482	ON	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	ON
483	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	ON
484	ON	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	ON
485	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	ON
486	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	ON
487	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	ON
488	ON	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	ON

Table 13, Ametek Speedometer Calibration Settings, 456 to 488

Specifications

Ametek Speedometer Calibration Settings, 489 to 521										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
489	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	ON
490	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	ON
491	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	ON
492	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON
493	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON
494	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON
495	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON
496	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON
497	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON
498	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	ON
499	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	ON
500	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON
501	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON
502	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON
503	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON
504	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON
505	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON
506	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON
507	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON
508	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
509	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
510	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
511	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON
512	ON	ON	ON	ON	ON	ON	ON	ON	ON	OFF
513	OFF	ON	ON	ON	ON	ON	ON	ON	ON	OFF
514	ON	OFF	ON	ON	ON	ON	ON	ON	ON	OFF
515	OFF	OFF	ON	ON	ON	ON	ON	ON	ON	OFF
516	ON	ON	OFF	ON	ON	ON	ON	ON	ON	OFF
517	OFF	ON	OFF	ON	ON	ON	ON	ON	ON	OFF
518	ON	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF
519	OFF	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF
520	ON	ON	ON	OFF	ON	ON	ON	ON	ON	OFF
521	OFF	ON	ON	OFF	ON	ON	ON	ON	ON	OFF

Table 14, Ametek Speedometer Calibration Settings, 489 to 521

Ametek Speedometer Calibration Settings, 522 to 554										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
522	ON	OFF	ON	OFF	ON	ON	ON	ON	ON	OFF
523	OFF	OFF	ON	OFF	ON	ON	ON	ON	ON	OFF
524	ON	ON	OFF	OFF	ON	ON	ON	ON	ON	OFF
525	OFF	ON	OFF	OFF	ON	ON	ON	ON	ON	OFF
526	ON	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF
527	OFF	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF
528	ON	ON	ON	ON	OFF	ON	ON	ON	ON	OFF
529	OFF	ON	ON	ON	OFF	ON	ON	ON	ON	OFF
530	ON	OFF	ON	ON	OFF	ON	ON	ON	ON	OFF
531	OFF	OFF	ON	ON	OFF	ON	ON	ON	ON	OFF
532	ON	ON	OFF	ON	OFF	ON	ON	ON	ON	OFF
533	OFF	ON	OFF	ON	OFF	ON	ON	ON	ON	OFF
534	ON	OFF	OFF	ON	OFF	ON	ON	ON	ON	OFF
535	OFF	OFF	OFF	ON	OFF	ON	ON	ON	ON	OFF
536	ON	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF
537	OFF	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF
538	ON	OFF	ON	OFF	OFF	ON	ON	ON	ON	OFF
539	OFF	OFF	ON	OFF	OFF	ON	ON	ON	ON	OFF
540	ON	ON	OFF	OFF	OFF	ON	ON	ON	ON	OFF
541	OFF	ON	OFF	OFF	OFF	ON	ON	ON	ON	OFF
542	ON	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF
543	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF
544	ON	ON	ON	ON	ON	OFF	ON	ON	ON	OFF
545	OFF	ON	ON	ON	ON	OFF	ON	ON	ON	OFF
546	ON	OFF	ON	ON	ON	OFF	ON	ON	ON	OFF
547	OFF	OFF	ON	ON	ON	OFF	ON	ON	ON	OFF
548	ON	ON	OFF	ON	ON	OFF	ON	ON	ON	OFF
549	OFF	ON	OFF	ON	ON	OFF	ON	ON	ON	OFF
550	ON	OFF	OFF	ON	ON	OFF	ON	ON	ON	OFF
551	OFF	OFF	OFF	ON	ON	OFF	ON	ON	ON	OFF
552	ON	ON	ON	OFF	ON	OFF	ON	ON	ON	OFF
553	OFF	ON	ON	OFF	ON	OFF	ON	ON	ON	OFF
554	ON	OFF	ON	OFF	ON	OFF	ON	ON	ON	OFF

Table 15, Ametek Speedometer Calibration Settings, 522 to 554

Specifications

Ametek Speedometer Calibration Settings, 555 to 587										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
555	OFF	OFF	ON	OFF	ON	OFF	ON	ON	ON	OFF
556	ON	ON	OFF	OFF	ON	OFF	ON	ON	ON	OFF
557	OFF	ON	OFF	OFF	ON	OFF	ON	ON	ON	OFF
558	ON	OFF	OFF	OFF	ON	OFF	ON	ON	ON	OFF
559	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	ON	OFF
560	ON	ON	ON	ON	OFF	OFF	ON	ON	ON	OFF
561	OFF	ON	ON	ON	OFF	OFF	ON	ON	ON	OFF
562	ON	OFF	ON	ON	OFF	OFF	ON	ON	ON	OFF
563	OFF	OFF	ON	ON	OFF	OFF	ON	ON	ON	OFF
564	ON	ON	OFF	ON	OFF	OFF	ON	ON	ON	OFF
565	OFF	ON	OFF	ON	OFF	OFF	ON	ON	ON	OFF
566	ON	OFF	OFF	ON	OFF	OFF	ON	ON	ON	OFF
567	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	ON	OFF
568	ON	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
569	OFF	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF
570	ON	OFF	ON	OFF	OFF	OFF	ON	ON	ON	OFF
571	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	ON	OFF
572	ON	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF
573	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF
574	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	OFF
575	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	OFF
576	ON	ON	ON	ON	ON	ON	OFF	ON	ON	OFF
577	OFF	ON	ON	ON	ON	ON	OFF	ON	ON	OFF
578	ON	OFF	ON	ON	ON	ON	OFF	ON	ON	OFF
579	OFF	OFF	ON	ON	ON	ON	OFF	ON	ON	OFF
580	ON	ON	OFF	ON	ON	ON	OFF	ON	ON	OFF
581	OFF	ON	OFF	ON	ON	ON	OFF	ON	ON	OFF
582	ON	OFF	OFF	ON	ON	ON	OFF	ON	ON	OFF
583	OFF	OFF	OFF	ON	ON	ON	OFF	ON	ON	OFF
584	ON	ON	ON	OFF	ON	ON	OFF	ON	ON	OFF
585	OFF	ON	ON	OFF	ON	ON	OFF	ON	ON	OFF
586	ON	OFF	ON	OFF	ON	ON	OFF	ON	ON	OFF
587	OFF	OFF	ON	OFF	ON	ON	OFF	ON	ON	OFF

Table 16, Ametek Speedometer Calibration Settings, 555 to 587

Ametek Speedometer Calibration Settings, 588 to 620										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
588	ON	ON	OFF	OFF	ON	ON	OFF	ON	ON	OFF
589	OFF	ON	OFF	OFF	ON	ON	OFF	ON	ON	OFF
590	ON	OFF	OFF	OFF	ON	ON	OFF	ON	ON	OFF
591	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	ON	OFF
592	ON	ON	ON	ON	OFF	ON	OFF	ON	ON	OFF
593	OFF	ON	ON	ON	OFF	ON	OFF	ON	ON	OFF
594	ON	OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF
595	OFF	OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF
596	ON	ON	OFF	ON	OFF	ON	OFF	ON	ON	OFF
597	OFF	ON	OFF	ON	OFF	ON	OFF	ON	ON	OFF
598	ON	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF
599	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF
600	ON	ON	ON	OFF	OFF	ON	OFF	ON	ON	OFF
601	OFF	ON	ON	OFF	OFF	ON	OFF	ON	ON	OFF
602	ON	OFF	ON	OFF	OFF	ON	OFF	ON	ON	OFF
603	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	ON	OFF
604	ON	ON	OFF	OFF	OFF	ON	OFF	ON	ON	OFF
605	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	ON	OFF
606	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	OFF
607	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	OFF
608	ON	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF
609	OFF	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF
610	ON	OFF	ON	ON	ON	OFF	OFF	ON	ON	OFF
611	OFF	OFF	ON	ON	ON	OFF	OFF	ON	ON	OFF
612	ON	ON	OFF	ON	ON	OFF	OFF	ON	ON	OFF
613	OFF	ON	OFF	ON	ON	OFF	OFF	ON	ON	OFF
614	ON	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF
615	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF
616	ON	ON	ON	OFF	ON	OFF	OFF	ON	ON	OFF
617	OFF	ON	ON	OFF	ON	OFF	OFF	ON	ON	OFF
618	ON	OFF	ON	OFF	ON	OFF	OFF	ON	ON	OFF
619	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	ON	OFF
620	ON	ON	OFF	OFF	ON	OFF	OFF	ON	ON	OFF

Table 17, Ametek Speedometer Calibration Settings, 588 to 620

Specifications

Ametek Speedometer Calibration Settings, 621 to 653										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
621	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	ON	OFF
622	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	OFF
623	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	OFF
624	ON	ON	ON	ON	OFF	OFF	OFF	ON	ON	OFF
625	OFF	ON	ON	ON	OFF	OFF	OFF	ON	ON	OFF
626	ON	OFF	ON	ON	OFF	OFF	OFF	ON	ON	OFF
627	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	ON	OFF
628	ON	ON	OFF	ON	OFF	OFF	OFF	ON	ON	OFF
629	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	ON	OFF
630	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	OFF
631	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	OFF
632	ON	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
633	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
634	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
635	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	OFF
636	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF
637	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF
638	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF
639	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF
640	ON	ON	ON	ON	ON	ON	ON	OFF	ON	OFF
641	OFF	ON	ON	ON	ON	ON	ON	OFF	ON	OFF
642	ON	OFF	ON	ON	ON	ON	ON	OFF	ON	OFF
643	OFF	OFF	ON	ON	ON	ON	ON	OFF	ON	OFF
644	ON	ON	OFF	ON	ON	ON	ON	OFF	ON	OFF
645	OFF	ON	OFF	ON	ON	ON	ON	OFF	ON	OFF
646	ON	OFF	OFF	ON	ON	ON	ON	OFF	ON	OFF
647	OFF	OFF	OFF	ON	ON	ON	ON	OFF	ON	OFF
648	ON	ON	ON	OFF	ON	ON	ON	OFF	ON	OFF
649	OFF	ON	ON	OFF	ON	ON	ON	OFF	ON	OFF
650	ON	OFF	ON	OFF	ON	ON	ON	OFF	ON	OFF
651	OFF	OFF	ON	OFF	ON	ON	ON	OFF	ON	OFF
652	ON	ON	OFF	OFF	ON	ON	ON	OFF	ON	OFF
653	OFF	ON	OFF	OFF	ON	ON	ON	OFF	ON	OFF

Table 18, Ametek Speedometer Calibration Settings, 621 to 653

Ametek Speedometer Calibration Settings, 654 to 686										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
654	ON	OFF	OFF	OFF	ON	ON	ON	OFF	ON	OFF
655	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	ON	OFF
656	ON	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF
657	OFF	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF
658	ON	OFF	ON	ON	OFF	ON	ON	OFF	ON	OFF
659	OFF	OFF	ON	ON	OFF	ON	ON	OFF	ON	OFF
660	ON	ON	OFF	ON	OFF	ON	ON	OFF	ON	OFF
661	OFF	ON	OFF	ON	OFF	ON	ON	OFF	ON	OFF
662	ON	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF
663	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF
664	ON	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF
665	OFF	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF
666	ON	OFF	ON	OFF	OFF	ON	ON	OFF	ON	OFF
667	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	ON	OFF
668	ON	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF
669	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF
670	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF
671	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF
672	ON	ON	ON	ON	ON	OFF	ON	OFF	ON	OFF
673	OFF	ON	ON	ON	ON	OFF	ON	OFF	ON	OFF
674	ON	OFF	ON	ON	ON	OFF	ON	OFF	ON	OFF
675	OFF	OFF	ON	ON	ON	OFF	ON	OFF	ON	OFF
676	ON	ON	OFF	ON	ON	OFF	ON	OFF	ON	OFF
677	OFF	ON	OFF	ON	ON	OFF	ON	OFF	ON	OFF
678	ON	OFF	OFF	ON	ON	OFF	ON	OFF	ON	OFF
679	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	ON	OFF
680	ON	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF
681	OFF	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF
682	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
683	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
684	ON	ON	OFF	OFF	ON	OFF	ON	OFF	ON	OFF
685	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	ON	OFF
686	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	OFF

Table 19, Ametek Speedometer Calibration Settings, 654 to 686

Specifications

Ametek Speedometer Calibration Settings, 687 to 719										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
687	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	OFF
688	ON	ON	ON	ON	OFF	OFF	ON	OFF	ON	OFF
689	OFF	ON	ON	ON	OFF	OFF	ON	OFF	ON	OFF
690	ON	OFF	ON	ON	OFF	OFF	ON	OFF	ON	OFF
691	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	ON	OFF
692	ON	ON	OFF	ON	OFF	OFF	ON	OFF	ON	OFF
693	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	ON	OFF
694	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	OFF
695	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	OFF
696	ON	ON	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
697	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
698	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
699	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	OFF
700	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF
701	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF
702	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF
703	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF
704	ON	ON	ON	ON	ON	ON	OFF	OFF	ON	OFF
705	OFF	ON	ON	ON	ON	ON	OFF	OFF	ON	OFF
706	ON	OFF	ON	ON	ON	ON	OFF	OFF	ON	OFF
707	OFF	OFF	ON	ON	ON	ON	OFF	OFF	ON	OFF
708	ON	ON	OFF	ON	ON	ON	OFF	OFF	ON	OFF
709	OFF	ON	OFF	ON	ON	ON	OFF	OFF	ON	OFF
710	ON	OFF	OFF	ON	ON	ON	OFF	OFF	ON	OFF
711	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	ON	OFF
712	ON	ON	ON	OFF	ON	ON	OFF	OFF	ON	OFF
713	OFF	ON	ON	OFF	ON	ON	OFF	OFF	ON	OFF
714	ON	OFF	ON	OFF	ON	ON	OFF	OFF	ON	OFF
715	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	ON	OFF
716	ON	ON	OFF	OFF	ON	ON	OFF	OFF	ON	OFF
717	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	ON	OFF
718	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	OFF
719	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	OFF

Table 20, Ametek Speedometer Calibration Settings, 687 to 719

Ametek Speedometer Calibration Settings, 720 to 752										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
720	ON	ON	ON	ON	OFF	ON	OFF	OFF	ON	OFF
721	OFF	ON	ON	ON	OFF	ON	OFF	OFF	ON	OFF
722	ON	OFF	ON	ON	OFF	ON	OFF	OFF	ON	OFF
723	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	ON	OFF
724	ON	ON	OFF	ON	OFF	ON	OFF	OFF	ON	OFF
725	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	ON	OFF
726	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	OFF
727	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	OFF
728	ON	ON	ON	OFF	OFF	ON	OFF	OFF	ON	OFF
729	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	ON	OFF
730	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	OFF
731	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	OFF
732	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF
733	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF
734	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF
735	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF
736	ON	ON	ON	ON	ON	OFF	OFF	OFF	ON	OFF
737	OFF	ON	ON	ON	ON	OFF	OFF	OFF	ON	OFF
738	ON	OFF	ON	ON	ON	OFF	OFF	OFF	ON	OFF
739	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	ON	OFF
740	ON	ON	OFF	ON	ON	OFF	OFF	OFF	ON	OFF
741	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	ON	OFF
742	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF
743	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF
744	ON	ON	ON	OFF	ON	OFF	OFF	OFF	ON	OFF
745	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	ON	OFF
746	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	OFF
747	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	OFF
748	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF
749	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF
750	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF
751	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF
752	ON	ON	ON	ON	OFF	OFF	OFF	OFF	ON	OFF

Table 21, Ametek Speedometer Calibration Settings, 720 to 752

Specifications

Ametek Speedometer Calibration Settings, 753 to 785										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
753	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	ON	OFF
754	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	OFF
755	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	OFF
756	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF
757	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF
758	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF
759	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF
760	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
761	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
762	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
763	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF
764	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
765	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
766	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
767	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF
768	ON	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
769	OFF	ON	ON	ON	ON	ON	ON	ON	OFF	OFF
770	ON	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF
771	OFF	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF
772	ON	ON	OFF	ON	ON	ON	ON	ON	OFF	OFF
773	OFF	ON	OFF	ON	ON	ON	ON	ON	OFF	OFF
774	ON	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF
775	OFF	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF
776	ON	ON	ON	OFF	ON	ON	ON	ON	OFF	OFF
777	OFF	ON	ON	OFF	ON	ON	ON	ON	OFF	OFF
778	ON	OFF	ON	OFF	ON	ON	ON	ON	OFF	OFF
779	OFF	OFF	ON	OFF	ON	ON	ON	ON	OFF	OFF
780	ON	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF
781	OFF	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF
782	ON	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF
783	OFF	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF
784	ON	ON	ON	ON	OFF	ON	ON	ON	OFF	OFF
785	OFF	ON	ON	ON	OFF	ON	ON	ON	OFF	OFF

Table 22, Ametek Speedometer Calibration Settings, 753 to 785

Ametek Speedometer Calibration Settings, 786 to 818										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
786	ON	OFF	ON	ON	OFF	ON	ON	ON	OFF	OFF
787	OFF	OFF	ON	ON	OFF	ON	ON	ON	OFF	OFF
788	ON	ON	OFF	ON	OFF	ON	ON	ON	OFF	OFF
789	OFF	ON	OFF	ON	OFF	ON	ON	ON	OFF	OFF
790	ON	OFF	OFF	ON	OFF	ON	ON	ON	OFF	OFF
791	OFF	OFF	OFF	ON	OFF	ON	ON	ON	OFF	OFF
792	ON	ON	ON	OFF	OFF	ON	ON	ON	OFF	OFF
793	OFF	ON	ON	OFF	OFF	ON	ON	ON	OFF	OFF
794	ON	OFF	ON	OFF	OFF	ON	ON	ON	OFF	OFF
795	OFF	OFF	ON	OFF	OFF	ON	ON	ON	OFF	OFF
796	ON	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
797	OFF	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
798	ON	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
799	OFF	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
800	ON	ON	ON	ON	ON	OFF	ON	ON	OFF	OFF
801	OFF	ON	ON	ON	ON	OFF	ON	ON	OFF	OFF
802	ON	OFF	ON	ON	ON	OFF	ON	ON	OFF	OFF
803	OFF	OFF	ON	ON	ON	OFF	ON	ON	OFF	OFF
804	ON	ON	OFF	ON	ON	OFF	ON	ON	OFF	OFF
805	OFF	ON	OFF	ON	ON	OFF	ON	ON	OFF	OFF
806	ON	OFF	OFF	ON	ON	OFF	ON	ON	OFF	OFF
807	OFF	OFF	OFF	ON	ON	OFF	ON	ON	OFF	OFF
808	ON	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF
809	OFF	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF
810	ON	OFF	ON	OFF	ON	OFF	ON	ON	OFF	OFF
811	OFF	OFF	ON	OFF	ON	OFF	ON	ON	OFF	OFF
812	ON	ON	OFF	OFF	ON	OFF	ON	ON	OFF	OFF
813	OFF	ON	OFF	OFF	ON	OFF	ON	ON	OFF	OFF
814	ON	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	OFF
815	OFF	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	OFF
816	ON	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF
817	OFF	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF
818	ON	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF

Table 23, Ametek Speedometer Calibration Settings, 786 to 818

Specifications

Ametek Speedometer Calibration Settings, 819 to 851										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
819	OFF	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF
820	ON	ON	OFF	ON	OFF	OFF	ON	ON	OFF	OFF
821	OFF	ON	OFF	ON	OFF	OFF	ON	ON	OFF	OFF
822	ON	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	OFF
823	OFF	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	OFF
824	ON	ON	ON	OFF	OFF	OFF	ON	ON	OFF	OFF
825	OFF	ON	ON	OFF	OFF	OFF	ON	ON	OFF	OFF
826	ON	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	OFF
827	OFF	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	OFF
828	ON	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
829	OFF	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
830	ON	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
831	OFF	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF
832	ON	ON	ON	ON	ON	ON	OFF	ON	OFF	OFF
833	OFF	ON	ON	ON	ON	ON	OFF	ON	OFF	OFF
834	ON	OFF	ON	ON	ON	ON	OFF	ON	OFF	OFF
835	OFF	OFF	ON	ON	ON	ON	OFF	ON	OFF	OFF
836	ON	ON	OFF	ON	ON	ON	OFF	ON	OFF	OFF
837	OFF	ON	OFF	ON	ON	ON	OFF	ON	OFF	OFF
838	ON	OFF	OFF	ON	ON	ON	OFF	ON	OFF	OFF
839	OFF	OFF	OFF	ON	ON	ON	OFF	ON	OFF	OFF
840	ON	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF
841	OFF	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF
842	ON	OFF	ON	OFF	ON	ON	OFF	ON	OFF	OFF
843	OFF	OFF	ON	OFF	ON	ON	OFF	ON	OFF	OFF
844	ON	ON	OFF	OFF	ON	ON	OFF	ON	OFF	OFF
845	OFF	ON	OFF	OFF	ON	ON	OFF	ON	OFF	OFF
846	ON	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF
847	OFF	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF
848	ON	ON	ON	ON	OFF	ON	OFF	ON	OFF	OFF
849	OFF	ON	ON	ON	OFF	ON	OFF	ON	OFF	OFF
850	ON	OFF	ON	ON	OFF	ON	OFF	ON	OFF	OFF
851	OFF	OFF	ON	ON	OFF	ON	OFF	ON	OFF	OFF

Table 24, Ametek Speedometer Calibration Settings, 819 to 851

Ametek Speedometer Calibration Settings, 852 to 884										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
852	ON	ON	OFF	ON	OFF	ON	OFF	ON	OFF	OFF
853	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	OFF
854	ON	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	OFF
855	OFF	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	OFF
856	ON	ON	ON	OFF	OFF	ON	OFF	ON	OFF	OFF
857	OFF	ON	ON	OFF	OFF	ON	OFF	ON	OFF	OFF
858	ON	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	OFF
859	OFF	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	OFF
860	ON	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
861	OFF	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
862	ON	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
863	OFF	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF
864	ON	ON	ON	ON	ON	OFF	OFF	ON	OFF	OFF
865	OFF	ON	ON	ON	ON	OFF	OFF	ON	OFF	OFF
866	ON	OFF	ON	ON	ON	OFF	OFF	ON	OFF	OFF
867	OFF	OFF	ON	ON	ON	OFF	OFF	ON	OFF	OFF
868	ON	ON	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
869	OFF	ON	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
870	ON	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
871	OFF	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	OFF
872	ON	ON	ON	OFF	ON	OFF	OFF	ON	OFF	OFF
873	OFF	ON	ON	OFF	ON	OFF	OFF	ON	OFF	OFF
874	ON	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	OFF
875	OFF	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	OFF
876	ON	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF
877	OFF	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF
878	ON	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF
879	OFF	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF
880	ON	ON	ON	ON	OFF	OFF	OFF	ON	OFF	OFF
881	OFF	ON	ON	ON	OFF	OFF	OFF	ON	OFF	OFF
882	ON	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF
883	OFF	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF
884	ON	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF

Table 25, Ametek Speedometer Calibration Settings, 852 to 884

Specifications

Ametek Speedometer Calibration Settings, 885 to 917										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
885	OFF	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF
886	ON	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF
887	OFF	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF
888	ON	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF
889	OFF	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF
890	ON	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF
891	OFF	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF
892	ON	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF
893	OFF	ON	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF
894	ON	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF
895	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF
896	ON	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF
897	OFF	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF
898	ON	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF
899	OFF	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF
900	ON	ON	OFF	ON	ON	ON	ON	OFF	OFF	OFF
901	OFF	ON	OFF	ON	ON	ON	ON	OFF	OFF	OFF
902	ON	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF
903	OFF	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF
904	ON	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF
905	OFF	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF
906	ON	OFF	ON	OFF	ON	ON	ON	OFF	OFF	OFF
907	OFF	OFF	ON	OFF	ON	ON	ON	OFF	OFF	OFF
908	ON	ON	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
909	OFF	ON	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
910	ON	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
911	OFF	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF
912	ON	ON	ON	ON	OFF	ON	ON	OFF	OFF	OFF
913	OFF	ON	ON	ON	OFF	ON	ON	OFF	OFF	OFF
914	ON	OFF	ON	ON	OFF	ON	ON	OFF	OFF	OFF
915	OFF	OFF	ON	ON	OFF	ON	ON	OFF	OFF	OFF
916	ON	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
917	OFF	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF

Table 26, Ametek Speedometer Calibration Settings, 885 to 917

Ametek Speedometer Calibration Settings, 918 to 950										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
918	ON	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
919	OFF	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	OFF
920	ON	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
921	OFF	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
922	ON	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
923	OFF	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	OFF
924	ON	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
925	OFF	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
926	ON	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
927	OFF	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF
928	ON	ON	ON	ON	ON	OFF	ON	OFF	OFF	OFF
929	OFF	ON	ON	ON	ON	OFF	ON	OFF	OFF	OFF
930	ON	OFF	ON	ON	ON	OFF	ON	OFF	OFF	OFF
931	OFF	OFF	ON	ON	ON	OFF	ON	OFF	OFF	OFF
932	ON	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
933	OFF	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
934	ON	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
935	OFF	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF
936	ON	ON	ON	OFF	ON	OFF	ON	OFF	OFF	OFF
937	OFF	ON	ON	OFF	ON	OFF	ON	OFF	OFF	OFF
938	ON	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	OFF
939	OFF	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	OFF
940	ON	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF
941	OFF	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF
942	ON	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF
943	OFF	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF
944	ON	ON	ON	ON	OFF	OFF	ON	OFF	OFF	OFF
945	OFF	ON	ON	ON	OFF	OFF	ON	OFF	OFF	OFF
946	ON	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	OFF
947	OFF	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	OFF
948	ON	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF
949	OFF	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF
950	ON	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF

Table 27, Ametek Speedometer Calibration Settings, 918 to 950

Specifications

Ametek Speedometer Calibration Settings, 951 to 983										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
951	OFF	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF
952	ON	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
953	OFF	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
954	ON	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
955	OFF	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF
956	ON	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF
957	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF
958	OFF	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF
959	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF
960	ON	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
961	OFF	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF
962	ON	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
963	OFF	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF
964	ON	ON	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
965	OFF	ON	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
966	ON	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
967	OFF	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
968	ON	ON	ON	OFF	ON	ON	OFF	OFF	OFF	OFF
969	OFF	ON	ON	OFF	ON	ON	OFF	OFF	OFF	OFF
970	ON	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	OFF
971	OFF	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	OFF
972	ON	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF
973	OFF	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF
974	ON	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF
975	OFF	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF
976	ON	ON	ON	ON	OFF	ON	OFF	OFF	OFF	OFF
977	OFF	ON	ON	ON	OFF	ON	OFF	OFF	OFF	OFF
978	ON	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF
979	OFF	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF
980	ON	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF
981	OFF	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF
982	ON	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF
983	OFF	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF

Table 28, Ametek Speedometer Calibration Settings, 951 to 983

Ametek Speedometer Calibration Settings, 984 to 1016										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
984	ON	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
985	OFF	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
986	ON	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
987	OFF	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF
988	ON	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
989	OFF	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
990	ON	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
991	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
992	ON	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
993	OFF	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
994	ON	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
995	OFF	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF
996	ON	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
997	OFF	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
998	ON	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
999	OFF	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF
1000	ON	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
1001	OFF	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
1002	ON	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
1003	OFF	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF
1004	ON	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
1005	OFF	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
1006	ON	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
1007	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF
1008	ON	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
1009	OFF	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
1010	ON	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
1011	OFF	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF
1012	ON	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
1013	OFF	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
1014	ON	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
1015	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF
1016	ON	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF

Table 29, Ametek Speedometer Calibration Settings, 984 to 1016

Specifications

Ametek Speedometer Calibration Settings, 1017 to 1023										
PPM/120	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
1017	OFF	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1018	ON	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1019	OFF	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1020	ON	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1021	OFF	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1022	ON	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
1023	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF

Table 30, Ametek Speedometer Calibration Settings, 1017 to 1023

General Information

The Ametek fuel level gauge system consists of a dash-mounted electrical gauge, a fuel level sensor mounted in the fuel tank, and the electrical wires that connect these components.

The fuel level gauge is a cross-coil electric gauge with a 90-degree sweep and a light bulb for illumination. See **Fig. 1**. For gauge removal instructions, see **Subject 100**.

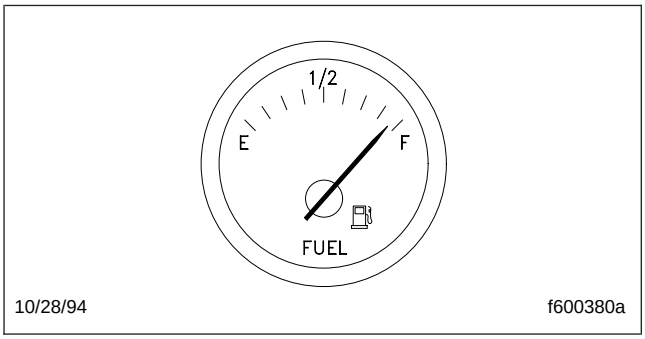


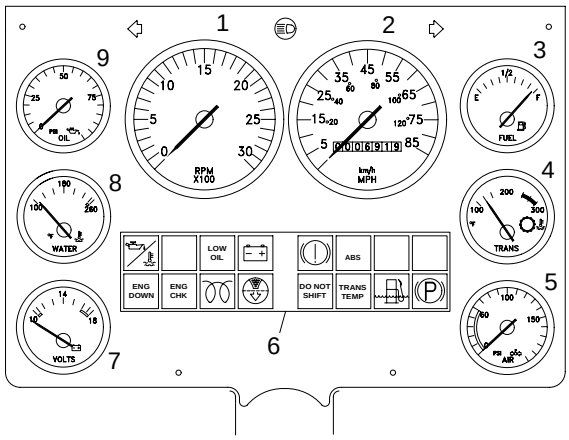
Fig. 1, Fuel Level Gauge

The fuel level sensor is serviced by removing a plate mounted to the outside of the fuel tank that holds the sensor float and arm. For detailed instructions, see **Subject 110**.

Fuel Level Gauge Removal and Installation

Removal

1. Apply the parking brake, shut down the engine, and chock the tires.
2. Disconnect the batteries.
3. Remove the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.



10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster

4. Remove the fuel level gauge from the dash.
   - 4.1 Using finger pressure, release the locking clip on the side of the gauge.
   - 4.2 Grasp the gauge firmly and pull it straight out of the mounting panel.

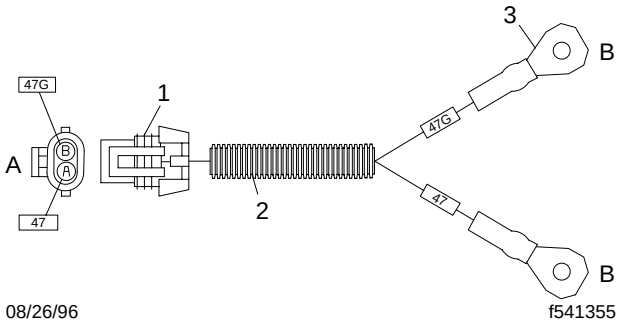
Installation

IMPORTANT: Don't touch the fuel level gauge face or pointer.

1. Install the fuel level gauge.
   - 1.1 Grasp the gauge firmly and insert it in the mounting panel.
   - 1.2 Make sure the gauge is firmly seated and that the locking clip is holding it in place.
2. Install the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see **Section 54.03, Subject 100**.
3. Remove the chocks from the tires.

Removal

1. Shut down the engine, apply the parking brake, and chock the tires.
2. If necessary, remove any body panels blocking access to the top of the fuel tank.
3. Remove the screws securing the fuel level signal and ground wires to the fuel level sensor, then disconnect the wires from the sensor. See **Fig. 1**. If the wire numbers are not visible, mark the wires for ease of assembly.



A. To Chassis Harness
B. To Fuel Level Sensor
1. Weather-Pack® Connector
2. Convoluted Tubing
3. Ring Terminal

Fig. 1, Fuel Level Sensor Harness

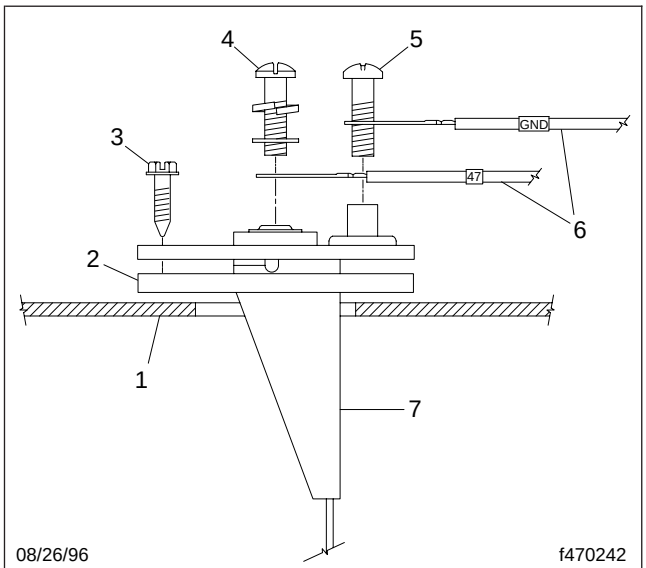
⚠ WARNING

WARNING: Do not service the fuel system in the presence of sparks, open flames, or intense heat. These could ignite the fuel, possibly causing severe burns.

4. Carefully remove the fuel level sensor and gasket from the tank. See **Fig. 2**.

   4.1 Using some kind of permanent marking device, make alignment marks on both the fuel level sensor and the fuel tank for ease of assembly.

   4.2 Remove the five 10–24 machine screws securing the fuel level sensor to the fuel tank.



1. Fuel Tank
2. Gasket
3. 10–24 Machine Screw
4. Positive Terminal Screw
5. Ground Screw
6. Wiring Harness
7. Fuel Level Sensor

Fig. 2, Fuel Level Sensor Mounting

IMPORTANT: Be careful to avoid bending the float arm or damaging the float assembly.

   4.3 Carefully withdraw the sensor and gasket from the tank. To avoid damage, tilt and rotate the sensor as necessary.

Installation

NOTE: If replacing the fuel level sensor with a new unit, make an alignment mark on the new sensor so that it will line up the same way as the old sensor.

1. Make sure a new gasket is in position on the fuel sensor assembly.
2. Insert the fuel level sensor into the fuel tank, being careful to avoid damage to the float or float arm.
3. Install the fuel level sensor in the fuel tank.

Fuel Level Sensor Removal and Installation

3.1 Rotate the sensor assembly as necessary to line up the alignment marks made on removal.

3.2 Install the five 10–24 machine screws, and tighten them 15 to 30 lbf·in (160 to 340 N·cm).

4. Connect the wiring harness to the fuel level sensor. See **Fig. 2**.

4.1 Connect the circuit 47 ring terminal to the positive terminal screw at the center of the sensor.

4.2 Connect the ground circuit ring terminal to the ground screw at the side of the sensor.

4.3 Tighten both terminal screws 20 lbf·in (220 N·cm).

5. Start the engine, check for leaks, and check the fuel level gauge for correct operation.

6. Install any body panels removed to gain access to the fuel tank.

7. Remove the chocks from the tires.

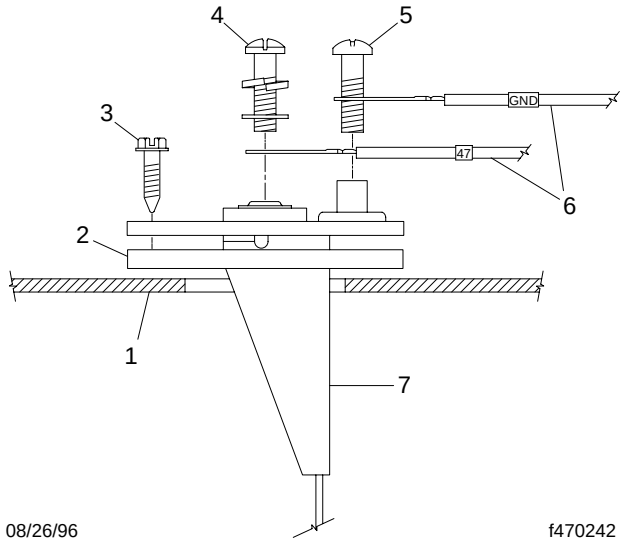
Troubleshooting Procedures

Fuel level gauge malfunctions are usually one of two types:

- The gauge does not operate at all (always shows empty)
- The gauge shows a fuel level that seems to be incorrect.

If an inaccurate gauge or sensor is suspected, confirm the actual fuel level by inserting a clean dipstick into the tank.

IMPORTANT: Over half of all fuel gauge problems are caused by poor connections at the fuel tank. Before doing any other troubleshooting, check the terminal connections and clean them if necessary. See **Fig. 1**.



1. Fuel Tank
2. Gasket
3. 10–24 Machine Screw
4. Positive Terminal Screw
5. Ground Screw
6. Wiring Harness
7. Fuel Level Sensor

Fig. 1, Fuel Level Sensor Mounting

A totally inoperative fuel level gauge may be caused by open circuits in the gauge, sensor, or wiring. To isolate the cause of an inoperative fuel level gauge, follow the troubleshooting procedures in the order given.

NOTE: Newer fuel level sensors may use a sealed plug-in connector.

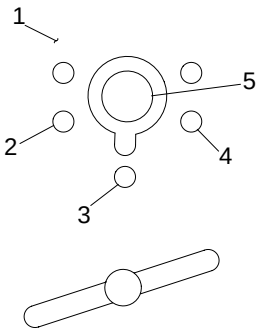
1. Disconnect the fuel level harness from the fuel level sensor.
   - 1.1 Shut down the engine and turn off the ignition keyswitch.
   - 1.2 Remove any body panels blocking access to the top of the fuel tank.
   - 1.3 Remove the positive terminal screw securing circuit 47 to the insulated center terminal of the fuel level sensor and tie off the wire so it can't touch either the sensor or the tank itself.
2. Switch on the ignition and observe the gauge needle; it should remain at the left end of the scale (empty tank indicated).
3. Switch off the ignition and, using a jumper wire, connect the fuel level gauge signal wire terminal (circuit 47) to the sensor ground terminal.
4. Switch on the ignition again and watch the gauge needle; it should move immediately to the extreme right or "full" end of the scale.
5. If the gauge operates as described in the above steps, it is functioning properly and the wiring to the gauge is okay. The problem is in the sensor; replace it following the instructions in **Subject 110** and verify that the gauge operates properly.

   If the gauge does not function as described above, go to the next step.
6. Check the fuel level sensor ground circuit.
   - 6.1 Switch off the ignition and disconnect the jumper previously installed between the sensor signal and ground wires.
   - 6.2 Connect one lead of an ohmmeter to a good ground source, and connect the remaining lead to the sensor ground terminal.
   - 6.3 If the resistance is more than 5 ohms, there is a problem in the ground circuit. Check for loose wires, corrosion at the terminal, or damaged wires.

Troubleshooting

If the resistance is less than 5 ohms, leave the sensor signal wire disconnected and go to the next step.

7. Remove the instrument cluster bezel and the fuel level gauge. For detailed instructions, see **Subject 100**.
8. Identify the fuel level gauge terminals that are part of the gauge mounting panel. See **Fig. 2**.



02/22/99 f601090

1. Gauge Mounting Panel
2. Ground Terminal
3. Ignition Power Terminal
4. Sensor Signal Terminal
5. Light Bulb

Fig. 2, Fuel Level Gauge Wiring Connections

9. Check the fuel level gauge ground circuit wiring for an open circuit.
   - 9.1 Turn the ignition keyswitch off.
   - 9.2 Connect the leads of an ohmmeter between a good ground source on the cab metal and the ground terminal in the gauge mounting panel.
   - 9.3 If the resistance is less than 5 ohms, go to the next step.

     If resistance is higher than 5 ohms, verify that you have good connections at both the terminal and the cab metal ground. Test the resistance again.
   - 9.4 If the connections are good, but resistance is still greater than 5 ohms, check for a damaged section of wiring between the terminal and ground. Repair the damage as necessary. For detailed instructions, see **Section 54.00, Subject 100**.
10. Check for an open signal circuit between the fuel level gauge and sensor.
    - 10.1 With the gauge still removed from the gauge mounting panel, connect one ohmmeter lead to the signal terminal on the mounting panel.
    - 10.2 Go to the fuel tank and connect the other lead to the disconnected signal wire on the fuel level sensor harness (circuit 47).
    - 10.3 If the resistance is less than 5 ohms, go to the next step.

      If the resistance is more than 5 ohms, check for loose connections or damaged sections of wire between the fuel level gauge connections and the sensor.
11. Check the sensor signal circuit for a short to ground.
    - 11.1 With the gauge still removed, measure the resistance between the signal terminal in the gauge mounting panel and a good ground source.
    - 11.2 If the ohmmeter reads anything less than infinite resistance, the signal wire is shorted to ground. Check between the gauge and the sensor for a pinched, chafed or otherwise damaged wire in circuit 47. Repair or replace as necessary.

      If the ohmmeter indicates infinite resistance, go to the next step.
12. Check for battery voltage at the fuel gauge power terminal in the gauge mounting panel.
    - 12.1 Turn the ignition keyswitch on.
    - 12.2 Connect a voltmeter (set on 20 volt scale, DC voltage) to the mounting panel terminals. Connect the positive (red) probe to the ignition power terminal and the negative (black) probe to the ground terminal.
    - 12.3 If the voltage reads at least 9 volts DC, replace the gauge. For detailed instructions, see **Subject 100**.

      If the voltage reads below 9 volts DC, check the circuit breaker that supplies power to the gauge. If the circuit breaker is okay, locate and repair the damage to the power circuit. For detailed wire repair

instructions, see **Section 54.00, Subject 100**.

13. Install the fuel level gauge and instrument cluster bezel. Connect the fuel level sensor harness. Make sure that the gauge now operates properly.

General Information

A spring-loaded air restriction indicator indicates how much air filter capacity has been used and how much remains. See **Fig. 1**. It registers the actual maximum restriction of the filter element when the engine is operating at full load.

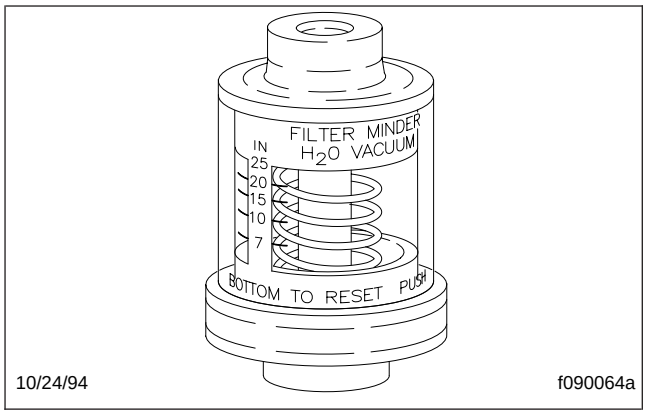


Fig. 1, Air Restriction Indicator

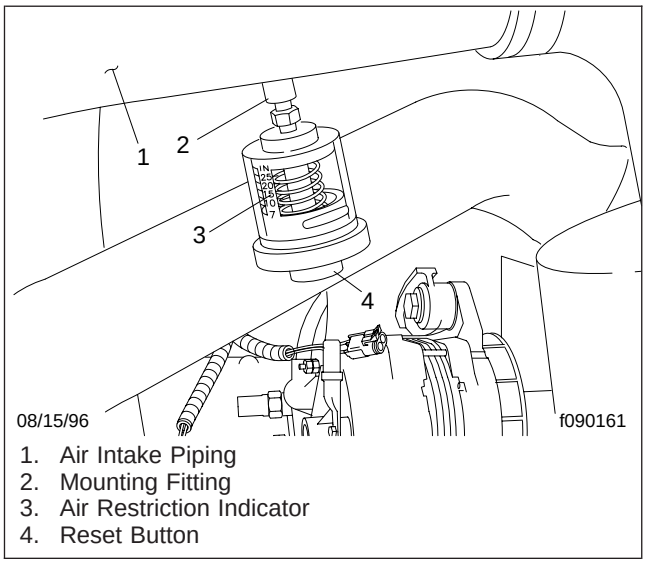
The standard air restriction indicator is mounted on the air cleaner intake piping and has a push-type reset button located at the end opposite the mounting fitting. See **Fig. 2**. There is an optional indicator that is mounted on the surge tank mounting bracket and is connected to a dash light that illuminates when the air restriction is too high.

Inside the air restriction indicator is 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.

NOTE: For more information on servicing, see **Group 09**.

The air restriction indicator and tap fittings sometimes become plugged from moisture or engine vapors, possibly causing an incorrect reading.

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 air restriction indicators. Keep these fluids away from the air restriction indicator.



1. Air Intake Piping
2. Mounting Fitting
3. Air Restriction Indicator
4. Reset Button

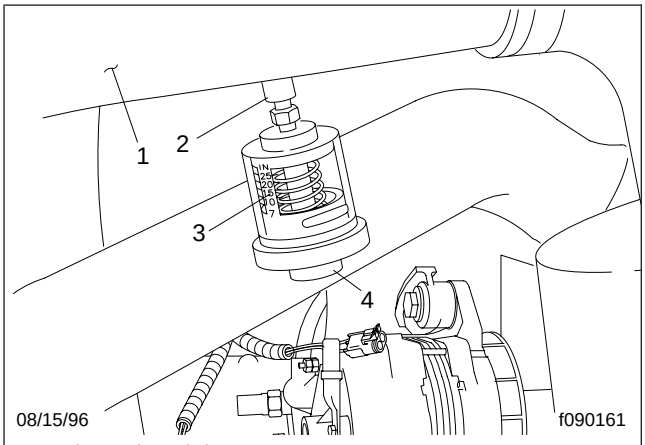
Fig. 2, Air Restriction Indicator Mounted on the Intake Piping

Air Restriction Indicator Replacement

Replacement

MOUNTED ON THE AIR INTAKE PIPING

1. Chock the tires, then tilt the hood. For instructions, see the chassis operator's manual.
2. Unscrew the indicator from the air intake piping by hand. If necessary, hold the fitting with a wrench. See **Fig. 1**.



1. Air Intake Piping
2. Mounting Fitting
3. Air Restriction Indicator
4. Reset Button

Fig. 1, Air Restriction Indicator Mounted on the Intake Piping

3. Install the new air restriction indicator in the air intake piping and tighten it firmly by hand.

NOTE: The fitting in the intake duct is a special fitting incorporating an orifice and a filter. Be sure that the correct fitting is installed.

4. Lower the hood and remove the chocks from the tires.

MOUNTED ON THE BULKHEAD

1. Chock the tires, then tilt the hood. For instructions, see the chassis operator's manual.
2. Disconnect the air hose from the bottom of the air restriction indicator.
3. Remove the two machine screws attaching the indicator to the surge tank mounting bracket.
4. Remove the backing from the press-to-apply adhesive strips and position the new indicator on the surge tank mounting bracket. Install the two machine screws.
5. Connect the air hose to the bottom of the air restriction indicator and check that it is securely attached.
6. Lower the hood and remove the chocks from the tires.

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.

Problem—High Restriction Readings

Problem—High Restriction Readings Possible Cause	Remedy
The filter element in the air cleaner is plugged or dirty.	Ultra-fine particles are difficult to remove. Carefully attempt to unplug the element; if unsuccessful, 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.

Specifications

See **Fig. 1** for a schematic of the Caterpillar CFE Series engine cab wiring.

See **Fig. 2** for a schematic of the Caterpillar CFE Series electronic engine wiring.

See **Fig. 3** for the Caterpillar CFE Series engine cab harness drawing.

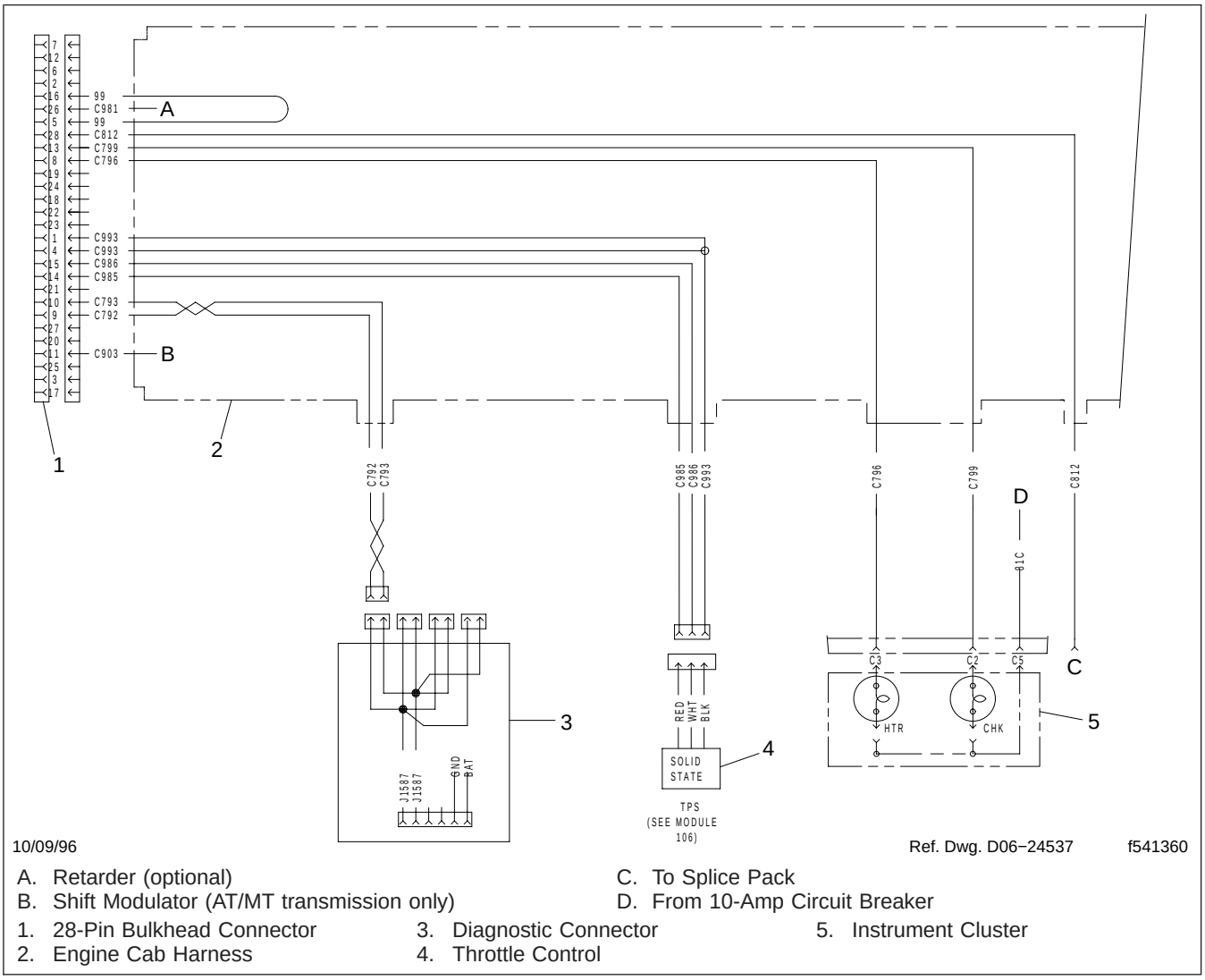
See **Fig. 4** for the Caterpillar CFE Series electronic engine harness drawing.

See **Fig. 5** for a detail drawing of the engine ECU connector.

See **Fig. 6** for the Caterpillar CFE Series power harness drawing.

See **Fig. 7** for the Caterpillar CFE Series engine harness drawing.

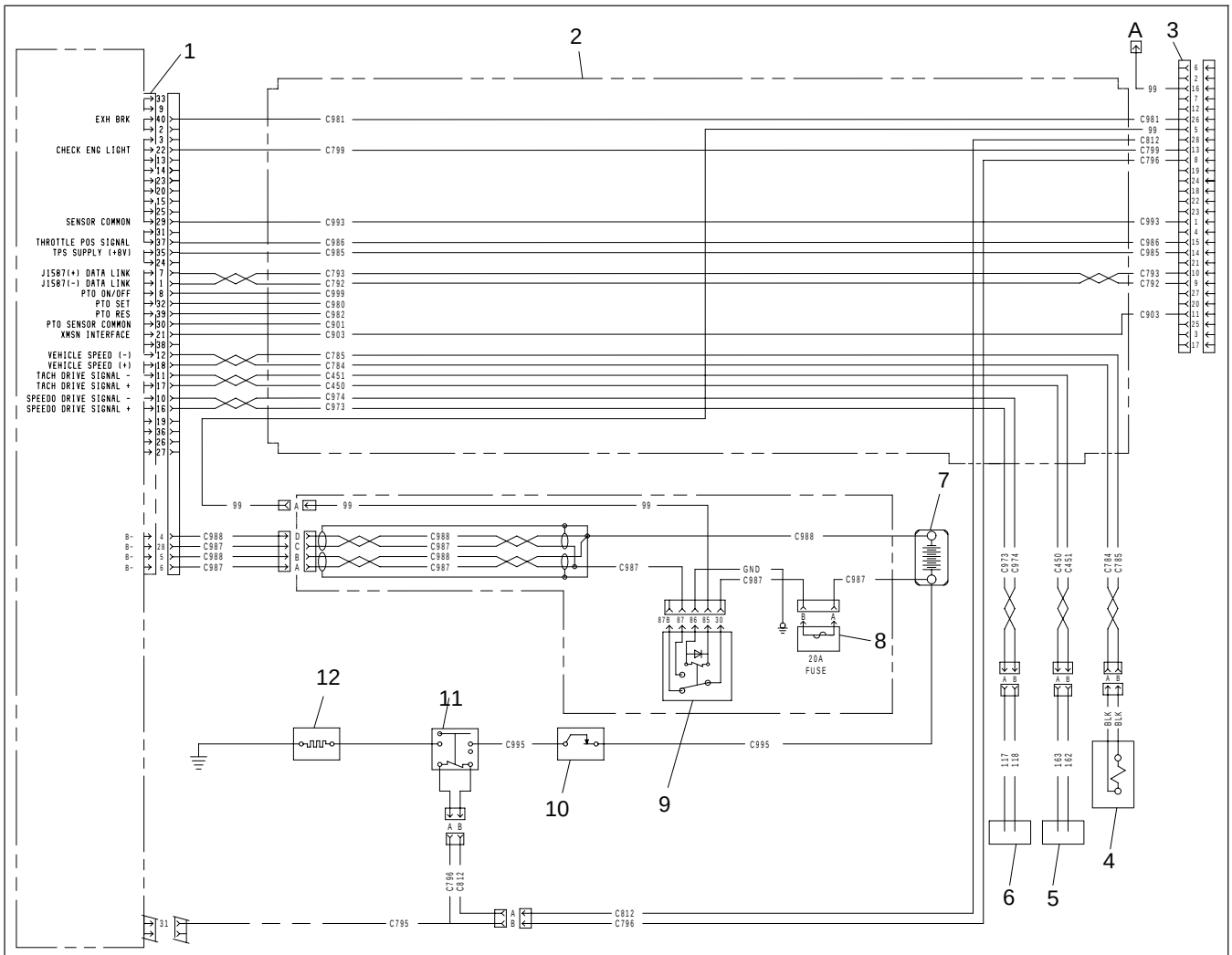
Specifications



A. Retarder (optional)
B. Shift Modulator (AT/MT transmission only)
C. To Splice Pack
D. From 10-Amp Circuit Breaker

1. 28-Pin Bulkhead Connector
2. Engine Cab Harness
3. Diagnostic Connector
4. Throttle Control
5. Instrument Cluster

Fig. 1, Engine Cab Wiring Schematic, Caterpillar CFE Series



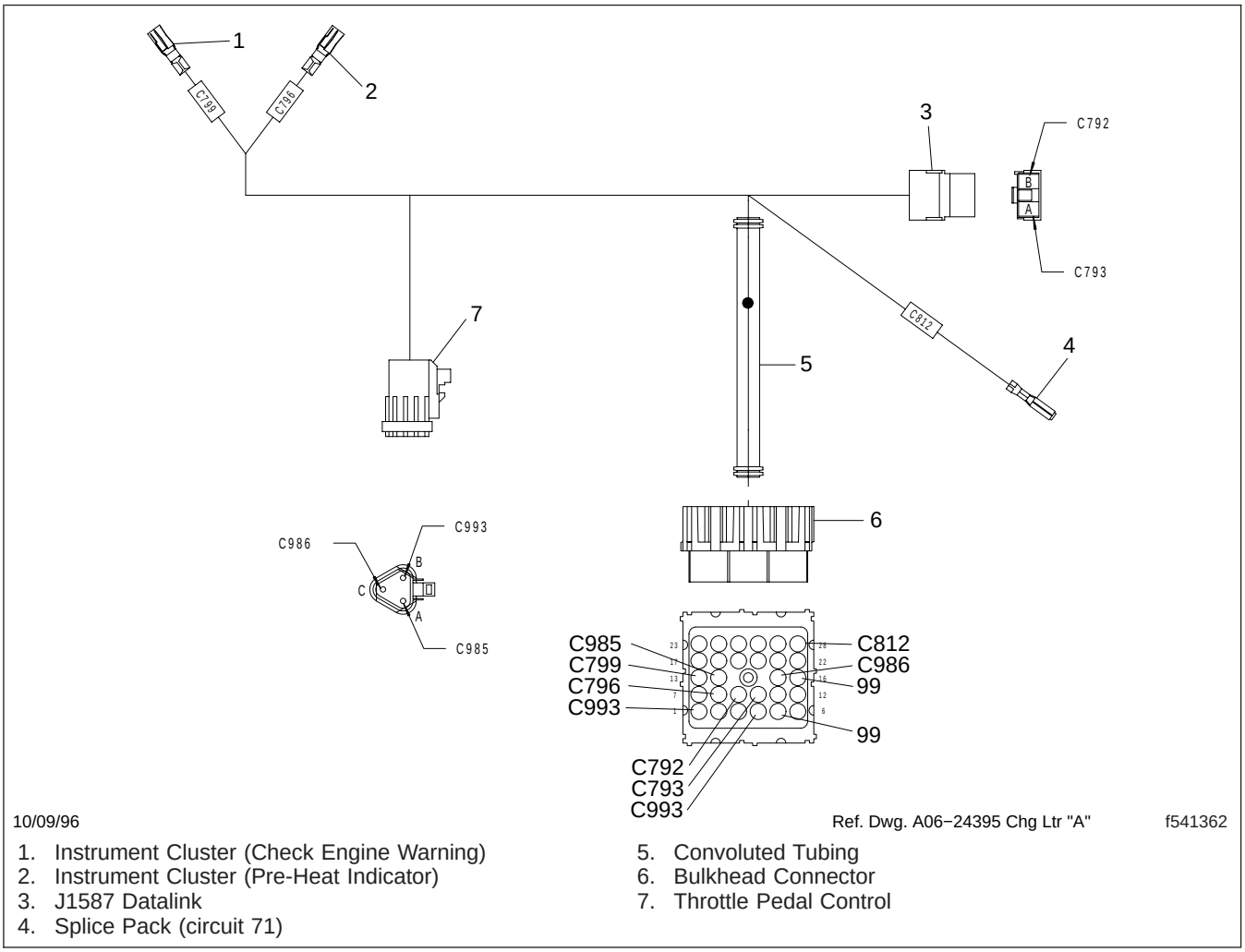
09/05/96 Ref. Dwg. D06−24537 f541361

A. To Fuel Solenoid

1. 40-Pin Engine ECU Connector
2. Electronic Engine Harness
3. 28-Pin Bulkhead Connector
4. Vehicle Speed Sensor
5. Tachometer Output
6. Speedometer Output
7. Battery
8. 20-Amp Fuse
9. Relay
10. 110-Amp Circuit Breaker
11. Pre-Heat Relay
12. Engine Pre-Heater

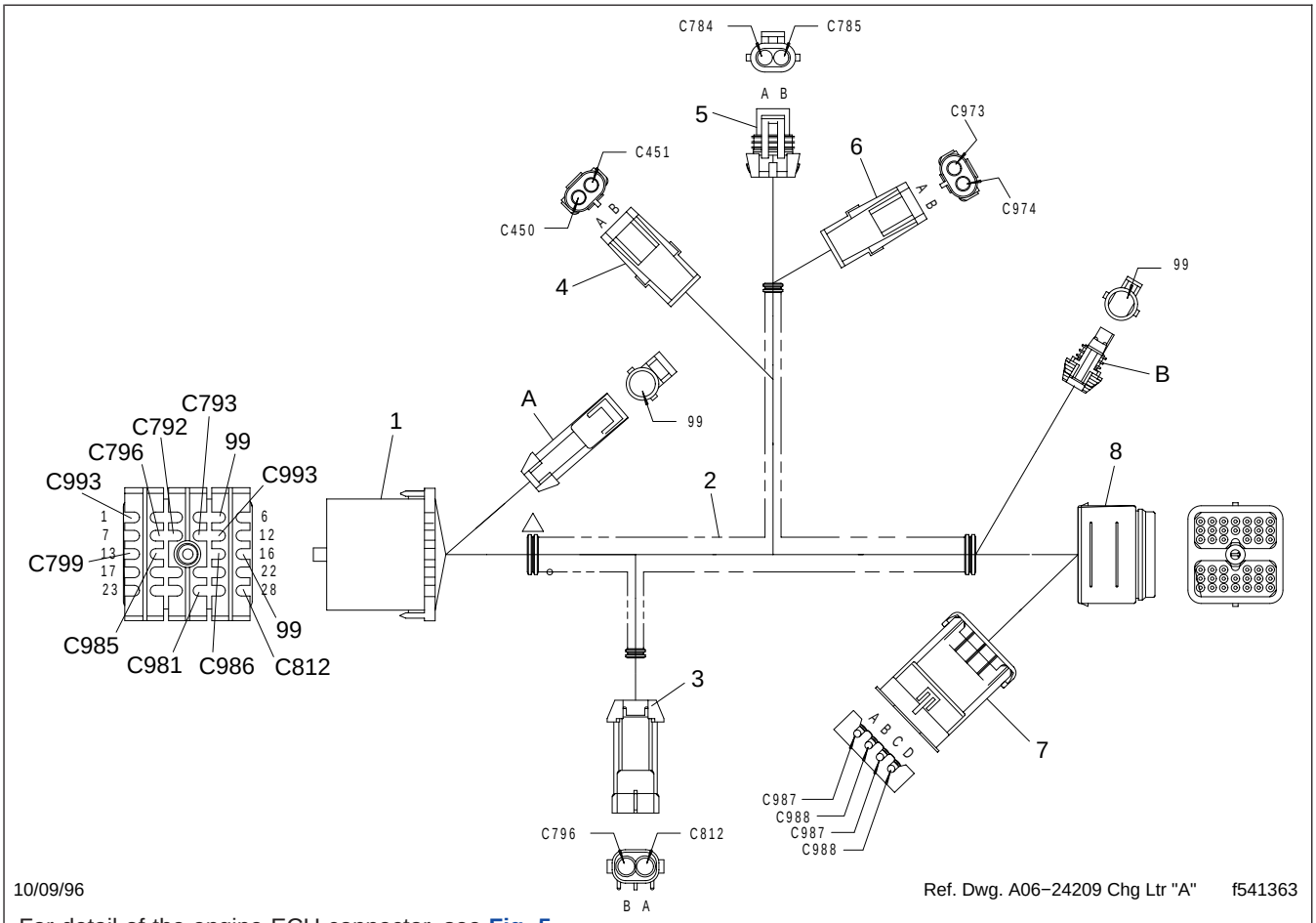
Fig. 2, Electronic Engine Wiring Schematic, Caterpillar CFE Series

Specifications



1. Instrument Cluster (Check Engine Warning)
2. Instrument Cluster (Pre-Heat Indicator)
3. J1587 Datalink
4. Splice Pack (circuit 71)
5. Convoluted Tubing
6. Bulkhead Connector
7. Throttle Pedal Control

Fig. 3, Engine Cab Harness Drawing, Caterpillar CFE Series



For detail of the engine ECU connector, see **Fig. 5**.

A. To Engine Harness
B. To Power Harness

1. 28-Pin Bulkhead Connector
2. Convoluted Tubing
3. Grid Heater
4. Tachometer Output
5. Vehicle Speed Sensor
6. Speedometer Output
7. 4-Pin Power Harness Connector
8. 40-Pin Engine ECU Connector

Fig. 4, Electronic Engine Harness Drawing, Caterpillar CFE Series

Specifications

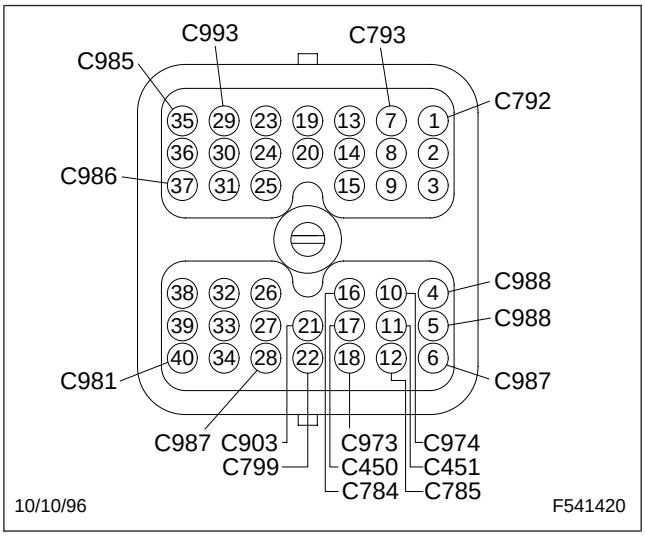
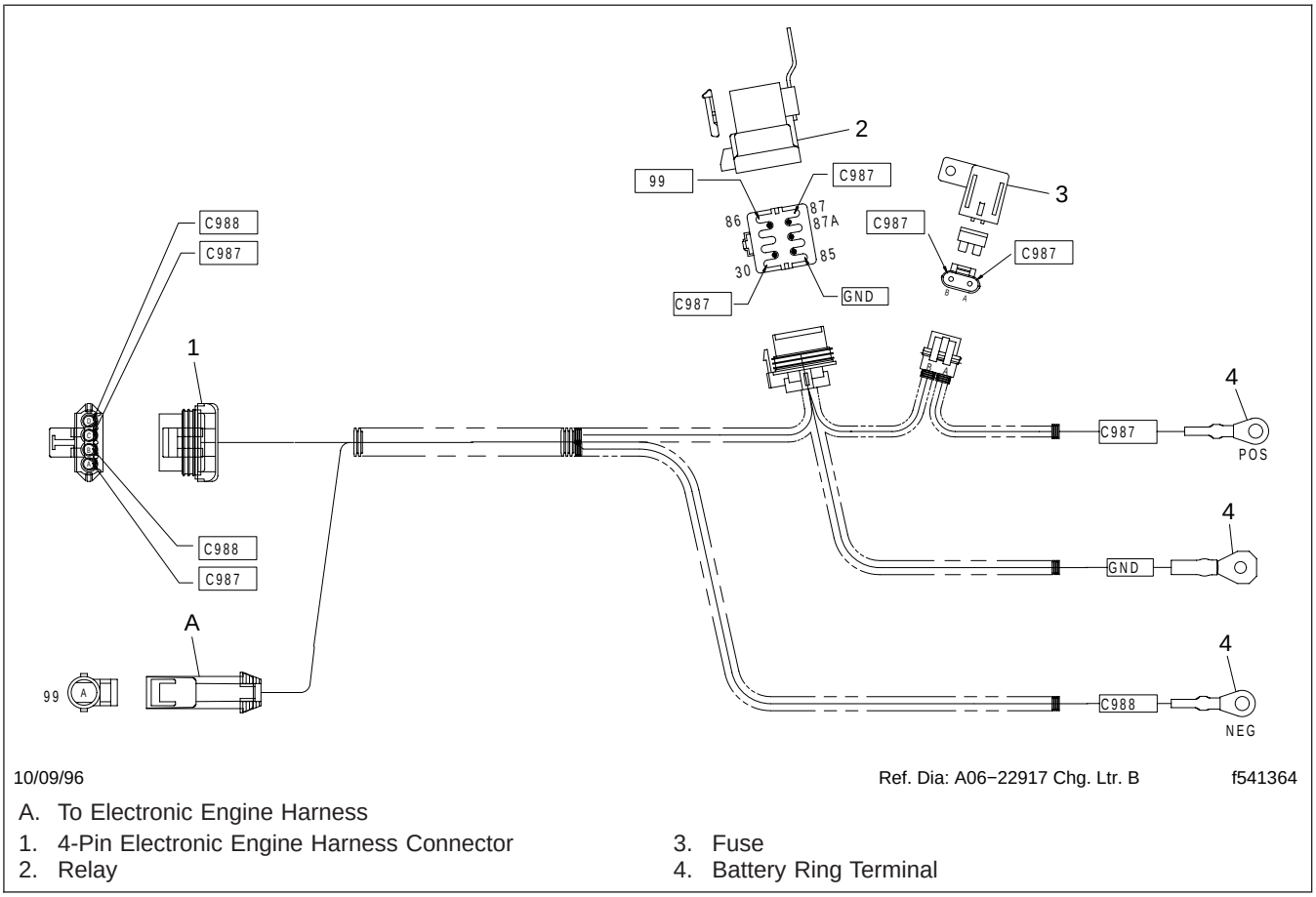
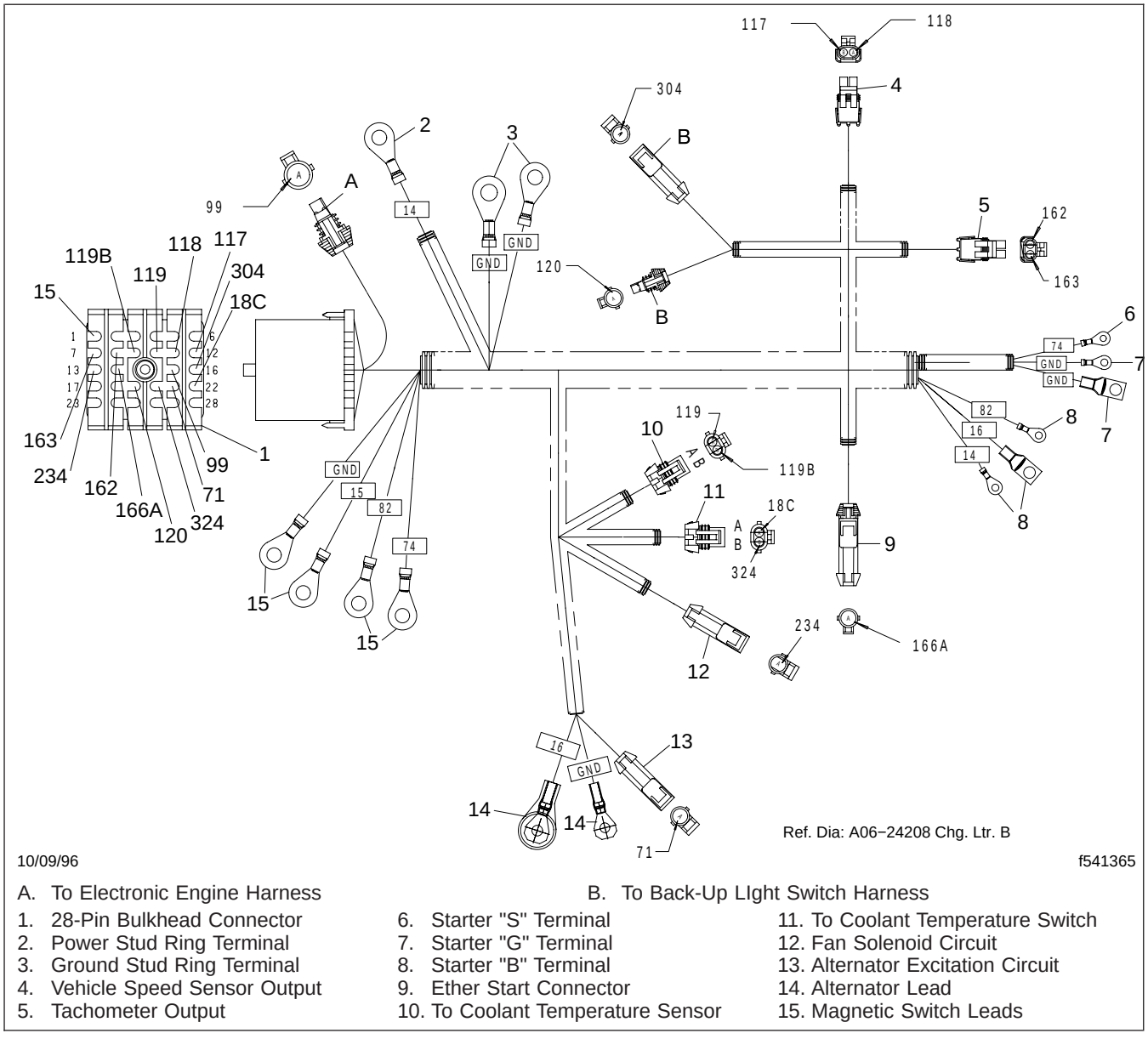


Fig. 5, 40-Pin Engine ECU Connector (Deutsch)



A. To Electronic Engine Harness
1. 4-Pin Electronic Engine Harness Connector
2. Relay
3. Fuse
4. Battery Ring Terminal

Fig. 6, Power Harness Drawing, Caterpillar CFE Series



A. To Electronic Engine Harness
B. To Back-Up LIght Switch Harness

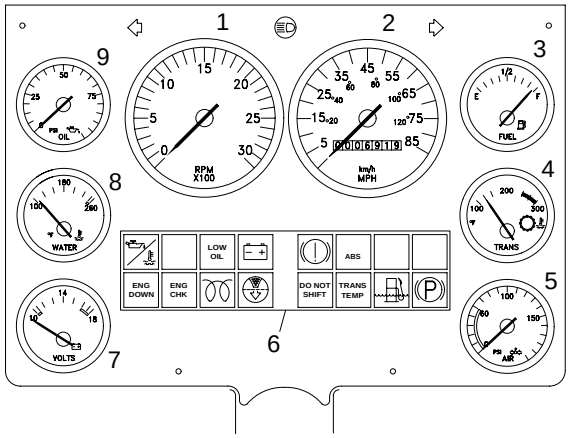
1. 28-Pin Bulkhead Connector
2. Power Stud Ring Terminal
3. Ground Stud Ring Terminal
4. Vehicle Speed Sensor Output
5. Tachometer Output
6. Starter "S" Terminal
7. Starter "G" Terminal
8. Starter "B" Terminal
9. Ether Start Connector
10. To Coolant Temperature Sensor
11. To Coolant Temperature Switch
12. Fan Solenoid Circuit
13. Alternator Excitation Circuit
14. Alternator Lead
15. Magnetic Switch Leads

Fig. 7, Engine Harness Drawing, Caterpillar CFE Series

General Information

The Ametek transmission fluid temperature gauge system consists of a dash-mounted electrical gauge, a fluid temperature sensor mounted on the transmission case, and the necessary electrical wires.

The transmission fluid temperature gauge is a cross-coil electric gauge with a 90-degree sweep and a light bulb for illumination. See **Fig. 1** for a typical instrument cluster with a transmission fluid temperature gauge installed. For gauge removal instructions, see **Subject 100**.



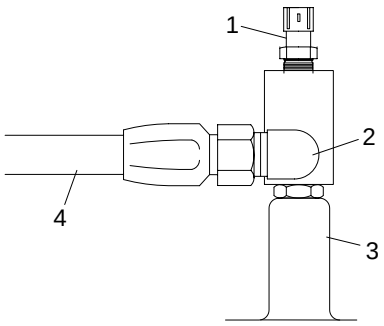
10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster with Transmission Fluid Temperature Gauge Installed

The temperature sensor screws into the fluid outlet port on the transmission case. See **Fig. 2**. For detailed instructions, see **Subject 110**.



02/22/99 f541357

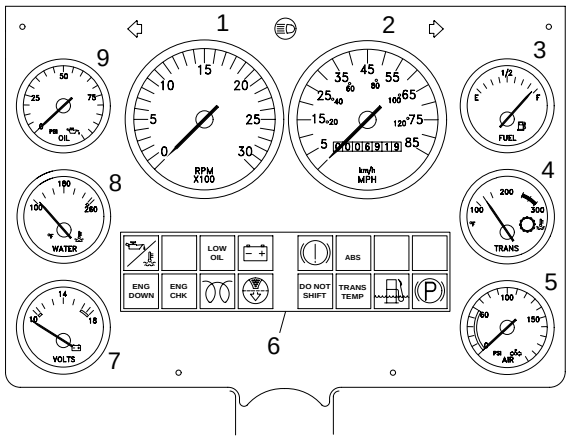
1. Temperature Sensor
2. 90° Elbow
3. Outlet Port
4. Outlet Line to Cooler

Fig. 2, Temperature Sensor Location

Transmission Fluid Temperature Gauge Removal and Installation

Removal

1. Apply the parking brake, shut down the engine, and chock the tires.
2. Disconnect the batteries.
3. At the instrument cluster, remove the instrument cluster bezel. See **Fig. 1**. For detailed instructions, see Section 54.03, **Subject 100**.



10/09/96 f601190

Typical installation shown; light and gauge layout may vary.

1. Tachometer
2. Speedometer
3. Fuel Level Gauge
4. Transmission Fluid Temperature Gauge
5. Dual Air Gauge
6. Warning and Indicator Lights
7. Voltmeter
8. Coolant Temperature Gauge
9. Engine Oil Pressure Gauge

Fig. 1, Instrument Cluster

4. Remove the transmission fluid temperature gauge from the dash.
   - 4.1 Using finger pressure, release the locking clip on the side of the gauge.
   - 4.2 Grasp the gauge firmly and pull it straight out of the mounting panel.

Installation

IMPORTANT: Don't touch the transmission fluid temperature gauge face or pointer.

1. Install the transmission fluid temperature gauge.
   - 1.1 Grasp the gauge firmly and insert it in the mounting panel.
   - 1.2 Make sure the gauge is firmly seated and that the locking clip is holding it in place.
2. Install the instrument cluster bezel. For detailed instructions, see Section 54.03, **Subject 100**.
3. Remove the chocks from the tires.

Transmission Fluid Temperature Sensor Removal and Installation

Removal

1. Shut down the engine, apply the parking brake, and chock the tires.

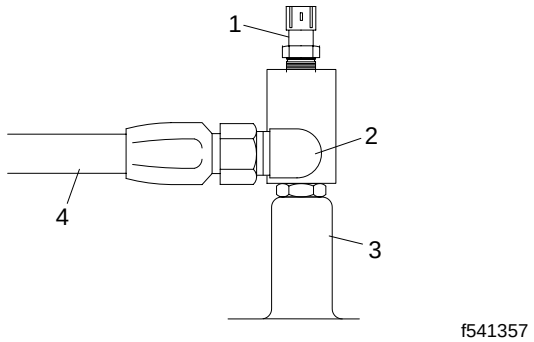
⚠ WARNING

Do not remove the temperature sensor until the transmission case has cooled. Touching a hot transmission case could result in burns to fingers and hands.

⚠ CAUTION

Automatic transmissions are sensitive to contamination of any kind. To prevent transmission damage, make sure that no dirt enters the system.

2. Remove the sensor from the transmission case. See **Fig. 1**.



1. Temperature Sensor
2. 90° Elbow
3. Outlet Port
4. Outlet Line to Cooler

Fig. 1, Transmission Fluid Temperature Sensor

2.1 Clean dirt and oil from the area around the sensor.

2.2 Disconnect the electrical connector from the sensor. Unscrew the sensor from the transmission outlet port.

2.3 To prevent contamination of the automatic transmission fluid (ATF), cover the hole with a shop towel.

Installation

1. Install the transmission fluid temperature sensor in the outlet port of the transmission case.

   1.1 Remove the shop towel and install the sensor into the port.

   1.2 Tighten the sensor to 18 lbf·ft (25 N·m).

2. Connect the wiring to the transmission fluid temperature sensor.
3. Start the engine and check for leaks.
4. Remove the chocks from the tires.
5. Test drive the vehicle to check the transmission fluid temperature gauge for correct operation.

Troubleshooting Procedures

Transmission temperature gauge malfunctions are usually one of two types: the gauge does not operate at all (it always shows that the transmission is cold), or the transmission temperature indicated by the gauge is incorrect.

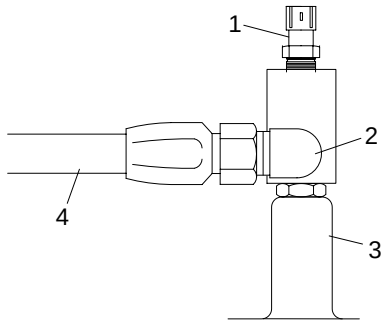
Malfunctions that would cause a totally inoperative transmission temperature gauge include open circuits in the gauge, sensor, or wiring. To isolate the cause of a faulty transmission temperature gauge system, follow the troubleshooting procedures in the order given.

1. Park the vehicle on a level surface. Shut down the engine. Set the parking brake and chock the rear tires.

⚠ WARNING

Do not touch the transmission case until the case has cooled. Touching a hot transmission case could result in burns to fingers and hands.

2. Turn the ignition key to the OFF position and remove the electrical connector from the transmission temperature sensor. See **Fig. 1**.



02/22/99 f541357

1. Temperature sensor
2. 90° Elbow
3. Transmission Outlet Port
4. Outlet Line to Cooler

Fig. 1, Transmission Temperature sensor Connection

3. Check the sensor unit with the electrical connector disconnected.

   3.1 Operate the vehicle until the transmission is at operating temperature. Carefully avoiding touching the hot transmission case, put the ohmmeter probes on the temperature sensor terminals. The ohmmeter reading should be less than 200 ohms when the transmission oil is hot.

   3.2 When the transmission cools to about 80° F (25° C) or less, connect one probe of an ohmmeter to one of the terminals on the sensor and the other probe to the other terminal. The ohmmeter reading should be at least 500 ohms. If the readings are not as indicated, replace the transmission temperature sensor, following the instructions in **Subject 110** and verify that the gauge operates properly.

4. If the sensor readings are within specifications, turn the ignition key to the ON position and, with the electrical connector to the sensor disconnected, observe the gauge needle. The gauge needle should remain at the left end of the scale (low temperature indicated). If not, find and repair the short circuit in the wiring or gauge.

5. Test the wiring harness and gauge.

   5.1 Turn the ignition key to the OFF position and connect both terminals in the harness connector together with a jumper.

   5.2 Turn the ignition key to the ON position again and watch the gauge needle; it should move immediately to the extreme right or "hot" end of the scale.

   If the gauge needle moves to full scale in this test, the gauge unit and the wiring to the gauge are functioning properly or the problem is intermittent.

   Turn the ignition key to the OFF position, remove the jumper from the wiring harness connector and reconnect the harness connector to the transmission temperature sensor.

   IMPORTANT: If the problem is intermittent, test the current carrying capacity of the wires and pins and replace any damaged parts.

   5.3 If the gauge needle stays at the low end of the scale with the jumper connected, test the harness ground circuit by connecting the jumper from ground to the sensor harness connector terminal for circuit 30.

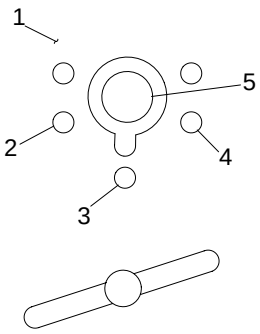
Troubleshooting

The gauge needle should move to the full scale position.

If the gauge now indicates full scale, the other wire in the sensor harness (from the harness connector to ground) is not making a good connection. Fix the wire problem and retest. If the gauge needle remains at the low end of the scale during this check, the gauge or the wire (circuit 30) from the sensor to the gauge has a problem.

6. If the previous tests indicate that the wiring and the sensor are good, check the gauge mounting panel and gauge.

   Remove the instrument cluster bezel and the transmission temperature gauge. If necessary, refer to **Subject 100**. See **Fig. 2** to identify the transmission temperature gauge terminals .



02/22/99 f601090

1. Gauge Mounting Panel
2. Ground Terminal (–)
3. Ignition Power Terminal (+)
4. Sensor Signal Terminal
5. Gauge Illumination Bulb

Fig. 2, Transmission Temperature Gauge Connection

7. Check the ground circuit wiring of the transmission temperature gauge.

   7.1 With the ignition key in the OFF position, connect the probes of an ohmmeter between the cab metal (an unpainted bolt or screw attached directly to cab structure works well) and the ground circuit terminal in the gauge mounting panel. See **Fig. 2**.

   7.2 The resistance should be less than 1 ohm. If it is, go to the next step. If the resistance is higher than 1 ohm, verify that you have good connections at both the terminal and the cab metal.

   7.3 If the connections are good, but the resistance is still greater than 1 ohm, locate the damaged section of wiring between the gauge ground terminal and ground. Repair the damage by splicing in a length of replacement wiring following the instructions in this group.

8. Check the signal circuit between the transmission temperature gauge and the sensor.

   8.1 With the gauge removed from the gauge mounting panel, connect one ohmmeter lead to the sensor signal terminal and the other lead to the mounting panel ground terminal. See **Fig. 2**.

   8.2 If the harness and sensor are good, the resistance will depend upon the transmission fluid temperature. The resistance should be more than 500 ohms for a cold transmission and less than 200 ohms for a transmission at operating temperature.

   8.3 If the sensor resistance at this test point is within specifications, the sensor and the wiring are functioning correctly. If the resistance is not with specifications, go to the next step to test for power to the gauge.

9. Check for battery voltage at the transmission temperature gauge terminal in the gauge mounting panel.

   9.1 Turn the ignition key to the ON position.

   9.2 Connect a voltmeter (set on the 20 volt scale, DC voltage) to the gauge terminals in the gauge mounting panel as follows; positive (red) probe to the ignition power terminal and the negative (black) probe to the ground terminal. See **Fig. 2**. The voltmeter should read between 9 and 16 volts DC.

   9.3 If the voltage is between 9 and 16 volts, the gauge itself is malfunctioning, and must be replaced. For instructions, refer to **Subject 100**. If the voltage reading is not within the limits mentioned above, check the circuit breaker that supplies power to

the gauge. If the circuit breaker is functioning correctly, locate and repair the damage to the power circuit.

General Information

The Kysor® engine warning and shutdown system alerts the driver to any problem associated with low engine oil pressure, and/or high coolant temperature. If a problem occurs in either of these systems, a dashboard warning light illuminates and a buzzer sounds.

The light and buzzer are activated by switches. The engine oil pressure switch is located on the bulkhead, near the engine electrical connectors. The coolant temperature switch is located on the engine block. For switch replacement, see **Subject 110**.

NOTE: The low oil pressure switch and the high coolant temperature switch activate the same warning light (OIL PRESSURE/COOLANT TEMPERATURE). The warning light comes on and the buzzer sounds whenever one of the following conditions occurs:

- The engine oil pressure drops below 9 psi (65 kPa); or
- The coolant temperature rises above 214°F (101°C) on Cummins engines, or 224°F (107°C) on the Caterpillar CFE engine.

Because power is supplied to these circuits through the ignition switch, turning the ignition switch off also shuts off the warning system.

If the coolant temperature continues to rise past a critical temperature, the ENGINE DOWN light comes on and the fuel solenoid (engine run) circuit is interrupted, shutting down the engine.

The critical temperatures vary according to the type of engine installed.

- 220°F (104°C) on Cummins engines
- 230°F (110°C) on the Caterpillar CFE engine.

Similarly, if engine oil pressure drops below 5 psi (35 kPa), the ENGINE DOWN light comes on and the engine shuts down.

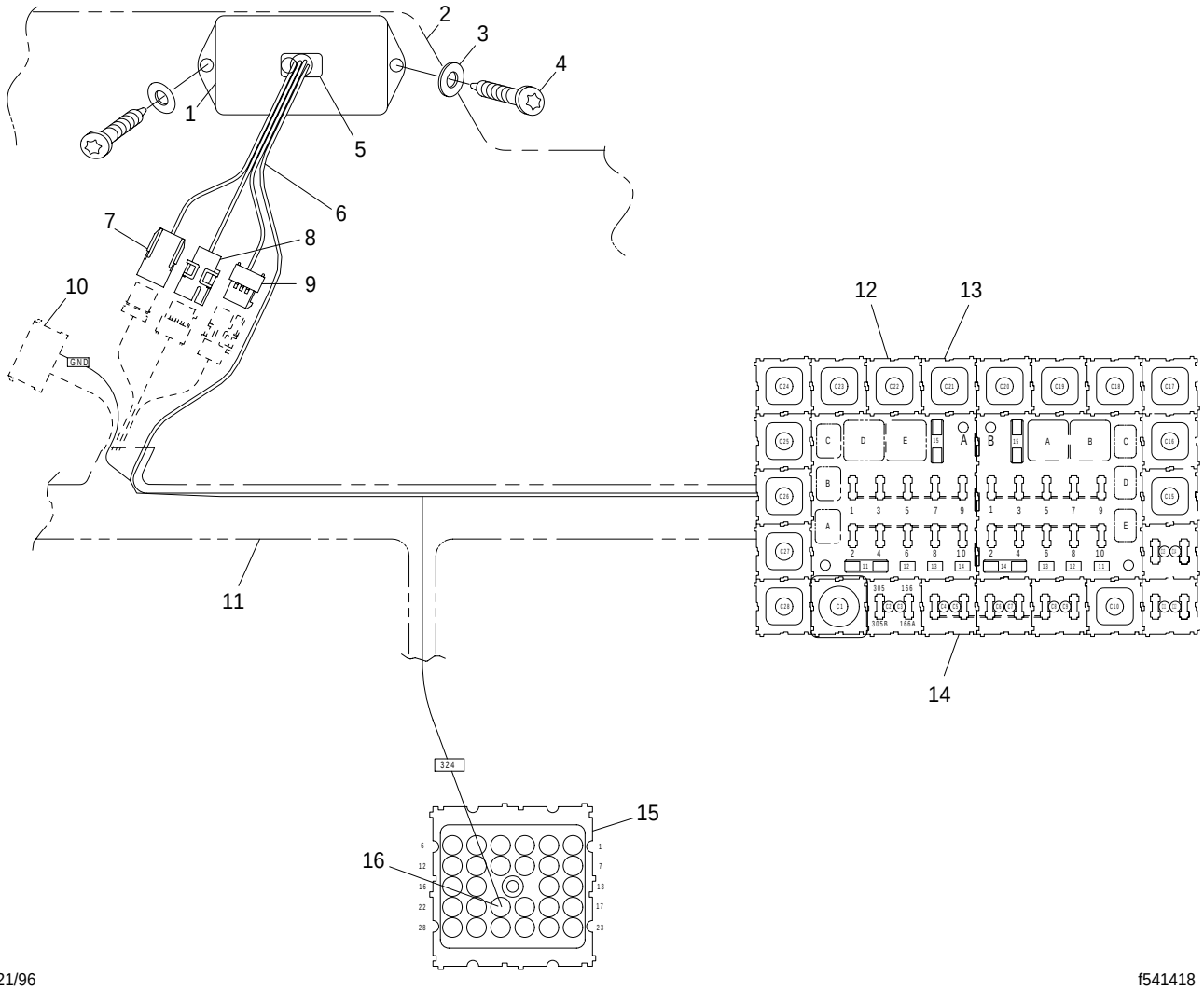
Both shutdown features have an automatic override. If necessary to move to a safer location, crank the engine: it will run for about 30 seconds before shutting down again.

A circuit overload protection system shuts down any overloaded output circuit. Therefore, intermittent shorts in the output circuits can cause intermittent false engine shutdowns. To restore full function, first remove the overload. Then reset the system by turning the ignition keyswitch off and then on again.

Replacement

1. Disconnect the warning and shutdown harness from the electrical connector on the face of the module. See **Fig. 1**.
2. Remove the two 10–24 machine screws and steel-plated washers from the sides of the module.
3. Remove the warning and shutdown module from the right-hand engine bulkhead extension.
4. Position the new module over the holes provided in the bulkhead extension.
5. Install two 10–24 machine screws and steel-plated washers.
6. Attach the warning and shutdown harness to the electrical connector on the face of the module.
7. Turn on the engine and check the buzzer and warning lights for proper operation.

Warning and Shutdown Module Replacement



1. Warning and Shutdown Module
2. Engine Bulkhead Extension (RH side)
3. Steel-Plated Washer
4. 10–24 Machine Screw
5. Electrical Connector
6. Warning and Shutdown Harness
7. 2-Pin Connector
8. 6-Pin Connector #1
9. 6-Pin Connector #2
10. Splice Pack (GND)
11. Main Cab Harness
12. Engine Shutdown Lights Relay
13. Engine Shutdown Relay
14. Power Distribution Module
15. Bulkhead Connector
16. Pin #20

Fig. 1, Warning and Shutdown Harness/Module

Replacement

HIGH COOLANT TEMPERATURE SWITCH

1. Remove the connector (with wires 18C and 324) holding the high coolant temperature switch. See **Fig. 1** for the Caterpillar CFE engine and **Fig. 2** for the Cummins B Series engine. Remove the switch from the connector.

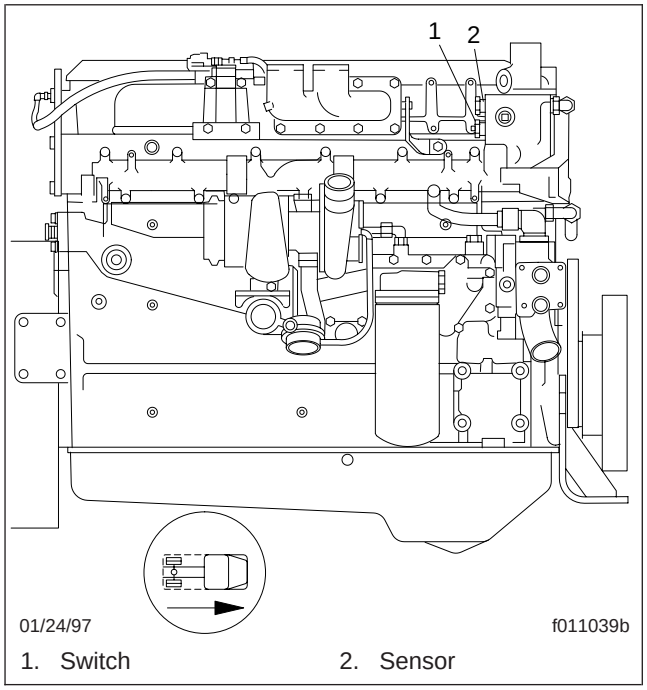


Fig. 1, Coolant Temperature Switch Location, Caterpillar CFE Engine

2. Install the new switch and attach the connector to the engine port.

LOW ENGINE OIL PRESSURE SWITCH

1. Turn off the ignition keyswitch.
2. Disconnect the ring terminals on wires 34 and 325 from the screw terminal mounted on the switch. See **Fig. 3**.
3. Remove the switch from the tee.

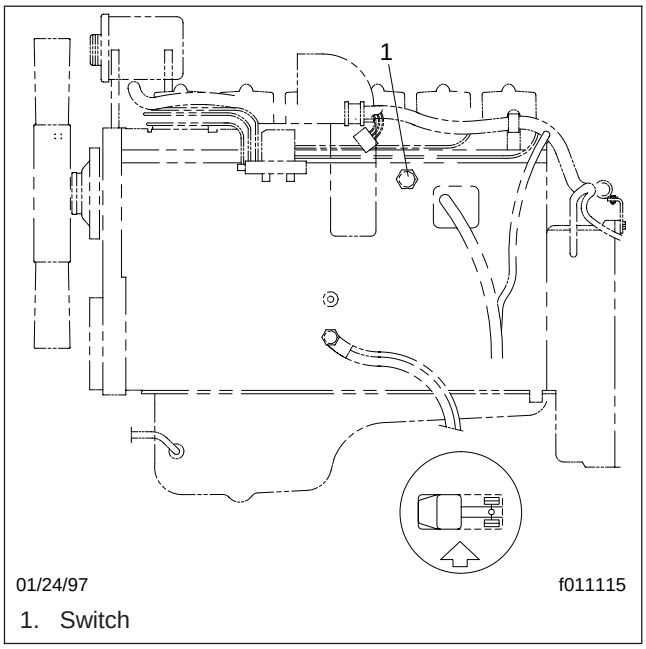
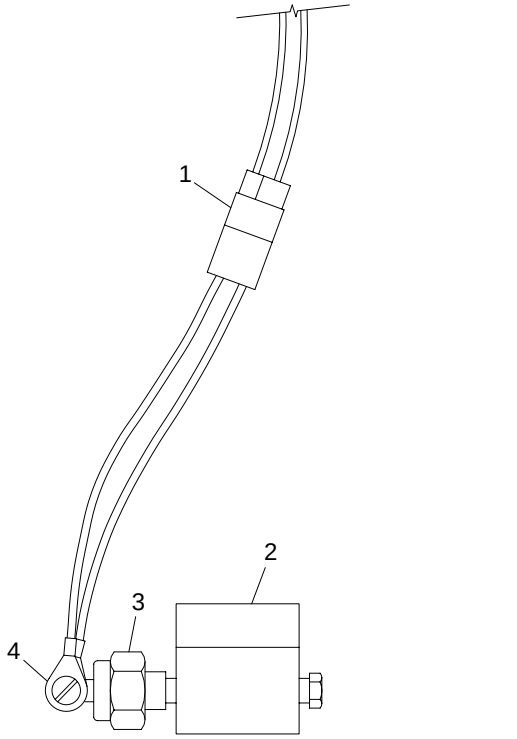


Fig. 2, Coolant Temperature Switch Location, Cummins B Series Engine

4. Install the new switch. Tighten securely, but do not overtighten. Connect wires 34 and 325 to the switch and tighten the screw terminal.
5. Start the engine and check that the warning light and buzzer shut off when the oil pressure reaches approximately 9 psi (65 kPa). Check the system to be sure there is no oil leakage, taking special care to note leakage around the switch installation.

Switch Replacement



1. Electrical Connector
2. Tee
3. Low Oil Pressure Switch
4. Terminal

Fig. 3, Low Engine Oil Pressure Switch Wiring

Replacement

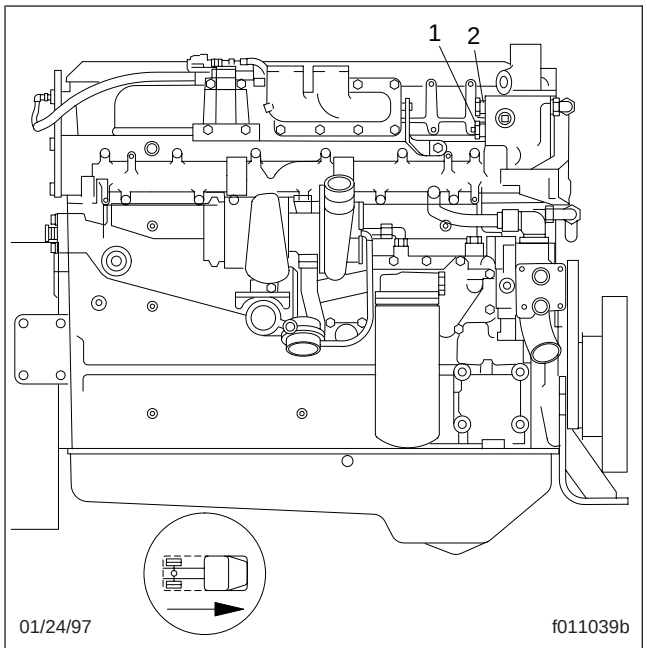
HIGH COOLANT TEMPERATURE SENSOR

1. Turn off the ignition switch and let the engine cool. Remove the surge tank cap to release system pressure.

⚠ WARNING

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

2. Drain the coolant from the engine.
3. Disconnect wires 119 and 119B from the coolant temperature sensor. See **Fig. 1** for the Caterpillar CFE engine and **Fig. 2** for the Cummins B Series engine. Remove the sensor.



1. Switch 2. Sensor

Fig. 1, Coolant Temperature Sensor Location, Caterpillar CFE Engine

4. Install the new sensor. Tighten securely, but do not overtighten. Connect wire 119 and 119B to the switch.

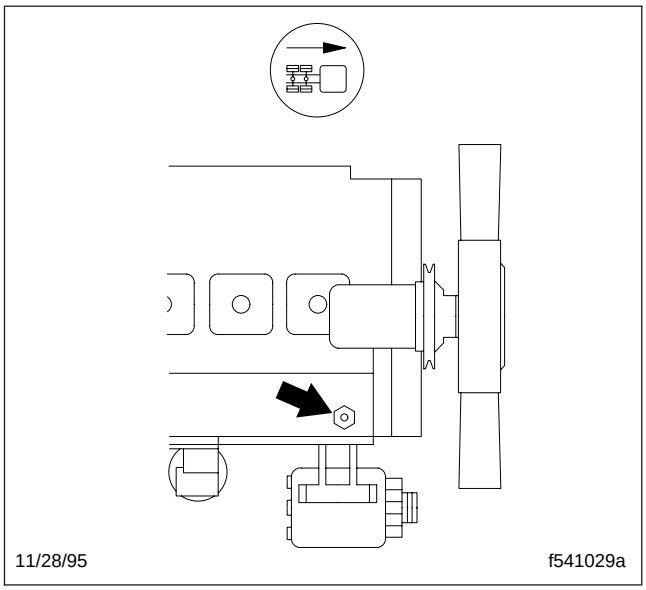


Fig. 2, Coolant Temperature Sensor Location, Cummins B Series Engine

5. Add coolant to the system as needed; then install the cap. Start the engine and check that the high coolant temperature light and buzzer do not stay activated. Check the system to be sure there are no coolant leaks, taking special care to note leakage around the sensor installation.

Troubleshooting Procedures

The ignition keyswitch must be on for the fuel solenoid to turn on. The ignition keyswitch is controlled by five separate inputs to the Kysor warning and engine shutdown system. See below for a test procedure for each input.

1. *Ignition Switch On*—Connect a voltmeter to the fuel solenoid wire 99, and turn on the ignition keyswitch. The voltmeter should register at least 12 volts for 25 to 35 seconds; then, the voltage should drop to zero.
2. *Starter Engage*—Turn on the ignition keyswitch and measure the voltage as above. After the voltage drops to zero, briefly engage the starter. There should be 12 volts at the fuel solenoid again for 25 to 35 seconds. Then, the voltage should drop to zero. This feature is activated through wire 150R, which has voltage only when the engine is being cranked.
3. *Temperature Sensing*—Disconnect wires 18C and 324 from the coolant temperature switch. Start the engine. Check that the oil pressure/coolant temperature light comes on and the warning buzzer sounds. The engine should shut down 20 to 40 seconds after starting, with the ENG DOWN light coming on at the same time.

   This circuit monitors the temperature switch continuity through wires 324 and 18C. If wire 18C or 324 shorts to ground, the high temperature alarm and shutdown features won't work. The engine could overheat and be damaged.

IMPORTANT: Perform the temperature sensing test at every scheduled vehicle service to ensure that there are no problems with circuit 18C or 324. Reconnect wires 18C and 324 to the coolant temperature switch.

4. *Low Oil Pressure Sensing*—oil pressure/coolant temperature light
   - 4.1 Disconnect wire 34 from the oil pressure switch.
   - 4.2 Start the engine. Check that the oil pressure/coolant temperature light comes on and the warning buzzer sounds.

   NOTE: Circuit 34 is ground-seeking at the coolant temperature switch, which is normally open. If the oil pressure falls below 9 psi (65 kPa), the switch opens and interrupts the ground to wire 34, turning on the oil pressure/coolant temperature light. An open circuit in wire 34 would cause a false low oil pressure warning, but a short to ground would prevent the light and buzzer from working.
5. *Low Oil Pressure Sensing*—ENG DOWN light
   - 5.1 With wire 34 still disconnected from the oil pressure switch, disconnect wire 325 from the oil pressure switch.
   - 5.2 Start the engine. Check that the oil pressure/coolant temperature light comes on and the buzzer sounds.
   - 5.3 Check that the ENG DOWN light comes on within 20 to 40 seconds after start up, and that the engine shuts down at the same time.

   NOTE: Like circuit 34, circuit 325 seeks ground through the normally open shutdown switch; if that ground is lost due to low oil pressure or an open circuit, the warning and shutdown module shuts down the engine. If circuit 325 shorts to ground, the low oil pressure shutdown function does not work.

Troubleshooting Tables

This subject contains the following troubleshooting tables:

- The engine cranks but will not start. The ENG DOWN light is on while the starter is cranking but goes off when the ignition keyswitch is released.
- The engine starts, then shuts down when the ignition keyswitch is released; the ENG DOWN light stays on during cranking and after the ignition keyswitch is released.
- The engine runs, then shuts down; the oil pressure/coolant temperature light and buzzer are not on; the ENG DOWN light is not on as the engine begins to lose rpm.
- The oil pressure/coolant temperature light and the warning buzzer are on, but the engine runs normally.

Troubleshooting

- The engine shuts down with the oil pressure/ coolant temperature light, the warning buzzer, and the ENG DOWN light on.

Problem—The engine cranks but will not start. The ENG DOWN light is on while the starter is cranking but goes off when the ignition keyswitch is released.

Possible Cause	Remedy
The engine may have fuel or mechanical problems.	While cranking, verify that the fuel pump solenoid retracts and stays retracted during cranking.
Wire 74A may be broken or loose (Cummins engines only).	Disconnect the electrical connector at the fuel pump solenoid. Check for battery voltage at wire 74A. Repair or replace wire 74A if battery voltage is not present.
The fuel pump solenoid is malfunctioning.	With the electrical connector at the fuel pump solenoid disconnected, ground the solenoid ground wire (black wire) and apply 12V to the white wire coming from the fuel pump solenoid. The solenoid should retract.

Problem—The engine starts, but shuts down once the ignition keyswitch is released; the ENG DOWN light stays on during cranking and remains on after the ignition keyswitch is released.

Possible Cause	Remedy
Poor ground on GND wire at Kysor control module.	Make sure GND wire is adequately grounded.
No start signal to Kysor control module. The voltage at wire 150R should measure 9 volts or higher while cranking the engine.	This is not a control module problem. Find the reason for the low voltage and correct the condition.
The fuel shutdown relay is malfunctioning.	Replace the relay.
The fuel solenoid or wire 99 is shorted to ground.	Correct the short in the fuel solenoid or wire 99. If the short cannot be corrected, replace the shorted solenoid or wire.
Wire 373 is broken.	Check continuity in circuit 373 from control module to fuel solenoid relay.

Problem—The engine runs, then shuts down; the oil pressure/coolant temperature light and buzzer are not on; the ENG DOWN light is not on as the engine begins to lose rpm.

Possible Cause	Remedy
Wire 99 or the fuel solenoid has intermittent open connections.	Repair the intermittent open connections.
Wire 373 from the ignition switch to the fuel solenoid relay has intermittent open connections.	Repair the intermittent open connections.
The fuel shutdown lights relay is malfunctioning.	Replace the relay.

Problem—The oil pressure/coolant temperature light and the warning buzzer are on, but the engine runs normally.

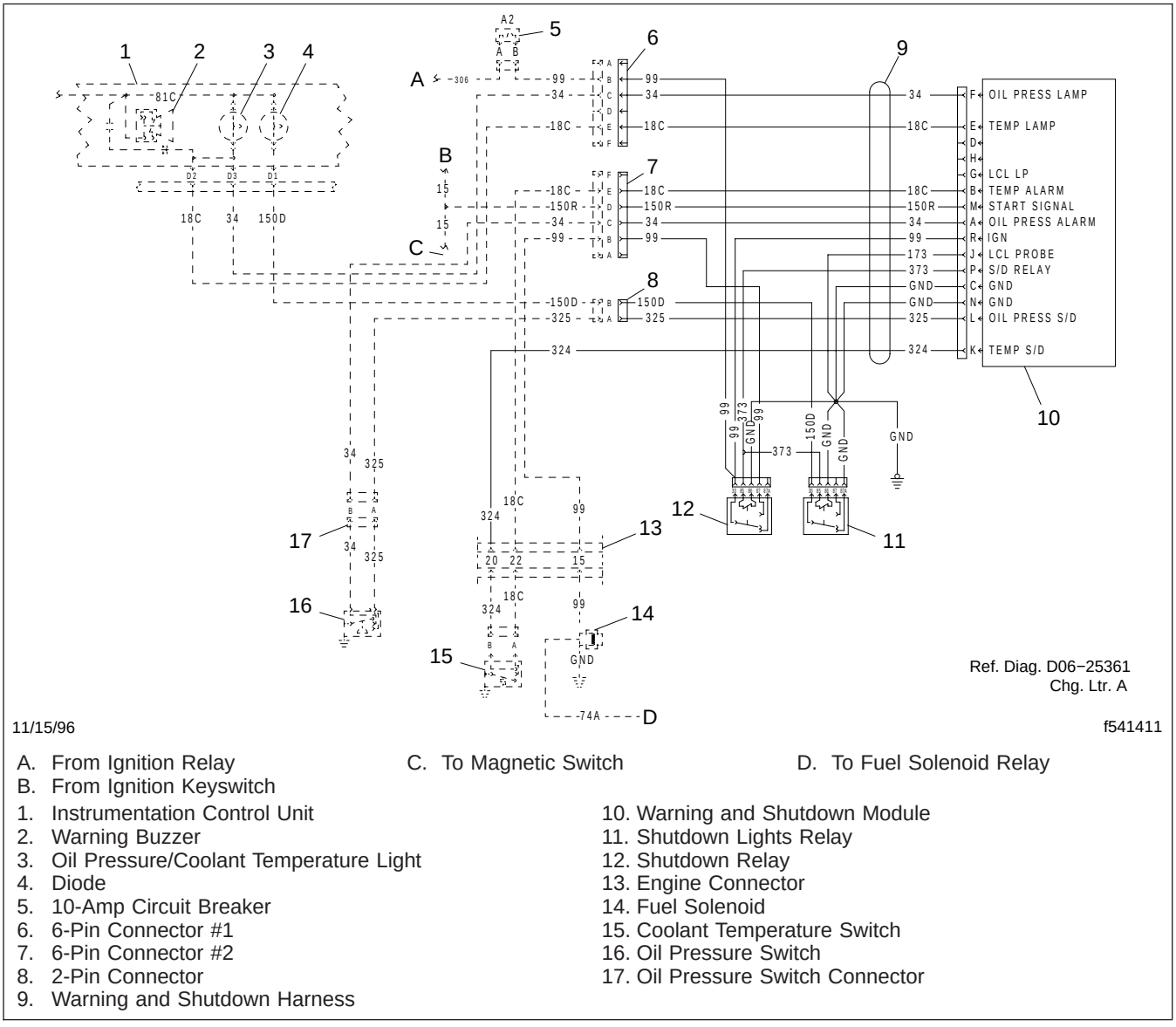
Possible Cause	Remedy
Wire 34 or 325 in the oil pressure shutdown circuit is broken or intermittently open.	Jump the switch end of wire 325 to ground. If the problem disappears, correct the open circuit or replace wire 34 or 325.
The oil pressure sensor is malfunctioning if the problem disappears when the sensor end of wire 325 is jumped to ground.	Jump the switch end of wire 325 to ground. If the problem does not disappear, replace the sensor.
The Kysor control module is malfunctioning.	Replace the module.

Problem—The engine shuts down with the oil pressure/coolant temperature light, the warning buzzer, and the ENG DOWN light on.

Possible Cause	Remedy
The engine is overheating.	Locate and correct the cause of overheating.
Wire 324 or 18C is broken or intermittently open.	Correct the open circuit or replace wire 324 or 18C.
The coolant temperature switch is malfunctioning.	Replace the switch.
The Kysor control module is malfunctioning.	Replace the module.
The engine oil pressure is low.	Check the engine manufacturer's manual for diagnostic and corrective measures.
The oil pressure switch is faulty.	Replace the switch.

For a schematic of the Kysor warning and shutdown system, see **Fig. 1**.

For a drawing of the Kysor warning and shutdown harness, see **Fig. 2**.

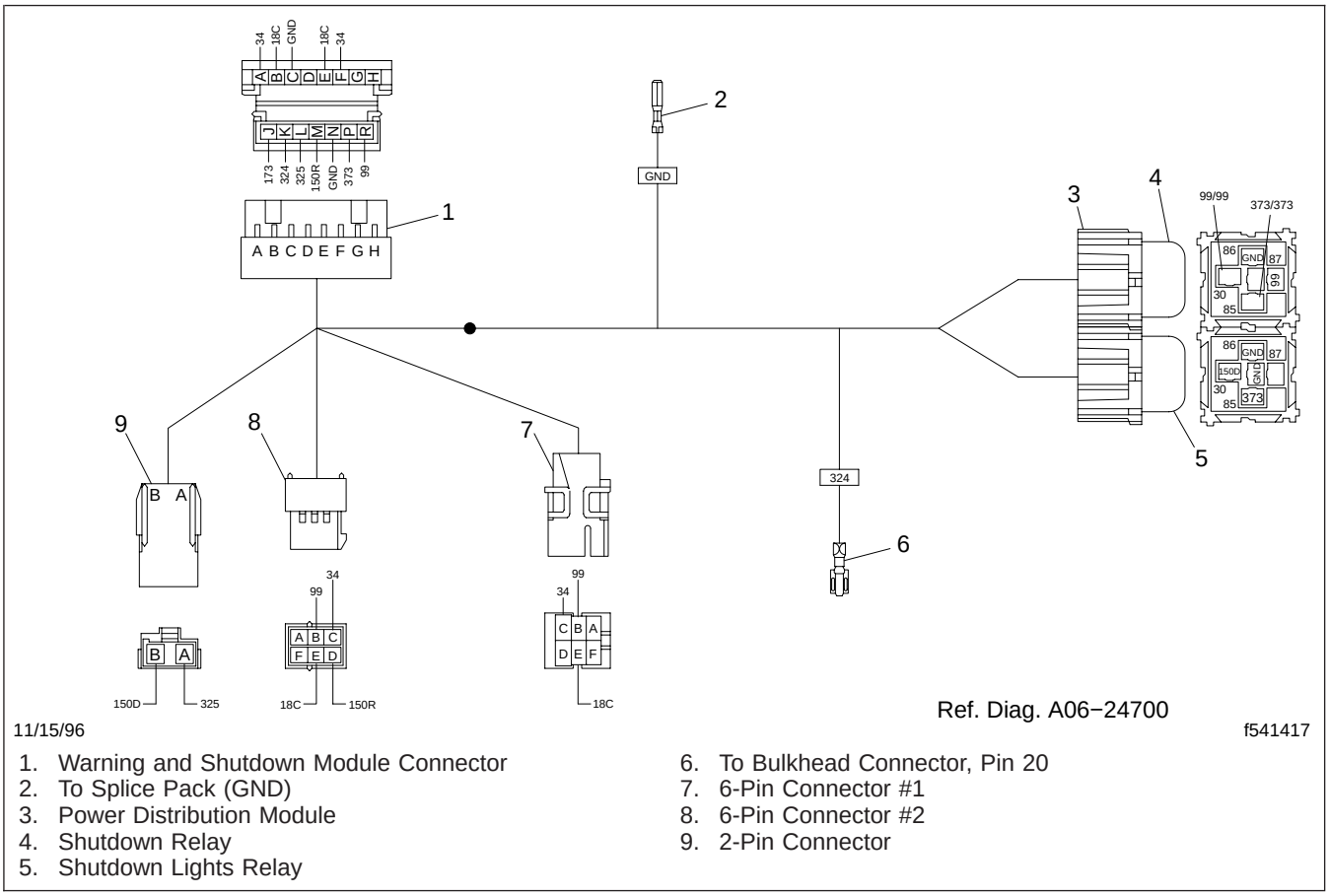


A. From Ignition Relay
B. From Ignition Keyswitch
C. To Magnetic Switch
D. To Fuel Solenoid Relay

1. Instrumentation Control Unit
2. Warning Buzzer
3. Oil Pressure/Coolant Temperature Light
4. Diode
5. 10-Amp Circuit Breaker
6. 6-Pin Connector #1
7. 6-Pin Connector #2
8. 2-Pin Connector
9. Warning and Shutdown Harness
10. Warning and Shutdown Module
11. Shutdown Lights Relay
12. Shutdown Relay
13. Engine Connector
14. Fuel Solenoid
15. Coolant Temperature Switch
16. Oil Pressure Switch
17. Oil Pressure Switch Connector

Fig. 1, Kysor Warning and Shutdown System Schematic

Specifications



1. Warning and Shutdown Module Connector
2. To Splice Pack (GND)
3. Power Distribution Module
4. Shutdown Relay
5. Shutdown Lights Relay
6. To Bulkhead Connector, Pin 20
7. 6-Pin Connector #1
8. 6-Pin Connector #2
9. 2-Pin Connector

Fig. 2, Kysor Warning and Shutdown Harness

For a schematic of the engine side wiring for the Cummins ISB electronic engine, see **Fig. 1**.

For a detailed (partial) schematic showing the engine ECM connectors, see **Fig. 2**. For a detailed (partial) schematic showing the electronic engine frontwall connector, see **Fig. 3**.

For a schematic of the cab side wiring for the Cummins ISB electronic engine, see **Fig. 4**.

For a detailed (partial) schematic showing the cab wiring behind the electronic engine frontwall connector, see **Fig. 5** and **Fig. 6**.

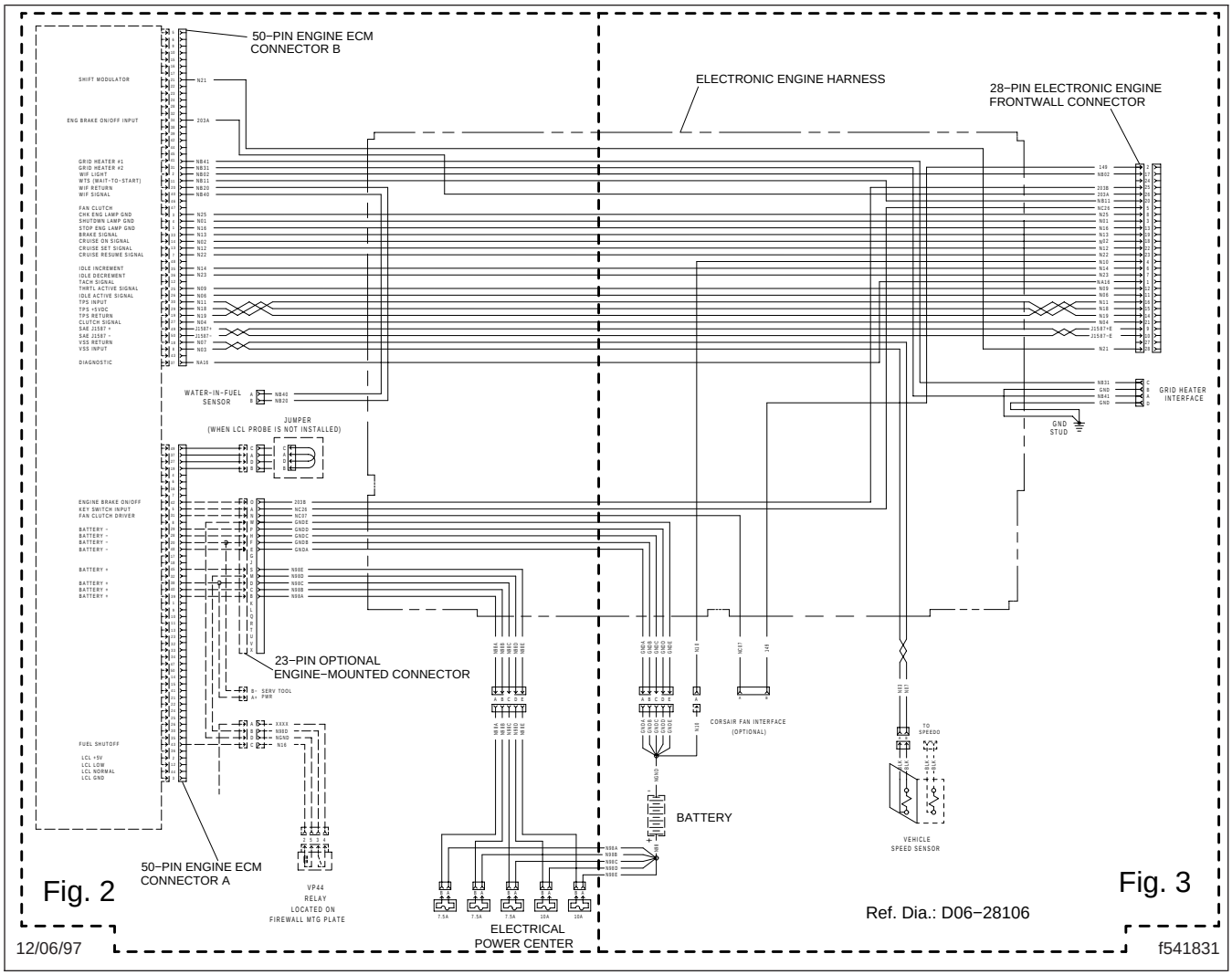


Fig. 1, Cummins ISB Engine Wiring Schematic

Specifications

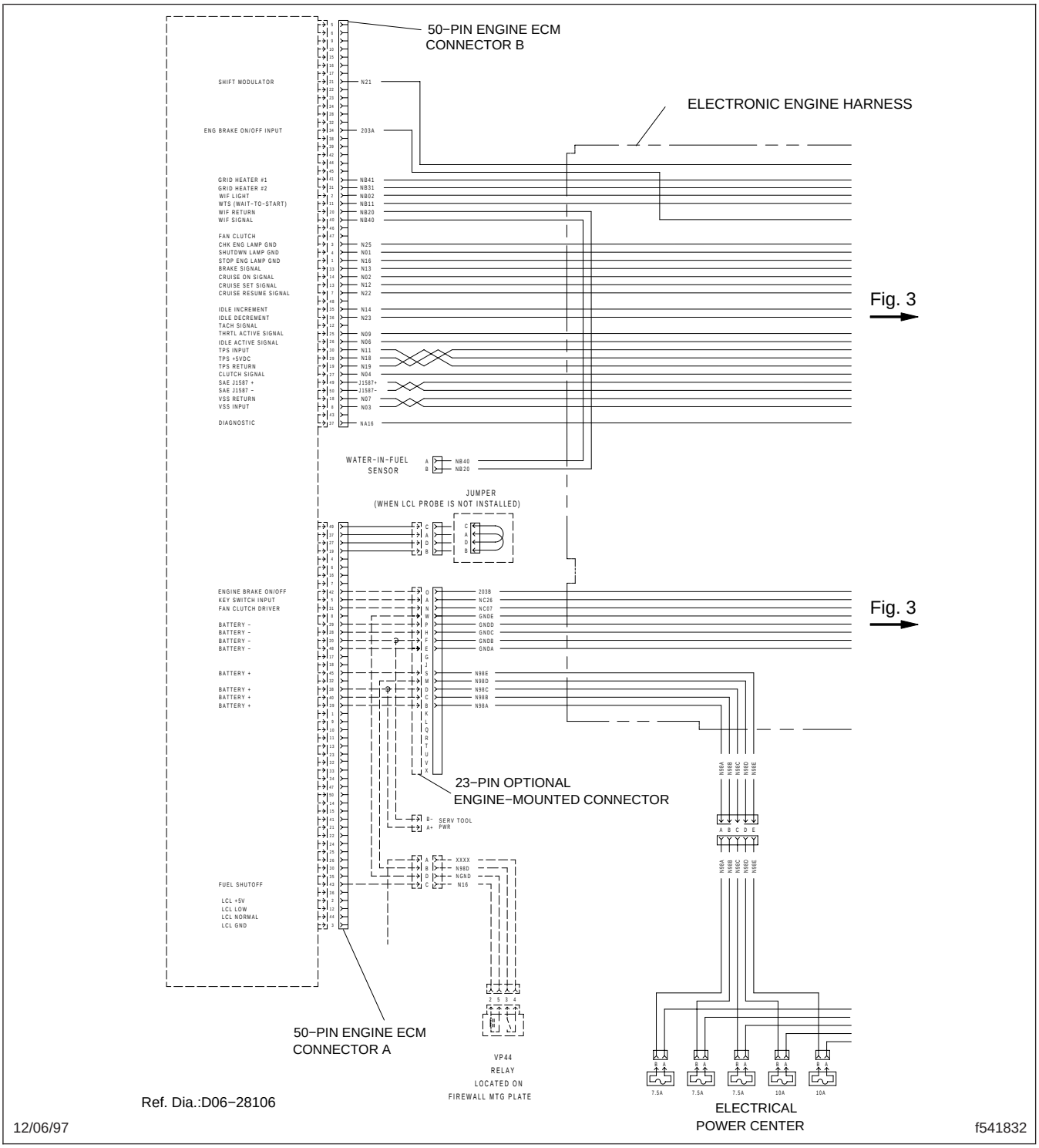


Fig. 2, Cummins ISB Engine ECM Connectors (detailed view)

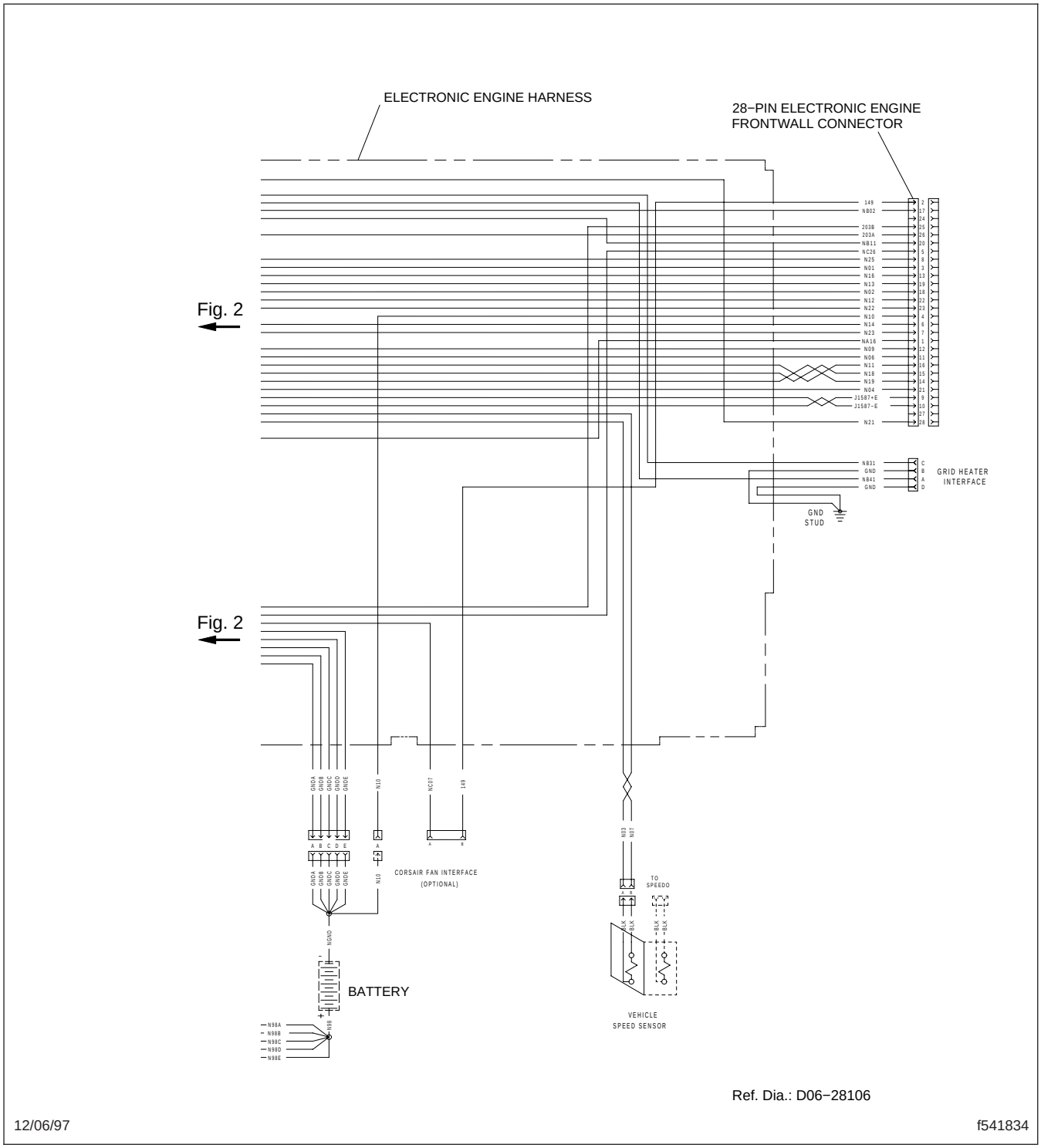


Fig. 3, Cummins ISB Engine Frontwall Connector (detailed view)

Specifications

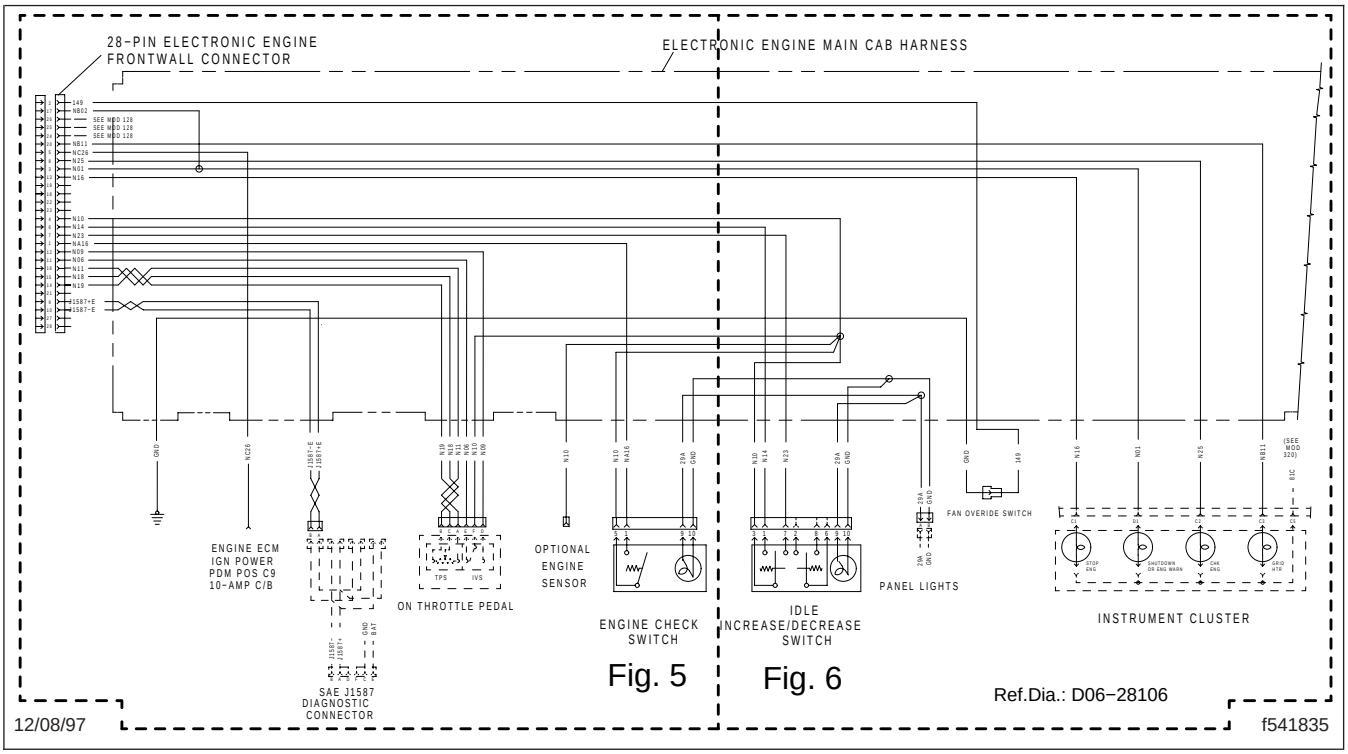


Fig. 4, Cummins ISB Engine Cab Side Wiring Schematic

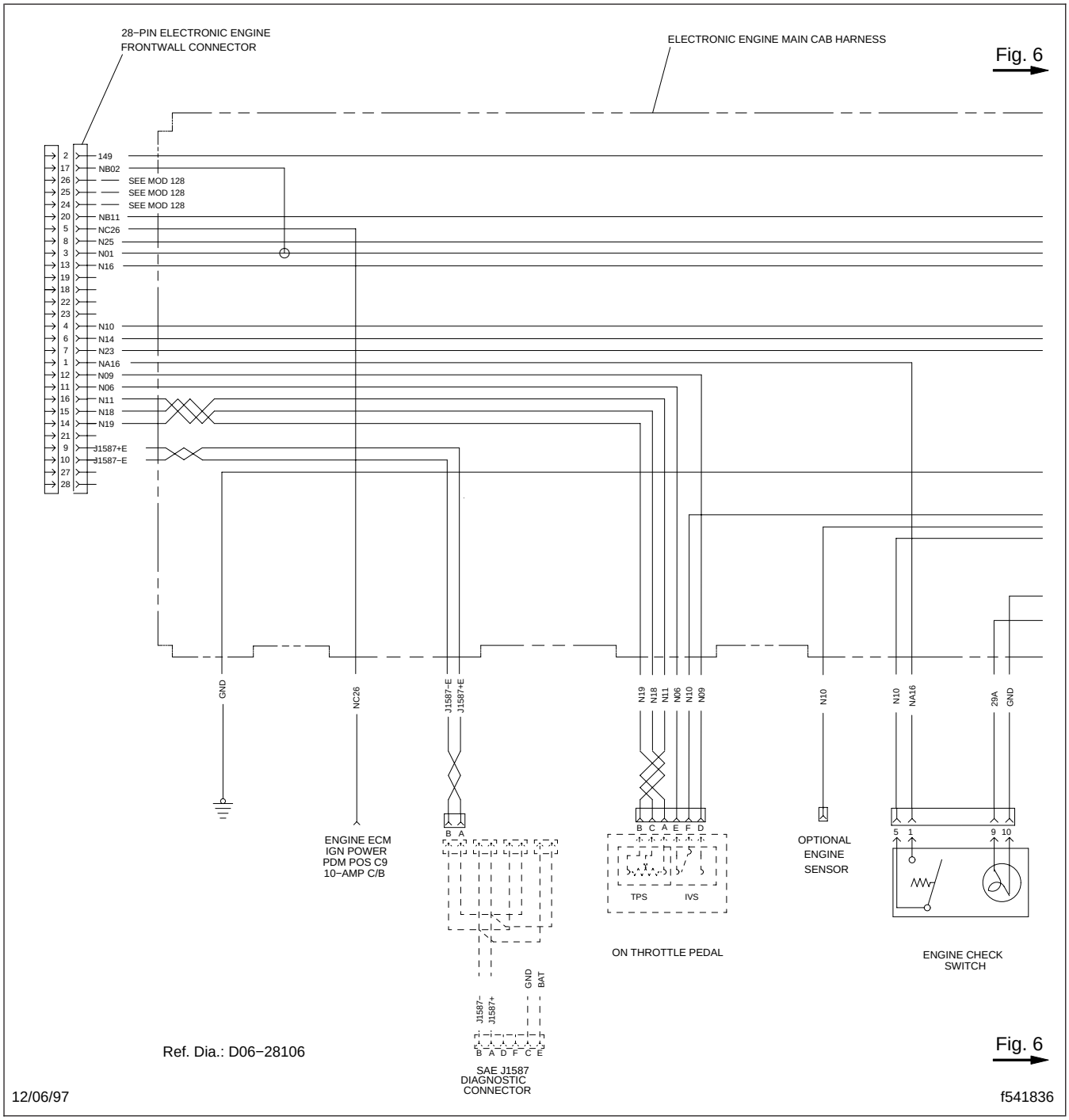


Fig. 5, Cummins ISB Engine Cab Side Wiring Schematic (detailed view)

Specifications

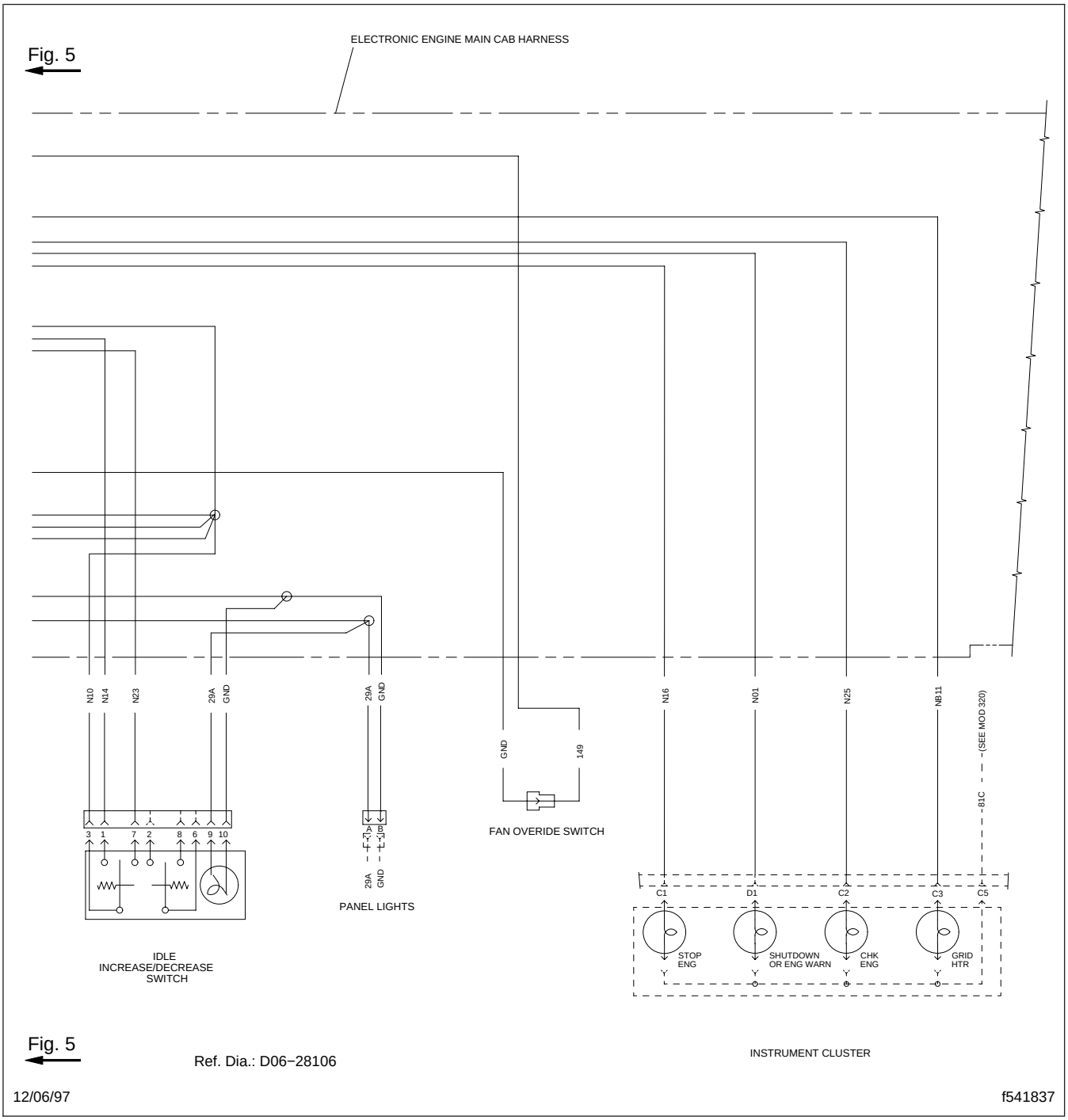


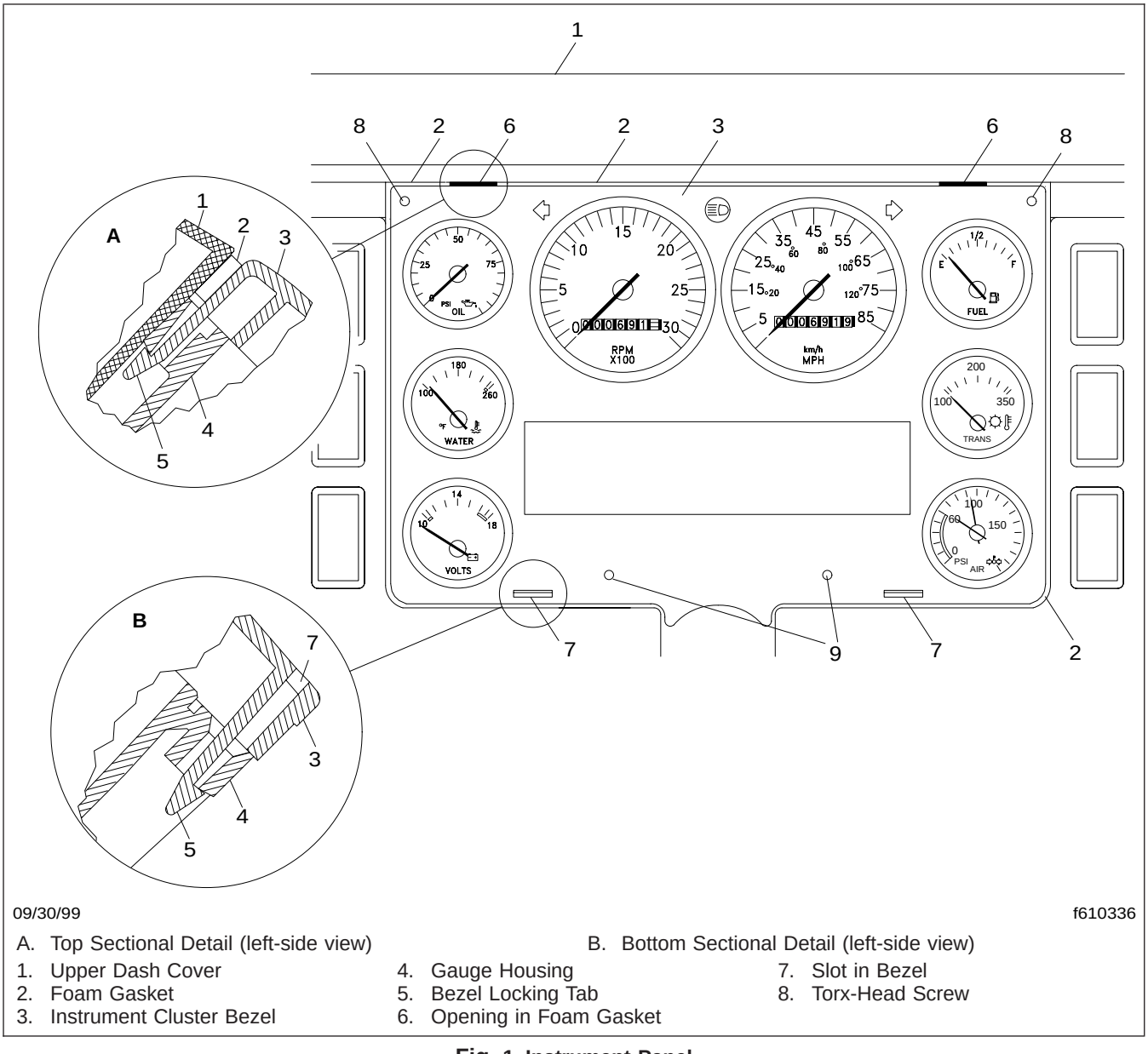
Fig. 6, Cummins ISB Engine Cab Side Wiring Schematic (detailed view)

General Description

The voltmeter is located in the lower left instrument panel. The voltmeter indicates battery voltage level, and should read 12.8 volts to 14.6 volts (or higher) when the engine is running. When the engine is being started, battery voltage will be lower than normal. Once the engine has been started, battery voltage will be temporarily higher than normal as the batteries are being recharged. If the voltmeter indicates a low or high voltage for an extended period of time, check the charging system and batteries.

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.
3. Remove the instrument cluster bezel. See **Fig. 1**.
   - 3.1 Remove the four Torx®-head screws from the bezel.
   - 3.2 Remove the instrument panel from the dash.
   - 3.3 Remove the bezel and set it aside.



09/30/99 f610336

A. Top Sectional Detail (left-side view)
B. Bottom Sectional Detail (left-side view)

1. Upper Dash Cover
2. Foam Gasket
3. Instrument Cluster Bezel
4. Gauge Housing
5. Bezel Locking Tab
6. Opening in Foam Gasket
7. Slot in Bezel
8. Torx-Head Screw

Fig. 1, Instrument Panel

Voltmeter Removal and Installation

4. Remove the voltmeter from the gauge mounting panel by firmly grasping the gauge and pulling it straight out of the mounting panel.

   The gauge illumination bulb will remain in the gauge mounting panel; do not remove the bulb unless it must be replaced.

Installation

1. Position the voltmeter over the gauge mounting panel, making sure that the panel terminals line up with the gauge sockets.
2. Push the gauge into place until it seats against the mounting panel.
3. Position the instrument cluster bezel against the instrument panel.
4. Install the Torx-head screws in the instrument cluster bezel and tighten until firm.
5. Connect the batteries.
6. Start the engine and verify that the voltmeter is operating properly.
7. Remove the chocks from the tires.

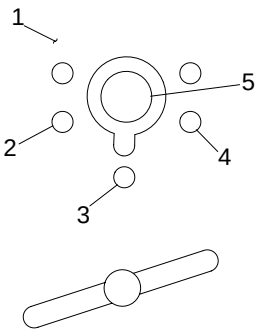
Troubleshooting Procedures

Voltmeter gauge malfunctions are usually one of two types: the gauge does not operate at all, or the gauge is believed to be incorrect.

Before proceeding with any troubleshooting when an inaccurate gauge is suspected, confirm the actual battery voltage and charging voltage with a known good voltmeter.

Malfunctions that would cause a totally inoperative voltmeter include open circuits in the gauge or wiring.

1. Remove the instrument cluster bezel and the voltmeter gauge. For instructions, see **Subject 100**.
2. Identify the voltmeter terminals that are part of the gauge mounting panel. See **Fig. 1**.



02/22/99 f601090

1. Gauge Mounting Panel
2. Ground Terminal
3. Ignition Power Terminal (12 volts)
4. Not Used
5. Illumination Bulb

Fig. 1, Voltmeter Connection

3. Check the voltmeter gauge ground circuit wiring for an open circuit.
   - 3.1 With the ignition switch turned off, connect the leads of an ohmmeter between the cab metal (an unpainted bolt or screw attached directly to cab structure works well) and the ground circuit terminal in the gauge mounting panel. See **Fig. 1**.
   - 3.2 Resistance should be very low—less than 5 ohms. If it is, go to the next step. If resistance is higher than 5 ohms, verify that you have good connections at both the terminal and the cab metal.
   - 3.3 If the connections are good, but resistance is still greater than 5 ohms, locate the damaged section of wiring between the terminal and ground. Repair the damage by splicing in a length of replacement wiring following the instructions in this manual.
4. Check for battery voltage at the voltmeter gauge power terminal in the gauge mounting panel with the ignition switch in the on position.
   - 4.1 Turn the ignition switch on.
   - 4.2 Connect a voltmeter (set on 20 volt scale, DC voltage) to mounting panel terminals as follows; positive (red) probe to the ignition power terminal and the negative (black) probe to the ground terminal. See **Fig. 1**. The voltmeter should read between 9 and 16 volts DC.
   - 4.3 If voltage is between 9 and 16 volts DC, the gauge itself is malfunctioning, and must be replaced. For instructions, see **Subject 100**. If the voltage reading is not between 9 and 16 volts DC, check the circuit breaker that supplies power to the gauge. If the circuit breaker is okay, locate and repair the damage to the power circuit. General wire repair information can be found elsewhere in this group.
5. Install the voltmeter gauge and instrument cluster bezel. Make sure that the gauge is now operating properly.

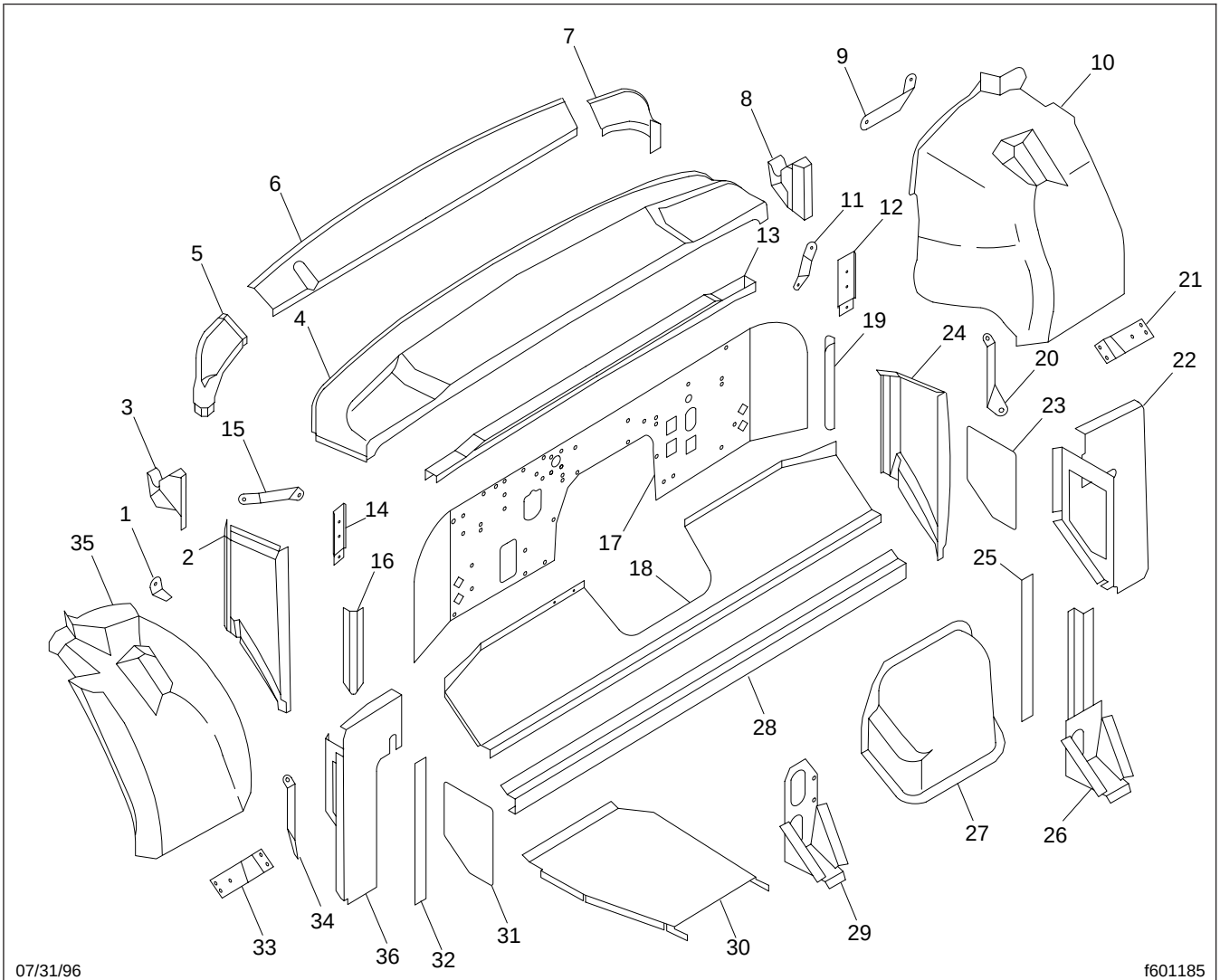
General Information

The cowling assembly provides support for the vehicle's 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 fastened to the bus body when the body is mounted to the frame rails.

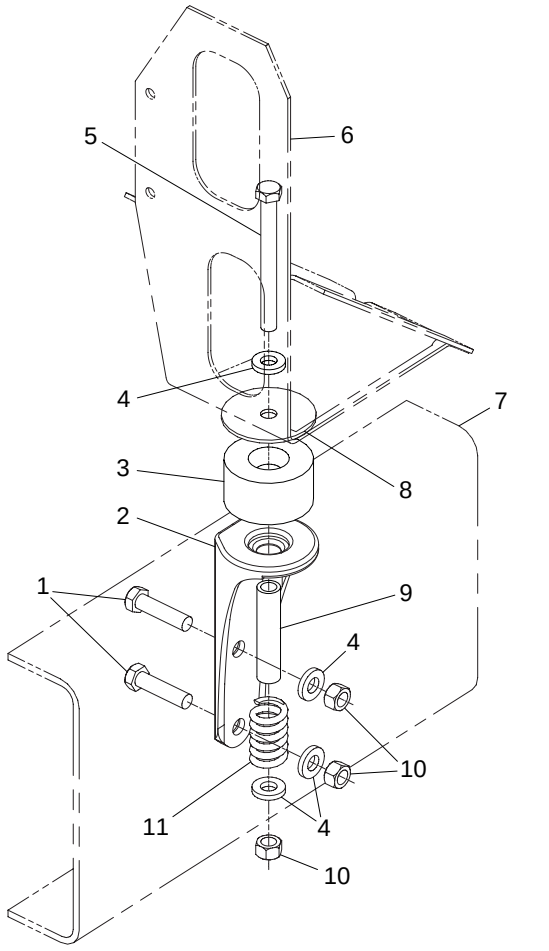
The body mounts, also know as "body outriggers" and "body shear clips," provide extra support for the bus body floor. See **Fig. 3**.

General Information



1. Half-Fender Support Bracket
2. Cowling Side Panel
3. Hood Support Bracket Assembly
4. Cowling Top Panel
5. Cowling Support Panel
6. Cowling Top Support Panel
7. Cowling Support Panel
8. Hood Support Bracket Assembly
9. Half-Fender Support Bracket
10. Half Fender
11. Hood Support Brace
12. Front-Panel Reinforcement Assembly
13. Cowling Top-Panel Reinforcement Assembly
14. Front-Panel Reinforcement Assembly
15. Hood Support Brace
16. Cowling Side-Panel Support
17. Front Panel
18. Toeboard Panel
19. Cowling Side Panel Support
20. Half-Fender Support Bracket, Lower
21. Hood-Latch Support Bracket
22. Cowling Side-Panel Reinforcement Assembly
23. Closure Panel
24. Cowling Side Panel
25. Tapping Plate
26. Cowling Mounting Assembly Support, Righthand Drive
27. Engine Tunnel
28. Toeboard Crossmember Panel
29. Cowling Mounting Assembly Support, Lefthand Drive
30. Raised Floor Panel
31. Closure Panel
32. Tapping Plate
33. Hood-Latch Support Bracket
34. Half-Fender Support Bracket, Lower
35. Half Fender
36. Cowling Side-Panel Reinforcement Assembly

Fig. 1, Cowling Assembly (exploded)

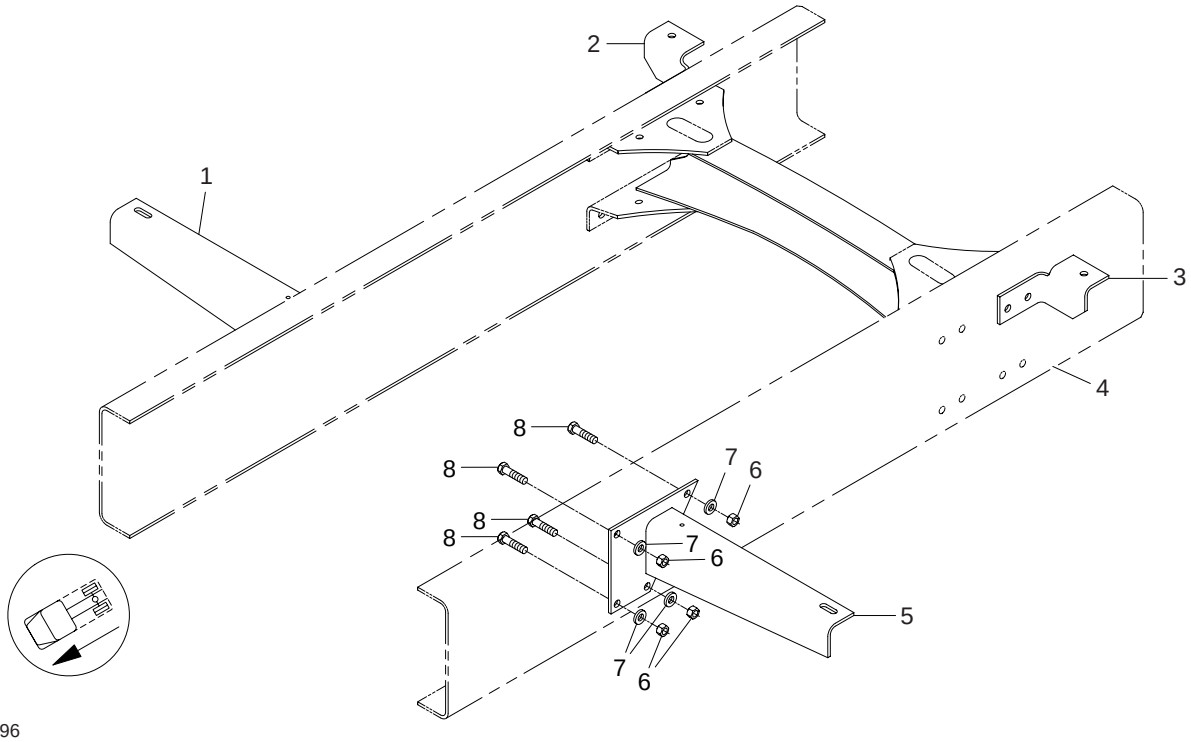


07/18/96 f601180

1. Hexhead Bolts, 1/2–13, Grade 8
2. Cowling Mounting Bracket
3. Isolator
4. Bearing Washers
5. Hexhead Bolt
6. Cowling
7. Frame Rail
8. Flat Washer
9. Cowling Mounting Spacer
10. Hexnuts, 1/2–13
11. Compression Spring

Fig. 2, Cowling Mount

General Information



07/19/96 f601181

1. Body Outrigger Bracket, right side
2. Body Shear Clip Bracket, right side
3. Body Shear Clip Bracket, left side
4. Frame Rail
5. Body Outrigger Bracket, left side
6. Hexnuts, 1/2–13
7. Bearing Washer
8. Hexhead Bolt, 1/2–13, Grade 8

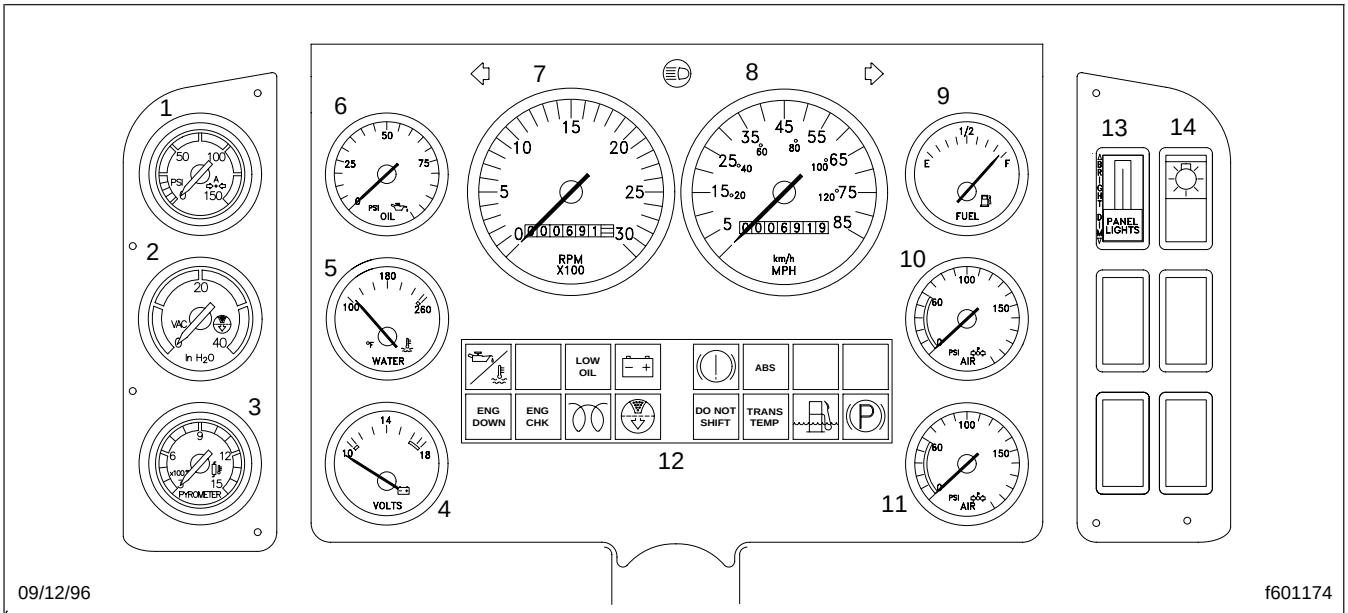
Fig. 3, Body Mounts

General Information

Figure 1 represents a typical instrument and control panel. The panel shown is equipped with all of the standard and many of the optional instruments and accessories. The panel houses all of the standard and optional warning and indicator lights.

Figure 2 is a detailed illustration of the warning and indicator light module. Warning and indicator lights activate whenever factors, such as temperature or fluid levels, exceed or fall below pre-set points.

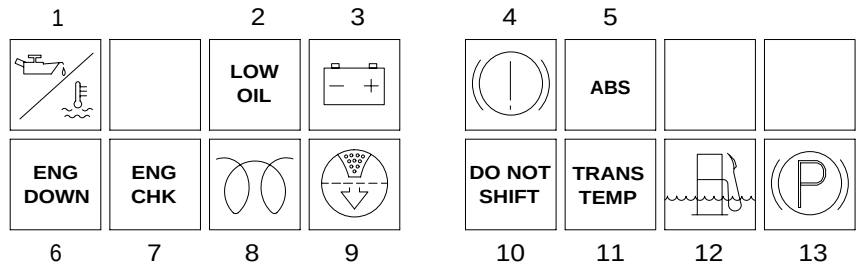
Dash panel components are shown in **Fig. 3**.



1. Application Air Pressure Gauge
2. Air Restriction Gauge
3. Pyrometer
4. Voltmeter
5. Water Temperature Gauge
6. Engine Oil Pressure Gauge
7. Tachometer
8. Speedometer
9. Fuel Gauge
10. Primary Air Pressure Gauge
11. Secondary Air Pressure Gauge
12. Warning and Indicator Light Module
13. Panel Light Rheostat
14. Headlight Switch

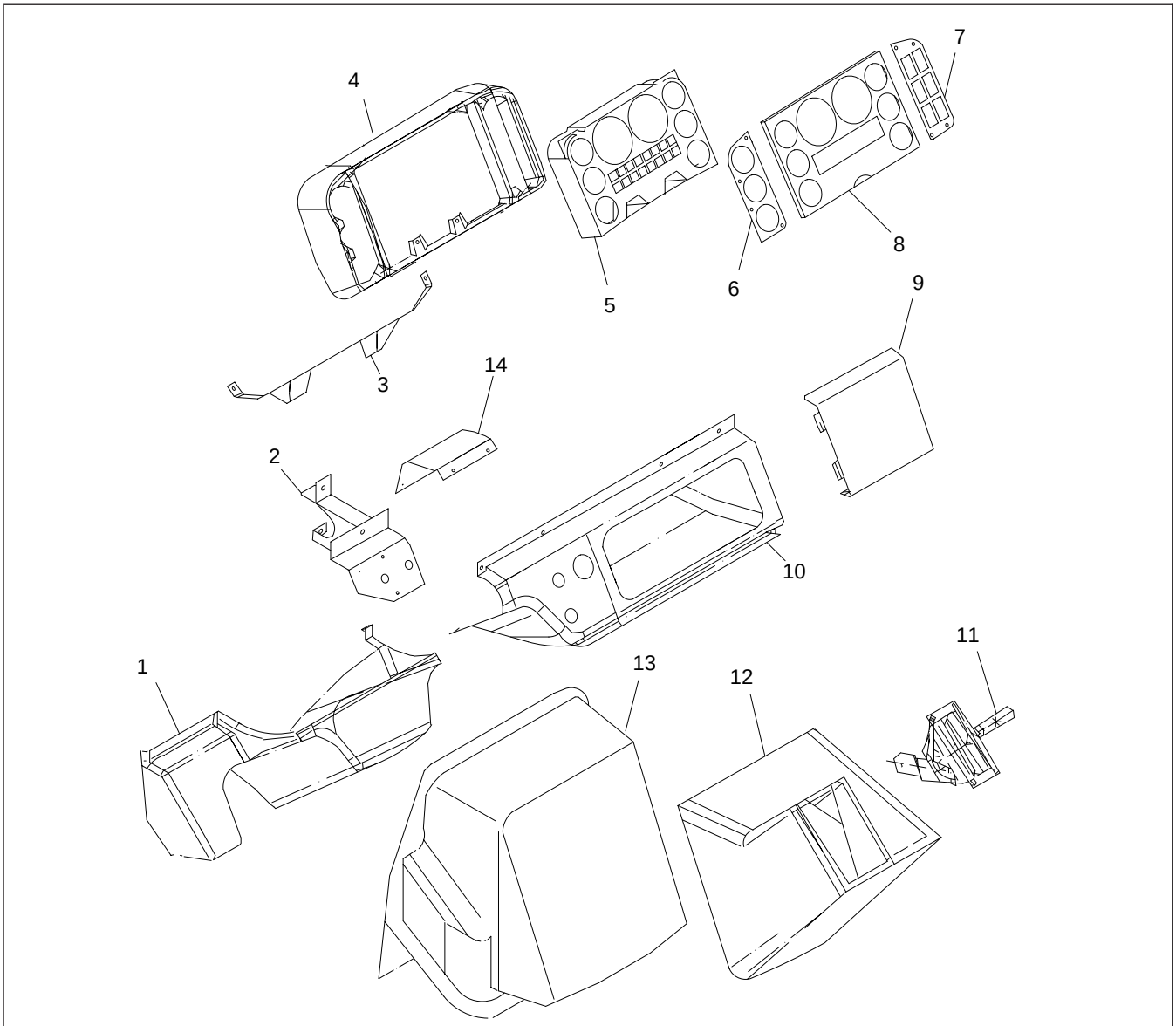
Fig. 1, Instrument Panel

General Information



1. Low Oil Pressure/High Water Temperature
2. Low Water Level
3. Low Engine Oil Level
4. Charging
5. Brake System Failure
6. ABS Tractor/Truck
7. Stop Engine
8. Check Engine
9. Glow Plug
10. Air Cleaner Restriction
11. Do Not Shift
12. Transmission Oil Temperature
13. Water in Fuel
14. Parking Brake Applied

Fig. 2, Warning and Indicator Light Module (detail)



07/29/96 f601183

1. Steering Column Cover
2. Central Dash Support Bracket
3. Instrument Cluster Stiffener
4. Instrument Panel Housing
5. Instrument Cluster
6. Instrument Panel
7. Switch Panel
8. Cluster Bezel
9. Fuse Block Cover
10. Lower Dash Panel
11. Shift Lever (automatic shown)
12. Shifting Housing
13. Engine Tunnel
14. Glove Box Support Bracket

Fig. 3, Dash Panel Components (exploded)

Replacement

Fuse Box Cover

Push in the tab on the right side of the fuse box cover and pull the cover outward. See **Fig. 1**. Reverse the procedure for installation.

Lower Dash Panel

Remove the fasteners in the dash panel cavity and along the top edge, as well as the fastener attaching the left side of the panel to the dash. See **Fig. 2**. Pull the panel over the top of the ignition switch. The ignition switch may need to be removed to remove the panel. Also, the brake valve and hand throttle switches need to be removed, if installed. Reverse the procedure for installation.

Shifting Housing

Remove the fasteners on each side of the shifting housing and slide free. See **Fig. 3**. Reverse the procedure for installation.

Steering Column Cover

Remove the three fasteners attaching the steering column cover to the dash unit. Reverse the procedure for installation.

Instrument Cluster

Remove the three fasteners (one at the top and two below on the cluster stiffener). Reverse the procedure for installation.

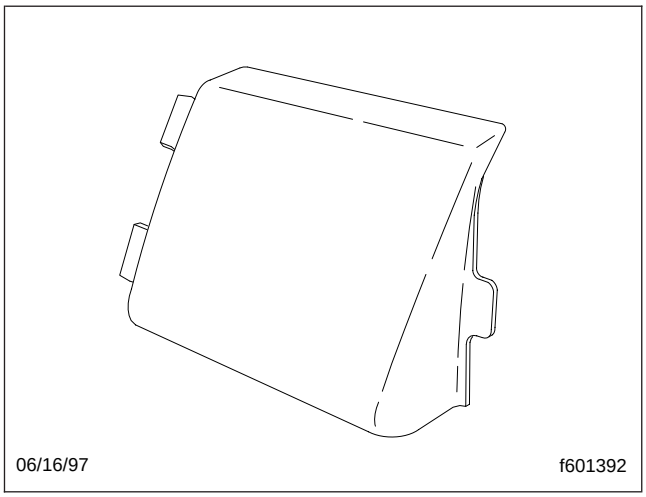


Fig. 1, Fuse Box Cover

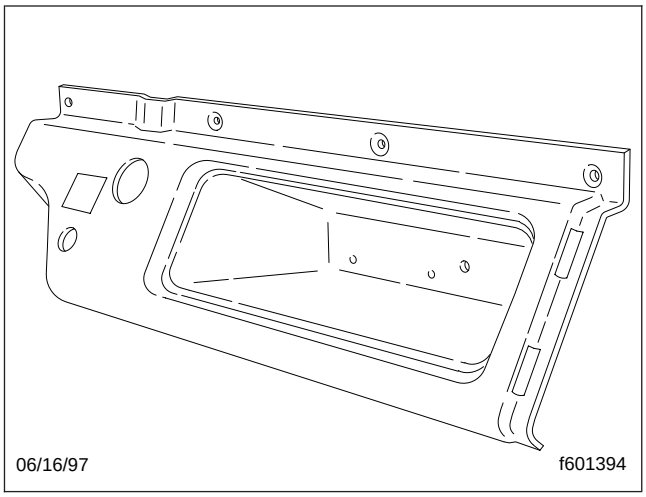


Fig. 2, Lower Dash Panel

Dash Component Replacement

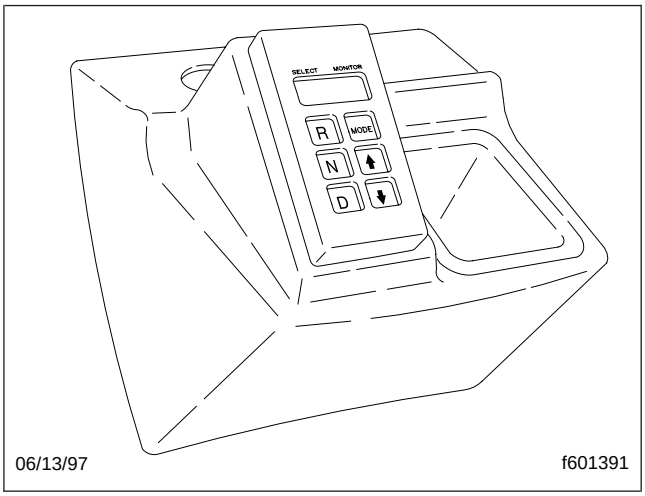
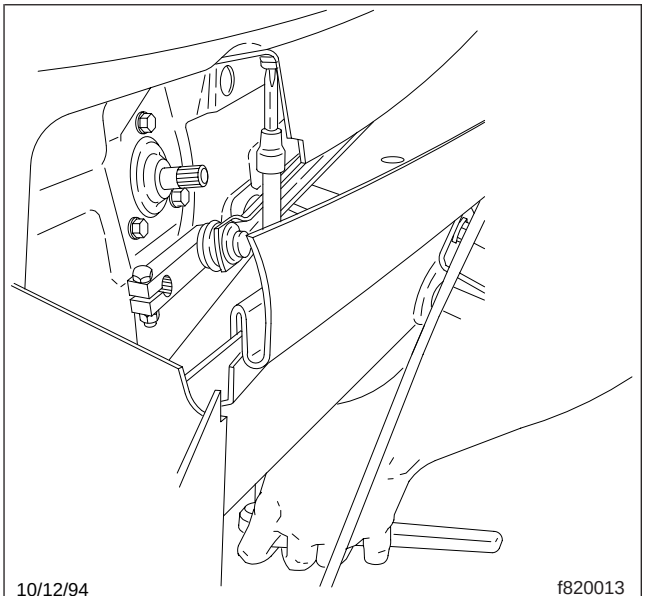


Fig. 3, Shifting Housing

General Information

The windshield washer reservoir is located outboard of the surge tank on a mounting plate projecting from the bulkhead on the right-hand side of the vehicle. See **Fig. 1**.



1. Surge Tank
2. Washer Reservoir
3. 3/8–16 Locknuts
4. Washer Pump

Fig. 1, Windshield Washer Reservoir

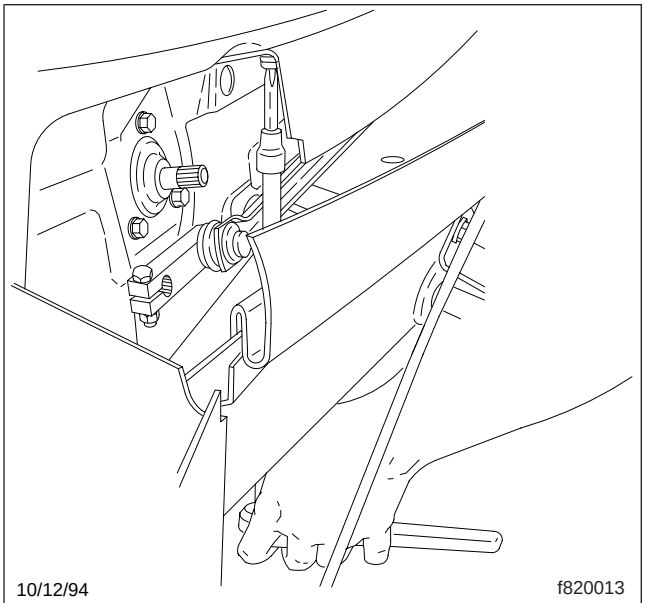
The washer pump sits on a pump seat molded into the front surface of the reservoir. In the base of the pump there is a grommet that ensures a tight-fitting seal to the pump seat. The pump and grommet are replaced as a unit.

The washer fluid delivery line is attached to the pump.

Washer Reservoir Removal and Installation

Removal

1. Park the vehicle on a level surface. Apply the parking brakes; then chock the rear tires.
2. Tilt the hood.
3. Disconnect the electrical connector attached to the washer pump.
4. Remove the washer fluid delivery line.
5. Remove the three 3/8–16 locknuts shown in **Fig. 1**.



1. Surge Tank
2. Washer Reservoir
3. 3/8–16 Locknuts
4. Washer Pump

Fig. 1, Windshield Washer Reservoir

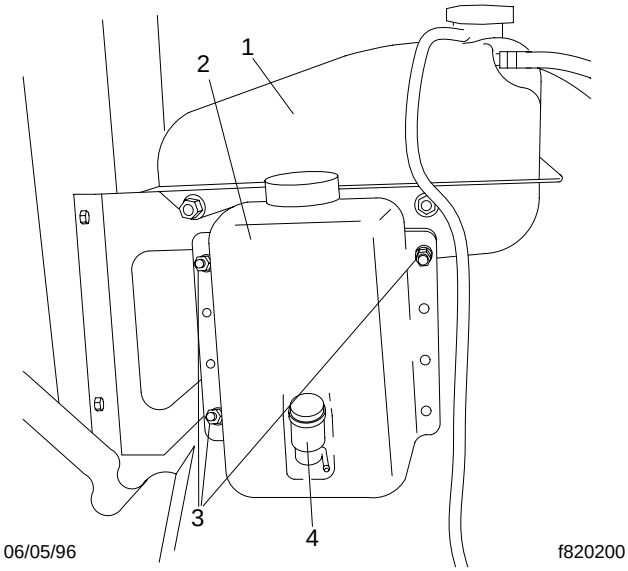
6. Remove the washer reservoir from the vehicle.

Installation

1. Position the reservoir on the surge tank mounting plate and install the 3/8–16 locknuts. Tighten the locknuts 26 lbf·ft (36 N·m).
2. Connect the electrical connector to the washer pump. For corrosion protection, pack the exposed ends of the connectors with pumpable dielectric grease, part number 48–02439–000.
3. Attach the washer fluid delivery line to the washer pump.
4. Lower the hood.
5. Remove the chocks from the tires.

Replacement

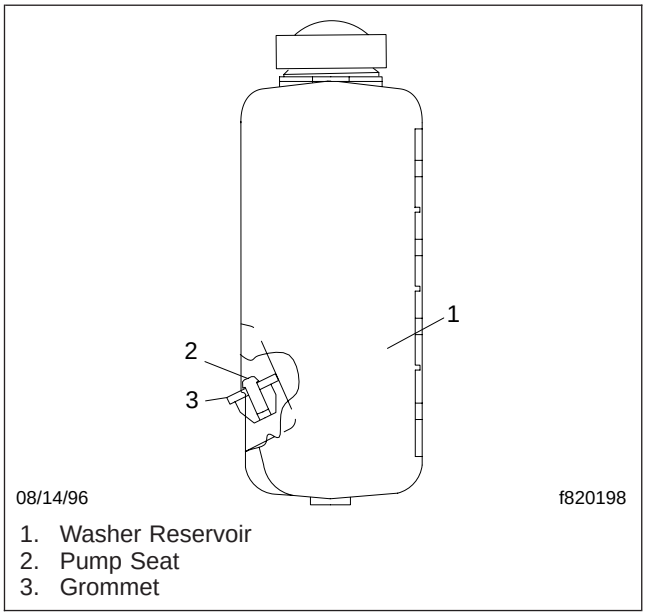
1. Disconnect the electrical connector attached to the washer pump.
2. Remove the washer fluid delivery line from the washer pump.
3. Free the pump from the pump seat and remove it from the front of the reservoir. Make sure that the grommet comes off with it. See **Fig. 1**.



1. Surge Tank
2. Washer Reservoir
3. 3/8–16 Locknuts
4. Washer Pump

Fig. 1, Windshield Washer Pump

4. Install a new pump, with grommet, on the pump seat. Make sure the pump is firmly seated. See **Fig. 2**.
5. Connect the electrical connector. For corrosion protection, pack the exposed ends of the connectors with pumpable dielectric grease, part number 48–02439–000.
6. Connect the washer fluid delivery line.
7. Test the operation of the pump. Check the delivery line connections.



1. Washer Reservoir
2. Pump Seat
3. Grommet

Fig. 2, Pump Seating

General Information

The Freightliner school bus chassis has a molded, fiberglass-reinforced-plastic (FRP) hood and fender assembly, and molded FRP half-fenders that mount to the cab sides. Several reinforcing members are bonded to the engine side of the hood. The argent-colored front grille is made of injection-molded plastic.

A recess in the hood, above the grille, provides the handle for hood tilting.

The one-piece hood tilts forward to allow engine access. The grille is mounted to the front of the hood and moves forward with the hood when the hood is tilted.

The hood and half-fenders are 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 moulding die. The preform is then heated to cure the resin binder. Next, the preform is moved to a compression molding press. Resin is dispersed onto the preform; then the preform is placed onto the male half of a matched metal mold. As the halves of the mold close, the resin is distributed throughout the part, and is cured under heat and pressure.

After molding, the hood (or half-fender) is trimmed and prepared for painting. Before priming, the fiberglass reinforcements and metal parts are bonded to the hood.

At the front of the hood, there are brackets mounted directly behind the front bumper at the outside of each frame rail, to support the hood-hinge pivots. Stop cables and a tilt-assist assembly limit the forward travel of the hood.

Vehicles built from June 6, 1997 have a tilt-assist torsion bar installed to reduce the effort needed to tilt the hood. This torsion bar attaches to two end support brackets, which are bolted to the hood hinges, and to a center support bracket, which is bolted to the front bumper.

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 cab through the air conditioner/heater air-inlet, a hood seal attaches to the cowl panel, ahead of the windshield.

Both the front hood-hinge pivots and the rear hood support brackets are adjustable forward and backward, and up and down. The front pivots are also adjustable right and left.

Splash shields under the hood extend to the inboard side of the tires. The left-hand splash shield attaches to the hood, and the right-hand shield attaches to the frame and the cab bulkhead.

On the underside of the hood are several 1-inch (25 mm) polyester polyurethane foam hoodliners, with a polymer-film facing. The liners reduce engine noise emissions.

Grille Removal and Installation

The grille is made of injection-molded, argent colored plastic.

Removal

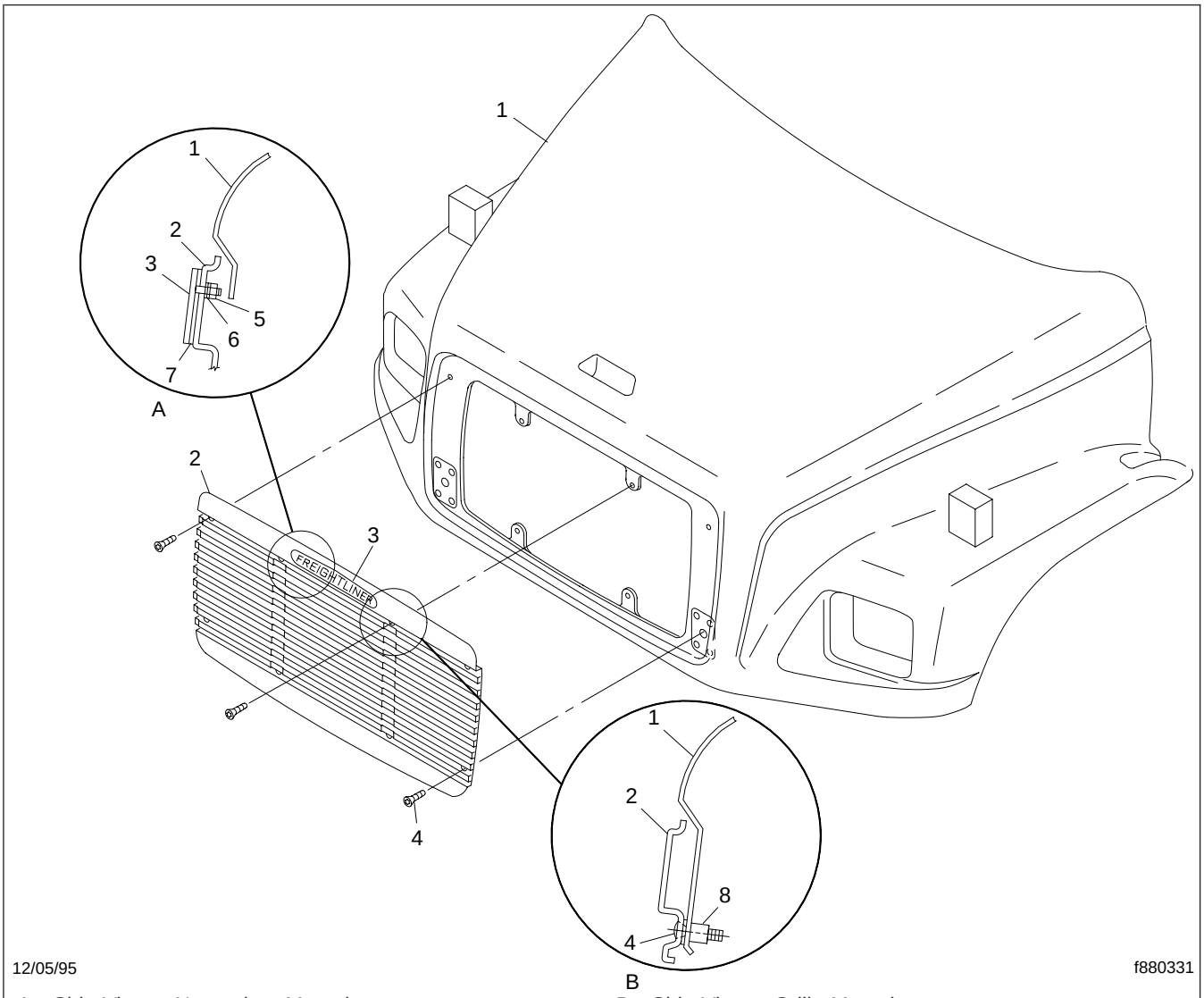
1. Apply the parking brakes and chock the rear tires.
2. With the hood in the normal, driving position, remove the grille-to-hood screws, using a T30 Torx®-head screwdriver. See **Fig. 1**.
3. Remove the grille.

Installation

NOTE: If the grille is being replaced, transfer the nameplate and gasket to the new grille.

1. Place the grille in the hood opening and align the screw holes.
2. Install the screws. Using a T30 Torx-head screwdriver, tighten them securely.
3. Remove the chocks from the rear tires.

Grille Removal and Installation



A. Side View – Nameplate Mounting
B. Side View – Grille Mounting

1. Hood
2. Grille
3. Nameplate
4. T30 Torx-head Screw
5. Self-Threading Hexnut
6. Flatwasher
7. Nameplate Gasket
8. Well Nut

Fig. 1, Hood-Mounted Grille Installation

Splash Shield Removal and Installation

Removal

1. Apply the parking brakes and chock the rear tires.
2. Tilt the hood.
3. To remove the *right-hand splash shield*, remove the quarter-turn stud that attaches the rear of the shield to its bracket on the rear hood-support bracket. See **Fig. 1**. Lift the rear of the shield about 1 in (25 mm), then pull it rearward about 1 in (25 mm). Lift it over the tire.

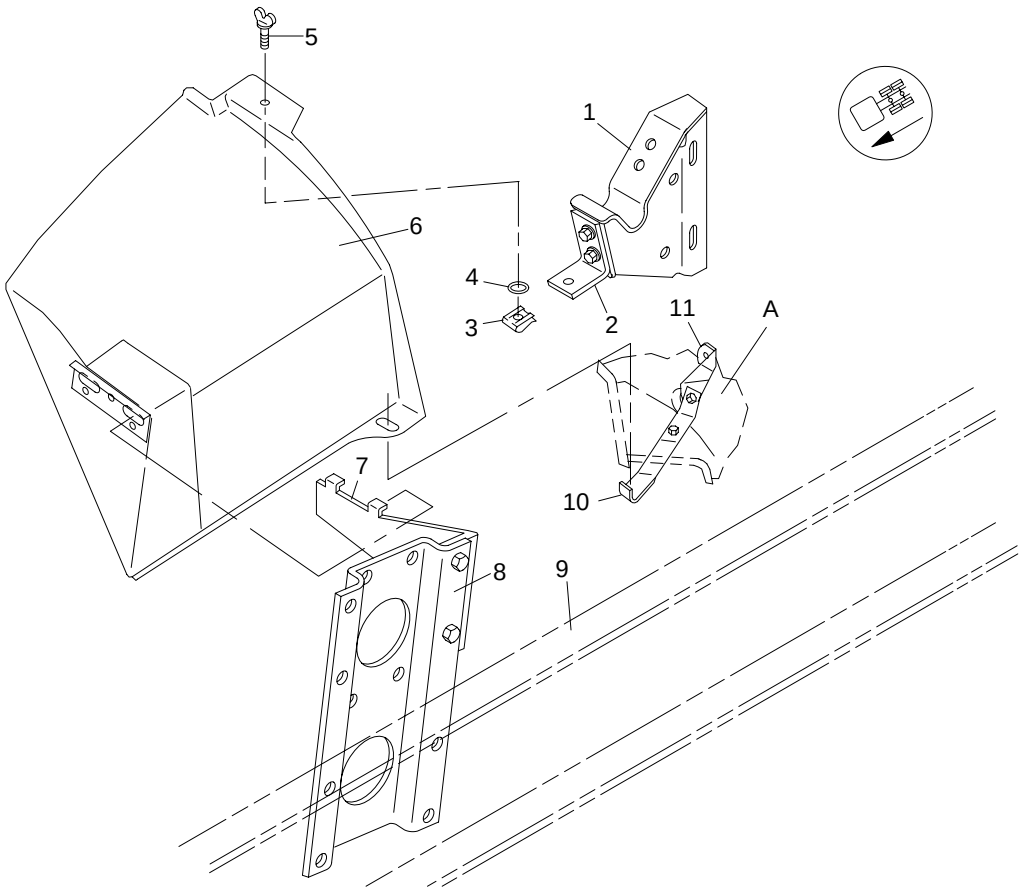
   To remove the *left-hand splash shield*, pull the upper edge of the splash shield sound-absorbent liner down far enough to access the splash shield rivets. Then use a drill and bit to remove the rivets and fender washers that attach the shield to the hood. See **Fig. 2**. Remove the shield.

Installation

1. To install the *right-hand splash shield*, position the tabs on the front mounting bracket in the slots in the front of the splash shield, then lower the rear of the shield until the tab on the rear inner mounting bracket is installed in the slot in the lower edge of the shield. See **Fig. 1**. Install the quarter-turn stud.

   To install the *left-hand splash shield*, position the shield against the reinforcement under the hood, and align the rivet holes. See **Fig. 2**. At each of the six holes, position the fender washer, then install a pop rivet to attach the shield to the reinforcement. Push the splash shield sound-absorbent liner into place.
2. Lower the hood, and remove the chocks from the tires.

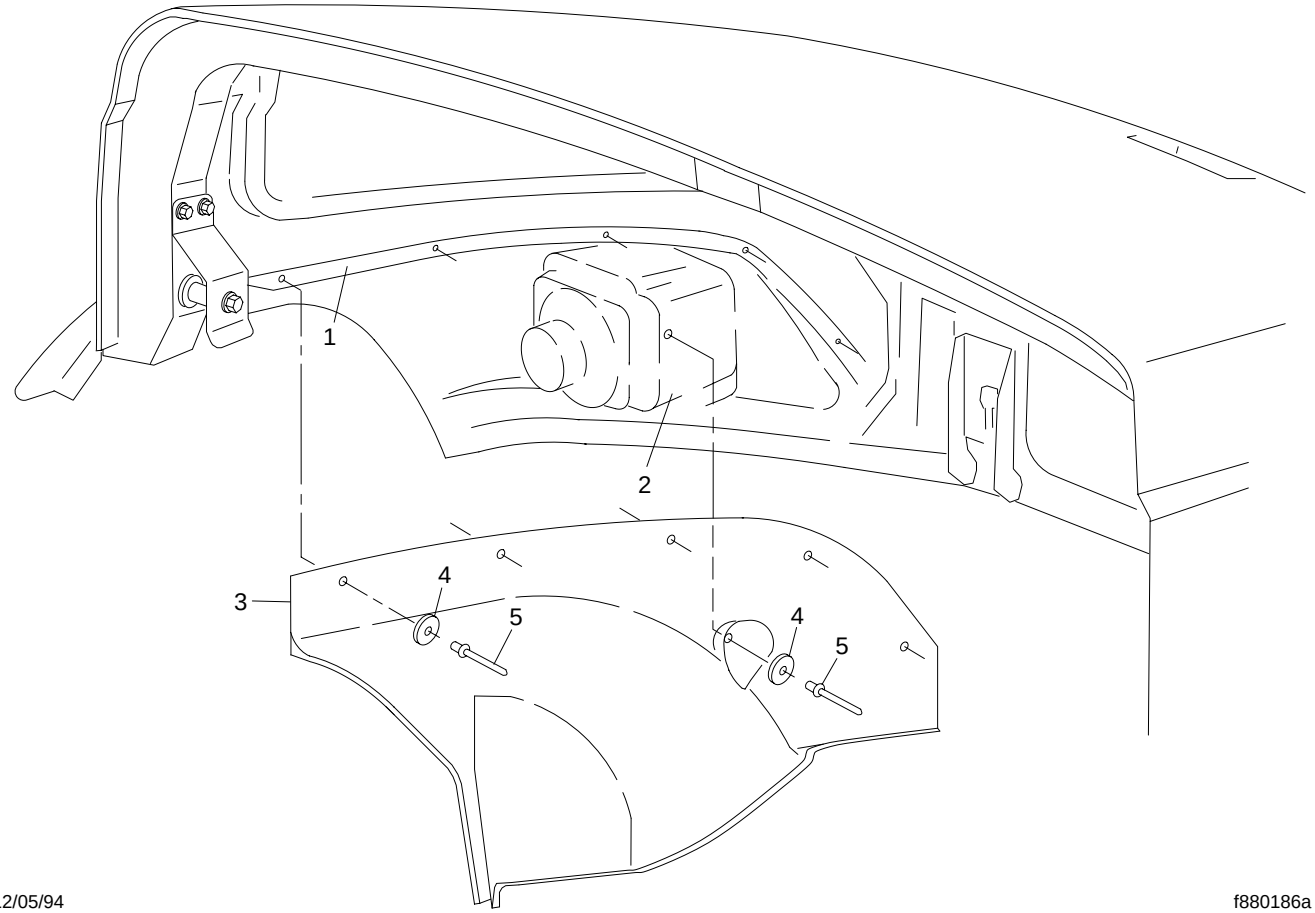
Splash Shield Removal and Installation



1. Rear Hood-Support Bracket (bulkhead-mounted)
2. Rear Outer Mounting Bracket
3. Split Ring Retainer
4. Quarter-Turn Receptacle
5. Quarter-Turn Stud
6. Right-Hand Splash Shield
7. Front Mounting Bracket
8. Air Cleaner Mounting Bracket
9. Right-Hand Frame Rail
10. Rear Inner Mounting Bracket
11. Half-Fender Upper Support

Fig. 1, Right-Hand Splash Shield

Splash Shield Removal and Installation



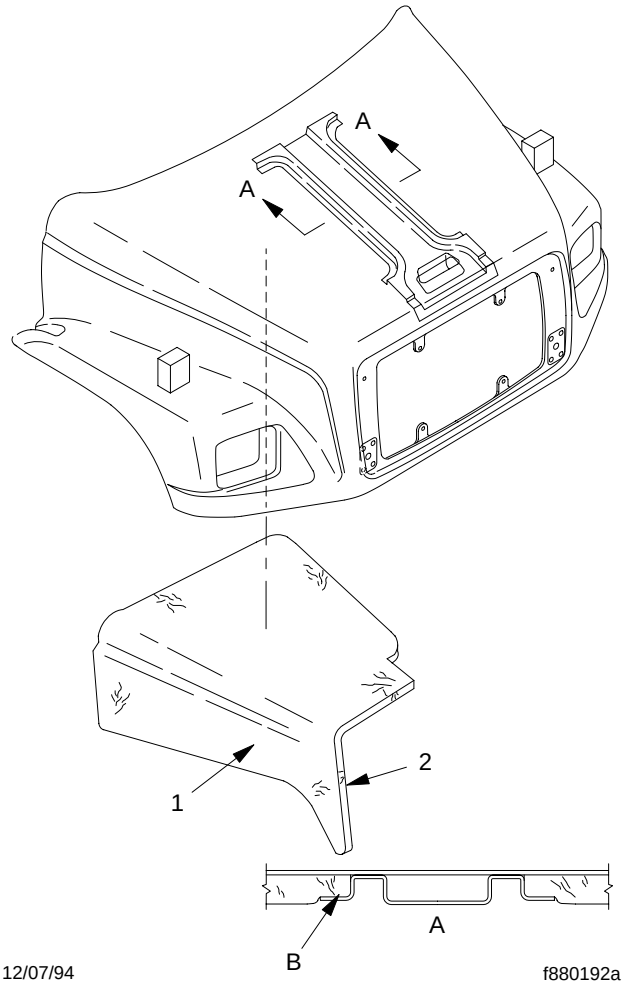
1. Hood Reinforcement (left-hand side)
2. Left-Hand Headlight Housing
3. Left-Hand Splash Shield
4. Fender Washer
5. Pop Rivet

Fig. 2, Left-Hand Splash Shield

Hood Liner Replacement

Noise insulation liners are fitted to the underside of the hood. The liners are made of 1-inch (25 mm) foam and have a polymer facing on both sides. There are 2 liners are attached to the underside of the hood.

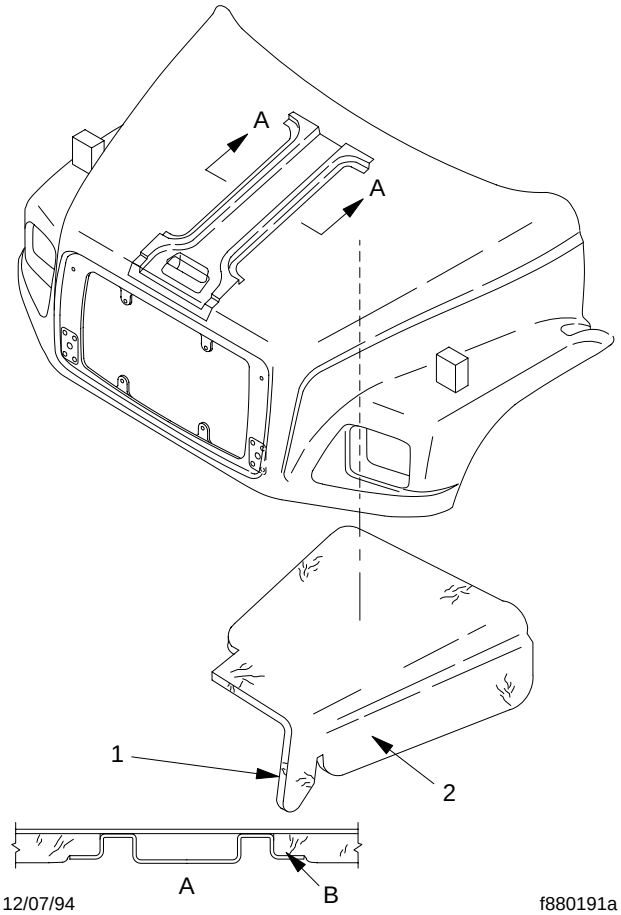
1. Apply the parking brakes and chock the rear tires.
2. If replacing either side hood liner, remove the grille. For instructions, see **Subject 100**.
3. Tilt the hood.
4. Remove the entire liner that is being replaced. See **Fig. 1** for the right-hand side hood liner, or **Fig. 2** for the left-hand side hood liner.
5. Use a wire brush to clean the area that was covered by the liner; then, thoroughly steam clean the area, and allow it to air dry.
6. Push the pressure-sensitive-adhesive side of the new liner into place, starting at one edge and working the liner into place from that edge toward the opposite edge. If installing either side hood liner, start by pushing the inboard edge of the liner into the center hood reinforcement. See the cross-section view in **Fig. 1** for the right-hand side hood liner, or in **Fig. 2** for the left-hand side hood liner.
7. Lower the hood. If removed, install the grille. For instructions, see **Subject 100**.
8. Remove the chocks from the tires.



A. Cross-section view, hood center reinforcement
B. First, push the inboard edge of the liner into the center hood reinforcement.
1. Pressure-Sensitive Adhesive Backing
2. Polymer Film Facing

Fig. 1, Right-Hand Side Hood Liner

Hood Liner Replacement



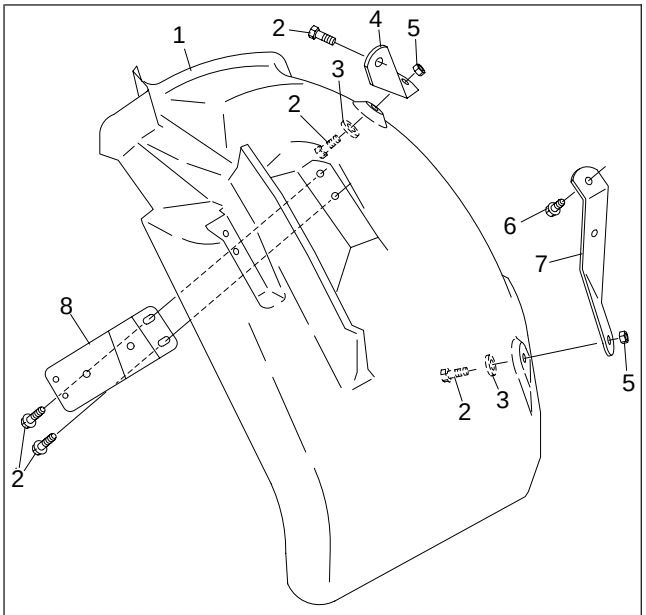
A. Cross-section view, hood center reinforcement
B. First, push the inboard edge of the liner into the center hood reinforcement.
1. Polymer Film Facing
2. Pressure-Sensitive Adhesive Backing

Fig. 2, Left-Hand Side Hood Liner

Half-Fender Removal and Installation

Removal

1. Apply the parking brakes and chock the rear tires.
2. Tilt the hood.
3. Remove the half-fender from the vehicle. See **Fig. 1**.



08/16/96 f880342

NOTE: Left-hand half-fender shown; right-hand opposite.

1. Half-Fender
2. 1-1/4" Flange Screw
3. Washer
4. Half-Fender Upper Support Bracket
5. 3/8–16 Grade 8 Locknut
6. 3/4" Flange Screw
7. Half-Fender Lower Support Bracket
8. Hood Latch Support Bracket

Fig. 1, Half-Fender Installation

3.1 Remove the two 1-1/4 inch flange screws that attach the half-fender to the hood latch support bracket.

3.2 Remove the 1-1/4 inch flange screw that attaches the half-fender to the lower half-fender support bracket.

3.3 Remove the 1-1/4 inch flange screw that attaches the half-fender to the upper half-fender support bracket.

4. If the half-fender is being replaced, remove the hood latch support bracket and upper and lower half-fender support brackets for installation on the new half-fender.

Installation

1. If removed, install the hood latch support bracket, and both the upper and lower half-fender support brackets. Tighten the grade 8 locknuts and flange screws 37 lbf·ft (50 N·m).
2. Install the half-fender on the vehicle. See **Fig. 1**.

2.1 Position the new half-fender against the cab, and install, finger-tight, the two fasteners that attach the fender to the hood latch support bracket.

2.2 Install the fasteners that attach the half-fender to the upper and lower support brackets.

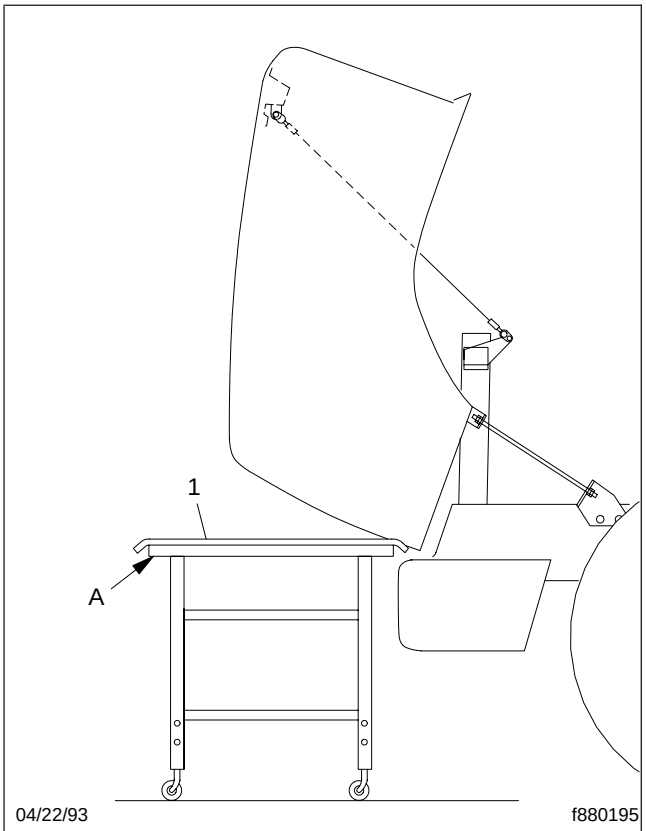
2.3 Tighten all the grade 8 locknuts and flange screws 37 lbf·ft (50 N·m).

3. Lower the hood, and remove the chocks from the tires.

Removal

1. Apply the parking brakes and chock the rear tires.
2. Tilt the hood.
3. Place a support between the floor and the front of the hood. See **Fig. 1**.

   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.



A. Top of support should be at same height as lowest edge of hood.
1. Cardboard, Carpet, or Furniture Pad

Fig. 1, Hood Support

4. Disconnect the headlight and turn-signal/parking light connectors behind the bumper on both sides of the vehicle. See **Fig. 2**.

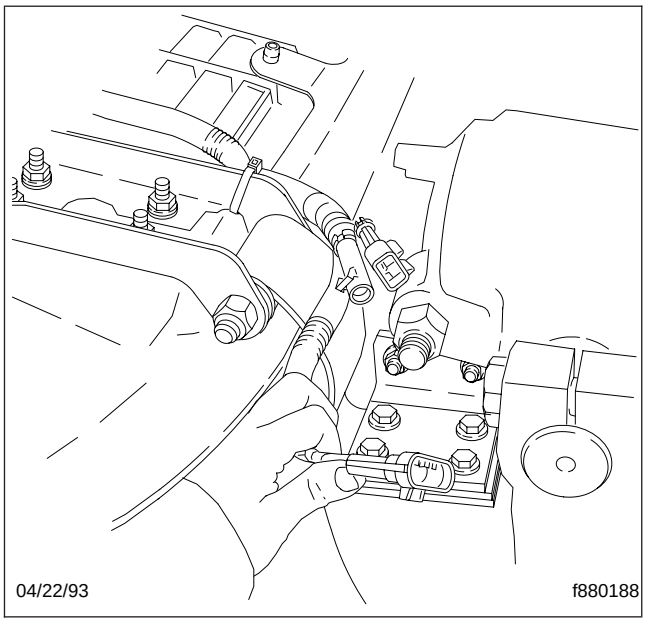


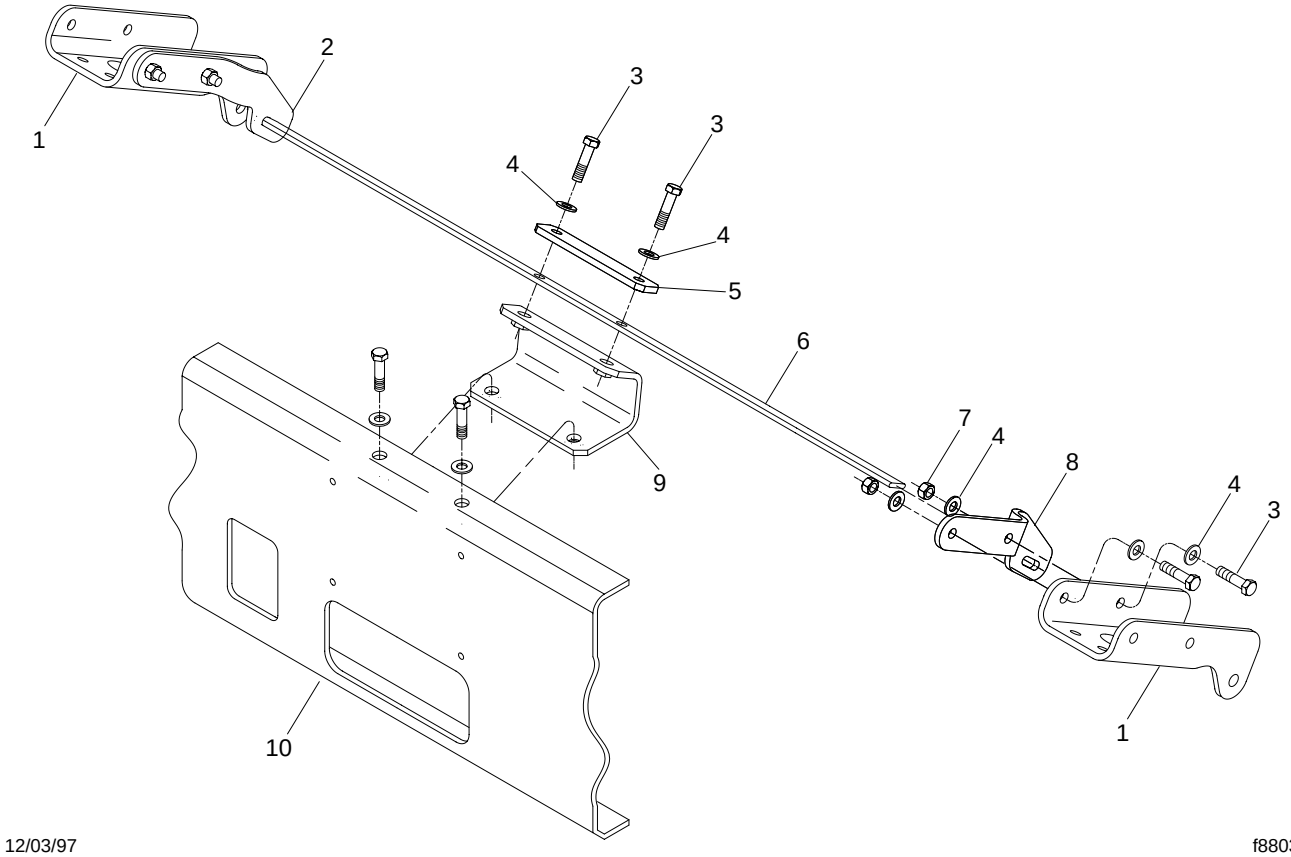
Fig. 2, Electrical Connectors

5. If the tilt-assist torsion bar is installed, remove the center support bracket from the front bumper. Retain the two 3/8–16 capscrews and hardened washers for later assembly. See **Fig. 3**.
6. Lower the hood until it is balanced over the pivots, relieving the tension on the stop cables and the tilt-assist assemblies. Have a co-worker hold the hood in this position.
7. Disconnect the stop cables and the tilt-assist assemblies from the brackets on the radiator. See **Fig. 4** and **Fig. 5**.
8. Carefully tilt the hood onto the support.
9. Remove the prevailing torque locknuts from the hood-pivot bolts. See **Fig. 6**. Drive out both hood-pivot bolts.
10. Carefully roll or slide the hood support away from the vehicle; don't try to lift the hood.

Installation

1. With the hood in the forward-tilt position and resting on the support at about the same height as the top of the bumper, move the support and hood into alignment with the front of the vehicle. Don't try to lift the hood.

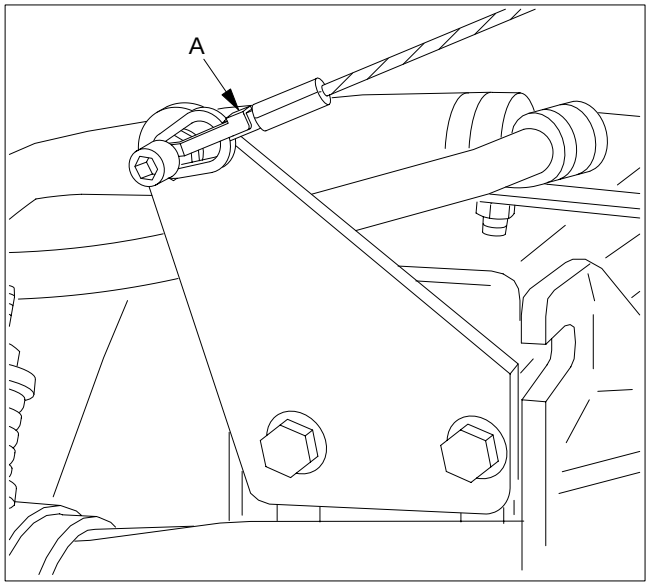
Hood Removal and Installation

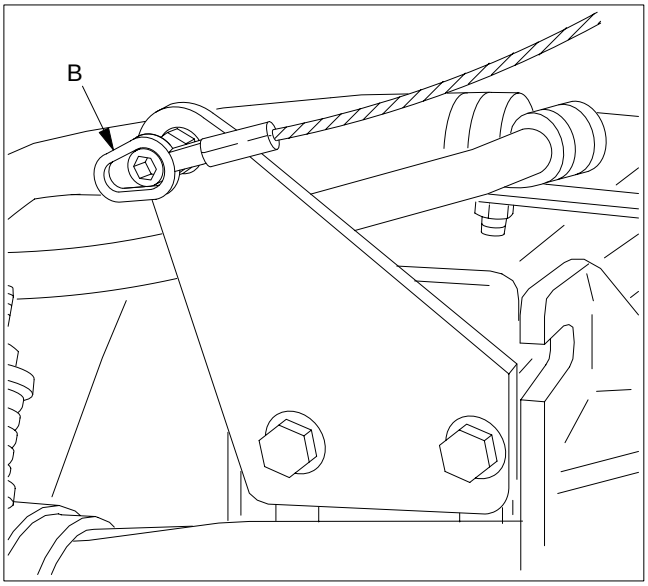


1. Hood Hinge
2. RH End Support Bracket
3. Capscrew, 3/8–16
4. Hardened Washer
5. Backing Plate
6. Torsion Bar
7. Locknut, 3/8–16
8. LH End Support Bracket
9. Center Support Bracket
10. Front Bumper

Fig. 3, Tilt-Assist Torsion Bar

2. Align the bolt holes of the hood hinge brackets with those in the lower hood hinges. Push the hood-pivot bolts into place from the inboard side. See **Fig. 6**. Install the prevailing torque locknuts, then tighten them 130 lbf·ft (176 N·m).
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 and tilt-assist assemblies.
   - 4.1 Connect the stop-cable assemblies to the brackets on top of the radiator. Install the keepers to prevent the cable eyes from coming off the ends of the allen-head bolts. See **Fig. 4**.
   - 4.2 Install each stop cable on the stud farthest back on the radiator bracket. Install the locknuts, tighten them until all the parts are flush against each other, then back off the locknuts 1/4 turn. See **Fig. 5**.
   - 4.3 Install each tilt-assist assembly to the forward stud on the radiator side-channel brackets, using a washer on each side of the tilt-assist cable hook, then a locknut. See **Fig. 5**. Tighten the locknuts until all the parts are flush against each other, then back off the locknuts 1/4 turn.



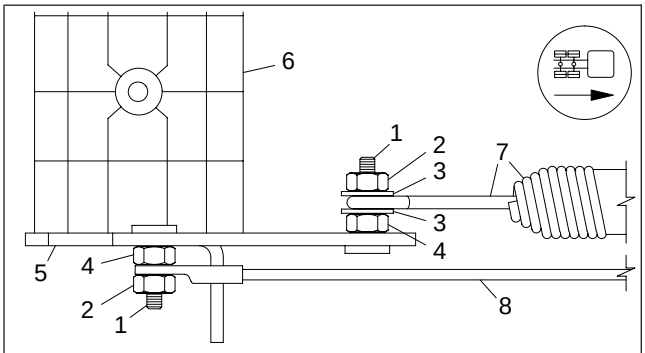


04/22/93 f880189

A. Remove this keeper.

B. Remove the cable eye from the allen-head bolt.

Fig. 4, Stop Cable



04/27/93 f880264

1. Stud
2. Locknut
3. Washers
4. Nut
5. Bracket
6. Radiator
7. Tilt-Assist Assembly
8. Stop Cable

Fig. 5, Tilt-Assist Assembly

5. Remove the hood support from the front of the vehicle and tilt the hood all the way open.
6. If the tilt-assist torsion bar is installed, install the center support bracket on the front bumper. Tighten the two 3/8–16 capscrews 28 lbf·ft (38 N·m). See **Fig. 3**.
7. Connect the headlight and turn-signal/parking light cables on both sides of the vehicle.
8. Lower the hood. Check the hood adjustment, and adjust the hood if needed. See **Subject 150** for instructions.
9. Remove the chocks from the tires.

Hood Removal and Installation

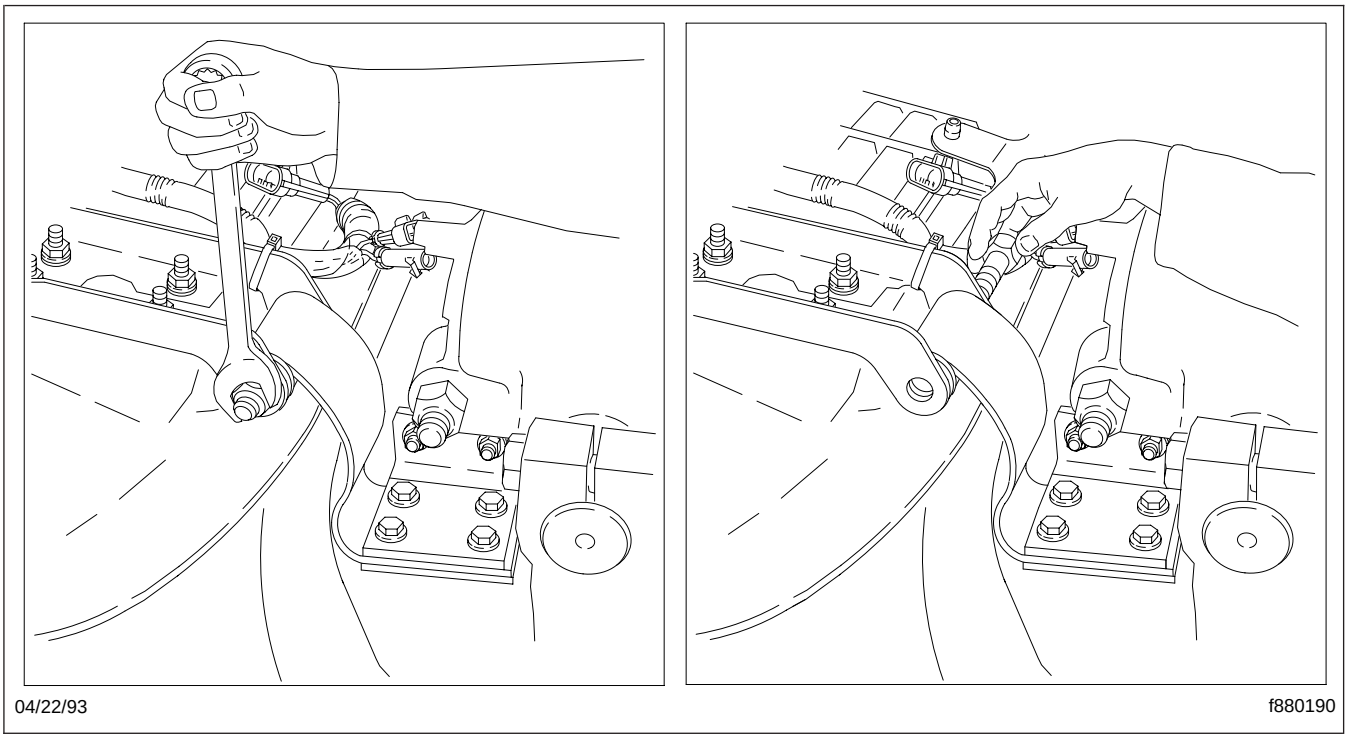
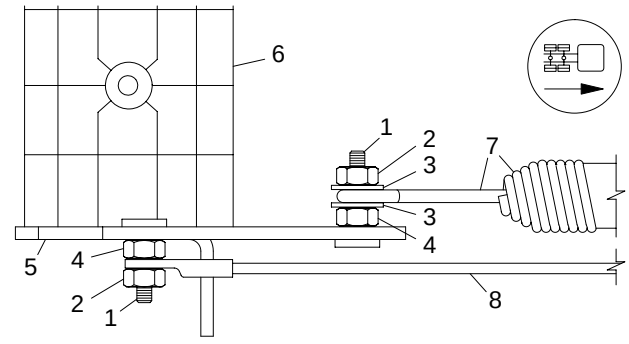


Fig. 6, Removing the Hood-Pivot Bolts

Replacement

1. Apply the parking brakes and chock the rear tires.
2. Tilt the hood.
3. Remove the tilt-assist assembly.
   - 3.1 Loosen and remove the locknut and washer holding the tilt-assist assembly to the bracket on the radiator side-channel. See **Fig. 1**.
   - 3.2 Loosen and remove the locknut holding the tilt-assist assembly to the stud on the hood bracket. See **Fig. 2**.
4. Remove the old tilt-assist assembly from the vehicle.

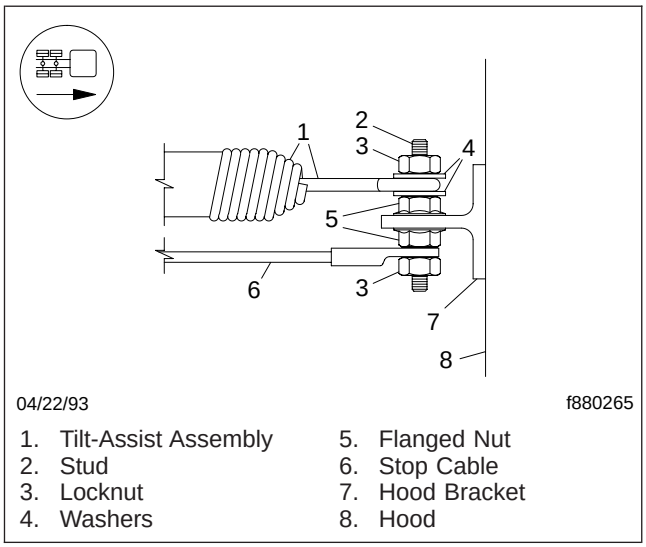


04/27/93 f880264

1. Stud
2. Locknut
3. Washers
4. Nut
5. Bracket
6. Radiator
7. Tilt-Assist Assembly
8. Stop Cable

Fig. 1, Radiator Bracket Fasteners

5. Install the new tilt-assist assembly.
   - 5.1 If there is none present, install a washer on the forward stud on the radiator side-channel bracket. Hook one end of the new tilt-assist assembly over the stud. See **Fig. 1**.
   - 5.2 Install a second washer and locknut on the stud; then tighten the locknut until all parts are flush against each other. Back off the nut 1/4 turn, to allow the tilt-assist assembly to rotate.
   - 5.3 If there is none present, install a washer on the stud in the hood bracket. Hook the other end of the tilt-assist assembly over the stud. See **Fig. 2**.
   - 5.4 Install a second washer and locknut on the stud; then tighten the locknut until all the parts are flush against each other. Back off the nut 1/4 turn to allow the hood tilt-assist assembly to rotate.
6. If replacing both tilt-assist assemblies, repeat the procedure for the other side of the vehicle.
7. Lower the hood. Check the hood adjustment, and adjust the hood if needed. See **Subject 150** for instructions.
8. Remove the chocks from the tires.



04/22/93 f880265

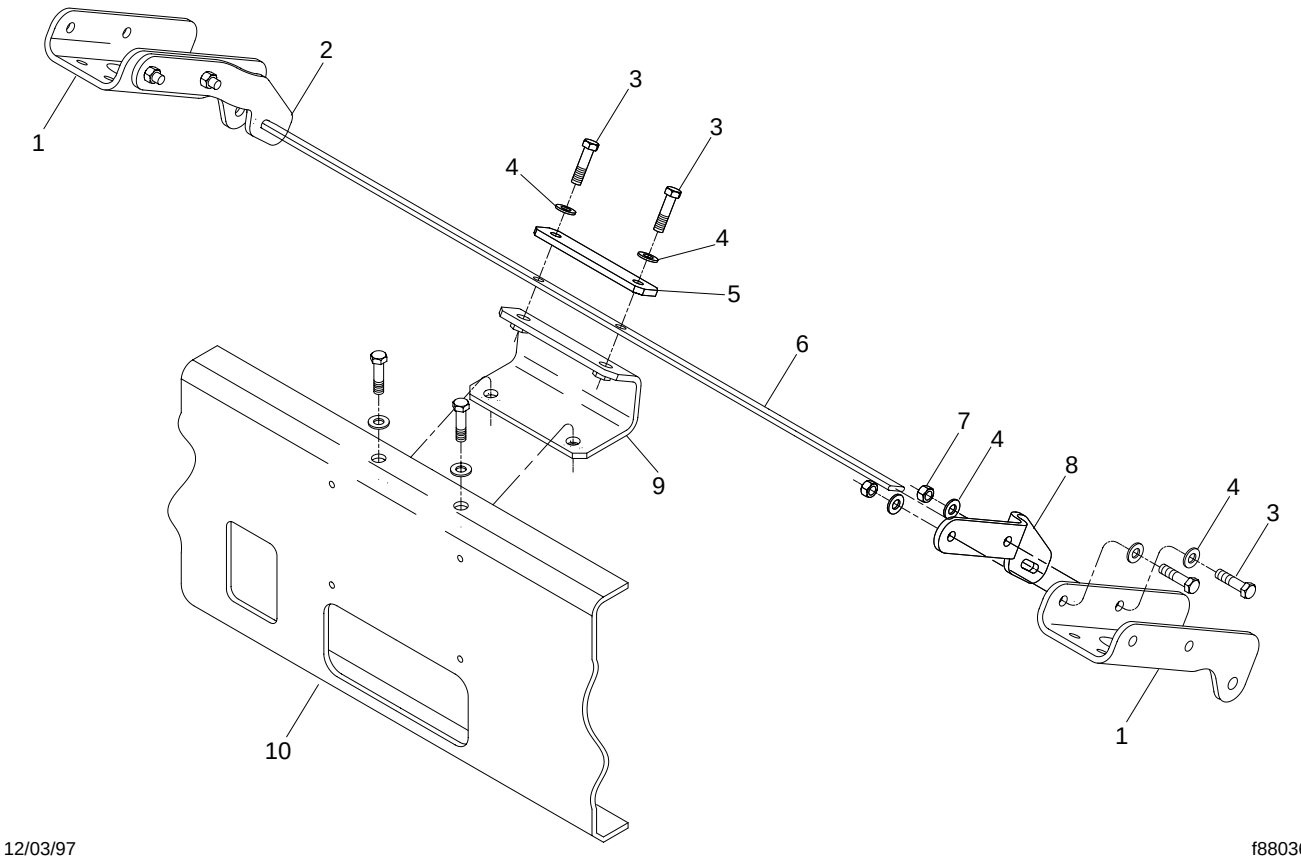
1. Tilt-Assist Assembly
2. Stud
3. Locknut
4. Washers
5. Flanged Nut
6. Stop Cable
7. Hood Bracket
8. Hood

Fig. 2, Hood Bracket Fasteners

Tilt-Assist Torsion Bar Replacement

Replacement

1. Apply the parking brakes and chock the rear tires.
2. Tilt the hood.
3. Remove the center support bracket from the front bumper. Retain the two 3/8–16 capscrews and hardened washers for later assembly. See **Fig. 1**.
4. Remove the end support brackets from the hood hinges.
   - 4.1 Remove the right-hand end support bracket and retain the two 3/8–16 locknuts, capscrews, and hardened washers for later assembly.
   - 4.2 Remove the left-hand end support bracket and retain the two 3/8–16 locknuts, capscrews, and hardened washers for later assembly.
5. Remove the torsion bar assembly from the vehicle.
6. Remove the end support brackets from the torsion bar.



1. Hood Hinge
2. RH End Support Bracket
3. Capscrew, 3/8–16
4. Hardened Washer
5. Backing Plate
6. Torsion Bar
7. Locknut, 3/8–16
8. LH End Support Bracket
9. Center Support Bracket
10. Front Bumper

Fig. 1, Tilt-Assist Torsion Bar

Tilt-Assist Torsion Bar Replacement

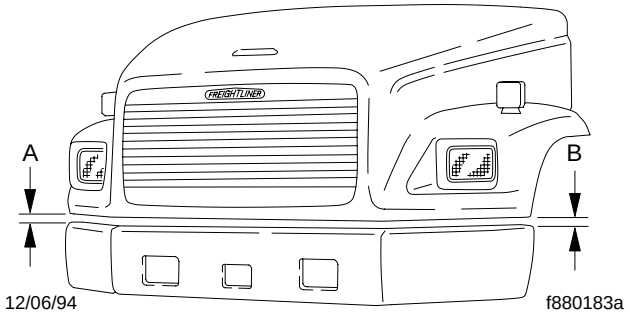
7. Remove the center support bracket and backing plate from the torsion bar. Retain the two 3/8–16 capscrews and hardened washers for later assembly.
8. Install the center support bracket on the front bumper. Tighten the two 3/8–16 capscrews 28 lbf·ft (38 N·m).
9. Attach the new torsion bar to the two end support brackets.
10. Install the end support brackets on the hood hinges. Tighten the 3/8–16 locknuts 28 lbf·ft (38 N·m).
11. Attach the torsion bar and backing plate to the center support brackets. Tighten the 3/8–16 capscrews 28 lbf·ft (38 N·m).
12. Lower the hood. Check the hood adjustment, and adjust the hood if needed. See **Subject 150** for instructions.
13. Remove the chocks from the tires.

Adjustment

1. Drive the vehicle back and forth to settle the frame and suspension. Park the vehicle on a flat, level surface.
2. With the hood in the operating position, and both hood latches latched, check the gap between the top of the bumper and the bottom edge of the hood on both sides. The edges should be parallel. See **Fig. 1**.

   If the edges *are parallel*, proceed to the next step.

   If the edges are *not* parallel, adjust the height of the front of the hood.



Dimension "A" must be equal to Dimension "B."

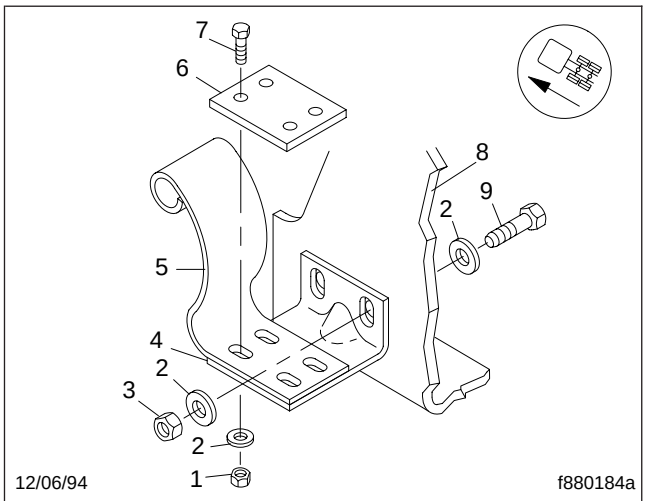
Fig. 1, Hood-Bumper Gap

   2.1 With the hood latched, on the side of the hood that's low, loosen the two sets of locknuts and capscrews that attach the hood-pivot support bracket to the frame rail. See **Fig. 2**.

   2.2 Raise that side of the hood until both sides are parallel. From its lowest to its highest position, each hood-pivot support bracket will adjust 11/32 in (9.0 mm). Tighten the fasteners 70 lbf·ft (95 N·m).

   2.3 If you can't move that side up enough to make both sides parallel, loosen the hood-pivot support bracket fasteners on the other side of the hood, and lower that side of the hood until both sides are parallel. Tighten the fasteners 70 lbf·ft (95 N·m).

   Go to the next step.



1. Lower Hood-Hinge Pivot Locknut
2. Flatwasher
3. Hood-Pivot Support Bracket Locknut
4. Hood-Pivot Support Bracket
5. Lower Hood-Hinge Pivot
6. Lower Hood-Hinge Pivot Reinforcement
7. 3/8–16 Locknut
8. Frame Rail
9. 1/2–13 Capscrew

Fig. 2, Hood-Pivot Adjustment

3. 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. 3**. The gap should be between 3/8 inch and 5/8 inch (10 to 16 mm).

   If the gap on both sides is within specifications, go to the step for checking the alignment of the hood/cab character lines.

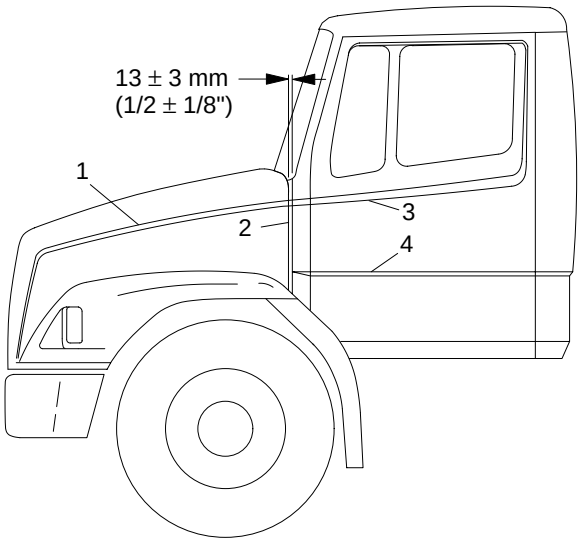
   If the gap is *not* within specifications on one or both sides, adjust the fore-and-aft position of the hood.

   3.1 Determine the amount that the hood must be moved at one or both sides, to correct the gap.

   3.2 Unlatch and tilt the hood.

   3.3 At the side(s) of the hood that must be moved, loosen the three capscrews that attach the rear hood support assembly to the hood, just enough to allow the hood to slide fore and aft for adjustment. See **Fig. 4**.

Hood Alignment Adjustment



Cab and cowl dimension must be 1/2" ±1/8" (13 mm ±3 mm)

1. Hood Character Line
2. Cab Cowl
3. Cab Character Line
4. Cab Feature Line

Fig. 3, Hood-Cab Positioning

On the side(s) to be moved, loosen the four locknuts and capscrews that attach the lower hood-hinge pivot to the hood-pivot support bracket. See **Fig. 2**. Slide that side(s) of the hood fore or aft the amount determined earlier.

Tighten the lower hood-hinge pivot locknuts 40 lbf·ft (55 N·m).

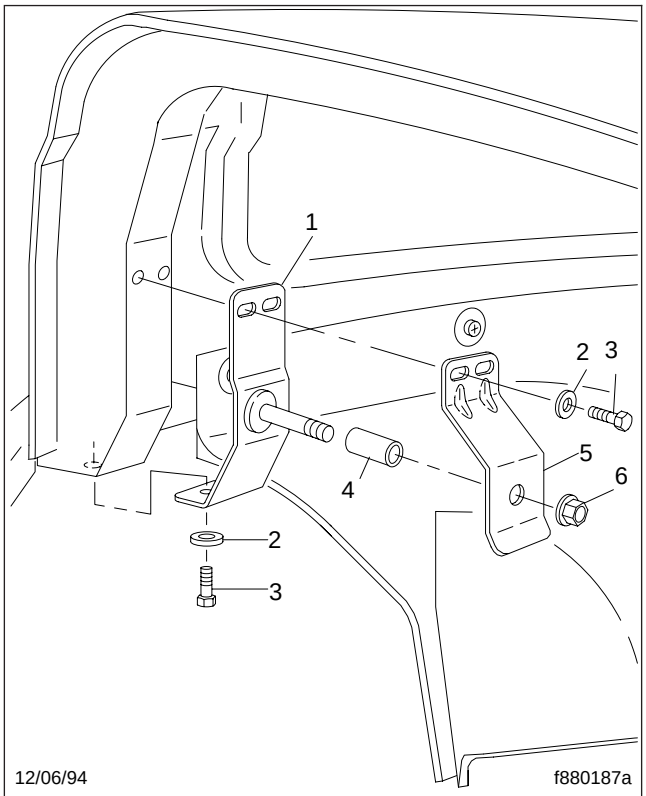
3.4 Return the hood to the operating position, and fasten the latches.

3.5 Again, check the gap at both sides of the hood. See **Fig. 3**.

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.

4. With the hood in the operating position, and both hood latches latched, check alignment of the cab and hood character lines. See **Fig. 3**. Or, if so equipped, check alignment of the cab and hood paint stripes.



1. Rear Hood Support Assembly
2. 3/8" Flatwasher
3. M10 Capscrew
4. Hood Pin Sleeve
5. Rear Hood Support Pin Brace
6. 3/4–11 Flanged Locknut

Fig. 4, Fore-and-Aft Adjustment

If the character lines (or paint stripes) are aligned, go to the step for tightening the rear hood assembly capscrews.

If the character lines (or paint stripes) are misaligned, adjust the up-and-down position of the rear of the hood.

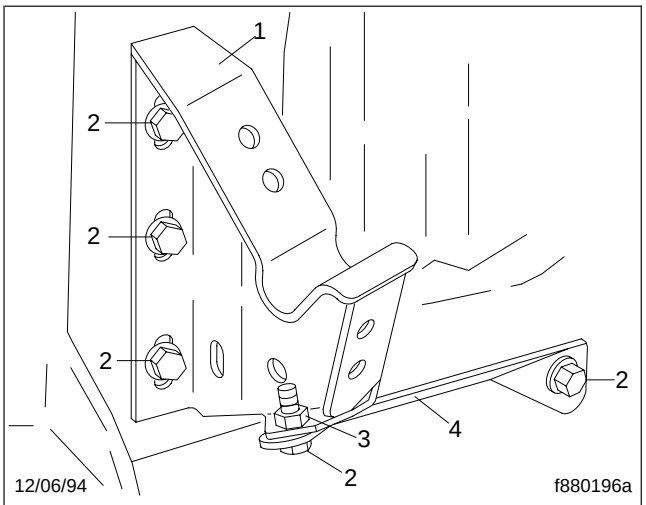
4.1 Unlatch and tilt the hood.

4.2 If not already done, at the side(s) of the hood that must be moved, loosen the three capscrews that attach the rear hood support assembly to the hood, just enough

to allow the hood support assembly to slide fore and aft for adjustment. See **Fig. 4**.

NOTE: Complete the steps for up-and-down adjustment of one side, before doing the other side.

4.3 At the side of the hood that must be moved, loosen the capscrews that attach the rear hood support bracket and hood support brace to the bulkhead. Also, loosen the locknut that attaches the hood support brace to the rear hood support bracket. See **Fig. 5**.



1. Rear Hood Support Bracket
2. M10 Capscrew
3. M10 Locknut
4. Hood Support Brace

Fig. 5, Up-and-Down Adjustment

4.4 Push the rear hood support bracket upward as far as it will go.

4.5 Return the hood to the operating position, but latch only the side that is *not* being adjusted.

4.6 At the side of the hood that's being adjusted, push down on the top of the hood until the character lines (or paint stripes) are aligned.

4.7 Carefully tilt the hood, without changing the position of the rear hood support bracket. Tighten 40 lbf·ft (55 N·m) the capscrews and locknuts for the rear hood support bracket and the hood support brace. See **Fig. 5**.

NOTE: If the other side of the hood needs to be adjusted, repeat required steps for up-and-down adjustment.

4.8 Go to the next step.

5. If loosened, tighten the capscrews that attach the rear hood support assembly to the hood 40 lbf·ft (55 N·m). See **Fig. 4**.

Repair Safety 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, don't 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 the cloth. Wash the clothing before wearing it 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. Don't perform repairs in areas where exposed (or stored) flammable liquids may contact an open flame or any burning material, such as a cigarette. Don't perform repairs in areas that are not well ventilated.

⚠ WARNING

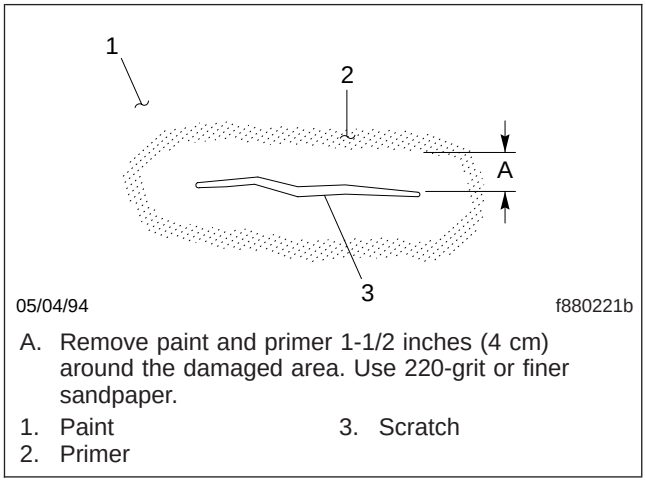
WARNING: Do fiberglass repairs in a safe workshop area to prevent severe personal injury due to explosion of flammable liquids or breathing of toxic fumes.

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 use an air purifying respirator, either a throwaway type or one with a replaceable particulate filter(s). Don't breathe 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, don't save leftover liquids. If liquids must be saved, store them in cool, dark areas, away from direct sunlight.

Surface Damage Repair

Surface damage refers to scratches, chips, or nicks on the outer surface of the hood or half-fender. Use the following instructions to repair surface damage:

1. Examine the damaged area. If there are cracks, see if they go all the way through the hood or half-fender. If they do, see "Structural Damage Repair" for instructions.
2. Clean the area with xylene, acetone, or an equivalent grease- and wax-removing solvent. 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). See **Fig. 1**.



A. Remove paint and primer 1-1/2 inches (4 cm) around the damaged area. Use 220-grit or finer sandpaper.

1. Paint
2. Primer
3. Scratch

Fig. 1, Damaged Area with Paint and In-Mold Coating Removed

4. Using an air nozzle, blow off all dust.

5. Apply Ashland Pliogrip 7775L self-leveling urethane adhesive over the non-coated area and spread a thin layer using a squeegee applicator. Cover the entire damaged area, overlapping onto the painted surface. Leave a crowned excess of adhesive, slightly higher than the painted surface.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

6. After the adhesive dries (about 50 minutes), sand it with a hand-held disc pad. Use 320-grit or finer sandpaper. Feather the edges of the fill so there are no visible sharp edges.
7. Clean the area with compressed air. Mask the area, then spot prime and paint it. Use Sherwin Williams BB–11 black conductive primer. See **Group 98** for spot-painting instructions.

Structural Damage Repair

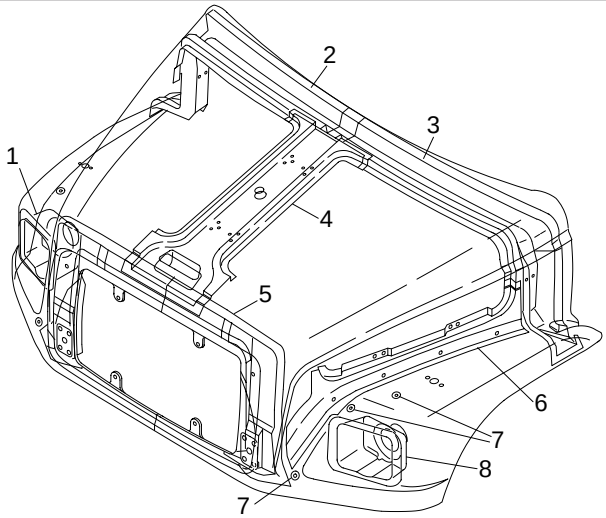
The Preform FRP (fiberglass reinforced plastic) hood consists of a one-piece hood and fender assembly. Inner reinforcements are bonded to the engine-side of the hood with a structural adhesive. See **Fig. 2**. If the hood is damaged, determine which parts are affected.

If there is damage to any of the reinforcements, the damage is not repairable. For example, if the grille area of the hood is damaged so badly that the reinforcement bonded inside the grille area is also damaged, replace the entire hood assembly.

If a joint between two reinforcements, or between a reinforcement and the hood skin, has separated and there is no damage at the joint area, the parts can be rebonded. Or, if a part of the hood skin is damaged and its adjoining reinforcement(s) aren't damaged, the reinforcement can be separated from the damaged part, the damaged part can be patched, and the reinforcement(s) rebonded in place.

If a half-fender has a small crack or hole, it can be repaired; if it has a puncture or large fracture, it must be replaced.

For rebonding parts, see "Hood Reinforcement Rebonding."



1. Right-Hand Headlight Housing
2. Right-Hand Rear Hood Reinforcement
3. Left-Hand Rear Hood Reinforcement
4. Center Hood Reinforcement
5. Front Hood Reinforcement
6. Left-Hand Side Hood Reinforcement
7. Bonded Fasteners
8. Left-Hand Headlight Housing

Fig. 2, Hood Assembly Components

For damage in the form of a crack or small hole, see "Crack or Small Hole Repair."

For larger damaged areas, see "Puncture or Large Fracture Repair."

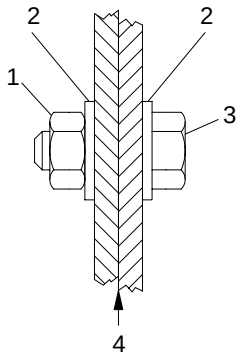
HOOD REINFORCEMENT REBONDING

1. If rebonding a joint that has partially separated, completely separate the reinforcement from the hood using a heat gun and putty knife. Remove as much of the old adhesive as possible. The heat gun will soften the adhesive and allow it to be peeled off the FRP.

   If the parts cannot be separated, work folded medium-grit sandpaper or a section of a steel hacksaw blade between the two surfaces to remove the old adhesive.
2. Scuff the surfaces with 80- to 220-grit sandpaper.
3. Clean the surfaces to be bonded with Ashland 6036 solvent or methylene chloride. Inspect the

area closely to be sure all of the old adhesive, dirt, water, grease, and oils are removed.

4. If replacing a large part, align the part on the hood and clamp it in place. Drill holes through the bonding surfaces and install clamping bolts in the holes. Use two washers, one on each side of the joint. See **Fig. 3**. There should be enough clamping bolts to hold the hood in place and keep the bonding surfaces together, or at least one bolt every 12 to 18 inches (30 to 45 cm). Remove the part for application of adhesive.



1. Nut
2. Washers
3. Bolt
4. Bond Joint

Fig. 3, Clamping Bolt at Bond Joint

5. Following the manufacturer's instructions, use enough adhesive to bond the parts together. Use Ashland Pliogrip urethane cartridge materials 7773 or 7779.

NOTE: When using Ashland Pliogrip 7773 or 7779, insert the two tubes of adhesive into the applicator and dispense a 3/8-inch (10 mm) diameter bead of uniform green-colored adhesive at the bonding surface. Discard any adhesive that does not show this uniform green color.

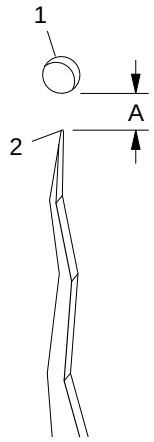
6. Within three and one half minutes (7773) or within 10 minutes (7779) of applying the bead, align the part on the hood and clamp it firmly in place. If it is a large part install the clamping bolts. Tighten the clamps or clamping bolts just enough to ensure that a uniform amount of pressure is applied along the seam. Ideally, the adhesive should be compressed to form a bondline one inch (25 mm) wide and 0.030 inch (0.76 mm) thick. This thickness can be ensured by sprinkling 0.030 inch (0.76 mm) glass beads into the adhesive before mating the parts.
7. Before it cures, remove any excess adhesive that squeezes out the edges of the bond.
8. Remove the clamps after the adhesive has cured for 30 minutes (7773) or for 60 minutes (7779).
9. If holes were drilled for clamping bolts, repair them using the instructions under "Crack or Small Hole Repair."
10. If necessary, prime and paint the repair area using the instructions under "Surface Damage Repair."

CRACK OR SMALL HOLE REPAIR

A crack (fracture) or small hole through the laminate requires repair with a fiberglass-reinforced patch.

1. Examine the damage to the hood or half-fender. Apply hand pressure all around the damaged area to check for any concealed damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.
3. Clean the damaged area on both sides of the hood or half-fender with xylene, acetone, or equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. If repairing a crack, use a 1/8-inch (3-mm) diameter bit to drill a hole completely through the uncracked laminate 1/8 inch (3 mm) from each end of the crack, to prevent the crack from lengthening. See **Fig. 4**.
5. On the engine side of the hood (or underside of the half-fender), use a router bit (on a grinder or a drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the damage. Taper the outside edge of the ground area. See **Fig. 5**.

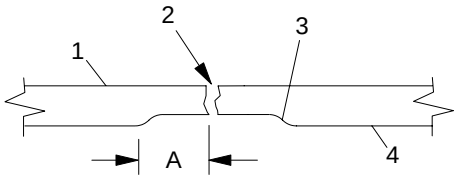
   If repairing a crack, grind outward to the drilled hole at the end of the crack, but not beyond. See **Fig. 6**, Ref. A.
6. Use 80- to 220-grit sandpaper to scuff an area at least one inch (25 mm) away from the fracture



05/04/94 f880222b

A. 1/8 inch (3 mm)
1. Drilled 1/8-inch (3-mm) Hole
2. End of Crack

Fig. 4, Drilling a Hole to Prevent the Crack From Lengthening



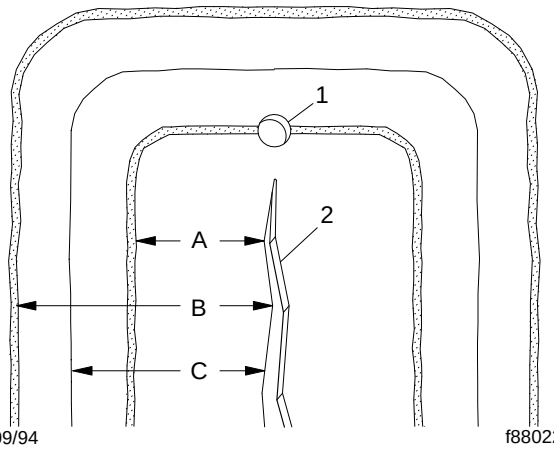
05/04/94 f880227b

A. Grind a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward in all directions from the damaged area.
1. Laminate
2. Crack
3. Slight Taper
4. Engine Side of Hood (or underside of half-fender)

Fig. 5, Recessed Area (cross-sectional view)

on all sides. Be sure to scuff thoroughly, since this will give the patch a surface to which it can stick. See **Fig. 6**, Ref. B.

7. Blow the dust away with compressed air and wipe the area with a clean cloth.
8. If necessary, align the panel sections on both sides of the crack, using weights or clamps to re-establish the original panel profile.



02/09/94 f880223a

A. Use a router to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from the damage. If repairing a crack, don't grind past the hole drilled at the end of the crack.
B. Use 80- to 220-grit sandpaper to scuff the area one inch (25 mm) around the damage.
C. Cut the fiberglass cloth to fully cover the damage, and overlay about 3/4 inch (20 mm).
1. Hole 2. Crack

Fig. 6, Preparing the Damaged Area on the Engine Side of the Hood

9. With a razor-blade knife, cut a section of woven fiberglass cloth to fully cover the crack and to overlay about 3/4 inch (20 mm). See **Fig. 6**, Ref. C.
10. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

11. Lay the cut section of fiberglass cloth on the repair area, centered over the damage. Using a fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.
12. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.

13. After two to five minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, mate the FRP parts to be bonded within one to four minutes after dispensing the adhesive.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after five minutes when the adhesive has set.

14. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface if required.
15. Repair the damage on the outside surface of the hood or half-fender, using the instructions in "Surface Damage Repair." Prime and paint both surfaces, using the instructions in **Group 98**.

PUNCTURE AND LARGE FRACTURE REPAIR (SECTION REPLACEMENT)

If a half-fender has a puncture or large fracture, replace the half-fender.

On very large damaged areas (for example, structural damage on the side surface of the hood covering an area of a square foot or more) it may be easier to do a section replacement rather than make a patch. Fenders and headlight reinforcements may be used in section replacements. Also, a second damaged hood with the needed section intact may be available as scrap.

IMPORTANT: A piece of Preform FRP laminate from a Short Conventional hood must be used for section replacement. Use of any other material may not allow the necessary bonding for the repair.

1. Push in on the area immediately surrounding and underneath the damaged area to determine the extent of damage.
2. If a sound-absorbent liner is present on the underside of the damaged area, peel away the liner to provide an adequate working area.
3. Clean the damaged area on both sides of the hood with xylene, acetone, or an equivalent grease- and wax-removing solvent. Inspect the area closely. All dirt, water, grease, and oils must be removed.
4. Using a sabre saw, cut out a large, straight-sided panel containing the damaged area. See **Fig. 7**, Ref. A.

   If the damage extends to a joint where a reinforcement is bonded to the hood, completely separate the reinforcement with a heat gun and putty knife before cutting. See "Hood Reinforcement Rebonding" for instructions.

⚠ WARNING

WARNING: Wear goggles and an air purifying respirator when grinding, cutting, or sanding during all fiberglass repairs. The ground dust and particles could cause temporary or permanent damage to your eyes and, if inhaled, could cause throat or lung irritation.

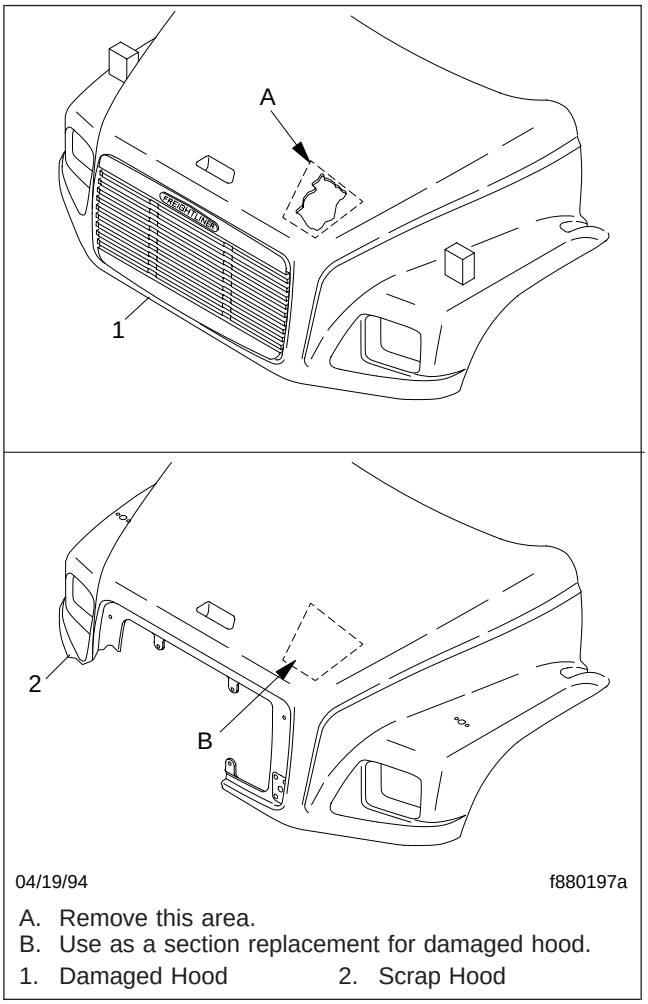
5. From a scrap hood, cut a section replacement panel from the same area, only slightly larger than the cut-out in the damaged hood. See **Fig. 7**, Ref. B. Then, trim the section replacement to fit both the size and contour of the original cutout.

   If the damage is next to a headlight reinforcement, but doesn't include the reinforcement, remove the headlight reinforcement from the replacement section (scrap hood), not the damaged hood.
6. After the trimming is completed, sand the edges to allow a 1/16- to 1/8-inch (2- to 3-mm) gap around the cutout.
7. On the engine side of the hood, use a router bit (on a grinder or drill) to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward from all sides of the cutout area. See **Fig. 8**, Ref. A.

   Also, grind 1/2 inch (13 mm) inward from all edges on the engine side of the section replacement. See **Fig. 8**, Ref. C.

   Slightly taper the outside edge of the ground area on the hood and the inside edge of the ground area on the section replacement. See **Fig. 9**.

Hood and Half-Fender Repair



A. Remove this area.
B. Use as a section replacement for damaged hood.
1. Damaged Hood
2. Scrap Hood

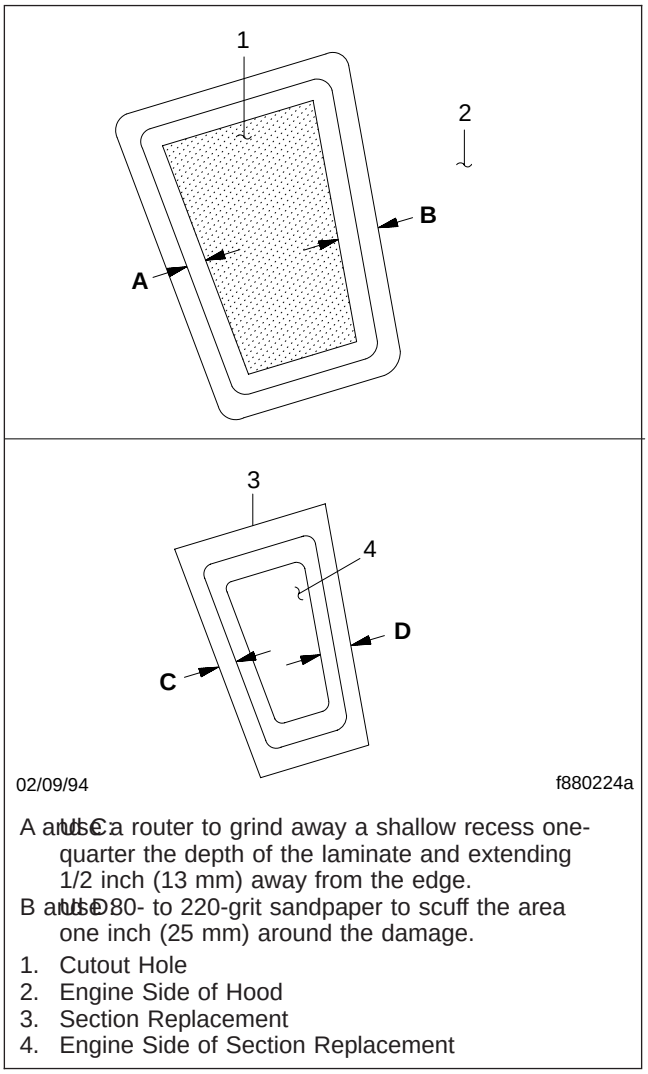
Fig. 7, Section Replacement of a Damaged Fiberglass Hood

8. Use 80- to 220-grit sandpaper to scuff an area at least one inch (25 mm) out from all sides of the cutout area. See **Fig. 8**, Ref. B.

   Also, scuff at least one inch (25 mm) in from all sides of the section replacement. See **Fig. 8**, Ref. D.

   Scuff thoroughly, since this will give the section replacement a surface to which it can stick. Be sure to completely sand off any undercoating sprayed on these areas.

9. On the outer sides of both the cutout and the section replacement, bevel the edges about 45 degrees. See **Fig. 10**.



A and C. Use a router to grind away a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) away from the edge.
B and D. Use 80- to 220-grit sandpaper to scuff the area one inch (25 mm) around the damage.
1. Cutout Hole
2. Engine Side of Hood
3. Section Replacement
4. Engine Side of Section Replacement

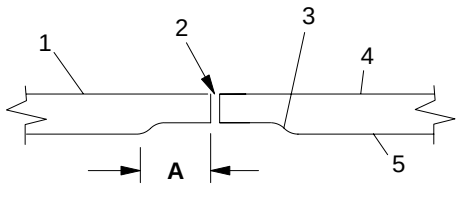
Fig. 8, Preparing the Section Replacement and Hood Cutout on the Unexposed Side

10. Gently feather the outer painted surfaces back about 1/2 inch (13 mm) beyond the edges of the repair areas (on both the cutout and the section replacement), using 220-grit or finer sandpaper.

11. Blow the dust away with compressed air, and wipe the area with a clean cloth.

12. If the section replacement is close enough to an edge, use clamps to temporarily secure it during the repair.

    If the replacement is too far from an edge to use clamps, use bond strips. See **Fig. 11**.

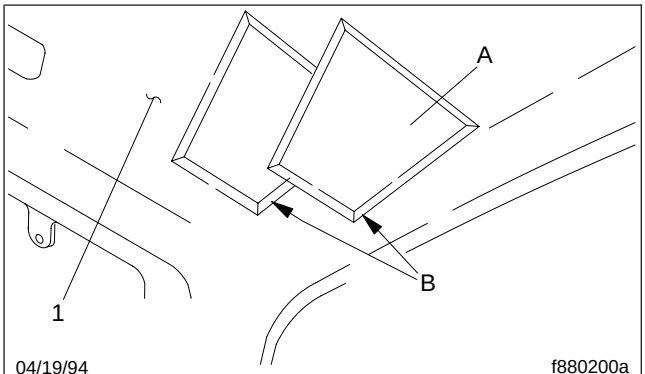


05/04/94 f880226b

A. Grind a shallow recess one-quarter the depth of the laminate and extending 1/2 inch (13 mm) outward in all directions from the damaged area.

1. Section Replacement
2. Gap
3. Slight Taper
4. Hood
5. Engine Side of Hood

Fig. 9, Cutout Area (cross-sectional view)



04/19/94 f880200a

A. Insert section replacement.
B. Bevel outer surface edges on all sides.

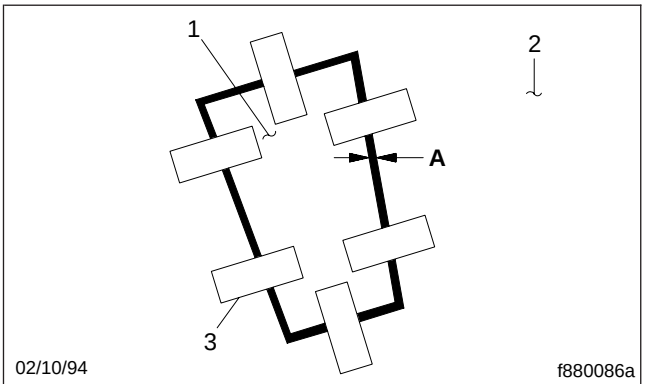
1. Exposed Side of Hood

Fig. 10, Areas to be Beveled

12.1 Cut some scrap FRP into strips. Make enough strips to hold the section replacement in position; about one every six inches (15 cm). If the surface of the replacement panel is contoured or curved, use many small bond strips; larger strips could deform the curves.

12.2 On the engine side of the repair, use 220-grit sandpaper to scuff sand the areas on the hood and section replacement panels where you plan to bond the strips.

12.3 If a joint between the hood and a reinforcement was separated for the repair, rebond the joint. See "Hood Reinforcement Rebonding" for instructions.



02/10/94 f880086a

A. Gap of 1/16 inch to 1/8 inch (2 to 3 mm)

1. Section Replacement
2. Engine Side of Hood
3. Bond Strip

Fig. 11, Securing the Section Replacement to the Hood Using Bond Strips

12.4 Holding the section replacement in position, bond the strips to both hood and replacement panels in the area already scuffed. Use Ashland Pliogrip 7773 to bond the strips.

NOTE: When using Ashland Pliogrip 7773, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uniform green color. Discard the initial few inches of discolored bead.

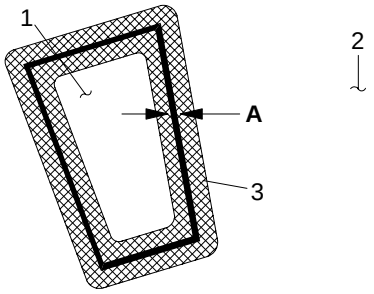
12.5 After the adhesive has hardened, use 80- to 220-grit sandpaper to scuff the bond strips.

12.6 Blow the dust away with compressed air, and wipe the area with a clean cloth.

13. With a razor-blade knife, cut sections of woven fiberglass cloth to fully cover the gap between the cutout and the section replacement, all the way around the damaged area. The cloth should overlay about 3/4 inch (20 mm) on both sides of the gap. See **Fig. 12**.

14. To bond the fiberglass cloth to the damaged panel, use Ashland Pliogrip 7775L urethane adhesive.

NOTE: When using Ashland Pliogrip 7775L, dispense the required adhesive from the cartridge in a continuous bead of uniform size and a uni-



NOTE: The fiberglass cloth should overlay about 3/4 inch (20 mm) on both sides of the gap.

A. Gap of 1/16 inch to 1/8 inch (2 to 3 mm)
1. Section Replacement
2. Engine Side of Hood
3. Fiberglass Cloth

Fig. 12, Overlaying the Gap with Fiberglass Cloth

form green color. Discard the initial few inches of discolored bead.

15. Use a plastic or metal device to spread a thin layer of adhesive over the scuffed area.
16. Lay the cut sections of fiberglass cloth on the repair area, centered over the damage. Using a fiberglass roller, press the cloth down firmly into the layer of adhesive to completely saturate the glass fibers.
17. Apply another layer of adhesive over the glass cloth. Spread the adhesive evenly using the fiberglass roller.
18. After two to five minutes, the adhesive will start to jell. It may take more time when cool, less when warm.

IMPORTANT: To avoid pre-jelling or skin-over, the FRP parts to be bonded should be mated within one to four minutes after the adhesive is dispensed.

NOTE: To get a smoother surface, press a piece of masking tape, wider than the repair, directly over the wet adhesive and smooth it before it hardens. The tape can be removed after five minutes when the adhesive has set.

19. The patch should be hard enough in 50 minutes to allow sanding to a smooth flat surface, if desired.
20. Repair the damage on the outside surface of the hood and paint the surface on both sides, using the instructions in "Surface Damage Repair."

Fastener Torques

Fastener Torque Values				
Description	Size	Grade	Torque	
			lbf·in (N·cm)	lbf·ft (N·m)
Hood Latch Locknuts	1/4–20	B	96 (1080)	—
Half-Fender Flange Screws	3/8–16	8	—	37 (50)
Half-Fender Locknuts	3/8–16	8	—	37 (50)
Hood-Pivot Bolt Locknuts	9/16–18	C	—	130 (176)
Hood-Pivot Support Bracket Locknuts	1/2–13	C	—	70 (95)
Lower Hood-Hinge Pivot Locknuts	3/8–16	C	—	40 (55)
Rear Hood Support Assembly Capscrews	M10	10.9	—	40 (55)
Rear Hood Support Bracket Capscrews	M10	10.9	—	40 (55)
Rear Hood Support Brace Locknuts and Capscrews	M10	10.9	—	40 (55)
Tilt-Assist Torsion Bar Mounting Capscrews and Locknuts	3/8–16	8	—	28 (38)

Table 1, Fastener Torque Values

Repair Tools and Materials List

SURFACE DAMAGE REPAIR

The following are required for surface damage repair:

- Xylene, acetone, or equivalent solvent
- Hand-held disc pad
- Self-leveling adhesive [1]
- Applicator squeegee
- 220- or finer grit sandpaper
- 320- or finer grit sandpaper
- Primer [2]

HOOD REINFORCEMENT REBONDING

The following are required for hood reinforcement rebonding:

- Heat gun
- Putty knife
- Hacksaw blade
- 80- to 220-grit sandpaper
- Solvent [3]
- Adhesive [4]
- Clamps, clamping bolts with washers
- Primer [2]
- 0.030 in (0.76 mm) glass beads (if needed)

CRACK OR SMALL HOLE REPAIR

The following are required for repair of cracks or small holes:

- Xylene, acetone, or equivalent solvent
- Drill and 1/8-inch (3-mm) diameter bit
- Router bit and grinder, or drill
- 80- to 220-grit sandpaper
- 220- or finer grit sandpaper
- 320- or finer grit sandpaper
- Woven fiberglass cloth

[1] Use Ashland Pliogrip 7775L self-leveling urethane adhesive. Premeasured tubes of adhesive, mixing nozzles, and caulking gun applicators are available through Freightliner PDCs. See **Table 2** and **Table 3**.
[2] Use Sherwin Williams BB–-11 black conductive primer. Contact your local Sherwin Williams automotive paint distributor to purchase this primer.
[3] Use Ashland 6036 solvent or methylene chloride. Contact Ashland Merchandising Group, telephone (419) 289-9588, to purchase this solvent.
[4] Use Ashland Pliogrip 7700 series adhesives. Part numbers 7773 and 7779 are those products referred to in the instructions above. Part numbers 7771 and 7770 may be substituted. A heat gun or paint oven may be used to speed curing times but do not heat these adhesives above 180°F (82°C). These products are available through Freightliner PDCs. See **Table 2**.

Specifications

- Wooden stir stick
- Clamps
- Self-leveling adhesive [1]
- Applicator squeegee
- Hand-held disc pad
- Razor-blade knife
- Primer [2]

PUNCTURE OR LARGE FRACTURE REPAIR

The following are required for repair of punctures or large fractures:

- Suitable section of Preform FRP from scrap hood
- Xylene, acetone, or equivalent solvent
- Sabre saw
- Heat gun
- Putty knife
- Router bit and grinder, or drill
- 80- to 220-grit sandpaper
- 220- or finer grit sandpaper
- Solvent [3]
- Adhesive [4]
- Razor-blade knife
- Woven fiberglass cloth
- Wooden stir stick
- Self-leveling adhesive [1]
- Applicator squeegee
- Hand-held disc pad
- Clamps
- Primer [2]

NOTE: Ashland Pliogrip 7700 and 8000 Series repair adhesives and accessories are available through Freightliner PDCs. The 7700 Series two-part urethane adhesives are specially formulated and packaged for repair of hoods and other fiber-reinforced plastics. Ashland Pliogrip 8000 Series two-part urethane adhesives are also available for those who prefer to use these earlier generation adhesives. The 7775L adhesive is a self-leveling mixture that is appropriate when a surface filler or glass fabric reinforcement repair is required.

The descriptions, working times, and curing times (sanding and repainting) of the different adhesives are shown below. See **Table 2** and **Table 4**. All working and curing times correspond to an ambient temperature of 73°F (23°C) in the workshop. Curing times may be shortened by using a heat gun or paint oven. Humidity does not affect these adhesives. All the adhesives develop the same bonding strength. Substitutions can be made to change working times.

See **Table 3** and **Table 5** for Ashland adhesive accessories.

IMPORTANT: To ensure a successful repair, do not heat these adhesives above 180°F (82°C).

7700 Series Adhesives				
Description	**Part Number**	**Working Time in Minutes**	**Curing Time in Minutes**	**Curing Time in Hours**
Adhesive, two 50 ml Cartridges, 3.4 oz (100 ml)	ACA 7771	1.5	10	—
Adhesive, two 50 ml Cartridges, 3.4 oz (100 ml)	ACA 7773	3.5	30	—
Adhesive, two 300 ml Cartridges, 20 oz (600 ml)	ACA 7773 300	3.5	30	—
Adhesive, two 50 ml Cartridges, 3.4 oz (100 ml)	ACA 7775L	5.0	50	—
Adhesive, two 50 ml Cartridges, 3.4 oz (100 ml)	ACA 7779	10	—	1.0
Adhesive, two 300 ml Cartridges, 20 oz (600 ml)	ACA 7779 300	10	—	1.0
Adhesive, two 50 ml Cartridges, 3.4 oz (100 ml)	ACA 7770	35	—	3.0

Specifications

7700 Series Adhesives				
Description	**Part Number**	**Working Time in Minutes**	**Curing Time in Minutes**	**Curing Time in Hours**
Adhesive, two 300 ml Cartridges, 20 oz (600 ml)	ACA 7770 300	35	—	3.0

Table 2, 7700 Series Adhesives

7700 Series Accessories	
Description	**Part Number**
Manual Applicator Gun for 300 ml Cartridges	ACA TS526C
1/4-in Mixing Nozzles for 50 ml Cartridges (100/box) *	ACA 583 238
Pneumatic Applicator Gun for 300 ml Cartridges	ACA TS525
3/8-in Mixing Nozzles for 300 ml Cartridges (100/box) *	ACA F 771072

* Each adhesive cartridge comes with two mixing nozzles. Once mixed, the adhesive in the nozzle will harden by the end of its working time. If making several small repairs, have extra nozzles on hand.

Table 3, 7700 Series Accessories

8000 Series Adhesives				
Description	**Part Number**	**Working Time in Minutes**	**Curing Time in Minutes**	**Curing Time in Hours**
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8104	4.0	30	—
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8110	10	—	1.0
Adhesive, Supermix 4:1, 12 oz (355 ml)	ACA 8145	50	—	8.0

Table 4, 8000 Series Adhesives

8000 Series Accessories	
Description	**Part Number**
Pneumatic Applicator Gun for 355 ml Cartridges	ACA 582 2241
3/8-in Mixing Nozzles for 8000 Series Cartridges (100/box) *	ACA F 771072

* Each adhesive cartridge comes with two mixing nozzles. Once mixed, the adhesive in the nozzle will harden by the end of its working time. If making several small repairs, have extra nozzles on hand.

Table 5, 8000 Series Accessories

General Information

Freightliner Corporation currently uses DuPont® high-solids Standard Urethane and Imron® 5000 paint on vehicles. To meet the new federal air quality regulations imposed by the EPA and local jurisdictions, both new products contain less solvent than earlier types (916Y, Centari®, and Imron), and both are formulated free of lead and chrome.

The procedures in this section are for use with DuPont products. Unless otherwise noted, all products are manufactured by E. I. du Pont de Nemours and Company, Inc. Obtain approval from a Freightliner Regional Office for use of topcoats produced by other manufacturers.

Color Matching

Imron 5000 is the recommended aftermarket paint for color-matching all high-solid Standard Urethane and Imron 5000 colors.

To ensure proper gloss, durability, and color-matching of enamel, use only Imron 5000 paint on previously painted panels of Imron 5000 painted vehicles.

The high-solids Standard Urethane is sold to original equipment manufacturers only, and is not available for aftermarket sale. To color-match the Standard Urethane, use only Imron 5000.

To determine the correct paint number for color-matching of any original finish on a vehicle, refer to the paint specification on the vehicle specification decal. See the vehicle operator's manual for the location of this decal.

To match DuPont Imron 5000 paint in the field with anything other than Imron 5000, the Imron 5000 code (e.g. N0006) must be converted to a code in the other paint quality.

To obtain the correct paint number of a paint other than Dupont, the Imron 5000 code (for example, N0006) must be cross-referenced to the other paint manufacturer's paint code. See **Table 1**.

If unable to find the correct paint number using the method above, contact a Freightliner Regional Office for assistance.

General Guidelines

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 sealers, 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.

IMPORTANT: Only experienced, qualified persons, using proper equipment, should attempt repainting and touch-up painting.

Preparation for Topcoating

To prepare a vehicle for topcoating with DuPont Imron 5000, Imron polyurethane enamel, or Centari acrylic enamel, proceed as follows:

1. Wash and dry the entire truck.

WARNING

Do not use solvent-based cleaners on large areas of fiberglass or plastic (such as a hood). Wiping down these large areas may cause a buildup of static electricity, and the resulting spark could cause a flash fire, and possible serious burns.

2. Using a clean cloth soaked with DuPont 3919S Prep-Sol—use DuPont Plastic Prep 2319S if wiping down a large area of fiberglass, such as a hood—wipe all surfaces to be painted. Remove all traces of wax, polish, grease, and silicones.

Manufacturer Code				Color
Imron 5000	Centari	Dulux	Imron	
N0001	99A	99D	99U	Black
N0006	817A	817D	817U	White
N0306	24160A	24160D	24160U	Blue
N0789	31A	31D	31U	Orange
N0481	5194A	5194D	5194U	Yellow
29198A	N0214	29198D	29198U	Red

Table 1, Sample Portion of DuPont Cross-Reference Chart

Preparation for Topcoating

2.1 Work on small areas at a time, wetting the surface liberally.

2.2 Wipe off the surface with a clean cloth before the Prep-Sol 3919S (or Plastic Prep 2319S) has a chance to dry. Change cloths frequently.

3. Feather-edge all repaired areas, chipped surfaces, and scratches, as follows:

3.1 Cut down the edges of broken spots with no. 220 sandpaper.

3.2 Feather the edges by hand, using a sanding block with no. 400 sandpaper.

4. Sand the entire area to be painted. Use a sanding block and no. 400 sandpaper to remove the gloss and to improve adhesion of the primer.

5. Using a clean cloth soaked with DuPont 3939S lacquer and enamel cleaner, remove any sanding dust.

6. Treat bare metal and rusted areas. For aluminum, use DuPont 225S aluminum cleaner; for all other metals, use 5717S metal conditioner.

6.1 Mix one part of the cleaner with two parts of water in a plastic bucket.

6.2 Apply the cleaner with a cloth or sponge. If corrosion is present, work the surface with a stiff brush or Scotch-Brite® pad.

6.3 While the metal is still wet, wipe off thoroughly with a clean, dry cloth. Allow the surface to dry before applying a conversion coating.

7. Apply a conversion coating to all bare metal. For aluminum, use DuPont 226S aluminum conversion coating; for steel, use 224S conversion coating; for zinc casings, or galvanized iron or steel, use 227S conversion coating.

7.1 Pour the conversion coating into a plastic container (do not dilute). Using a Scotch-Brite or similar abrasive pad, apply the conversion coating to the metal surface. Work only as much area as can be coated and rinsed before the solution dries.

7.2 Leave the coating on the surface for two to five minutes. Then, rinse off the solution with cold water, or mop with a damp sponge or cloth rinsed occasionally in clean water.

NOTE: If the metal surface dries before rinsing, reapply the conversion coating, then repeat the previous substep.

7.3 Wipe the surface dry with a clean cloth, or air dry.

8. With paper and tape, mask all areas that are not to be painted, then prime immediately.

NOTE: DuPont Corlar® epoxy primer may be used. The procedure for its application is listed below.

9. Prime all bare metal and feathered areas with DuPont Corlar epoxy primer 824S, as follows:

9.1 Clean all cracks and surfaces with dry compressed air.

9.2 Using a tack cloth, wipe all surfaces to be painted.

IMPORTANT: 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.

9.3 Stir Corlar 824S primer thoroughly; then mix two parts of Corlar primer with one part of DuPont 826S activator. Reduce three parts of this mixture with one part of DuPont 3602S Lacquer thinner (viscosity reading 18 to 22 seconds, no. 2 Zahn cup). Stir thoroughly.

9.4 Wait one to two hours from time of mixing before using. This provides time for complete chemical induction.

9.5 Spray one full wet coat to give a dry film thickness of 0.7 to 1.0 mil. Allow the primer to dry two to four hours before applying the topcoat.

9.6 Clean equipment with DuPont 3602S lacquer thinner.

10. Clean all cracks and surfaces with dry compressed air.

11. Using a tack cloth, wipe all surfaces to be painted.

Imron 5000 Urethane Application

⚠ WARNING

Do not breath paint vapor or spray mist. Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC–19C), while spraying Imron 5000, 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 Imron 5000 enamel thoroughly. Then, mix three parts of Imron 5000 enamel with one part of 193S activator.

NOTE: The pot life is about two to four hours at 70°F (21°C).

2. If faster curing time or an extended pot life is desired, add Imron 5000 fast-dry accelerator 389S. Add up to two fluid ounces (60 mL) to one gallon (3.8 L) of mixed material.
3. Mix thoroughly and strain.

NOTE: The viscosity of the mixture is about 9 to 20 seconds in a Zahn no. 3 cup, depending on the color. No further reduction is required. Adding reducer could affect the color match on some metallics.

Spraying Solid Colors and Metallics

1. For gravity feed systems, set the air pressure to 60 to 70 psi (414 to 483 kPa) at the gun.

   For pressure feed systems, set the air pressure to 60 to 70 psi (414 to 483 kPa) at the gun, and set the fluid delivery at 10 to 12 ounces (296 to 355 mL) per minute.
2. Hold the spray gun about 10 to 12 inches from the surface. Using a cross-coat technique, spray one medium wet coat in a north-to-south direction, flash 3 to 5 minutes, and follow with a second medium-wet coat in an east-to-west direction. A third medium-wet coat may be needed for poor hiding colors.
3. To air dry, allow 2 to 4 hours with accelerator 389S, and 6 to 8 hours without accelerator.

   To force dry, wait 15 minutes following the application of the final coat, then dry for 30 minutes at 140°F to 180°F (60°C to 82°C).
4. Two-toning, striping, and lettering may be applied in 4 to 6 hours if accelerator 389S is used. Wait 10 to 12 hours if no accelerator is used.

   Decals may be applied in 12 to 16 hours if accelerator 389S is used. Wait 24 hours if no accelerator is used.
5. Wearing a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC–23C), clean all spray equipment immediately after use with Acrylic Lacquer Thinner 3602S or Imron 5000 Reducer 8685S. Do not leave mixed paint in the equipment.

Spot Repair Touch-Up

1. Sand or grind all dents and scratches.
2. Sand the area being repaired with a 320 or finer wet grit sandpaper, or a Scotch-Brite pad.
3. Clean the area with DuPont 3812S solvent; then, wipe with a tack cloth.
4. Apply a wash primer 0.5 to 0.7 mil thick. See the applicable table in **Specifications, 400** for recommended primer. Dry according to the manufacturer's instructions.
5. Apply a sealer primer 0.9 to 1.1 mils thick. See the applicable table in **Specifications, 400** for recommended primer. Dry according to the manufacturer's instructions.

IMPORTANT: Use wash primer and sealer primer from the same manufacturer. Primers from different manufacturers may not be compatible. Use DuPont Imron 5000 as the topcoat with both DuPont and PPG primers.

IMPORTANT: Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC–19C), while spraying Imron 5000, and until the work area has been exhausted of all vapor and spray mist.

6. Stir the Imron 5000 enamel thoroughly. Then, mix three parts of Imron 5000 enamel with one part of DuPont 193S activator.

7. To speed the drying time of activated Imron 5000 color, add up to two fluid ounces (60 mL) of fast-dry accelerator 389S to one gallon (3.8 L) of mixed material.

Spot Repair: Metallics

1. Mix eight parts of 500S urethane with one part 193S activator.
2. Reduce the activated 500S urethane 50 percent with 8685S reducer.
3. Use 50 to 60 psi (345 to 414 kPa) air pressure at the paint gun.
4. Apply a medium-wet coat of 500S urethane over the entire repair area, and well beyond where the color will be applied. Allow two to three minutes for the application to flash before applying Imron 5000.
5. Apply at least two topcoats of Imron 5000 color. Allow five to ten minutes drying time between topcoats. Each color topcoat should extend beyond the preceding topcoat to provide the proper taper and to avoid a visible ring.
6. After the Imron 5000 color has dried, apply a coat of 500S urethane clear to melt in the overspray edges.

IMPORTANT: Coat only the edge of each color coat with 500S urethane. Excess in the center of the color coats could cause the paint to sag.

7. For a uniform flake appearance, immediately apply a mist of Imron 5000 color over the 500S urethane clear.
8. Use 3401S Blending Clear to melt in the tapered edge to the OEM finish. (Or use activated Imron Clear 500S reduced 100 percent with Imron Reducer 8685S.)

Spot Repair, Solid Colors

Use the same application steps as for metallics, but eliminate the first coat of Imron Clear 500S. Use 3401S Blending Clear to melt in all edges.

Buffing

1. Clean the area carefully with mild soap and water.
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 with a clean foam pad at low speed (about 1600 rpm) using one of the following products: Dupont 1500S, Meguiar's No. 2, or 3M Finesset Two 5928. Using medium pressure, buff slowly in an overlapping pattern until the imperfection has been eliminated. Repeat as necessary.
4. Rinse the area with clean water, then dry.
5. With a clean pad (3M Waffle Pad) apply one of the following products: DuPont 3000S, Meguiar's No. 9, or 3M 5996. With 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.

Imron Polyurethane Application

IMPORTANT: Wear a positive-pressure, supplied-air, vapor and particulate respirator approved by NIOSH or MSHA (TC–19C), while spraying Imron, and until the work area has been exhausted of all vapor and spray mist.

Mixing

1. Stir Imron enamel thoroughly. Then, mix three parts of Imron enamel with one part of DuPont 192S activator.
2. If faster curing time is desired, add DuPont 189S accelerator at the rate of 4 fl oz (120 mL) to one gallon (3.8 L) of mixed material.

NOTE: Mix no more material than can be used in an eight-hour period.

3. Spray viscosity should be 18 to 22 seconds, no.2 Zahn cup. Check viscosity every four hours. No further reduction is necessary for application. If desired, material may be further reduced with DuPont Y–8485S reducer.
4. Mix thoroughly and strain.

Spraying Solid Colors

1. Hold the spray gun about 8 inches (20 cm) from the surface. Use 50 psi (345 kPa) gun pressure, and spray a minimum first coat.
2. Allow the first coat to dry until tacky, then follow with a second full coat.

Spraying Metallics

1. Hold the spray gun about 8 inches (20 cm) from the surface. Use 65 psi (448 kPa) gun pressure, and spray a light to medium coat.
2. Wait 20 minutes, then apply a second light to medium coat.
3. Reduce the paint mixture 15 percent with DuPont Y–8485S reducer (17 to 18 seconds, no. 2 Zahn cup), then apply the third light coat, followed, if desired, by a fourth light coat.

Tape-Time and Curing

1. Two-toning, striping, lettering, and decals may be applied in 2 to 4 hours if DuPont 189S accelerator was added to the Imron. Wait 6 to 10 hours if no accelerator was used.
2. For topcoats cured over 72 hours, scuff-sand with no. 400 sandpaper before recoating, striping, lettering, or applying decals.
3. Wearing a properly fitted vapor and particulate respirator, approved by NIOSH or MSHA (TC–23C), clean all spray equipment immediately after use with lacquer thinner or retarder. Do not leave mixed material in equipment.

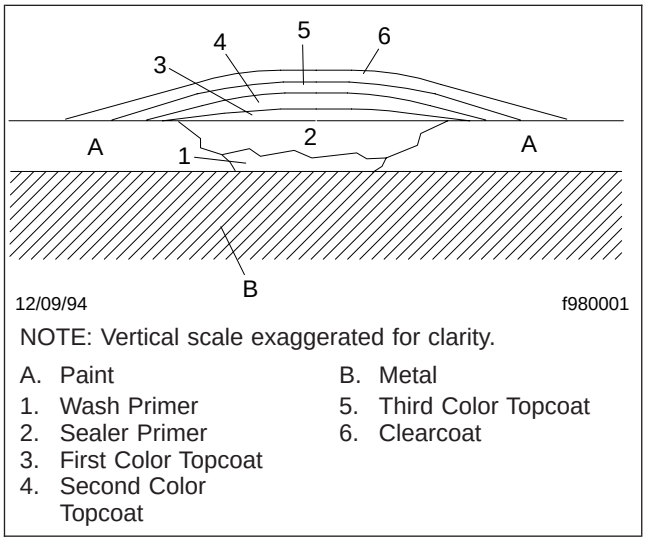
Spot Repair Touch-Up

IMPORTANT: DuPont recommends that Imron be panel-repaired to achieve best results. However, small areas are often spot-repaired. Successful spot repair depends on operator skill and should not be attempted in high visibility areas such as door panels or hoods.

1. Sand or grind all dents and scratches.
2. Sand the area being repaired with a 400 or finer wet grit sandpaper or 600 dry grit sandpaper.
3. Clean the area with DuPont 3812S solvent; then, wipe with a tack cloth.
4. Apply a wash primer 0.5 to 0.7 mil thick. See **Fig. 1**. See the applicable table in **Specifications, 400** for recommended primer. Dry according to the manufacturer's instructions.
5. Apply a sealer primer 0.9 to 1.1 mils thick. See **Fig. 1**. See the applicable table in **Specifications, 400** for recommended primer. Dry according to the manufacturer's instructions.

IMPORTANT: Use wash primer and sealer primer from the same manufacturer.Primers from different manufacturers may not be compatible. Use DuPont Imron as the topcoat with both DuPont and PPG primers.

6. Scuff-sand the primer with 320 to 400 dry grit sandpaper.
7. Stir the Imron enamel thoroughly. Then, mix three parts of Imron enamel with one part of DuPont 192S activator.



NOTE: Vertical scale exaggerated for clarity.

A. Paint
1. Wash Primer
2. Sealer Primer
3. First Color Topcoat
4. Second Color Topcoat
B. Metal
5. Third Color Topcoat
6. Clearcoat

Fig. 1, Cross-Section, Paint Layers

8. Thin the activated Imron color with 8485S solvent no. 2 Zahn cup. Use no more than 25 percent thinner by volume.
9. Use 50 to 60 psi (345 to 414 kPa) air pressure at the paint gun.

IMPORTANT: Wear a positive-pressure, supplied-air, vapor and particulate respirator ap-

proved by NIOSH or MSHA (TC–19C). Wear the respirator while spraying, and until the work area has been exhausted of all vapor and spray mist.

10. Apply at least three topcoats of Imron color. Each color topcoat should extend beyond the preceding topcoat to provide the proper taper and to avoid a visible ring. See **Fig. 1**.
11. Coat the outer edge of each color topcoat with a *mist* of solvent while the color topcoat is still wet.
    - When the ambient temperature is below 80°(27°C), use 8485S solvent.
    - When the ambient temperature is 80°F (27°C) or higher, use a mixture of 8485S and 8100S.

IMPORTANT: Coat only the edge of each color coat with solvent mist. Excess solvent in the center of the color coats could cause the paint to sag.

Centari Acrylic Application

IMPORTANT: Wear a positive-pressure, supplied-air, vapor and particulate respirator, approved by NIOSH or MSHA (TC–19C), when spraying Centari mixed with 792S or 793S hardener.

Mixing

1. Stir Centari enamel thoroughly; then, add one pint (0.5 L) of DuPont 792S hardener to one gallon (3.8 L) of unreduced Centari acrylic enamel, when color-matching spot repairs. Or, add one pint (0.5 L) of DuPont 793S hardener to one gallon (3.8 L) of unreduced Centari acrylic enamel, when painting the entire vehicle or complete panels.
2. Add one part of reducer to two parts of catalyzed enamel for a viscosity reading of 18 to 22 seconds, no. 2 Zahn cup. See the applicable table in **Specifications, 400** for the appropriate reducer, as determined by temperature range. Stir thoroughly and strain.

NOTE: Pot life of Centari after 792S hardener has been added is six to eight hours. Pot life of Centari after 793S hardener has been added is three to four hours.

Color-Matching Spot Repairs

1. Using 30 to 40 psi (207 to 276 kPa) gun pressure, hold the spray gun 8 to 10 inches (20 to 25 cm) from the surface and apply a medium coat. Allow to set for 20 to 30 minutes. This is the sealer coat.
2. Apply three or more medium coats until hiding is achieved, extending each coat beyond the previous one. Allow each coat to flash before applying the next coat.
3. Increase the gun pressure to 65 to 70 psi (448 to 482 kPa), then spray a full wet coat beyond the previous one.
4. Empty the spray cup, then refill it with DuPont 8022S reducer or a blend of 8022S and 8093S.

NOTE: A mist coat of five parts of color to three parts of 8022S is recommended when applying metallics.

5. Lower the gun pressure to 15 to 20 psi (103 to 138 kPa), then carefully blend the edge of the repair with even coats to melt in the overspray. Spray one or two medium coats of the reducer over the entire area. If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500S one-step polish.

Repainting Entire Vehicle; Painting Complete Panels; Two-Toning

1. Use 65 psi (448 kPa) pressure at the gun. If using pressure pot equipment, use 20 psi (138 kPa) pot pressure for a fluid flow of 20 to 25 fl oz (591 to 739 mL) per minute, and 70 psi (482 kPa) gun pressure.
2. Apply three full wet coats, allowing each coat to flash before applying the next coat.
3. If color-matching is required, empty the spray cup, then refill with DuPont 8022S reducer or a blend of 8022S and 8093S.

NOTE: A mist coat of five parts of color to three parts of 8022S is recommended when applying metallics.

4. Lower the gun pressure to 15 to 20 psi (103 to 138 kPa), then carefully blend the edge of the repair with even coats to melt in the overspray. Spray one or two medium coats of the reducer over the entire area. If a haze appears around the edge after the reducer has dried, lightly rub the edge with DuPont 1500S one-step polish.

Tape-Time and Curing

1. Under normal drying conditions, two-toning, striping, lettering, and decals may be applied any time after four hours. For topcoats cured over 72 hours, scuff-sand with no. 400 sandpaper before recoating, striping, lettering, or applying decals.

NOTE: Wait 60 days before waxing.

2. Remove all masking tape immediately after the final color is applied, to prevent tape marking. Avoid masking paper contact with fresh enamel.
3. Wearing a properly fitted vapor and particulate respirator, approved by NIOSH or MSHA (TC–23C), clean all spray equipment, immediately after use, with DuPont 3602S lacquer thinner.

Specifications

Ambient Air Temperature	DuPont Reducer
80°F (26°C) or Above	8093S, or a blend of 8093S and 8022S
70°F (21°C) to 80°F (26°C)	8022S
Under 70°F (21°C)	8034S, or a blend of 8034S and 8022S

Table 1, DuPont Reducer Selection Per Ambient Air Temperature, for Mixing Centari

Product	PPG Brand Name	DuPont Brand Name
Cleaning Solvent	—	3812S/3832S/3939S
Wash Primer	DX 1791	Variprime 615S
Sealer Primer	DP-48	Corlar 824S
Topcoat	—	Imron 5000
Topcoat Solvent	—	8685S
Clearcoat	—	500S
Accelerator	—	389S

Table 2, Materials Needed for Spot Repair Touch-Up With Imron 5000